International Commission on Large Dams

Book of Extended Abstracts

Symposium Hydro Engineering

2 - 3 July 2018

Vienna, Austria

26th World Congress ICOLD 2018 86th Annual Meeting

1 - 7 JULY, VIENNA www.icoldaustria2018.com

Österreichisches Umweltzeichen Green Meetings

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SYMPOSIUM HYDRO ENGINEERING - FOREWORD

The ATCOLD Symposium Hydro Engineering will pave the way for presentations and discussions on specific issues of hydraulic structures serving for energy from renewable resources, irrigation, drinking water supply and flood protection. Hydro Engineering requires a wide range of knowledge and expertise. Therefore, many specific disciplines are involved. Research effort is needed to give answers effectively to challenges during project realization, operation and maintenance. Problem solutions should be sustainable and economically feasible in a wide range. To present and discuss specific issues in the field of hydro power production, this Symposium Hydro Engineering focus on the following topics:

- Climate Changes Reservoir Operation
- Permission and Safety Assessment
- Dam and Foundation Sealing
- Caverns and Power Water Ways
- Stability of Reservoir Slopes

Additionally, two special seminars will be held about the following topics:

- Oroville Dam Spillway Incident
- High Strength Steel in Hydro Power Plants

To allow ICOLD Technical Committee's to present and discuss their work, in parallel to the Symposium Hydro Engineering "Technical Committee Workshops" are organized. Especially Workshops are organized by the following Technical Committees:

- Resettlement due to Reservoirs, Embankment Dams and Dam Safety
- Joint Workshop

  A - Committee on Computational Aspects of Analysis & Design of Dams
  B - Committee on Seismic Aspects of Dam Design

As green meeting, we provide one printed book of extended abstracts containing, the contents of the contributions and on 2 pages the abstract version of the contributions. Full papers are published electronically and are available for downloading.

We thank all the authors for their efforts and contributions to the Symposium. Based on reviews and authors preferences we selected 240 papers and posters from 55 countries for presentations in parallel sessions and during poster presentations.

We would like to express our deepest gratitude towards all the members of the review panel for their effort, and to the organizing committee members especially - Harald Breinhälter, Josef Schneider, Franz-Georg Pikl, Shervin Shahriari and Edwin Staudacher.

Gerald Zenz
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T2: PERMISSION AND SAFETY ASSESSMENT
(Construction and operation of hydraulic structures, inspection & assessment of operating devices)

T3: DAM AND FOUNDATION SEALING
(Long term behaviour and assessment of uplift distribution)

T4: CAVERNS AND POWER WATER WAYS
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COMMISSION INTERNATIONALE
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VINGT-SIXIÈME CONGRÈS DES
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CAPITALIZATION OF BENCHMARK WORKSHOPS RESULTS SINCE BERGAMO 1991

Guido MAZZA'

Chairman of ICOLD Committee A "Computational Aspects of Analysis and Design of Dams, RICERCA SUL SISTEMA ENERGETICO RSE S.P.A.

ITALY

EXTENDED ABSTRACT

Policies on energy and water resources all around the world poses an increasing demand of clean energy and sustainable water resources. These needs require both refurbishment programs of many old dams in those countries where dam construction dates back at the beginning of the industrialization process, such as Europe and USA, and the construction of new infrastructures where the need of water resources and renewable energy is more pressing.

ICOLD in 1988 decided to appoint the Committee *Computational Aspects of Analysis and Design of Dams* with the aim to contribute to the diffusion of computer software in the field of dam engineering and to fill the gap existing between the specialists of mathematical modelling and dam designers, authorities, and managers. As a matter of fact, numerical modelling represents nowadays a key tool for dam engineers to perform efficiently the design making process, the construction stage as well as the whole operational dam life until the possible decommissioning phase. The activities of the Committee have contributed to make fully accepted the numerical models in the engineering practice.

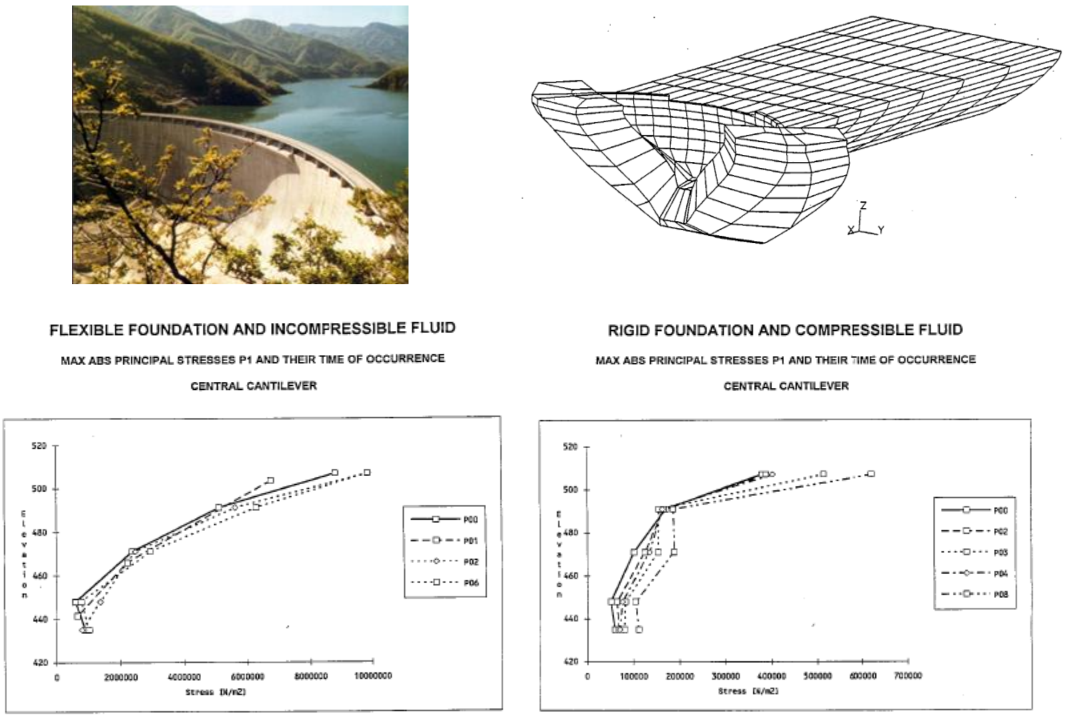
Today and future activities of the Committee are oriented towards:

- ✓ creating a stronger link between the observed dam behavior and the modelling process with the aim to contribute to the preservation and maintenance of existing dams;

- ✓ promoting mathematical modelling improvements to approach safety-related problems that cannot at present be properly analyzed;
- ✓ issuing guidelines to be used for educational purposes in the current practice. The Committee is strongly committed to contribute in the process of a suitable transfer of experience, skill and knowledge across generations.

The work done by the Committee during its long activity has given rise to the issuing of three Technical Bulletins (N. 94, *Computer software for dams. Validation*, 1994; N. 122, *Computational procedures for dam engineering*, 2001; N. 155, *Guidelines for use of numerical models in dam engineering*, 2013).

Moreover, the Committee has promoted the organization of benchmark-workshops (BWs), with the aim to guide dam engineers in the correct use of computer programs. The benchmarking program started in Bergamo (Italy) in 1991 and continued up to 2017 with the 14th workshop held in Stockholm.



Bergamo (Italy), 1991-1992. Seismic analysis of Talvacchia dam: the dam seen from the left abutment; the FE model; some results of the seismic analyses

The benchmarking activity represents a reference for the whole dam community, and in particular for young engineers engaged in the challenging task of dam safety assessment and design. To facilitate the accessibility and a critical review of the proceedings related to the 14 BWs held so far, a capitalization activity of the tremendous amount of data at disposal has been recently started.

The preparation of a new Bulletin to provide a synthesis of the BWs results and comments on the progresses achieved on the numerical modelling methods and the strategies to be used to tackle most of the dam engineering problems is foreseen for the end of 2019.

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50 YEARS OF COMMITTEE ON SEISMIC ASPECTS OF DAM DESIGN

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SWITZERLAND

EXTENDED ABSTRACT

The Committee on Seismic Aspects of Dam Design is one of ICOLD's oldest technical committees, which at present comprises dam and earthquake experts from 34 different countries from all continents. The Committee was created in 1968 and will celebrate its 50th anniversary in 2018. Guidelines on (i) different seismic hazards affecting storage dams, such as fault movements in the footprint of dams, and reservoir-triggered seismicity, (ii) seismic design criteria, (iii) dynamic analysis of dams, (iv) conceptual guidelines for earthquake-resistant design of dams and design of appurtenant structures, and (v) seismic monitoring and inspection of dams after earthquakes, have been published. These guidelines, listed below, represent the international state-of-the-art in the seismic design, construction and safety assessment of large storage dams, i.e.
Bulletin 52 (1986): Earthquake analysis procedures for dams,
Bulletin 112 (1998): Neotectonics and dams,
Bulletin 113 (1999): Seismic observation of dams,
Bulletin 120 (2001): Design features of dams to resist seismic ground motion,
Bulletin 123 (2002): Earthquake design and evaluation of structures appurtenant to dams,
Bulletin 137 (2011): Reservoirs and seismicity,
Bulletin 148 (2016): Selecting seismic parameters for large dams, and
Bulletin 166 (2016): Inspection of dams following earthquakes

Among these guidelines, Bulletin 137 provides information on reservoir-triggered seismicity (RTS), a hazard unique to large storage dams, which is often a key dam safety argument brought forward by opponents against new dams. For properly designed and constructed dams, RTS is not a new safety concern for dams. However, the publication with the greatest long-term impact on the seismic design and safety assessment of existing dams is Bulletin 148, which includes the concept of two earthquake levels for dams and safety-critical elements, i.e. the Operating Basis Earthquake (OBE) and the Safety Evaluation Earthquake (SEE). The safety-critical elements are the spillway and low level outlets, which are needed to control the reservoir level after the SEE or for lowering for repair works or for increasing the safety of a dam. This is new. Bulletin 120 complements Bulletin 148 as it includes conceptual features for the seismic design of dams, which are extremely important, as it is well known that it will be difficult to have a structure to perform well during an earthquake, when the basic seismic design concepts are not observed.

Dams were the first structures designed against earthquakes, on a worldwide basis, starting in the 1930s. At that time, the ground shaking was the main seismic hazard and was represented by a seismic coefficient of typically 0.1, almost irrespective of the seismic hazard at the dam site, which was often unknown. The seismic analysis was done with the pseudostatic method, ignoring the dynamic characteristics of dams. Because of its simplicity, this method is still in use today, although it has become clear that this method is obsolete following the observations made during the 1971 San Fernando earthquake. The pseudostatic method is also not compatible with current seismic guidelines (Bulletin 148) and, therefore, this obsolete method shall no longer be used for the safety checks of large storage dams. One of the main tasks of the Committee is to promote good practice in dam engineering, which includes the dissemination of the international state-of-the-art. Using the pseudostatic concept, the seismic load case was very seldom the governing one. This has changed by using today's rational concepts for seismic hazard analyses and dynamic analyses of dams. The earthquake load case has become the dominant one for most dams.

Since the formation of the seismic committee, the magnitude 8 Wenchuan earthquake of May 12, 2008 that occurred in Sichuan province, China, was the most important earthquake for dam engineers as it damaged some 1580 dams. Most of them were small earth dams, but also some large dams were damaged. The main lesson from this earthquake was that the seismic hazard is a multi-hazard. Thousands of mass movements occurred in the mountainous epicentral region. Mass movements that can be triggered by strong earthquakes are often ignored or the hazard is assessed using criteria, which are different from those used for the dam body. Based on the past experience, it is obvious that dams are not inherently safe and can be damaged by strong earthquakes. The most vulnerable dams are those, which are poorly constructed and/or designed. Still a lot of work is required in order to ensure that all dams comply with modern seismic safety criteria, which is the main concern of the Committee..

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NUMERICAL METHODS APPLIED AND INTERPRETED FOR SAFE DAM BEHAVIOUR

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AUSTRIA

1. INTRODUCTION

Dams are designed to serve in a secure and safe way to our society under any environmental and operational conditions throughout their lifetime. During design and construction models are needed to be set up to account for the safety approach. This models are based on practical experience gained from the performance of existing structures and rely on models we assume for possible failure modes. To set up and apply advanced numerical models and interpret their results a detailed discussion within the engineering community is need. To show the abilities and the meaningful interpretation of numerical investigations the "Technical Committee on Numerical Analysis and Design of Dams" organizes since 1991 benchmark workshops. These results are published in proceedings and concluded in ICOLD Bulletins. Herein a short summary of the content of investigations and a further step to disseminate the results is undertaken. It is to emphasize the requirement to develop a model about the system behavior of dams based on their foundation, reservoir slopes, catchment area and environment. Numerical models and the interpretation of the gained results are one essential part within this ICOLD network to guarantee for the safe dam operation.

International Benchmark Workshops on Numerical Analysis of Dams are intended to provide an in-depth examination of the computational methods and software used for dam analysis. It is an international forum to share the latest information regarding state-of-the-art software and techniques available for the analysis of dams' behavior. For the community of Dam Engineers, a possibility is given to discuss on assumptions, results and conclusions drawn by the help of numerical analyses. The Benchmarks are organized by members of the ICOLD "Technical Committee on Computational Aspects of Dam Analysis and Design". During a period now of 29 years the working group is active in discussing computational aspects and concluding the major results in Bulletins. However, the effort is based on the activities of their members, Vice-Chair and especially their Chair as these are from the beginning: Olgierd Zienkiewics, Michele Fanelli, Gabriella Giuseppetti, Alian Carrere, Ignacio Escuder and the current chair Guido Mazza.

The results and outcome of benchmarks workshops result in working group discussions; their work is being published in Bulletins ([1],[2],[3]). These Bulletins aims to offer a support to dam engineers to choose the most suitable computational strategies to cope with the engineering problems under examination in the best possible way having in mind potentialities and possible shortcomings.

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SEISMIC ASPECTS IN THE DESIGN OF EMBANKMENT AND ROCKFILL DAMS

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EXTENDED ABSTRACT

Historically, embankment dams have usually performed well during earthquakes. However, earthquakes can undesirably affect embankment dams in different ways. One of the most obvious way is by causing instability or large deformations in the dam, due either to strong shaking, or to increases in pore pressure and resulting decreases in strength (caused by cyclic loading). One of the most well-known cases of liquefaction and instability of a dam during an earthquake, is the Lower San Fernando Dam, where a portion of the embankment liquefied during the 1971 San Fernando earthquake and slid, leaving only about 3 feet of freeboard remaining to contain the reservoir. Dams have also failed due to erosion through cracks caused by an earthquake. Consequently, earthquakes may induce instability in the slopes of the dam, differential settlements and cracks. The assessment of the behavior of an embankment dam under seismic loading typically includes the following aspects:

1. Identifying and characterizing potential sources of earthquake loading, whether known faults or historic seismicity not associated with known faults.

2. Determining the appropriate loadings to apply in the analyses.

3. Determining the properties of the embankment and foundation materials,

4. Analyzing the post-earthquake stability of the embankment, including the evaluation of a possible drastic loss of shear strength.

5. Estimating the extent of deformations resulting from earthquake shaking and reduction in material strengths.

6. Determining the potential for dam failure by the overtopping of deformed embankment, erosion through cracks in the embankment, or other possible failure mechanisms.

7. Evaluating other structures, such as spillway walls adjacent to the embankment, whose failure could cause failure of the embankment dam by allowing overtopping or by creating unfiltered exit points for internal erosion.

The presentation will focus on the different seismic aspects to consider in the design of an embankment dam and some of the available numerical methods to evaluate the different failure mechanisms of a dam under seismic conditions, including, stability of the dam, deformation prediction and liquefaction potential.

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COLLAPSE OF AGRICULTURAL EARTH-DAMS BY A RECENT EARTHQUAKE AND ITS RECONSTRUCTION

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JAPAN

1. COLLAPSE AND RECONSTRUCTION OF IRRIGATION DAMS

A pair of old irrigation dams in Fukushima Prefecture collapsed by the 2011 Great East Japan Earthquake (Fig. 1a). The collapse was due to generally poor soil compaction and the use of inadequate soil type (sandy soil) in the top layer despite homogeneous type of the dam in addition to a prolonged strong seismic motion. The new dams (Fig. 1b) were constructed to be much more stable by the use of adequate type soils, good compaction and an adequate structure.

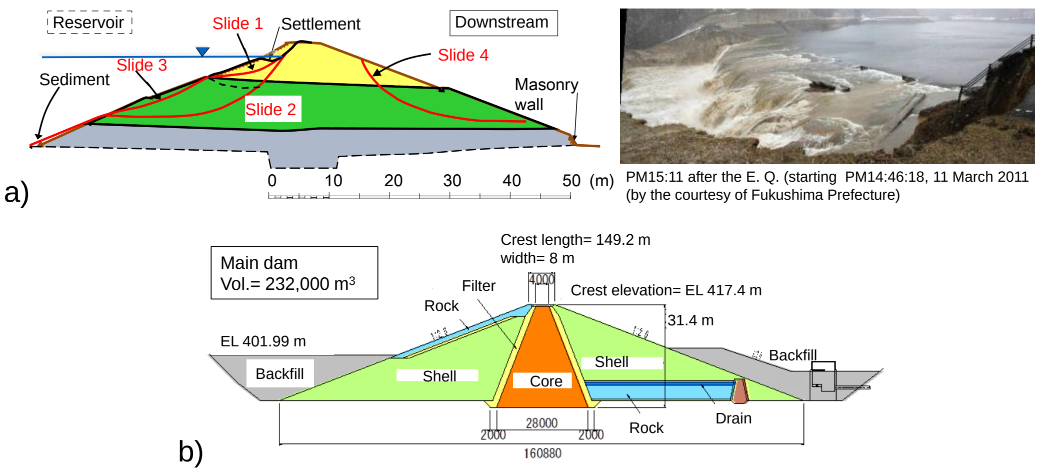

Fig. 1. Fujinuma dam, Fukushima Pref. Japan: a) collapsed; & b) reconstructed.

In soil compaction, the target values of dry density and water content were specified to be equal to the maximum dry density and the optimum water content by Standard Proctor while controlling the degree of saturation to become the optimum degree of saturation (i.e., $S_r = (S_r)_{opt}$) irrespective of variations in the soil type and compaction energy in actual compaction. When $S_r = (S_r)_{opt}$, the highest dry density (so, the highest shear strength and stiffness) and sufficiently low hydraulic conductivity of saturated soil is obtained under any given field condition.

2. STABILITY AND DEFORMATION ANALYSIS

The collapse was successfully simulated by simplified practical analysis incorporating the time histories of undrained stress-strain relation and peak strength of saturated soil that degrade by cyclic undrained loading during an earthquake (Figs. 2a & b). The residual slip evaluated by the Newmark method and the residual deformation outside the slip layer by pseudo-static FEM, both incorporating the time history of response acceleration, were summed up. No slip with very small residual deformation of the new dam by the seismic load by which the old dams collapsed was confirmed by analysis by this method. The effect of compaction on the dam stability is tremendous. Fig. 2c shows the average drained and undrained shear strengths mobilized along the critical slip circles in the top zone of the old and new main dams (as shown in Fig. 2a). With the new dam, the average degree of compaction (Standard Proctor) D_c is equal to 101 %, thus the undrained shear strength at the end of seismic loading is higher than the drained strength while substantially higher than the value at D_c= 87 % of the old dam.

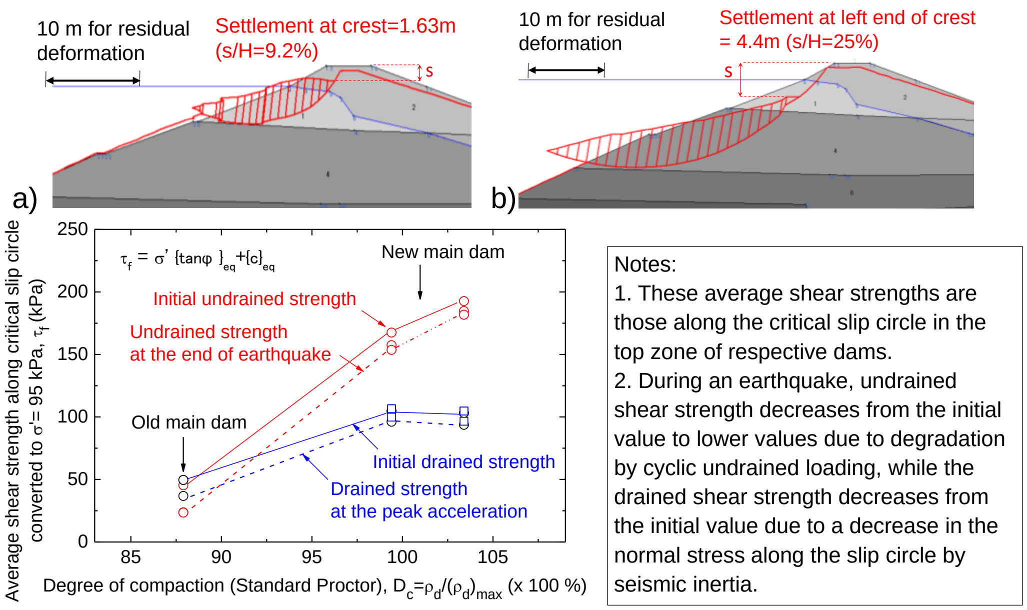

Fig. 2 a) & b) Residual deformation for two critical slip circles by numerical analysis of the old dam; & b) average shear strengths mobilized in the upper zone.

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COMPARISON OF MEASURED AND ANALIZED SEISMIC BEHAVIOR OF CONCRETE DAMS AND EMBANKMENT DAM IN JAPAN

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JAPAN

1. INTRODUCTION

Many earthquakes have hit Japan and informative data about seismic behavior has recorded at dams during large earthquakes [1]. The report shows some examples of dynamic analyses of existing dams with efforts in order to reproduce seismic performances exactly. In this abstracts, outlines of an arch dam case and an embankment dam case are briefly explained.

2. CASE OF ARCH DAM [2]

The earthquake record observed at the crest of Yagisawa Dam (dam height of 131m, Fig.1) in Chuetsu Earthquake (Oct.23, 2004) was 656cm/s^2. In the reproduction analysis, modification of the foundation - reservoir coupling conditions has been conducted as compared with generally used conditions in Japan. By using the modified analysis, reproduced behavior of the dam in the earthquake has higher precision than previous method as shown in Fig. 2.

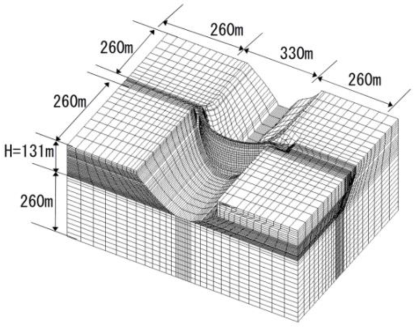


Fig. 1
Analysis Mode

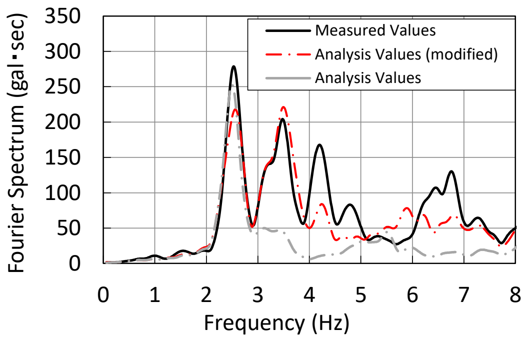
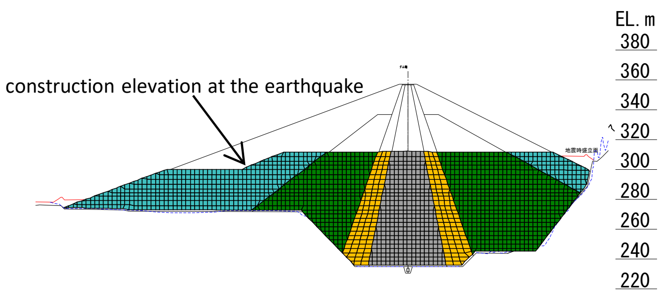


Fig. 2
Fourier Spectrum at Dam Crest
(Upstream-downstream direction)

3. CASE OF EMBANKMENT DAM [3]

Due to the Iwate-Miyagi Nairiku Earthquake in 2008, settlement without sliding deformation was observed at Isawa Dam (ECRD, Fig. 3). The dynamic strength tests for construction materials and deformation analysis using cumulative damage theory were conducted. Through the analysis, the settlement can be reproduced accurately and it is important to consider saturated/unsaturated conditions in dam body for accurate evaluation (see Fig. 4).



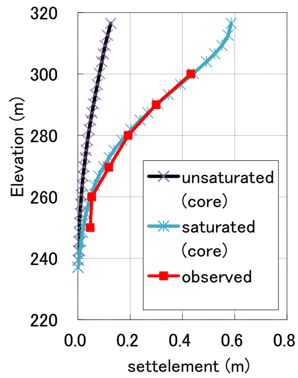


Fig. 3
FEM element

Fig. 4
Vertical distributions of settlements

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CURRENT CHALLENGES OF SEISMIC NUMERICAL MODELLING FOR DAMS: SOME ITALIAN EXPERIENCES

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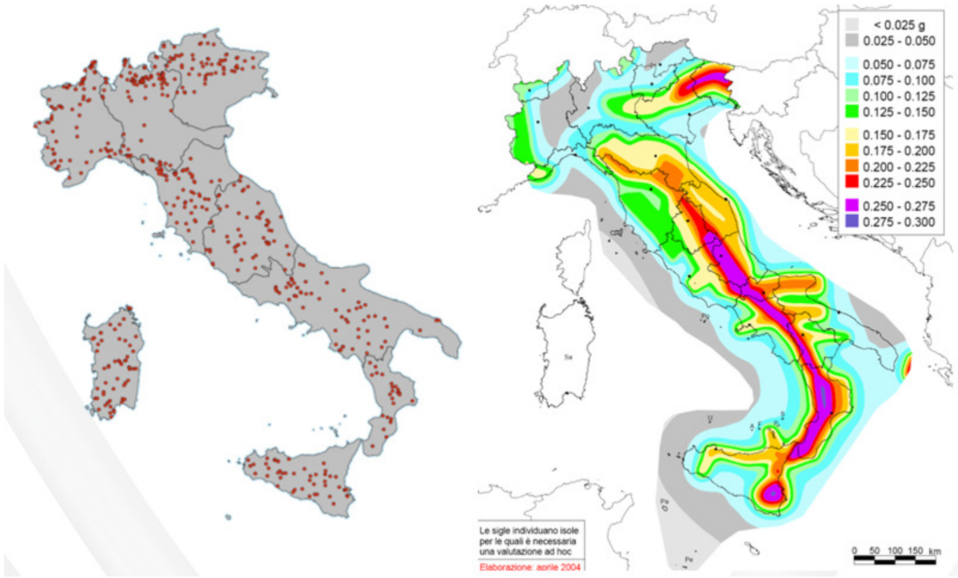
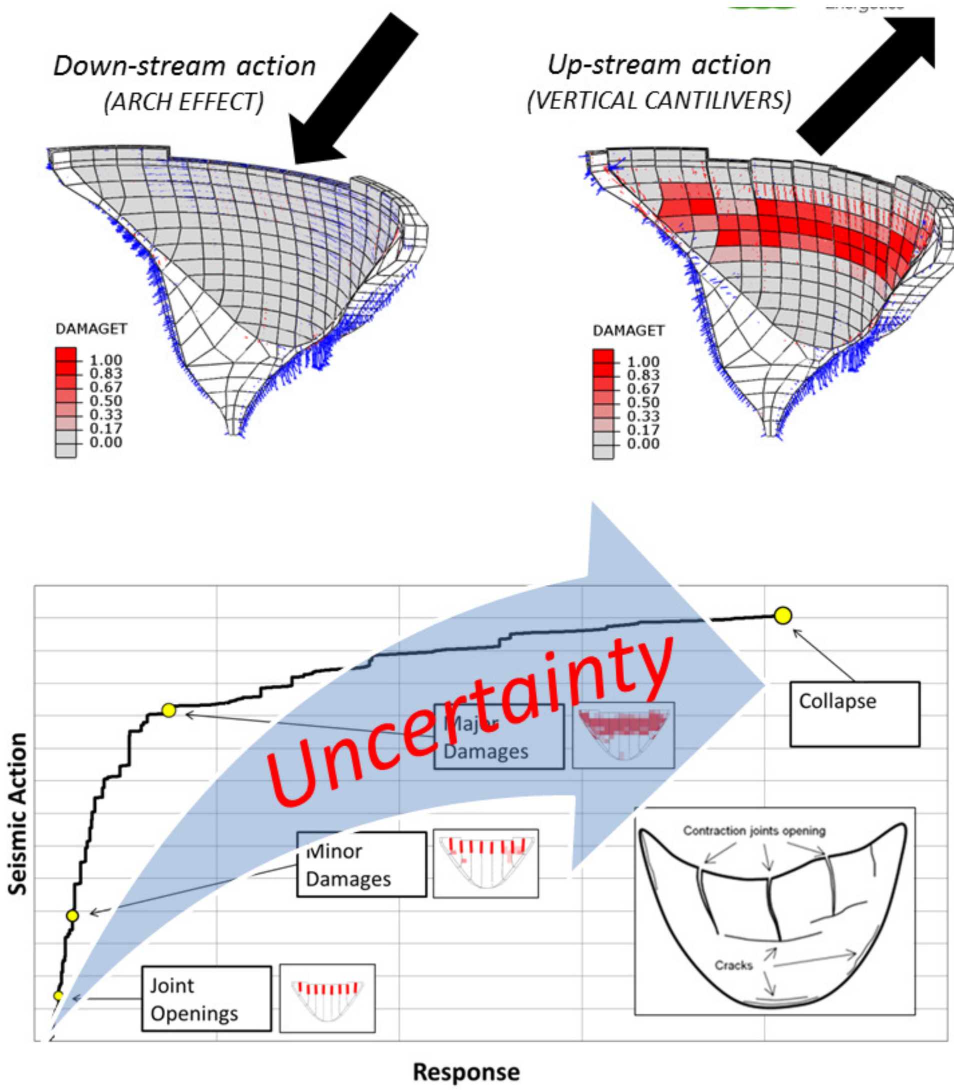
ITALY

EXTENDED ABSTRACT

The dynamic FEM analysis is currently the most effective tool to simulate the seismic response of dams. However, as the seismic forces increase up to the level of intensity typically corresponding to MCE, the complexity of the models and the computation time increase dramatically, having to take into account the non-linear behaviour of both materials and interfaces (joints and pre-existing cracks). At the same time, the overall models uncertainty increases, which in combination with the lack of information on the real response of dams when subjected to strong earthquakes, makes models calibration and subsequent seismic analysis a very challenging, expensive and often impractical task. To cope with that, RSE adopted and further developed, a simplified dynamic method - the Endurance Time Analysis method (ETA) - which allows drastic reductions of the computational effort, to analyze the non-linear response of several large concrete dams in Italy and to obtain their "capacity curves" ranging up to collapse. In such way, even if the overall model uncertainty is still not properly addressed and quantified, the comparison of such curves within the dams portfolio allowed to develop simplified "risk indexes" to rank their relevant seismic risk, so that resource allocation for safety assessment can be definitely optimized.



Italian dam locations (left) and seismic hazard map of Italy (right)



Typical behaviour of arch dams for intensifying seismic actions

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QUALIFICATION OF DYNAMIC ANALYSES OF DAMS AND THEIR EQUIPMENT---OUTCOME OF JCOLD-CBFR TECHNICAL EXCHANGE---

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JAPAN AND FRANCE

1. JCOLD-CFBR TECHNICAL EXCHANGE

The technical exchange between CFBR and Japan Commission on Large Dams (JCOLD) has been conducted for the qualification of seismic dam analyses in last five years since 2013. The first objective was the comparison between the new French legislation and the current Japanese legislation, discussion about their implementation, the performance of dams under strong motions and the feedback from such performance on dam modeling. The second objective was the validation of dynamic analysis by modeling the performance of some large dams under strong motions earthquakes. The third objective was the calibration of simplified methods according to the large seismic data gathered in Japan. Therefore, the analytical procedure ranges from simplified methods for providing preliminary assessment to sophisticated methods for simulating the nonlinear deformation of dams during large earthquakes. Analyses of appurtenant structures of dams are also included.

2. OUTCOME OF COLLABORATION

CFBR developed own analysis methods and focused on the verification of them through the reproduction simulations of various dam types using the seismic records that were monitored in large dams in Japan. The spillway gates in French dams were roughly assessed for the seismic capability by comparing the dimensional data with ones in Japan. JCOLD provided some cases of the reproduction simulations of the concrete gravity dam, the arch dam and the facing rockfill dams. In addition, state-of-the-art research on the seismic analysis method and material characteristics of a largely deformed rockfill dam due to the seismic impact was introduced. The technical discussion and exchange between CFBR and JCOLD resulted in creative outcomes involving the adequate verification of the methods and finding further technical issues addressed in the future. These results are disseminated to many dam engineers in five workshops and two international symposiums held in French and Japan. An e-book compiling the above technical activity as 36 technical papers will be issued this year as titled "Qualification of Seismic Dam Analyses and their equipment."

The main topics of the book are the following:

a. Analysis on acceleration data of dams collected by JCOLD
b. Practical guide for selecting seismic parameters and numerical models
c. Material properties and performance of embankment dams ·
d. Performance and analysis of AFRD and CFRD
e. Qualification of simplified analysis of embankment dams
f. Qualification of detailed analysis of embankment
g. Dynamic modeling, experimental and in-situ results of concrete dams
h. Effects of radiative boundary conditions and spatial variability of the seismic ground motion
i. Dynamic behavior of concrete dam : lessons learned from the JCOLD database
j. Characterization of the dynamic behavior of an arch dam by means of forced vibration tests
k. Comparison between numerical analyses and seismic records on dams
l. Simplified analyses for gravity dam
m. Displacement-Based Seismic Assessment of Concrete Dams
n. Comparison of design criteria of gates between Japan and France
o. Analysis of gates compared to field measurements

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OBSERVATIONS OF PERFORMANCE OF EARTHFILL EMBANKMENTS DURING RECENT EARTHQUAKES IN NEW ZEALAND

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NEW ZEALAND

1. INTRODUCTION

Many earthfill embankment water storage dams have been constructed near Seddon, New Zealand since 2004 for the purposes of irrigating grapes. They range up to 26m in height. They were subject to very strong earthquake ground motion from earthquakes in 2013 and 2016. Peak horizontal ground accelerations of close to 0.75g were recorded at Seddon during the Mw6.6 Lake Grassmere earthquake (16 August 2013) and the Mw7.8 Kaikoura earthquake (14 November 2016). The performance of eleven water storage dams located near Seddon that were subjected to these two earthquakes is summarized. The embankments were generally designed in accordance with guidelines published by the New Zealand Society on Large Dams (NZSOLD).

2. OBSERVATIONS

Observations of embankment performance are summarized in Table 1. In general, there was minor to no damage to dams that were designed and constructed to modern standards. Some dams were affected more by the Lake Grassmere earthquake. This is explained by this earthquake being closer, even though the Kaikoura earthquake had a much longer duration of strong shaking.

Two dams (F and I) that had deficiencies and were damaged in the 2013 earthquake were repaired and subsequently performed much better in the 2016 earthquake. Seiches were noted in some reservoirs in the 2016 earthquake with heights estimated to be at least 1.2m and in one case overtopped a saddle dam.

Table 1
Summary of observations

Dam ID	H^1 (m)	Lake Grassmere Earthquake		Kaikoura Earthquake	
		R_{rup}^2 (km)	OBSERVATIONS	R_{rup} (km)	OBSERVATIONS
A	17	12.4	Movement of riprap, minor cracks	26	Minor movement of riprap
B	19	14.1	No damage	28	No damage
C	13	14.1	No damage	29	No damage
D	26	17.0	No damage	20	No damage
E	17	13.7	Deformation upstream shoulder, cracks in crest	20	Additional deformation and cracks
F	10	10.7	Deformation upstream shoulder, cracks in crest	22	No damage
G	15	11.4	No damage	22	No damage
H	6	4.1	No damage	20	No damage
I	12	7.0	Deformation of upstream shoulder, cracks in crest	22	Minor cracks
J	8	15.0	No damage	31	No damage
K	11	6.1	Not constructed	21	Minor cracks upstream side dam crest

[1]H = embankment height
[2]R_{rup} = closest distance to fault rupture

3. CONCLUSIONS

Earthfill embankments designed to modern standards and constructed to high standards can withstand very high levels of ground motion with minor damage. Embankments where the earthfill is not properly conditioned and poorly compacted can be expected to deform with the potential for significant longitudinal cracking and some potential for transverse cracking where the abutment profile is irregular or stepped.

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LESSONS LEARNED FROM RECENT INTERNATIONAL WORKSHOPS ON SEISMIC NUMERICAL MODELLING FOR CONCRETE DAMS

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FRANCE

EXTENDED ABSTRACT

From 2013, the author participated to several workshop dedicated to the safety assessment of concrete dams under earthquakes:

- Several ICOLD benchmark on numerical analyses of arch dam:
  - Graz 2013 on the fluid-structure interaction effect on arch dam under earthquakes,
  - Lausanne 2015 on the safety assessment of Luzzone arch dam following the Swiss guidelines,
  - Stockholm 2017 with increasing complex numerical analyses on Janeh gravity-arch dam assessment under earthquake

- USSD workshops:
  - in 2016 for a blind prediction with numerical analyses of the recorded behavior of Monticello arch dam under M4.1 earthquake, 16km away from the dam
  - in 2017 on the seismic analyses of concrete dams

- Several workshop from 2013 to 2016 during the collaboration between Japanese and French committees on large dams, on seismic behavior of dams.

The presentation will summarized the main lessons learned by the author from theses workshops.

First, the numerical modeling of concrete dams under earthquakes will discussed: from commonly used simplified finite-element model using Westergaard added masses and massless foundation to more complex numerical analyses using advanced soil-fluid-structure interaction with fluid element and viscous-spring foundation boundaries for example. Comparisons of finite-element analyses with simplified and advanced methods will be presented.

Second, the qualification of the numerical methods with earthquakes records on dams will be discussed: devices to records and save dam’s response under earthquake are now easily available and such data can be used to evaluate and improve numerical tools.

Finally, a software is currently under development by the author to go through the Japanese database of records on dams and foundation. Such tool might prove very useful to analyze the increasing number of dam’s response under earthquake and to evaluate dynamic properties such as eigenfrequencies and damping values during earthquake.

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SEISMIC HAZARD ANALYSIS OF HARD-ROCK DAM SITES

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CANADA

EXTENDED ABSTRACT

Current ground motion models for western North America (WNA) characterize site effects based on scaling with respect to V_{S30}, the time-averaged shear wave velocity (V_S) in the uppermost 30 metres. The upper limit on this V_{S30}-scaling in these models is in the range of 1100 to 1500 m/s and reflects the paucity of earthquake recordings from rock sites with V_{S30} > 800 m/s. A review of earthquake recordings on hard-rock shows that shear wave velocity alone does not fully explain observed trends and that another characteristic of the rock, *kappa* (k), a measure of shallow crustal damping, is required to better capture or reproduce the observations in the data. In general, kappa decreases as V_{S30} increases but there is no explicit *kappa* scaling in available WNA ground motion models and hence *kappa* is not directly included in seismic hazard analysis

Most hard-rock sites in British Columbia are glaciated and have V_{S30} values higher than 800 m/s, sometimes as much as three times higher. Hence, until such time that the development of these models incorporates data from high V_{S30} sites, seismic hazard analysis for hard-rock sites has to be performed in two stages. First, a seismic hazard analysis is conducted for a reference rock with a known V_{S30} (usually < 800 m/s) and a known inherent *kappa*. Secondly, relative amplifications based on the site-specific V_{S30} and site-specific *kappa* are calculated and applied to the computed reference hazard to derive the site-specific seismic hazard. Figure 1 shows different response spectra (with kappa varying from .05 to .01 seconds) for a structure on a hard-rock site that needs to safely resist a M_w6.5

earthquake occurring about 25 km away. If the structure is a concrete dam or supports safety-critical electromechanical equipment sensitive to short period (< 0.2 to 0.3 seconds) shaking, then kappa largely controls the spectral accelerations in this range and the ground motion almost doubles or triples at certain periods. It is therefore imperative that dam owners and their engineers know the values of V_{s30} and *kappa* for their hard-rock dam sites in order to reduce the uncertainty in the ground motion estimates.

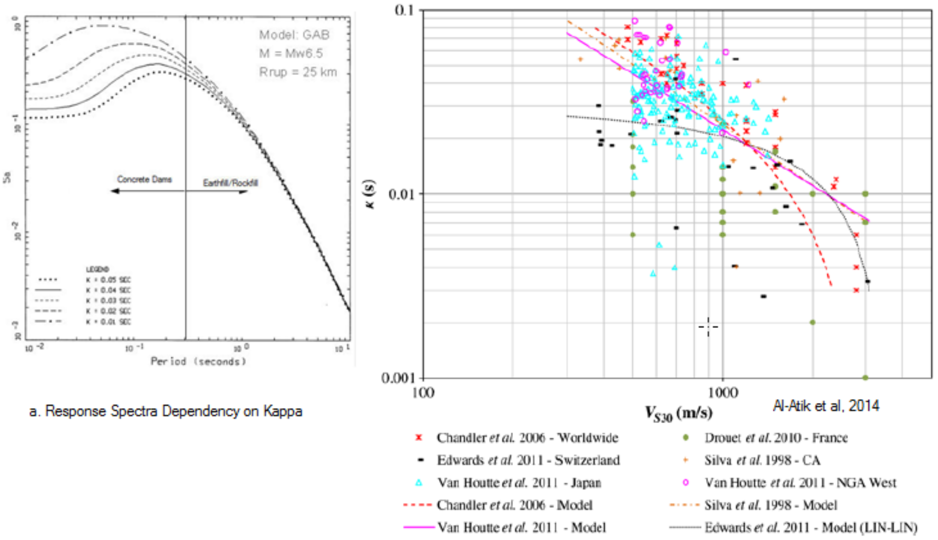

Figure 1 Response Spectra and Shear Wave Velocity Variation with Kappa

At BC Hydro, relative site amplifications based on site-specific properties are calculated and applied to probabilistic seismic hazard based on a reference rock with a V_{S30} of 760 m/s and a kappa of 0.040 seconds. Initial results show that empirical amplifications from field data are generally consistent with analytical amplifications using a hard-rock kappa of 0.015 seconds. The results also show that computed ground motions generally decrease with higher V_{S30} at all frequencies but tend to be significantly underestimated at high frequencies (> 5 Hz) if kappa and its uncertainty are not appropriately considered in the computation of the amplifications. This finding has significant loading implications for high frequency response dams and other safety-critical structures.

Also shown in Figure 1 is an approximate relationship between Kappa and Vs30 from available global data (Al Atik et al, 2014). Due to the poor correlation, it is preferable to obtain site-specific kappa values rather than rely on its dependency on Vs. To measure kappa, one needs to deploy an energy source powerful enough to excite the top 2-5 km of the earth's crust (which is impractical even if possible) or install strong motion accelerographs (SMAs) and patiently wait for an earthquake to occur. Kappa can then be estimated from the slope of the high frequency (5-20 Hz) portion of the Fourier amplitude spectrum (where it is linear in log-linear space) of an earthquake recording if the event hypocenter is within 50 km or so. Data from the SMAs, if remotely accessible, can also be used to timely inform decision-making on earthquake emergency response planning, further underscoring the importance and urgency of installing SMAs on 'significant' consequence dam sites.

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MODELLING THE UNCERTAINTY OF INFLOW TO SHORT-TERM RESERVOIR OPERATION USING FUNCTIONAL EXPANSION-BASED METHOD

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1. INTRODUCTION

Single trace of inflow forecast that is commonly used for guiding short-term reservoir operation, is gradually being replaced by ensemble streamflow prediction [1] (ESP), i.e., a collection of multiple inflow forecasts, to account for the inflow uncertainty. The study use a functional expansion-based method namely Karhunen-Loeve expansion[2] to model the uncertainty associated with the ESP and demonstrate its high efficiency with a case study.

2. METHODOLOGY

The KL expansion is a representation of a random process as a series expansion involving a complete set of deterministic functions with corresponding random coefficients. The KL expansion of can be represented by:

$$Q(t) = \overline{Q(t)} + \sum_{k=1}^{\infty} \sqrt{\lambda_k}\,\psi_k(t)\,\xi_k \qquad [1]$$

where $Q(t)$ is a random process and $\overline{Q(t)}$ is its mean. $\{\psi_k, \lambda_k\}_{k=1}^{=\infty}$ is the orthogonal eigen-functions and the corresponding eigen-values, respectively, and are solutions a Fredholm integral equation of the second kind. $\{\xi_k\}_{k=1}^{=\infty}$ is a sequence of uncorrelated random variables (coefficients) with mean 0 and variance 1.The form of the KL expansion in Eq. [1] is often approximated by a finite number of discrete terms (e.g. M), for practical implementation(called truncated KL). The higher the correlation of the random process, the fewer the terms that are required for the approximation [3].

3. CASE STUDY

The Qinshitan Reservoir in Southeast of China is taken as a case. A period of two weeks during flood season is considered as the short-term operational horizon. The ESP for the two weeks (Fig.1) is treated as a random process and the first 10 eigen-values are calculated using the KL expansion (Fig. 2). It is observed that the first 3 eigen-value are much larger than the rest, meaning significant portion of the random process can be approximately represented by the first 3 terms (Namely M=3 in this case).

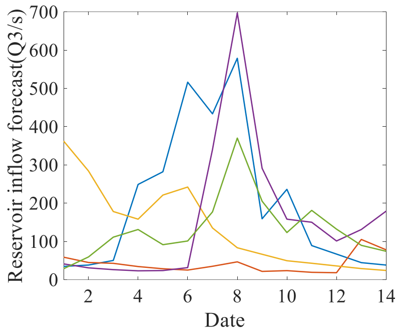

Fig. 1
ESP of Qingshitang Reservoir

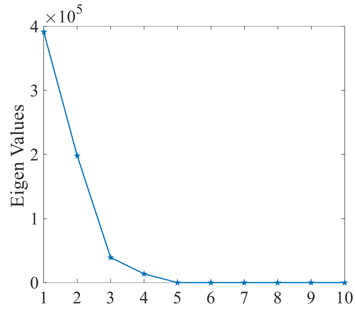

Fig. 2
The First ten Eigen Values of the ESP

4. CONCULUSION

The ensemble inflow and its associated uncertainty can be modelled by a KL representation with only three terms, meaning three variables. This result in a high efficiency in modelling the propagation and optimal control of the inflow uncertainty in reservoir operation, comparing to Monte Carlo method which normally sampling thousand times in each optimization routine.

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INCREASE EFFICIENCY OF VORTEX SETTLING BASIN IN IMBIBITION OF DAM'S RESERVOIR IN TIME OF FLOODWATER

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1. EXTENDED ABSTRACT

One obstacle of in imbibition of dam's reservoir in time of Floodwater is the Existence of Suspended sediment in floodwater. On the other hand because the lack of water resources in arid regions, providing of water is dependent on imbibition of dams. Thus existence of Suspended sediment in reservoir's water can malfunction in the imbibition programs. Also Entry of this sediments to hydraulic structures can disorder their Performance.

Using vortex settling basins can be suggested as a solution to control the amount of sediments. One of negative point of this basins is settling some part of sediments and not flashing from bottom outlets. In current paper we recommend

to use curvature submerge vanes for solving previous problems. The main propose of using this vanes is to adjust and increase the power of vortex flow and to locate the best place for installing curvature submerge vanes in the basin floor. The tests results illustrate that using this vanes with appropriate arrangement can flush out sediments of basin floor, while keeping basins efficiency. The best efficiency is for arrangements which are far away from orifice. More over while increasing Input flow and decreasing radial section of vanes, improves the efficiency of use curvature submerge vanes.

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GROWING NEED FOR STORAGE AS AUSTRALIA TRANSITIONS FROM COAL ENERGY TO RENEWABLES

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AUSTRALIA

1. INTRODUCTION

Climate change is a global problem. On 10 November 2016, Australia ratified the Paris Agreement, committing to achieve a 26 to 28 per cent reduction in greenhouse gas (GHG) emissions below 2005 levels by 2030. The energy sector accounts for 79 per cent of Australia's emissions and therefore will play a key role in Australia's reduction targets.

Australia's electricity system was founded on centralised, carbon-intensive coal-fired generation. Currently, coal-fired generation (both brown and black coal) makes up 78 per cent of electricity generation across Australia's National Electricity Market (NEM). The sector is the single largest contributor to GHG emissions, and contributes approximately a third of Australia's total emissions. As coal-fired power stations reach the end of their lives they will need to be decommissioned. A total of 45 TWh of coal-fired generation is set to retire in Australia.

Because of this, Australia's National Electricity Market (NEM) is going through a transition as it moves towards low-carbon-emissions generation in response to climate change. This is resulting in new opportunities for existing hydropower generators, leading to potential changes in operating regimes.

2. PROPOSED SOLUTION

The CSIRO’s Low Emissions Technology Roadmap has identified that the most likely pathway for Australia to meet its commitment to reduction in GHG emissions is to replace coal-fired generation with renewable energy, mainly wind and solar PV. However, these renewables are highly variable and non-dispatchable.

3. RESULTING NEED

As the proportion of variable renewable energy increases, increased storage is required for supply–demand matching to manage the variability in generation and provide the required system flexibility. Hydropower storage plays an expanding role in integrated power systems internationally and can enable increased use of intermittent renewable energy sources such as wind and solar.

With an increased amount of renewable energy within the Australian grid, hydropower storage has gained an increased focus, whether this be pumped storage hydropower, like the Kidston pumped storage project in Northern Queensland, or better use of existing hydropower storages, like Tasmania’s “Battery of the Nation” concept. Since connecting to the National Energy Market via Basslink in 2006, Tasmania’s flexible hydropower system has already acted as a giant 500 MW battery for Australia, because of our water in storage. This paper provides a brief summary on a number of hydropower storage projects currently being considered in Australia.

4. CONCLUSION

This paper demonstrates the growing importance of storage in Australia’s NEM as coal-fired generation is replaced by variable renewables. It also highlights the importance of hydro storage and how this can be achieved through either pumped storage hydropower or better utilisation of existing hydropower storages. It is highly probable that the transition to renewables will lead to a change in the way existing hydro storages are operated, not only providing energy but also grid reliability and flexibility.

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CLIMATE EFFECT ANALYSIS OF THREE GORGES PROJECT

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1. ABSTRACT

The climate effect of the reservoir is mainly reflected in the change of the earth's underlying surface from the original land to the water body ,It brings differences in thermal properties, radiation balance, heat balance and surface roughness, etc,The impact on the local microclimate in and around the reservoir area. Although the international community still has great controversy over the ecological and environmental impacts of large reservoirs, it is generally believed that the impact of reservoir completion and storage on large-scale climate is not obvious.

Chinese scholars study a series of large and medium-sized reservoirs, such as Longyangxia and Liujiaxia, and the results of the assessment of the impact of the local climate are also shown : After the reservoir is built, there will be some influence on the climate in the reservoir area and the adjacent area, but the range and extent of the influence are not large. The range of the temperature, precipitation, humidity and wind is generally not more than 10km, and the influence decreases with the distance.

Over the past 50 years the average temperature rise, precipitation has interdecadal characteristics. from 1999 the rainy period was less rain, The change of temperature and precipitation is basically the same as that in the southwest and the Yangtze River Basin .After the completion of the Three Gorges reservoir, the temperature in the vicinity of the reservoir area was fine-tuning, warm in winter and cool in summer . After the change of water level, the impoundment only has a slight

effect on the climate in some areas, but the influence range is not more than 20 kilometers. There is no obvious change in the climate of the reservoir and surrounding areas.

KEY WORD

Climate, Reservoir, Three Gorges Project

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DETERMINATION OF CONTROL WATER LEVEL ON SUTAMI AND LAHOR RESERVOIR TO AVOID THE POSSIBILITY OCCURS OVERTOPPING DUE TO PROBABILITY MAXIMUM FLOOD

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INDONESIA

EXTENDED ABSTRACT

This study needs to be done considering the extreme weather changes in recent years and the issue of global warming in the last decade that impacted the high intensity of rainfall and the change of land use in the upstream which affects the rise of runoff so that the flood discharge in the river becomes larger. Beside that, Sutami Dam and Lahor Dam at the time of planning (1975) is still designed with 1000 year return period of flood, while the dam safety standard set by the Dam Security Commission is currently the flood discharge of Probability Maximum Flood (PMF).

it is necessary to raise awareness of the possibility of a PMF by evaluating the spillway performance of the PMF discharge that exceeds the initial flood discharge. So that the effort of awareness raising that can be done by the dam operator is by maintaining the Control Water Level (CWL) of the reservoir, so that during the PMF discharge, the reservoir can still reduce the flood and the overtopping can be avoided or the frequency can be reduced minimally .It is an effort to manage the dam safety in the Brantas River Basin.

In the normally calculation of the PMF discharge can only represent the annual value. If this value is applied to the reservoir operation to maintain CWL it will cause a big losses. Because the volume of water that can be utilized must be wasted to maintain the CWL. Probability of PMF discharge is different for every month. Therefore it is necessary to do research to get the value of PMF discharge for each month to get different CWL for each month.

In the design flood analysis and flood routing analysis there are some related things that affect that is:

- The Sengguruh Dam located on the upstream of the Sutami Dam, resulting in a flood reduction by Sengguruh Reservoir. Biside that the outflow from Hydroelectric Power Plant of Sengguruh also affect the flood discharge into the Sutami Reservoir.
- The connection tunnel between the Lahor Reservoir and Sutami Reservoir affect on flood routing analysis. On the analysis also considered the incoming or outgoing discharge through the tunnel simultaneously by water level difference in both reservoirs.
- The outflow from hydroelectric Power Plant of Sutami is also taken into flood routing analysis of Sutami - Lahor Dam because the outflow value can reduce the peak flood discharge that occurring.

Several stages for the completion of this study are hydrological data processing which is principally rainfall design analysis for design flood and flood routing which include; a. Daily maximum rainfall analysis, b. Design rainfall Gumbel type I method, c. Probability Maximum Precipitation (PMP) analysis, d. Frequency distribution match analysis (Chi square & Smirnov Kolmogorov), e. Synthetic unit hydrograph analysis (Nakayasu), f. Design Flood hydrograph analysis, g. Curve reservoir capacity analysis and widespread reservoir (storage area curve), h. Spillway capacity analysis, flood routing analysis (spillway) and river routing analysis, i. CWL determination as a safe guideline to get flood peak reduction in order to avoid the possibility of overtopping, j. recommendations on maximum water level control at each month as a guideline for reservoir operations related to avoid the possibility occurs overtopping.

The method used in this study is to analyze of the design flood of PMF discharge & 1000 year return period discharge and simultaneously flood routing in the both of the reservoir, because both reservoirs are connected by a connection tunnel which connecting Lahor and Sutami Reservoir.

From the hydrology analysis annual PMF discharge of potentially occured on Sutami Dam value is 11.629,14 m3/dt, which is equivalent to 2,31 x Q1000 years return period discharge. While the annual QPMF potentially occur on Lahor Dams the dam value is 2731.00 m3/dt which QPMF is equivalent to 2,70 x Q1000 years. Based on the results of analysis of QPMF flood routing monthly CWL results that the maximum value moves in the range of minimum reservoir water level elevation of + 257.00 m and the maximum + 267.00 m. Where this value gives the analysis results that the potentially Sutami Dam overtopping still occur as much as 3 times the incidence in one year with the high water elevation 3.09 m above on top of dam elevation. Therefore, to anticipate the possibility of overtopping, structurally necessary to making an emergency spillway in Sutami Dam. While in Lahor Dam with a parapet wall hight of 1 m was not potentially overtopping.

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IMPACT OF UPPER YANGTZE CASCADE RESERVOIRS OPERATION ON THREE GORGES RESERVOIR IN IMPOUNDMENT PERIOD

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1. INTRODUCTION

The Three Gorges Reservoir (TGR) is the key backbone project for controlling and utilizing the water resources of the Yangtze River. Its normal storage level is 175 m, flood control level is 145 m, flood control capacity is 22.15 billion m3.TGR start to impound on October 1 each year and will impound water to 175m by the end of October or November. The impoundment of TGR is an important prerequisite for giving full play to its huge water supply benefits.A large number of reservoirs with large storage capacity and good regulation capacity have been built or will be built in the upper reaches of the Yangtze River. As the upstream reservoirs are gradually put into operation, the regulation of runoff by the cascade reservoirs will become more and more obvious.

2. METHODS

Based on the long series of runoff data used in the preliminary design, the long runoff data of TGR from September to October was calculated by considering the impact of reservoir water storage in upstream reservoirs at different levels.

Without reducing the design flood control standards of the Three Gorges Reservoir, a number of water storage schemes are formulated to calculate the full capacity of the Three Gorges Reservoir and seek for a better water storage scheme.

3. RESULTS

After the operation of the upstream large reservoirs, the runoff of Three Gorges Dam from September to October is 9.7billion m3 and 22.2 billion m3 less than that of the initial design value respectively, which has a great impact on the impoundment of TGR.In 2017 level year, TGR began to impound from September 10th and reached 90% of the designed rate. In the future level year, due to the large storage capacity of new reservoirs, it was necessary to store water in advance until September 1st, so that the design storage rate of 90% could be achieved.According to the present situation of scheduling rules, TGR began to impound from September 10th. Compared with the 145m water level, if the initial water level of TGR is raised up to 148m, 150m, 152m and 155m respectively,the average discharge can be increased by 350m3/s, 590m3/s, 860m3/s and 1310m3/s during the impoundment period.

4. CONCLUSION

In the 2017 level year, it is reasonable for TGR to start impounding on September 10 based on the current joint storage of cascade reservoirs in the basin. But the initial water level should be raised to the increase the discharge during the impoundment period.In the prospective level year, due to the large storage capacity of new large reservoirs,the impounding time of TGR will need to be arranged on September 1 in advance,in order to reach the designed full storage rate .The contradiction between the centralized storage and downstream water supply will be further exacerbated after the operation of the constructed and proposed reservoirs in the upper reaches of the Yangtze River .Therefore, the water storage scheme of TGR needs to be optimized continuously.

KEY WORDS

RESERVOIR OPERATION; RESERVOIR CAPACITY; FLOOD STORAGE; THREE GORGES RESERVOIR

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STUDY ON THE INFLUENCE OF CLIMATE CHANGE ON THE THREE GORGES RESERVOIR AND ITS COUNTERMEASURES

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CHINA

1. INTRODUCTION

Due to the climate change in the Yangtze River basin, it is found that the precipitation and runoff also changed obviously since the impoundment of Three Gorges reservoir. Also, extreme weather events such as frequent drought in dry season, strong flood in flood season, rare flood in non-flood season, aggravating the difficulty and complexity of dispatching in the TGP reservoir. This paper focuses on the impact of climate change on the operation of the TGP reservoir, and puts forward countermeasures for it: On the one hand, optimizing the TGP reservoir's dispatching mode, to adapt to the new runoff condition and regulation demand, and on the other hand, improving the emergency dispatch system and strengthening the reservoir's emergency management and control capability.

2. METHODS

According to the trend that the runoff decreased in flood season and the improved hydrological forecast technology, the TGP reservoir tries to take full use of flood resources rather than defensing flood singly. It regulates small-mid-flood by using the storage capacity below 155m combines with the hydrological forecast. Also, the impounding strategy is initially judged according to the long-term prediction and constantly and correcting according to the short-term prediction with high accuracy in the later. When the inflow forecast shows low, storing water in advance appropriately and making full use of the water in late flood season. If the forecast shows low continuity in the storage period, raising the water level in stages in this period, and the water level should be raised in different degrees according to the runoff reduction degree in the forecast.

In the emergency dispatching, the TGP reservoir management organization established a coordination system with different departments; also, enhancing operation situation analysis and premeditated simulation of accident, to prepare the emergent schemes in advance; thirdly, building the orderly emergency management system.

3. RESULT

Under the implementation of this optimization method, the TGP reservoir combines the flood control and water storage work. Flood resources in late flood season are fully utilized. The TGP reservoir has successfully stored to 175m for eight years since 2010.

The TGP reservoir made many breakthroughs for emergency assistance with the orderly system, and gives great assist in the electricity guarantee, shipping, water replenishing water and flood control.

4. CONCLUSION

The utilization of flood at the end of the flood season can create favorable conditions for the water storage. The water level elevation in September can effectively ensure the reservoir’s full filled. It regulates with separated methods in different wet level can guarantee the completion of water storage tasks at different runoff levels. Also, with the emergency system, the TGP reservoir improves its ability to deal with emergencies and brings remarkable social benefits.

KEYWORDS

Climate change、Runoff change、Extreme weather event、Optimal dispatching、Emergency dispatching

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A CHANGING FLOW REGIME IN CENTRAL GERMANY: MAGNITUDES, CAUSES AND EFFECTS ON RESERVOIR MANAGEMENT*

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ABSTRACT

The Harz is the main water tower in central Germany and its water resources have been developed since the 16th century to support the mining industry and since the 19th century for public water supply. Today, nine multi-purpose dams in the Harz provide high quality raw water for public water supply. Neustadt dam is the Southernmost and smallest of these nine dams and is fulfilling its water supply function since 1905. At present, all safely available water is committed in a raw water supply contract and the buyer – a local water company – has requested to increase the water withdrawal in the future. On the other hand, with a fully committed water balance, any long-term or sudden changes in the dam's inflow regime would have a direct negative impact on safe water withdrawal. In this paper, long-term records from the dam's inflow gauging station, two nearby stream gauges, two met stations, three rain gauges and a phenological station were analysed for any shifts or changes. The investigation revealed significant changes in in the flow regime. Firstly, starting in the late 1980s, monthly maximum reservoir inflow shifted from April towards the beginning of the year. Secondly, mean summer runoff had decreased by 35 %, and in some months by up to 55 % in the last 30 years. A breakpoint analysis revealed 1987/88 as a statistically highly significant point in time when these

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* *Changement du regime hydrologique en Allemagne centrale: magnitude, causes et effets sur L'EXPLOTATION DU RESERVOIR*

changes occurred, this finding was independently confirmed by data from two nearby gauging stations. The observed changes in the flow regime could not be explained by precipitation data at the site, which showed neither any significant trends nor any breakpoints. This implies a change in the partitioning of precipitation into runoff, evapotranspiration and groundwater recharge. Because of the geological characteristics of the catchment area, both groundwater recharge and subsurface runoff are negligible. The working hypothesis is that a shift of runoff volume towards evapotranspiration has occurred after the 1987/88 breakpoint. This hypothesis is supported by the direct link between measured increases in air temperature and potential evapotranspiration. Furthermore, phenological observations and seasonal temperature sums provide clear evidence of an earlier onset and longer duration of the vegetation season at the site. Going forward, it is expected that future trends and sudden shifts of meteorological and hydrological parameters will potentially increase the demand and expectations of society on dams and their buffering role in the hydrological cycle. However, some of these functions and purposes are contrarian to each other, hence dam management will potentially become more challenging. Finally, several remedial adaptation strategies for dam operators with a fully committed water balance are discussed in general and the two approaches towards increasing safe water withdrawal from Neustadt dam are briefly outlined.

Figure 1.
Neustadt dam in the Southern Harz mountains

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STUDY ON RISK ANALYSIS FOR FLOOD PREVENTION AND DAM SAFETY BASED ON STOCHASTIC SIMULATION*

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1. INTRODUCTION

Risk depends on probability of failure and loss of hazard. In this article, we focus on dam failure probability caused by flood related problems. Based on dam failure statistics, the flood-related risk probability for dam failure is approximately 10^{-4}. Based on stochastic simulation, we researched in the view of: (1) flood control potential of dam itself, (2) flood control capability of dam and, (3) flood prevention for downstream regions provided by dam. The case study is 4 built cascade reservoirs in the Jinsha River, China. Based on statistical parameters obtained from observed 49-year flood peak series of 3 hydrological stations in the study area, climate change is studied and stochastic simulation is adopted to reflect the uncertainty of flood inflow. The calculation and procedure will contribute to conduct flood-related risk analysis for dam safety.

* *titre de l'article complet*

2. METHOD

Based on annual flood peaks series observed in representative hydrological stations, The GAMLSS (Generalized Additive Models for Location, Scale, and Shape) model is introduced to reveal the trend of flood peaks and identify a stationary series. The average (EX), coefficient of variation (Cv) and skewness (Cs) are calculated following a P-III frequency distribution and 40000 flood peak samples are generated. Based on hydrological analogy method and typical hydrograph, flood inflow is obtained. After flood regulation, the maximum stage of reservoir under different probability can be calculated. The probabilities of not exceeding initial stage, exceeding stage of check criterion and overtopping are acquired.

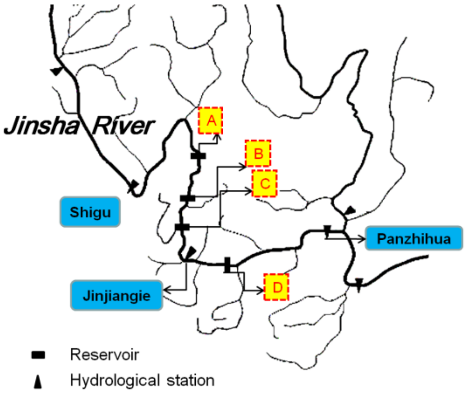

Fig. 1: Location of cascade reservoirs and hydrological stations (The 1st, 2nd and 3rd cascade reservoirs were located between the 1st and 2nd hydrological station, and the 4th reservoir lies between the 2nd and 3rd hydrological station)

3. RESULT

For the case study, the probability of overtopping determines dam safety, which must be lower than 9.47×10^{-5}. The probability of exceeding stage corresponding to check criterion of flood prevention reflects flood control capability of dam, which need satisfy check criterion for flood prevention of dam (in this article, the value is 2.0×10^{-4}). The probabilities of not exceeding initial stage shows flood prevention for downstream regions provided by dam.

KEYWORDS

Flood control; hydrology; safety of dams; Risk analysis; risk analysis for dam safety; flood control and dam safety; overtopping risk analysis

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EROSION AND SEDIMENTATION OF UPSTREAM ASAHAN AND ITS COUNTERMEASURES FOR THE SUSTAINABILITY OF SIRUAR DAM NORTH SUMATERA

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1. INTRODUCTION

Asahan River becomes the main source of water flow for Siruar, Sigura gura and Tangga Dam. The Siruar dam serves to regulate the stability of the water coming out of Lake Toba to the Asahan River and to supply water to the power station constantly to the Asahan hydroelectric power plant (Asahan I, Siguragura and Tangga power plant). This type of dam is a mass concrete with a height of 39 meters.

Since the changes of land use in the most Asahan catchment area, erosion and sedimentation became problem for the Siruar Dam especially for the operation of Asahan I hydroelectric power plant. Jasa Tirta I as state own enterprise which has authority to manage water resources in Toba Asahan River Basin (given by Government with Presidential Decree No. 2/2014) conducted comprehensive study to indentify the rate and sources of sedimentation and the countermeasures as well in 2016 - 2017.

2. DATA COLLECTING METHOD

The primary data taken by topographic survey, bathymetry and also sediment sampling along 14.5 km of upstream Asahan and 5 km of its tributaries which are Bolon and Mandosi River, and water sampling for quality test. In order to get deeper analysis, secondary data also collected through government institutions such as statistical agency, planning and development agency, geophysics and meteorology agency, ministry of public works and ministry of forestry.

3. ANALYSIS AND RESULTS

The study identified that the sediment rate per year is 20.25 ton/ha. The grain sediment analysis also showed that 50% of sediment which setlles in river bed is sand. The sources of the sediment were from the lake and from Asahan tributaries which are Bolon and Mandosi river. From the water quality analysis, chlorine has significant parameter for the Asahan water. Asahan River, of which a major part is used by the people around Toba Samosir Regency, is utilized as a place for washing, bathing, industry, and agricultural activity runoff.

THE COUNTERMEASURES OF SEDIMENTATION

Based on the Technical Plans for Rehabilitation of Forest and Land Asahan Barumun Water Catchment Area 2015–2029 by Ministry of Forestry, targets of erosion control in the study area are established to be at least equivalent to the target of erosion control in the Toba Asahan watershed.

Table 1
Proposed Program for Sediment Countermeasure (data processing 2017)

Indicator	Natural Condition	Exsisting Condition	Target of Sediment Control by Ministry of Forestry	Proposed Target of Study	Projection
The erotion hazard level → light and very light	78,3 %	63%	>50%	>70%	72,8%
Sediment rate per year	11,5 ton/ha	20,25 ton/ha	<20 ton/ha	<15 ton/ha	14,7 ton/ha

Gully plugs	= 300 units
Check dams	= 10 units
Strip Vegetation	= 160 ha
Reforestation	= 13.074 ha

Another approach for sediment control management is dredging works. The analysis showed that dredging works have to be done regularly with estimate volume of 21.000 m3 in order to maintain sedimentation.

4. CONCLUSION

The objective of this study is to identify the rate and sources of sedimentation at Upstream Asahan and the countermeasures as well in order to ensure the sustainability of Siruar Dam and Asahan hydroelectric power plant. From the analysis, the rate of sedimentation reached 20.25 ton/ha/year and 50% which settled in river bed was sand. Changes of land use has important role to speed up the sediment rate, therefore conservation of land, reforestation and civil conservation approach such as check dams, gully plugs have to be done. Another technical approach to maintain deposit sediment in the river is dredging works. The study recommends for regular dredging with estimate volume of 21.000 m^3 sediment per year.

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EVALUATION OF SEDIMENT MANAGEMENT EFFECTIVENESS TO EXTEND THE WLINGI RESERVOIR LIFETIME

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EXTENDED ABSTRACT

Wlingi Reservoir is one of the reservoirs in the Brantas River Basin management system. Besides as a flood control, this reservoir has an important role as a supplier of 2 x 27 MW of electrical and serves irrigation area of 15,132 Ha. The reservoir was completed in 1979 and has total storage capacity of 24 million m3, however due to severe sedimentation caused by Mt. Kelud eruption and critical catchment condition, by the year of 2016 its capacity decreased to only 2.55 million m3 or 10.63% of the initial capacity.

Total volcanic eruption in 1990 (estimated by the Volcanic Directorate of the Department of Energy and Mineral Resources) was approx. 125 million m3, which 22.3 million m3 of it deposited at Wlingi Reservoir through the Lekso, Semut, Jari, Putih and Kali Abab rivers. Wlingi Reservoir has a sedimentation rate of 0.81 million m3 per year or 3.34% of reservoir per year, which the Sutami Reservoir, the largest reservoir in the same basin, has a sedimentation rate of 5.07 million m3 per year or 1, 47% of reservoir per year. From the data it appears that the sedimentation rate at Wlingi reservoir is 2.3 times the largest reservoir in the same river basin. This indicates that the sedimentation rate in Wlingi Reservoir is very large.

To extend the economic lifetime of the reservoir, many efforts have been undertaken, including some preventive activities through conservation in the upstream areas as well as some corrective measurements. Some corrective measurements that have been done are sedimentation dredging (through spoil bank disposal and riverine disposal) and sedimentation flushing. Based on technical and financial aspect, sedimentation flushing is considered more efficient than the other measurements. Based on the technical evaluation, sedimentation flushing can remove approx. 300,000 m3 to 1,2 million m3 sediment per year from reservoir, which is higher than the sedimentation dredging that only remove approx. 100,000 to 350,000 m3 per year. Based on the financial evaluation, sedimentation flushing can save the cost of Rp. 35.85 billion compared to dredging with spoil bank disposal, while dredging with riverine disposal to channel below can save about Rp. 14.96 billion compared to the dredging with spoil bank disposal. Another advantage of sedimentation flushing is the supply of 300,000 m3 up to 1.2 million m3 of sediment per year that may tackle the issue of riverbed degradation at the downstream part of the reservoir, which is currently the riverbed degradation is happened approx. 2 to 8 m caused by rapid illegal sand mining. However flushing implementation should consider the availability of water so it cannot be done every year.

Over the past five years, the average sediment that flows to downstream is 350,865 m3/year. While the amount of sediment that can be supply form dredging with riverine disposal to channel below is 250,475 m3/year. If the amount of illegal sand mining along the Brantas River in lower reach of Wlingi dam is 2,470,600 m3/year, and there is no dredging with riverine disposal to channel below, flushing should be done 7 times a year. This is very difficult because the implementation of flushing is depend on the available inflow. Implementation of dredging 2.4 million m3/year with riverine disposal to channel below in Wlingi Reservoir requires a huge cost which. The possible efforts have be done through sustainable public persuasive and constructive actions through controlling the illegal sand mining.

KEYWORDS

Wlingi Dam, flushing, dredging, sedimentation.

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EVALUATION AND MITIGATION OF THE BOGEL RIVER FLOOD, BLITAR, PROVINCE OF EAST JAVA, INDONESIA

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ABSTRACT

Bogel River located in Sutojayan area, Blitar, Province of East Java. It collected into the Brantas River about +1.5 km from the upstream of Lodoyo Dam. It have several subordo river in the upstream there are Kedungpuring River, Kedungunut River, Pijeran River, Kedungriwuk River, and several other subordo river. Seasonal type, Bogel River often overflow and impact of flood in the surrounding area, especially in Sutojayan area. Its because of the land condition in the catchment area already critical / bald and the silting up of the several suborder river in the upstream. Beside that Bogel River system is also used for irrigation. Jasa Tirta I Public Corporation have developed an early warning system and done the handling activities during flood events, although it’s not included in working area of the Jasa Tirta I Public Corporation. Mitigation of Bogel River flood until today just partial and emergency activities. So it is necessary for arrange the comprehensive and integrated study and flood mitigation management, supported by the Government and related stake holder. To get the right solution for mitigation the flood of the Bogel River, need a concept in all aspects and stages, so it can give the real benefits and on target. The method used are direct controlling by (a) operating the Lodoyo weir according to Dam Operational Guidelines, Procedures and Work Instructions of Flood Control, (b) arrange the evaluation for historical flood that ever happened, (c) arrange the concept of the proposed for flood mitigation by making the comprehensive study of flood mitigation, short term action 2016, middle term-long term cction, (d) completing the hydrology observation instruments in Bogel River System. By these integrated flood mitigation concepts in Bogel River will completing the efforts that have been done by Jasa Tirta I Public Corporation, directly and emergency action by participation from all stakeholders according to the authority. By normalitation of the condition and function of the existing water resources infrastructure, the flood control system can be implemented optimally. Of course, the real efforts can be realized so as to built the preparedness for possible flood and reduce the impact that especially for regions and communities in the district Sutojayan, Blitar. It is also become the responsibility of Jasa Tirta I Public Corporation in water resources integrated management.

KEYWORDS

flood, mitigation management, Lodoyo weir, Bogel River

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SETTING UP DREDGING AND SPOILBANK MANAGEMENT METHOD TO RECOVERY HYDROPOWER PRODUCTIVITY OF SENGGURUH DAM

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ABSTRACT

Sengguruh dam located in Brantas River watershed, East Java, Indonesia was completed in 1988. The objectives is for generating hydroelectric power plant with installed capacity 2 x 14,5 mW produce of 91 million kWH per year. Located at uppermost of the series dams in Brantas River Basin and therefore is utmost suffered of sedimentation. Also, it prevents sediment comes to the Sutami which is the biggest reservoir at down stream part. The inflow come from two main rivers, namely Brantas River and Lesti River has a catchment area of 1.659 km^2. The condition currently declining due to the high rate of sedimentation. Based on the echosounding result conducted in 2016, is known that effective capacity has been reduced to 0,6 million m^3, or approximately 24% of the initial conditions of 2,5 million m^3 and electric generation has been reduced to 68,8 x 10^6 kWH. The dredging activity has been done routine every year from year of 2001 with an average dredging volume of 300,000 m^3/year. Total achievement of the volume of dredging result seems large, but it is not adequate. Based on the present evaluation, particularly in the zone at front of hydropower intake (namely zone 1), was in fact already quite critical because the sediment is getting closer. The zone distance is about 100-200 m with the difference elevation from sediment surface reaching 7-12 m above desired reference base elevations. On contrary, the dredging has been done in the upstream area which is quite far away ± 1,500-2,000 m from zone 1 due to get close of spoilbank location. In order to sort out the problem and to support President Joko Widodo's Government policy in energy security, the dredging method in 2016 was changed. The innovation and development of methods to improve its effectiveness are (a) with the combination of 2 dredging types using available dredgers and additional heavy equipment (amphibious excavators) to take out sediment which located at positions could not be done by dredgers (dry-wet excavation), (b) installation of booster pump and floating pipe as support of the dredgers, (c) modification of dredger ladder, (d) management of spoilbank by re-arrange of hauling and reloading cycles, and accelerate sediment material drying by installing vertical-horizontal drainage. By these methods the dredging of sediment can be implemented more effectively and efficiently to ensure high hydropower production, maintain effective storage capacity and prolong age of reservoir with of course considering environmental aspect around the area.

KEYWORDS

dredging, sedimentation, hydropower productivity, Sengguruh Dam

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NUMERICAL SIMULATION AND EXPERIMENTAL RESEARCH ON REGULAR MECHANISM OF LOCAL CLIMATIC CHANGES AROUND GIANT HYDROPOWER RESERVOIR

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1. INTRODUCTION

Hydropower station and giant reservoir have great effect on local climate when water level and quantity are variable,especially in the transitional seasons.How does they effect the surrounding and what could be done to use its advantages as well as avoid risks are quite important to the society development.

2. GENERAL LAYOUT

2.1. METHODS

A calculated model was built based on the theory analysis and contrasted with eight-year measured data of more than 10 biliion m^3 reservoir to verificate processing principles.

2.2. RESULTS AND CONCLUSION

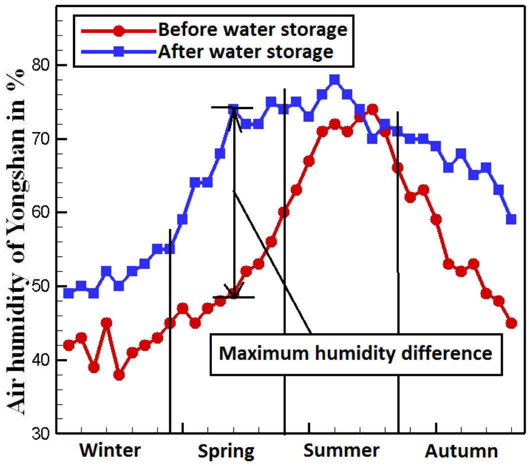

Fig. 1: Air humidity comparison of A County pre and post water storage

Air temperature of A County and B County display some differences pre and post water storage,especially in the winter and summer seasons,with the maximum temperature differencesbeing7℃ and 3.8℃ respectively.

After water storage in the reservoir,air temperature is more stable than previously. In addition, air temperature effects depend on the distance from the dam to the data measuring points and are more obvious at closer locations.

After water storage in the reservoir,air humidity increases largely in the seasons of winter,spring and autumn, with little rise in summer.Air humidity of A County behave similarly to B County,but the former is more obviously affected than the latter.The maximum air humidity differences are 25% and 18% respectively.

Precipitation of A County and B County increase all year round, as well as during the flood season.Annual increases in precipitation are 70% and 31 % respectively,and the main precipitation is concentrated during the flood season,which warns that human beings should expect extreme weather events and potential flood disasters in this period.

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RUNOFF AND SEDIMENT TRANSPORTATION IN UPPER AND MIDDLE REACHES OF JINSHA RIVER

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EXTENDED ABSTRACT

Jinsha river is the lower stretch of the source region of the Yangtze river, whose runoff mostly delay on the melting of glaciers, and is greatly affected by climate change. Otherwise the hydropower resources is rich in Jinsha basin, and since the Jin Anqiao Hydropower Station has been built in December 2010, several reservoirs have impounded successively. A reservoir group has been formed in middle reach of Jinsha river basin, which plays a huge role in intercepting sediment.

Through statistical analysis of water and sediment data of Zhimenda, Shigu and Panzhihua hydrologic stations in the upper and middle reach of Jinsha river basin, this paper presents the sediment transport characteristics of the reach, including the sediment sources and distribution, the annual variation and annual distribution of sediment load. Then, the method of multiple regression analysis was used to evaluate the sediment trap amount of the reservoir group in the middle stretch.

The calculated results showed that, during year 2001 to 2016, the annual average runoff amount of the Zhimenda station has increased about 24.24% than that of year 1957 to 2000, but the runoff of Shigu and Panzhihua stations haven't changed much. Compared to the annual average sediment discharge of year before 2000, during year 2001 to 2010, the three stations have increased 6.97%, 28.94%,4.75%,respectively; during year 2011 to 2016, the Zhimenda and Shigu station both increased about 11%, however, the Panzhihua Station decreased

about 88.21%. The sediment trap amount of the reservoir group in the middle reach of Jinsha river is about 2.08×108t during year 2011 to 2016.

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STUDY ON THE SEDIMENTATION CHANGES IN THE MANWAN RESERVOIR ON THE LANCANG RIVER*

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1. INTRODUCTION

The Lancang - Mekong River, originating from the Tanggula Mountains in Qinghai-Tibet Plateau of China, flows from north to south successively across Qinghai, Tibet and Yunnan in China, and then Myanmar, Thailand, Laos, Cambodia and Vietnam.The Manwan HPP is the most typical case of reservoir sedimentation problems of the Lancang River.

2. METHODS

According to the current situation and characteristics of the reservoir area of the Manwan HPP, the following underwater topographic survey plan shall be implemented: A multi-beam sounding system shall be used to collect the cloud data of underwater high-density points.For topographic survey on the shore, GPS-RTK shall be the main collecting mode while using the total station as assistance.

The sedimentation of the main stream of the reservoir is calculated by the constant flow unbalanced sediment transport method through the program SUSBED_2 provided by Wuhan University of Hydraulic and Electrical

*titre de l'articlecomplet

Engineering. The WUHEE Zhang Ruijin Formula is adopted as the sediment carrying capacity formula of suspended load.

3. RESULTS

According to the calculated results: Affected by the sediment retaining of the Xiaowan HPP located upstream, the inflow sediment volume in the Manwan HPP decreased a lot, and it is predicted that the sedimentation volume below the normal water level will be 18.6 million m3 after 20 years, of which the sediment-caused storage loss rate is 6.17% compared with 2014; The sedimentation volume within the dead storage capacity is 11.32 million m3, of which the sediment-caused storage capacity loss rate is 9.63% compared with 2014; and the sedimentation volume of effective storage capacity is 7.29 million m3, of which the sediment-caused storage capacity loss rate is 3.97% compared with 2014.

4. CONCLUSION

Sediment of the whole reservoir is mainly deposited below the dead storage capacity. The Xiaowan HPP was impounded in 2009, which greatly relieved the sediment problem of the Manwan HPP. The storage below NWL, dead storage capacity and effective storage capacity have little change compared with the previous data. The total loss rate of the effective storage capacity below the normal water level - of 994m is 15.21%, and the total loss rate of the storage capacity below the dead water level - elevation: 982m is 77.47%.

Suggestions:

(1) After completion of the Xiaowan Reservoir, the data of the inflow and outflow sediment have been changed fundamentally, the sediment observation and analysis shall be conducted to know the rules for the sediment transport in the Manwan Reservoir, forecast the sediment problem in the reservoir and instruct the operation of the plant.

(2) Regularly (normally 2---3 years) measure the cross section of sedimentation in the main stream and tributaries and the topographic map in the Manwan Reservoir.

(3) Pay attention to the soil and water conservation. Continuously insist on the operation mode of the reservoir - “Storing Clear Water and Releasing Muddy.”

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ANALYSIS OF KEY INFLUENCING FACTORS FOR THE EVOLUTION OF THE SAND BAR IN THE TRIBUTARIES IN THE XIAOLANGDI RESERVOIR AREA

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1. INTRODUCTION

Sand bar is a geomorphologic pattern. For reservoirs, San bar blocks river mouth of tributaries, reduces storage volume of reservoirs [1]. Limited by the complexity of the problem and traditional techniques, former research on sand bar mainly fixed on the influence of a single factor [2]. With the development of new analysis techniques, now the research turns to be quantitative [3] and modelling [4].

2. METHODS

Using dimensionless parameters, this paper set a multiple regressive formula between the height increment of sand bar and different influencing factors. The form of the formula is as follows:

$$\hat{Y} = K\hat{X}_1^{\alpha_1}\hat{X}_2^{\alpha_2}\ldots\hat{X}_n^{\alpha_n} \tag{1}$$

in which $\hat{Y}$ is a dimensionless dependent variable ($\hat{Y}_1$ means a dimensionless factor of the annual height increment of sand bar, $\hat{Y}_2$ means a dimensionless factor of the annual depositing volume of sand bar), $\hat{X}_1, \hat{X}_2, \ldots, \hat{X}_n$ are dimensionless independent variables (including water and sediment conditions, local terrain conditions and local flow regimes), K, α_1, α_2,…, α_n are undetermined coefficients.

3. RESULTS

A selecting regression model was obtained separately by forward and stepwise regressive methods as follows:

$$\hat{Y}_1 = 0.0736\hat{X}_1^{0.415}\hat{X}_6^{1.151} \qquad (R^2=0.631) \qquad (2)$$

$$\hat{Y}_2 = 3.540\hat{X}_2^{*1.428} \qquad (R^2=0.801) \qquad (3)$$

4. CONCLUSION

The evolution of sand bar in Xiaolangdi reservoir area, is related to the water and sediment conditions, local terrain factors in the tributaries and main channel, location of the front of the delta in the reservoir area and others.

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SEDIMENT MANAGEMENT STRATEGIES FOR HYDROPOWER RESERVOIR IN AGRICULTURAL AREA

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ABSTRACT

Ringlet reservoir is a multipurpose reservoir that is part of Cameron Highlands – Batang Padang Hydroelectric Scheme. The reservoir has the original design storage of 6.7 million m^3, of which 2 million m^3 is dead storage and 4.7 million m^3 is live storage. The catchment is a famous tourist area with active highland agricultural activities. Changes in land use have been significant since 1960's, showing an increase in agricultural area and reduction of forest cover.

A number of studies were conducted in the past to examine the effects of land use changes on the operation of the hydroelectric scheme. Based on survey and sediment monitoring records, the sedimentation rate has increased by 6 times from original design of 25,000 m^3/year (in 1960's) to an average of 139,712 m3/year in 2010, causing a significant reduction of total storage capacity of Ringlet Reservoir from 6.7 million m^3 in 1965 to 3.1 million m^3 in 2008. Bertam Intake, which is the main power intake is often choked by the sediment built up within the area.

To continue the hydropower operation, various mitigation strategies have been implement such as development of an Integrated Lake Basin Management Plan for Cameron Highlands' catchment to control sediment production at source. At the same time, sediment in Ringlet Reservoir is continuously removed via dredging. The dredged material is dried temporarily at the designated decantation area and disposed at the selected areas. Dredging is not a sustainable solution, mainly due to larger sediment loads entering the reservoir as compared to capacity of removal. Land availability for disposal area is becoming limited in the future and subsequently increase the total cost of removal. Another strategy considered is construction of two (2) check dams and settling basins at the main inlet rivers into Ringlet Reservoir, namely Habu and Ringlet check dams. Mechanical excavation at the check dams is cheaper than deploying dredger to remove sediment from inside the reservoir.

In conclusion, managing hydropower operation in rapidly changing land use especially in agricultural area is challenging. Rate of reservoir sedimentation in this area can easily exceed the original design, causing the reservoir operators to carefully plan ahead to manage the potential problems. TNB as the responsible manager, has done extensive works to manage and mitigate the sedimentation problem faced at Ringlet Reservoir. Other options such as controlling the reservoir operating regime and operation of the low level outlet can also be considered. There are still other ways to improve the current sediment management practice and they require extra effort to ensure the sustainability of the operation.

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OBSERVATION AND ESTIMATION METHOD OF SEDIMENT PRODUCTION IN KAMANASHIGAWA BASIN, FUJIKAWA RIVER SYSTEM TOWARD AN ACCURATE ESTIMATION OF DAM SEDIMENT VOLUME

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1. INTRODUCTION

The sediment storage in a dam is usually designed based on the cases which have similar watershed condition or sediment discharge in the nearby area, but not calculated directly from the sediment observation data in the watershed. Furthermore, the inflow of sediment due to flood events after dam construction is only accounted by total sediment volume. Besides, the sediment that flow into dam reservoir during a flood and the unstable sediments reserved in upstream that will become the supply resource in the future, are not under observation yet.

In this paper, some consideration to improve the estimation method for sediment discharge in a watershed were conducted for sediment management in dam operation, by combining observation data of the sediment transport obtained by various equipment such as hydrophone, turbidimeter, and that predicted by satellite SAR image interference analysis, in Omukawa River, a right branch of Kamanashigawa, Fujikawa river system, Japan(Fig.1).

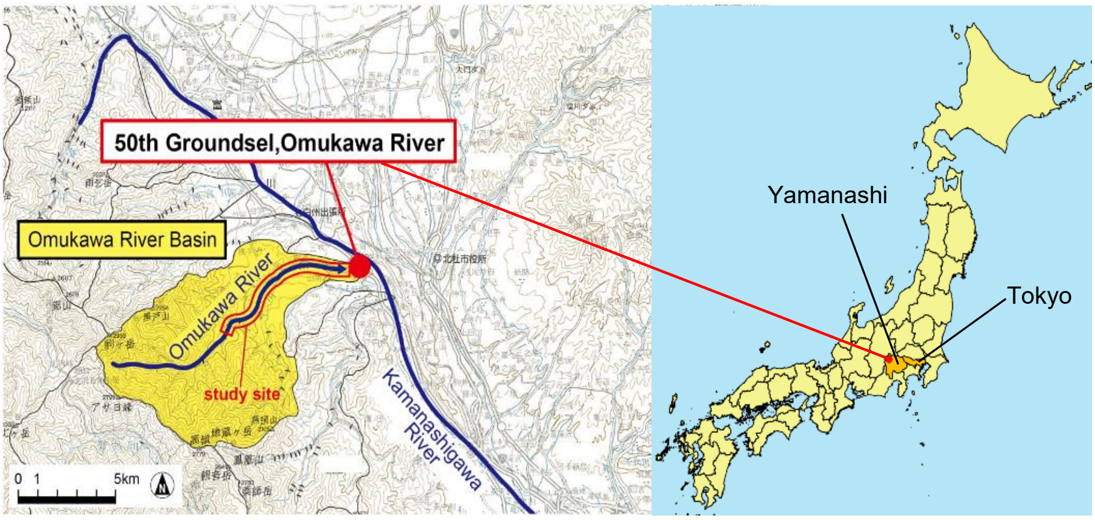

Fig. 1
Sediment discharge observation site map

2. ANALYSIS METHODS

Using the middle to downstream section of Omukawa River (extension L = 8.3 km, gradient 1/58) as a study site, a comparison between the volume of sediment transport obtained by SAR image interference analysis using 9 SAR images acquired by the ALOS-2 satellite passing over JAPAN, and the sediment discharge observed by hydrophone, turmidimeter and sediment trap pit during 2014-2016 period, is conducted. Some considerations were made for the results.

3. RESULTS AND CONCLUSION

The result shows that, although the data show relatively large scattering, an approximate linear correlation was recognized.

The reason of the difference between two data is assumed that sediment discharge is measured in only 2.0m wide area with respect to the river width of 72 m, which is not adequate for representing the entire river cross section.

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EXPERIMENTAL DESIGN OF A TARGETED WATER RELEASE TO FLUSH SAND OUT OF THE BYPASSED REACH OF THE SELVES RIVER*

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Integrated management of sediment and flows downstream of dams is still relatively rare, including in France. Flow experiments are often necessary to determine appropriate management actions and to verify that environmental objectives (often various) are being met. One of these objectives may concern reducing sand accumulations in downstream reaches that occur as a result of reduced bed-mobilizing flows and high sediment load from tributaries.

This is the case of the Selves River (164 km² watershed in the Massif Central - France) downstream of the Maury dam, which creates a reservoir with a 35 million m3 storage capacity. Flow diversion has a major influence on both average flows and floods. Dam spillovers are infrequent : a single event has occurred since the impoundment of the dam in 1947. The bypassed section downstream of the dam is approximately 11 km long. This section is located in a

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* *Dimensionnement de lâchers d'eau expérimentaux pour dessabler le tronçon court-circuité de la rivière Selves*

narrow valley with numerous tributaries, which load large quantities of sand during thunderstorms. Because of flow reduction downstream of the Maury dam, most of this sand accumulates in the riverbed of the bypassed section. This sand accumulation has been documented by both stakeholders and the local hydroelectric company, Electricity of France (EDF), for several years. It has therefore been decided jointly to implement targeted water releases to remove the excess sand in order to improve fish habitat (refuges and reproduction zones).

The objective of this presentation is to present the targeted water release experiment that was designed and implemented to flush the accumulated sand further downstream. The first empirical calculations estimated that the displacement rate of the sand would be about 10 m3/s. Implementing a water release at a discharge below this value would risk using water with no significant effect on riverbed morphology. Therefore, 3 operational water release tests (10, 15 and 20 m3/s) were carried out in September 2016 to define the discharge necessary to transport a maximum of sands without mobilizing the coarser elements (gravels and pebbles) necessary to aquatic organisms. The release duration was limited to 5h for each test to minimize environmental impacts and potential problems associated with dam operations.

Suspended sediment monitoring carried out during the releases show a recovery of the stock of fine sediments (clays - silts) present in the bypassed section. This monitoring was supplemented by geomorphological monitoring in the bypassed section. At 116 transects along the bypassed section, numerous morphological variables were measured before and after the releases: water depth, fine sediment thickness, bankfull width, etc.). At 5 stations spread across the length of the bypassed section were used to describe more precisely the evolution of the most sandy areas, using different techniques (densified transects, painted tracer particles, scour chains, etc.). At one of the stations, fluorescent particles (2-4 mm) were added prior to releases to observe the distance traveled by the particles as a function of the released discharge. Finally, on the most downstream section, monitoring by Helley Smith and with a hydrophone was carried out, in particular to test and improve the performance of this type of equipment for small sediment grain sizes. In addition, biological monitoring is underway to elucidate the long-term ecological effects of the releases. The latter two approaches will only be partially discussed here.

The results indicate that the flow rates were selected in the appropriate range for the stated objectives. Furthermore, it was possible to determine the optimum discharge for future releases: a flow rate equal to 10 m3/s allows a significant mobilization of suspended sediments and a flow rate of 15 m3/s allows for substantial mobilization of the sandy elements. Above 15 m3/s, although the risk of mobilizing coarse elements remains relatively low, the cost-benefit ratio of this discharge level does not appear to be advantageous. From an environmental perspective, the different objectives were achieved. The evacuation of fine sediments from the bypassed section was effective. The releases did not cause a significant export of coarser particles and did not lead to clogging of the slow or deep habitats, which could serve as a refuge or spawning areas for aquatic fauna.

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DAMS AND RESERVOIRS - CLIMATE CHANGE ADAPTATION STRATEGY

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1. INTRODUCTION

The aim of the project (funded by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, BMUB) is to develop adaptation strategies for dams and reservoirs that take into account shifting precipitation regimes and their resulting discharge and water quality conditions. The emphasis is on the early recognition of droughts and the respective reservoir management. Suitable hydro-meteorological indices are selected and further developed in order to identify the need for counter action at an early stage. Based on this, necessary site-specific solutions can be worked out for each reservoir. The course of action identified during the research project is considered to be transformed into a guideline for Germany.

2. METHODS AND FIRST RESULTS

Hydro-meteorological indices play a crucial role in the project. As indices have differing inertia and apply to different periods, they can be used for predictive operation. The appropriateness of these indices, the way they should be interpreted and their skill regarding early detection of hydrological stress, is tested by conducting hindcast experiments. Indices providing the best skill are selected for conducting forecasts using data from climate centers. For a start, the

Standardized Precipitation Index (SPI) was used for various ground stations in Germany. Forecast data on precipitation from the National Oceanic and Atmospheric Administration (NOAA) are utilised. Since May 2011, NOAA issues long-range predictions based on monthly values. Bias correction was performed by formation of monthly factors. The results were evaluated by means of goodness of fit measures such as Pearson coefficient, bias error, mean absolute error and mean square deviation. A direct comparison of original NOAA monthly mean values with the values of the stations showed that amplitudes are not sufficiently reflected. After the bias correction, the range of observed values was covered and an improved representation of inter-annual patterns was accomplished. Based on observed and bias-corrected NOAA data, the SPI was then calculated for different aggregation periods. The SPI using only observed data was compared with the SPI obtained by considering different fractions of observed records and NOAA forecasts. Fig. 1 shows results for a ground station in eastern Germany. The SPI using NOAA forecasts reveals a good fit in comparison to the SPI based on measured data and more significantly exhibits the same tendency for upcoming dry periods.

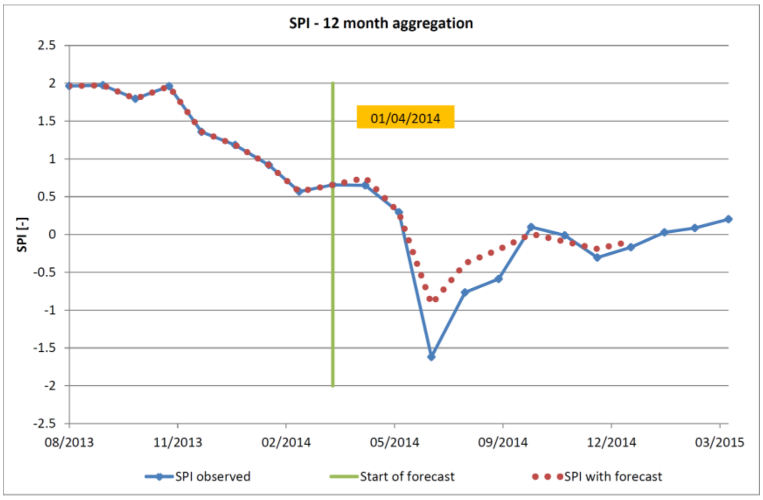

Fig. 1

SPI calculated with observed / NOAA forecast data, example eastern Germany

3. CONCLUSIONS

Conclusions are that using hydro-meteorological indices instead of a direct use of NOAA forecasts results in a better robustness of drought detection. The SPI calculated using forecasted data adequately represents the SPI calculated from observed data. In particular, upcoming dry periods can be detected using the forecasts. Further steps in the study will involve testing different indices and establishing generalized approaches for integrating index forecasts into reservoir operation.

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APPLICATION OF WATER QUALITY INDEXES FOR QUALITY ASSESSMENT OF ZAYANDEHROOD DAM RESERVOIR

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1. INTRODUCTION

The storage water in Zayandehrood dam reservoir is supplies drinking water demand of around 5 million peoples and also for agricultural and industrial consumption. The reservoir nominal capacity is 1.5 B m^3 and nowadays deceased to less than 200 M m^3 due to drought period. The present study aimed to explain the water quality of the reservoir with water quality index (WQI), national sanitation foundation water quality index (NSFWQI) and Carlson's trophic state index (CTSI).

2. MATERIALS AND METHODS

Five points were sampled within dam reservoir form 2016 to 2017. At each point, for bacterial, nutrient, heavy metal, and pesticide analysis, the surface (< 1 m depth) samples were collected and transferred to the laboratory. The other parameters including chlorophyll *a* and physicochemical parameter were measured on site by using CTD (Sea & san Technology: CTD 75M). The WQI, NSFWQI and CTSI were calculated.

3. RESULTS AND DISCUSSION

The pH and EC was relatively stable among and within the stations. Seasonally, high levels of turbidity were observed mainly during the cold weather.

The higher values of COD (sampling point No. 02) indicate water pollution, which is related to wastewater effluents discharged from recreational town. The CTD profiles at sampling point No. 05 for a chlorophyll *a*, temperature, DO, EC and pH were presented in Fig. 2. For other sampling point, the CTD profile was provided but data are not shown.

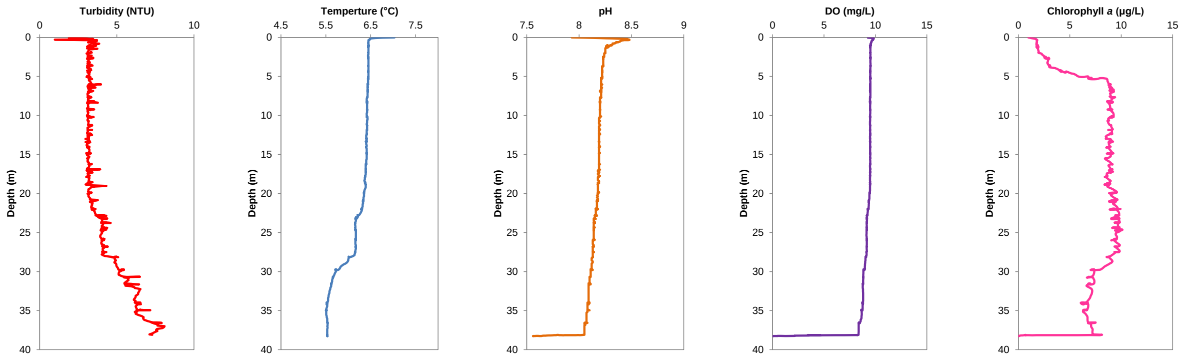

Fig. 1. CTD profiles at sampling point No. 05 (Winter 2016)

As seen in Fig. 2, the increasing of water depth led to decreasing of temperature, DO and pH values. But, the other parameters including turbidity and chlorophyll a showed the different pattern and increased. As seen in Fig. 2, at sampling point No. 05 (deepest point), the thermocline was typically at a depth of 25 to 30 m. The separation of the epilimnion from the hypolimnion is fundamental to lake processes because the stratification typically isolates the hypolimnion from sunlight and atmospheric oxygen. Thus, stratification typically separates the nutrient depleted, slightly less saline and algal enriched epilimnion from the oxygen depleted, nutrient enriched and slightly more saline hypolimnion.

Since, the analytical cost involved could be a limiting factor for reservoir quality assessments in developing countries, certain quality indices were used in this study. Fig. 3 shows comparison of WQI evaluations and trophic level for Zayandehrood dam reservoir.

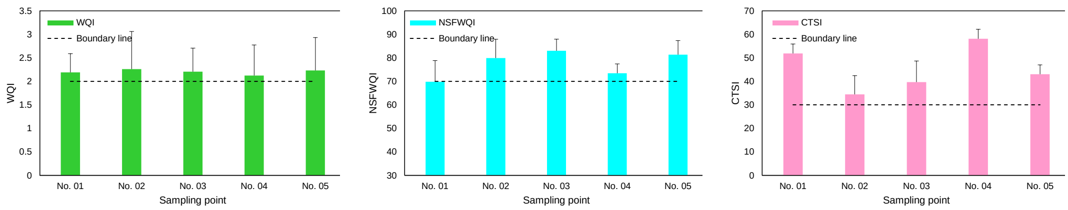

Fig. 2. Variations of WQI, NSFWQI and CTSI (2016-2017)

The values of WQI (WQI and NSGWQI) are in good agreement. The results indicated that WQI 2-3, NSFWQI from 70-90, while CTSI 35-60 for overall studied period.

4. CONCLUSION

Through WQI, NSFWQI and CTSI, it can also be concluded that physicochemical and biological and also trophic characteristic of Zayandehrood dam reservoir water shows sign of well physicochemical and biological characteristic, but mesotrophic (moderately productive) and eutrophic (highly productive) state.

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ON THE ESTIMATION OF SEDIMENTATION LEVE IN IMHA DAM RESERVOIR, KOREA

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This study examined how to determine the optimal sediment level in dam reservoir for efficient plan and operation of dam. Currently, Korea is applying a horizontally accumulated method for sediment level estimation for the safety design of dam and so the method estimated relatively higher level than others. However, the sediment level of dam reservoir should be accurately estimated because it is an important factor in assessing life cycle of a dam. The sediment level in dam reservoir can be determined by SED-2D model linked with RMA-2, horizontally accumulated method, area increment method, and empirical area reduction method. The estimated sediment level from each method was compared with the observed sediment level measured in 2007 in Imha dam reservoir, Korea and then the optimal method was determined. Also, the future sediment level was predicted by each method for the future trend analysis of sediment level. As the results, the most accurate sediment level was estimated by the empirical area reduction method and the future trend of sediment level variation followed the past trend. Therefore, we have found that the empirical area reduction method is a proper one for more accurate estimation of sediment level and it can be validated by the results from a numerical model of SED-2D linked with RMA-2 model.

Table 1 Comparison of the method for sediment level estimation by case

Method for sediment level estimation	Sediment level (El.m)				Remark
	2007	Present (2017)	After 50 years (2067)	After 100 years (2117)	
Observed	110.00	Unobserved	Unobserved	Unobserved	Upstream of dam
RMA-2 & SED-2D model	110.58	111.21	112.43	114.22	
horizontally accumulated method	113.70	114.78	118.53	126.48	
empirical area reduction method	110.25	110.79	111.93	113.50	
area increment method	111.95	112.38	114.35	117.58	

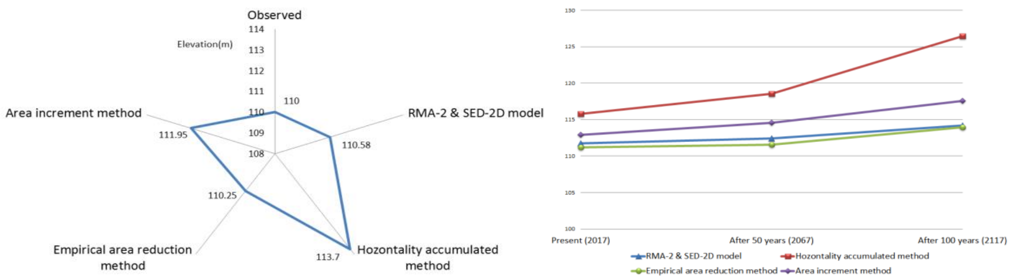

Fig. 1 Trend for the estimated sediment levels by each method

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RESERVOIR OPERATION RULE OF HEPP POSO DAM, INDONESIA

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1. INTRODUCTION

Up to the third quarter of 2014, the electrical system of Central Sulawesi Province is supplied by power plant generator centers, diesel and hydropower with total installed capacity is 314 MW with the composition of the plant is still dominated by diesel-fueled HSD amounted to 224.1 MW, or 71 % of total generating capacity, followed by hydropower for 63 MW or 20% of the total generating capacity of 27 MW and a power plant or 9% of total generating capacity. With the completion of construction of 150 kv transmission network Poso-Palu will maximize the evacuation of power from Poso hydropower electricity system, Central Sulawesi.

Hydroelectric Power Plant Poso-1 (4x30MW Nett) is located in Poso River, administratively located in the District of North Pamona, Poso regency, Central Sulawesi Province.

2. ELECTRIC POWER DEVELOPMENT PLAN IN CENTRAL SULAWESI

The generation facilities construction plan in the Central Sulawesi Province regard to potential of local primary energy (hydropower) include the distribution pattern of population. Large hydropower potential of Poso watershed can be developed into a large-scale hydropower up to 575 MW. To meet the electricity needs until 2024, an additional generating capacity was planned about 457 MW with the following details:

Construction of Hydroelectric Power Plant (HEPP) Poso-1 with 4x30 MW capacity will utilize water resources derived from Poso River, with headwaters in the form of Lake Poso.

Poso-1 Dam construction is part of Poso-1 hydroelectric project that serve as a regulating dam through Poso River from Poso Lake in Central Sulawesi Province. The purpose of the construction of Dams Poso-1 (regulating dam) is:

- Regulating water for electric power.
- Water supply in dry season.

3. CONCLUSION

Based on the results of hydropower potential investigation and analysis in Central Sulawesi shows that:

- The potential for hydropower development in Sulawesi stored is still very large.
- Poso hydropower development can improve the welfare of people especially in the Centre Sulawesi.

Keywords: Reservoir Operasion Rule, Poso Dam, Hydropower Plant

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ROPES: RESERVOIR OPERATION SIMULATOR FOR ENVIRONMENTAL SUSTAINABILITY

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1. BACKGROUND

The construction of dams and reservoirs is experiencing a worldwide renaissance. There are international standards for the construction, the design and the safety of dams. However, similar standards for the subsequent operation of reservoirs do not exist. In contrast to construction, design and safety, the importance of decade-long reservoir operation and its impacts on environmental, economic and social issues is strongly undervalued.

Neglect, inadequate monitoring and data management, a lack of strategies for dealing with competing uses and insufficiently trained personnel lead to enormous problems that translate to failure to meet water usage goals, an inefficient use of resources and considerable environmental impacts. This applies in particular to developing parts of the world such as Africa and South-East Asia. In contrast, reservoir operation e.g. in Germany is very sophisticated, involving detailed release strategies, risk management, coordinated operating rules for reservoir systems, the use of real-time models to support operation and even the use of scenario simulations to account for climate change and other uncertainties.

2. PROJECT DESCRIPTION

The goal of the project is to support classic knowledge transfer (training) regarding reservoir operation with an innovative piece of software called the Reservoir Operation Simulator (ROPES).

The simulator is a tool for raising awareness and transferring existing knowledge regarding efficient, sustainable and environmentally friendly reservoir operation to regions where this is lacking and can thus aid in strengthening resource efficiency, reducing environmental strains and improving sustainability.

The Reservoir Operation Simulator (ROPES) can be used to train local reservoir operators regarding reservoir operation while considering different climatological and hydrological conditions and competing uses and goals.

Similar to a flight simulator, ROPES mimics the actual control interface for reservoir operation and exposes the trainee to different conditions, in which he must make decisions regarding the operation of the reservoir. The simulator takes the trainee’s decisions as input and calculates the effects of the decisions within the entire system.

The ROPES interface is highly customizable so that it can simulate any real-world control interface. The interface only exposes those variables to the trainee that he would be able to access during actual operation. Additionally, these variables can be overridden in order to simulate situations in which the operator receives false readings from a malfunctioning instrument.

ROPES can simulate the entire range of possible operating conditions, including exceptional events such as extreme rainfall or failure of control components. The training scenarios are determined by the trainer and are unknown to the trainee beforehand.

ROPES can be customized to simulate any existing, planned or fictional, reservoir or even entire reservoir systems, including the catchment and water courses upstream and downstream of the reservoirs. It can utilize archived or real-time monitoring data from ground stations or remote sensing as input and can also integrate forecasts into the simulation.

ROPES is based on the software Talsim-NG, which was developed by SYDRO and has been proven and tested as a simulation tool for reservoir operation, rainfall-runoff calculation and flood routing both in planning stages and in real-time operation for more than 15 years. ROPES uses Talsim-NG as a backend for performing the actual simulations.

Institutions such as the Nile Basin Initiative, the Eastern Nile Technical Regional Office, the Mekong River Commission, the Ethiopian Institute of Water Resources of the Addis Ababa University and the Walailak and Kesetsart Universities in Thailand have already expressed their interest in conducting a pilot study and aiding in the dissemination of the project’s ideas.

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UNSTEADY STATE APPROACH FOR ESTIMATION OF RESERVOIR SEDIMENTATION

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1. ABSTRACT

Quantitative estimate of sediment transport in alluvial channels is one of the most important task in river engineering for project planning, design, construction, operation and maintenance of hydraulic structures such as river (bridges and training dikes), reservoirs (dams and barrages,), lakes and coastal (jetties, berths, breakwaters, dikes, wave absorbers, revetment, seawalls and bulkheads). Even today, numerical models of sediment transport processes are confronted with some difficulties, often of conceptual nature. One of these difficulties is the simulation of unsteady non-uniform sediment transport. This paper describes sediment transport theory in brief, empirical equations proposed by different investigators such as Camenen and Larson, Engelund and Hansen, Ackers and White's, Meyer-Peter and Muller, Nielsen, Bagnold, Bijker, method. Macroscopic concept based on single sediment size has been used for computations. Present research paper is compilation of work carried out by various investigators for steady state and unsteady state flow condition. Published data of Sediment Transport collected over 20 years in Punatsangchhu river basin by Division of Water Resources Engineering, Bhutan is used for analysis. Performance of empirical equations for Bhutan/Indian sub continent is evaluated and presented in a tabular form. New mathematical equations in a log, power and binomial form for steady state flow are compared with various methods as mentioned above. Results obtained by unsteady state equation proposed by author match with observed quantum of sediment. This equation precisely predicts sedimentation well within

1.7% bandwidth. The variation in sedimentation predicted by proposed equation and observed was accurate initially up to concentration of 2500 mg/l and beyond it is within ± 5%. as shown in the Fig. 1

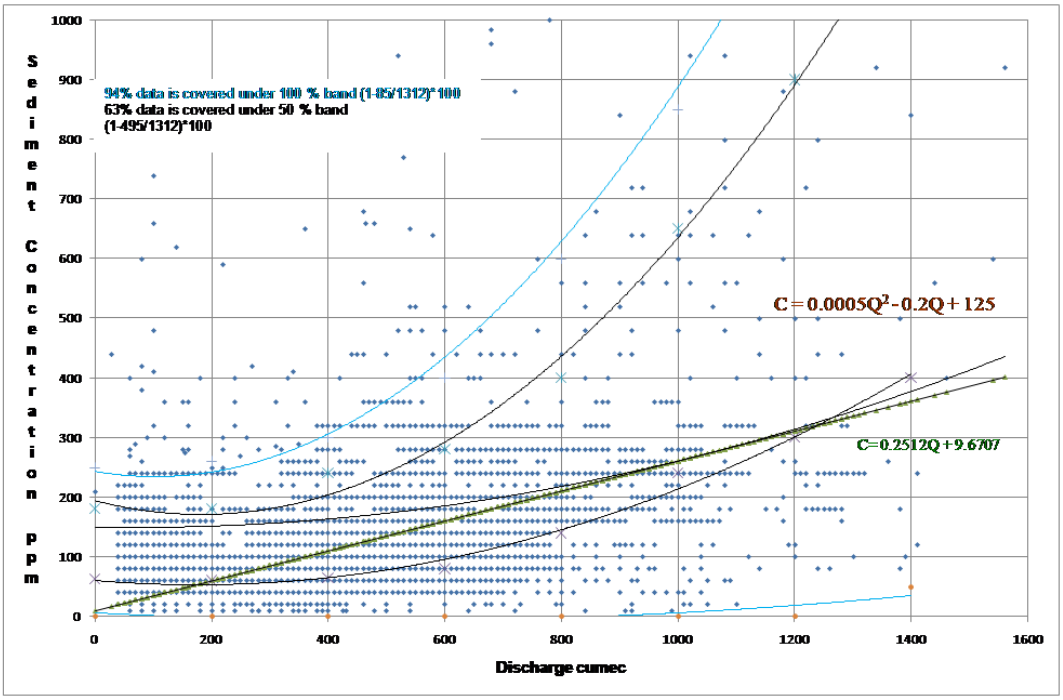

Fig. 1 Discharge and Sediment data used analysis

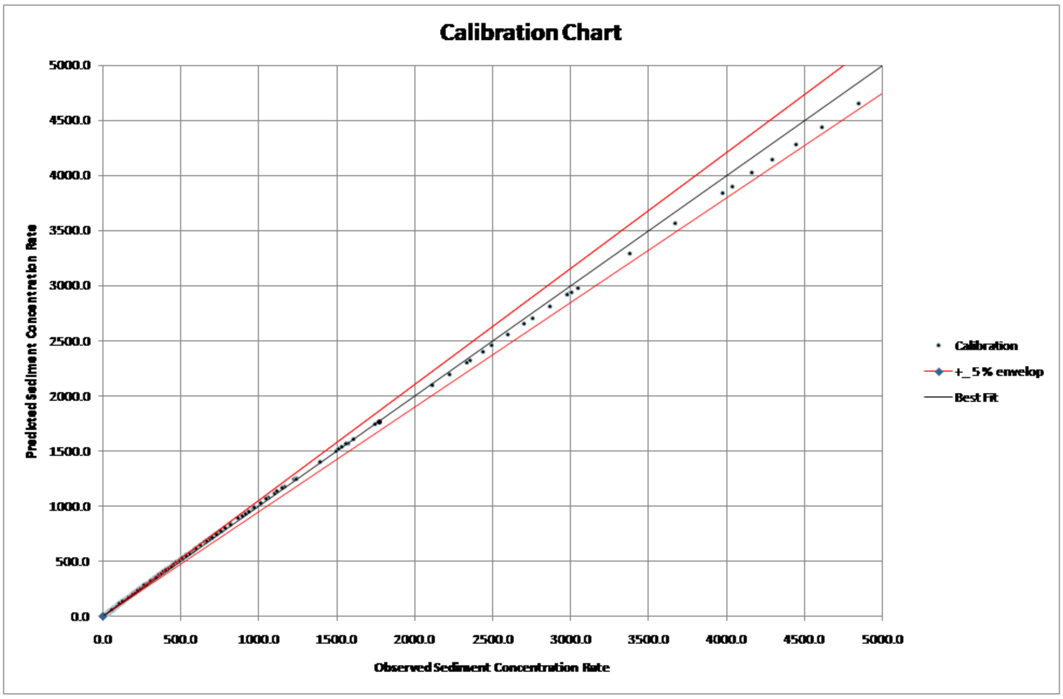

Fig.2: Variation of observed and Predicted data by Equation 18

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FINDING BALANCE BETWEEN WATER CONSERVATION, SEDIMENTATION, AND ENERGY IN DAM MANAGEMENT OF SERAYU-BOGOWONTO RIVER BASIN TERRITORY. CASE STUDY OF WADASLINTANG AND SEMPOR

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INDONESIA

1. INTRODUCTION

Sedimentation has been the most challenging problem that is faced by any dams in the world, which is worsen by climate change effects. The climate change shifted the rainy season in Java Island to heavier rainfall in shorter period of time, which forced the upstream farming area produce extra sedimentation to the dams downstream. The study uses case of two large dams in Serayu-Bogowonto River Basin Territory: Wadaslintang and Sempor. Both are located in mid-stream of the rivers and faced with different scale of sedimentation problems.

Fig. 1
Dams in comparison: Wadaslintang (left) and Sempor (right)

This paper seeks to compare what is considered as ‘the balance of water conservation-sedimentation-energy’ for both locations using Nexus approach for water governance [1]. The locations are selected based on existence of data for the bio-ecological review [2]. The result of the review is compared with the periodical data of the dams operation throughout the last 20 years and the regulation on Indonesian dam management [3]. Both dams were built in the 1980’s, but data availability constraint limits to these range of time. The methods used are site visits, comparison of ‘sedimentation-energy-water quality’ models and document analysis of published materials.

2. RESULTS

In this paper, the Nexus tool is used to give a simple overview of what the approach is about and to show case that it can be used as a fast assessment towards dam management condition. This can be addressed through introducing and advancing awareness of the water management interrelations to other resources in the river basin level using the Nexus approach. It also recommends the policy makers to make use of the models for easy visualizations to see these interrelations.

Keywords: dam operation, ecology, sedimentation.

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A STUDY ON THE VULNERABILITY RANKING USING HYDROLOGICAL SAFETY EVALUATION RESULT OF EXISTING DAMS CONSIDERING CLIMATE CHANGE

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1. ABSTRACT

In this study, hydrological safety vulnerability assessment on dam facilities was estimated using dams' hydrological safety evaluation result and in-depth inspection assessment result and considering climate change scenario. Hydrological safety assessment of the existing dam was performed by calculating the pmp/pmf using the climate change scenario. Using the results, Multi-Criteria Decision Making was used for vulnerability ranking decision on dams, and assessment scores and weights of hydrological safety evaluation considering climate chage were applied as payoff matrix and weight coefficient. In this study, it was evaluated vulnerability ranking that hydrological safety evaluation of existing dam considering climate change.

2. ACKNOWLEDGEMENTS

This work is supported by the Korea Agency for Infrastructure Technology Advancement(KAIA) grant funded by the Ministry of Land, Infrastructure and Transport (Grant 17AWMP-B083066-04).

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SUMMARY

In this study, it was evaluated vulnerability ranking that hydrological safety evaluation of existing dam considering climate change. Using climate change scenario rcp 4.5 2040s.

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EXPERIMENTAL STUDY ON BED EROSION DOWNSTREAM FROM A DAM*

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ABSTRACT

The nature of flow, sediment transport and bed erosion were studied in a laboratory flume using mixed-size sediment under clear water conditions. During each experiment, water depth, bed and water surface elevation, bedload transport and bed state were continuously monitored. Steady inflows were established with an unit discharge of about 0.01 m(2) s(-1) to 0.03 m(2) s(-1). Well sorted gravel and sand were employed to compose four kinds of sediment beds with different gravel/sand contents, i.e., uniform 100% gravel bed, uniform 100% sand bed, and two graded sediment beds respectively with 53% gravel and 47% sand as well as 22% gravel and 78% sand. For different sediment beds, the experiments were conducted under the same discharges, thereby allowing for the role of sediment composition in dictating the bed erosion to be identified. The measured bed elevation for all the twenty runs show that significant degradation is spotted, yet the scour is mainly confined to the upstream part. For a specific sediment sample, the degradation enhanced with the increase of the inlet flow discharge. Under a specific unit-width flow discharge, the degradation for the four sediment samples generally follows the rule that the scour process increases with the increase of sand content in the sediment bed. However, it also exhibits an interesting phenomenon that the maximum scour depth with pure sand is not the largest, instead the case with 78% sand content features the deepest scour. In line with this observation, the scour with pure sand extended considerably farther

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*titre de l'articlecomplet

downstream along the channel than other beds. In fact, bed forms like small dunes were present in cases with pure sand, which were not discerned in other sediment beds. This has important implications for the evaluation of the scour hole evolution, echoing that the sediment bed composition has significant and complicated effects on the scour dimensions below sills, as identified in previous studies.

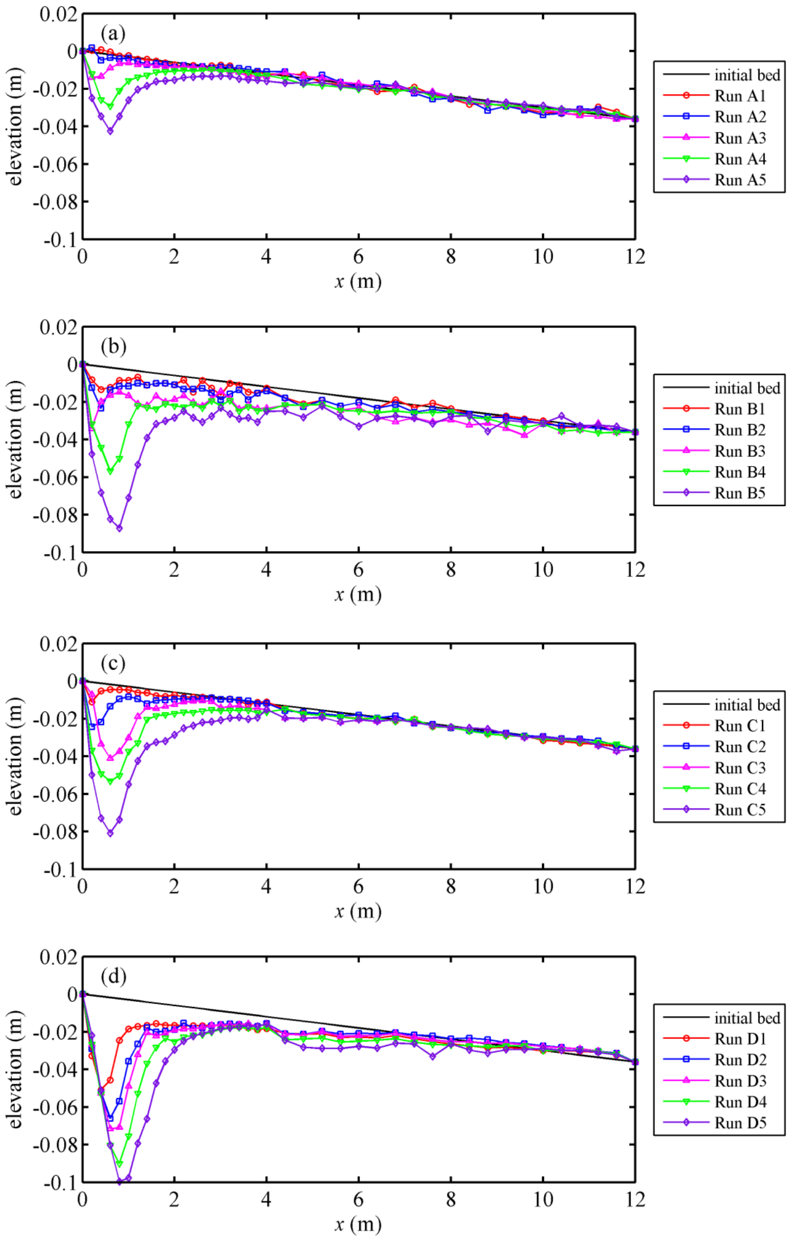

Fig. 1. Cross section averaged final bed elevation in relation to different inflow discharges for (a) uniform 100% gravel bed, (b) uniform 100% sand bed, (c) 53% gravel and 47% sand bed, and (d) 22% gravel and 78% sand bed.

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STUDY ON MECHANISM OF RESERVOIR INDUCED SEISMICITY AND COUNTERPLOTS FOR RESERVOIR OPERATION UNDER EXTREME WEATHER*

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ABSTRACT

The odds of extreme weather events increased significantly recently against the backdrop of global climate change, in which China is one of the most affected countries especially for typhoon and rainstorm. The water level will change rapidly if the typhoon or rainstorm occurred in the reservoir region, which is seemed to increase the occurrence probability of Reservoir-Induced Seismic (RIS). The RIS means typically minor earthquake sequence resulting from reservoir impoundment or variation of water level. The damage of RIS may probably be much bigger than that of natural earthquake because its focal depth is very shallow. Therefore, it is necessary to study the mechanism of extreme weather induced RIS events, as well as provide some corresponding countermeasures for reservoir operation management.

Shanxi reservoir is located in the upper stream of Feiyun river (Zhejiang Province, China) with capacity of $18.24\times10^8 m^3$, and the height of the concrete face rockfill dam is 156.8m. Shanxi reservoir region will be affected by typhoon from June to September every year. The impoundment of the reservoir stared from May 12th, 2000. And a M_L3.5 seismic events in reservoir region has been recorded in July 28th, 2002[1]. From that time on, the seismic activities in Shanxi reservoir never stopped. In this study, a seismic catalogue contains 5908 records are used to study the seismic activity of Shanxi reservoir region (27°62' ~ 27°78'N, 119°83' ~ 120°08

'E), which is recorded from July 28th, 2002 to Jul 16th, 2016. The frequency of seismic activities in Shanxi reservoir region increases after the impoundment but are mainly weak or micro earthquakes. In addition, the biggest seismic event is M_L4.6 (Feb 9th, 2006).

The double-difference earthquake location approach[2] is used to get higher resolution results of source parameters such as hypocenter location and focal depth. The spatial distribution of the 2014 seismic clusters indicate that the seismic events are distributed along the Shuangxi-Jiaoxiyang fault (F3), which strike is N310°W (see Fig.1). 4. The results of double-difference location algorithm suggest that the branch fault F3-3 is the causative fault of 2014 seismic cluster. Actually, almost all of the seismic events in 2014 are occurred after the typhoon season. We consider the most possibly reason is that there are some hydraulic connections between the raised water and the branch fault F3-3. The water will erode the fault plane, and reduce the effective stress. In case the water level dropped or changed rapidly, the related fault will loss stability and cause earthquake. Consider the statistical results of seismic activities and the operating experience, we suggest that the changing rate of water level in dam operation should be controlled in a relative low level, especially for the water level decreasing rate must be limited to no more than 2m/day.

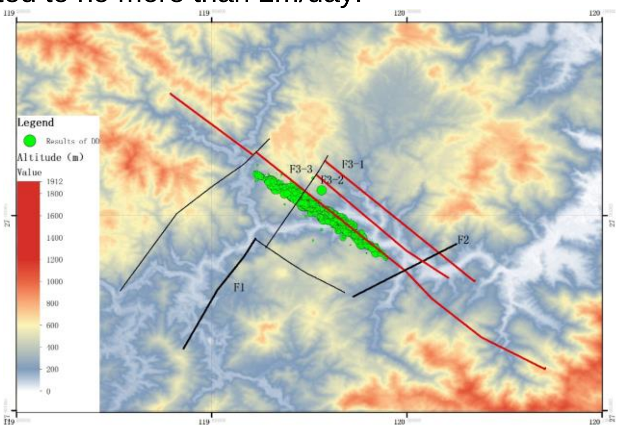

Fig. 1:
Spatial distribution of hypocenters in 2014 seismic cluster
Red line: Shuangxi-Jiaoxiyang fault,

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IMPACT OF CLIMATE CHANGE ON THREE LARGE RESERVOIRS OPERATION IN CITARUM RIVER – INDONESIA

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On the Citarum River there are three stair-shaped reservoirs (cascade) with a classification of large dams, namely Saguling, Cirata, and Jatiluhur. The water resources in the Citarum river is the main source of raw water supply other than the surrounding rivers that are integrated in the Jatiluhur infrastructure system for various purposes. Climate change is already a fact. The doubling of CO_2 emissions (ppm) compared with the Industrial Revolution in the 19th century is defined as a half degree of world temperature rise. This will lead to an increase in half the degree of global warming for decades to come, due to the inertia of the climate system (Javornik, 2008).

The principles (limits) in determining the operation of the Citarum cascade reservoir are: runoff is avoided, water level elevation at the end of the year is equal to or more than the water level at the beginning of the year and the principle of equal-sharing operation, ie the proportion of clean reserves for each reservoir against the total system is constant, ie 18.8% for Saguling, 24.4% for Cirata and 56.8% for Ir. H. Djuanda.

Changes in the operating principle of Citarum cascade reservoir will have implications for the economic potential value generated from electricity generation. At the present stage, the adaptation of Citarum's cascade reservoir operation to reduce the impact of climate change is done by optimizing the capacity of the container to hold water in the wet season as much as possible in the dry season but by providing space for flood control.

On the other hand, with the influence of climate change, especially on hydrological regimes that are closely linked in reservoir operations, the operation of the reservoir needs to be strengthened by considering these conditions in its operations to reduce its impact. Climate change must be understood as one of the business risks that can result in the decline in electricity production. This should also be considered in terms of operation and management of reservoirs.

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DETERMINATION OF GERMI CHAY DAM RESERVOIR SEDIMENTATION PROCESS

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1. INTRODUCTION

Prediction of sediment distribution in reservoirs is an important issue for dam designers to determine the reservoir active storage capacity, outlet sill elevation, dam stability, recreational facilities, and backwater conditions. A lot of methods such as physical, mathematical and experimental models are provided in this field. One of the most important experimental methods to study sediment distribution in the reservoir is area reduction method. Several mathematical models for predicting reservoir sedimentation have been developed based on the equations of motion and continuity for water and sediment. Some of these models have additional specific features such as the GSTARS which is developed Molinas and Yang (1986). In this research, GSTARS3 sediment transport model and areareduction method was used to simulate sedimentation processes in Germi Chay dam reservoir. Germi chai dam is a multi-purpose earth-fill dam with central clay core which has been constructed on Ghermi chai river in the northwest of Iran. Sediment distribution in various reservoir levels is computed and Area-Volume-Height curves for period of 80 years through previously mentioned methods are computed, drawn and compared.

2. DISCUSSION AND CONCLUSION

GSTARS3 sediment transport model was used in this study to predict sediment load from the watershed discharged to reservoir. In order to study the problem and calibrate the models, the results are compared with the experimental method of reducing the level. The results of the experimental method of Area Reduction can be reliable, especially at high reservoir levels. The comparison graphs of Volume-Elevation and Area-Elevation before and after simulation (after a 80-year sedimentation period) are shown in Fig.1 to 2.

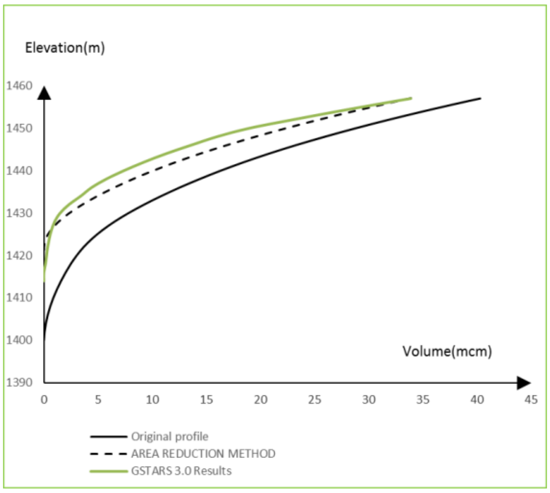

Fig. 1
Volume-Elevation graphs before and after simulation (after a 80-year sedimentation) period

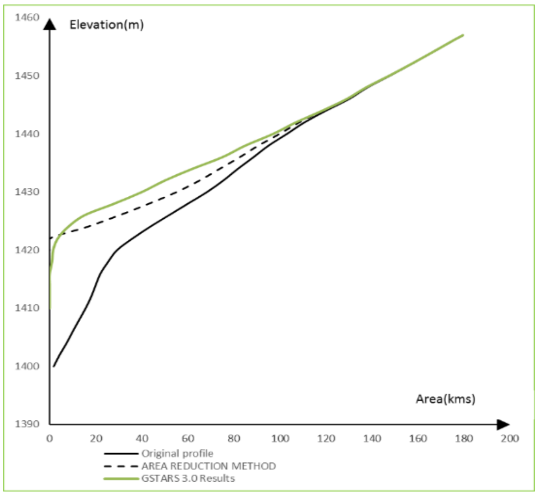

Fig. 2
Area-Elevation graphs before and after simulation (after a 80-year sedimentation) period

According to the research, the Area Reduction Method to estimate the sedimentation in the reservoir of Garmi Chay dam is a priority. Considering that this method can not predict the exact model of sedimentation in the reservoir of the dam such as longitudinal profile, bottom line of reservoir and sedimentation in different sections of the dam reservoir, this is done using the GSTARS3.0 Model.

Comparison of the results of the software in the single-dimensional model and the experimental method of Area Reduction in the low levels of the dam reservoir indicates that the GSTARS 3.0 model is inaccurate near the dam body and transfers a significant amount of sediment input to the outside of the study area.

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NUMERICAL SIMULATION OF THE MORPHDYNAMIC CHANGES BY SEDIMENT SUPPLY AT THE DOWNSTREAM OF YOUNGJU DAM

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River restoration can involve various methods, from the management of a riverbed for ecosystem recovery to the positive improvement of river channels and flood plains. Reduction of the sediment inflow in the river by a dam construction upstream may change the geomorphic features of the river or disturb the ecosystem habitats in the dam downstream, affecting the aquatic ecosystem. Decrease of the sediment supply to a dam downstream lowers the bed elevation, changes the sediment size in the bed, separates gravel from fine sediment to form an armored layer and spreads the layer to the downstream. Recently, various methods have been employed in South Korea to improve the river environment in dams downstream. In particular, methods of sediment supply have been prepared to improve the river environment by supplying sediment to dams downstream.

In this study, a numerical simulation has been conducted to investigate the efficiency of the plans as a preliminary study. The effect of sediment supply was evaluated in the Yeongju Dam downstream of the Naeseongcheon River under discharge conditions that were dependent on the dam operation.

This study used a physical-based morphodynamic model, Nays2DH, developed by Shimizu(Iwasaki et al., 2015). This model solves the two-dimensional depth-averaged flow equations and calculates sediment transport and sediment sorting, and geomorphic changes. The numerical model was validated by using the experimental result provided by Cui *et al.* (2003) who conducted experiments to investigate how the sediment supplied to a channel as discontinuous pulses were moved to the downstream of the channel. The transport and diffusion of the sediment pulse found in the experiment was well simulated numerically.

The effect of sediment supply was evaluated in the Naeseongcheon Stream under discharge conditions that were dependent on the dam operation. The bed elevation in the immediate downstream of the dam decreased over time. In addition, as time passed, the sediment pulse scoured and moved to the downstream of the channel, and then deposited at positions where the flow velocity decreased. BRI, representing the dynamics of the bed, increased with time, and was found to be greater in the channel downstream than upstream. In addition, as discharge increased, BRI increased because the higher discharge had a greater effect on the bed, increasing the dynamics of the river channel.

This study showed that a higher discharge enhanced the dynamics of the bed with the sediment supply upstream, and that the river was more dynamic at the downstream of the channel than in the immediate downstream of the dam, being affected more by the sediment supply. A study on the actual implementation of the sediment supply method should be conducted in future research.

ACKNOWLEDGEMENTS

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ASSESMENT OF OPERATIONAL PERFORMANCE AND RISKS CONSIDERING THE EFFECT OF CLIMATE CHANGE ON THE TIBETAN PLATEAU

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1. INTRODUCTION

Reservoirs in mountainous regions are built for many generations to come. Climate change will definitely be a factor of decisive order. In consequence assessing performance and risk of a hydropower plant, it becomes necessary to quantify the impact of climate change. A methodology is proposed which allows the mathematical formulation of changes of performance over time.

2. QUANTIFICATION OF PAST CHANGES AND PREDICITIONS

The archives of LANDSAT, IKONOS, Sentinel and RapidEye images cover a period of 40 years. In case that sufficient satellite images are available, changes within that period can be identified. The following phenomena have been studied:

- Retreat of glaciers and related changes in the creeks
- Indicators for the change in permafrost expressed in debris flow starting at higher elevations
- Changes in shape and volume of natural lakes and ponds
- Changes in vegetation, particularly the lower and upper tree lines
- Changes in vegetation density and character
- Traces of events that happened in the observation period including forming relevant statistics
- Changes in the riverbed and its contributories

The fact that quality and resolution of images has changed over time has to be compensated. Software for change detection is readily available. Nevertheless, plausibility checks are always recommended. Rock falls and all kinds of sliding events receive priority in operational risk assessment.

3. DIGITAL IMAGE PROCESSING

Different satellite data and image processing tools were tested in order to find out whether the satellite data can contribute to the detection of causal factors influencing the susceptibility to slope failure and to seasonal landscape monitoring.

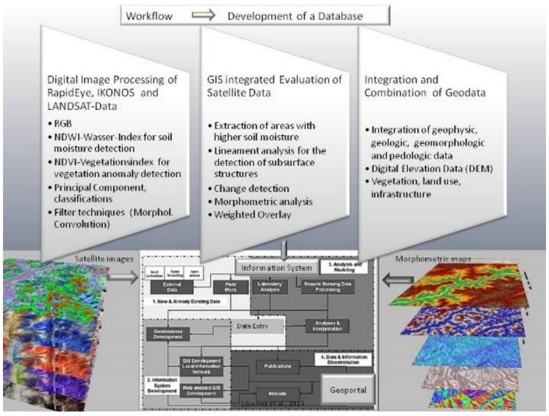

Fig. 1: Data and Workflow

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COUNTERMEASURE OF SEDIMENTATION PROBLEM ON WONOGIRI RESERVOIR, INDONESIA

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1. ABSTRACT

The Wonogiri Dam should continue to contribute to stabilization of people's livelihood as well as improvement of social welfare at least in coming 100 years. This goal will be achieved only in the way to secure and maintain the expected function of the Wonogiri reservoir in terms of flood control, irrigation water, domestic and industrial water supply and hydropower generation.

The Wonogiri reservoir will be seperated by closure dike into two reservoirs, namely a Sediment Storage Reservoir with New Gates and a large main Wonogiri Reservoir, and operated independently.

In construction of new dike with saturated soils with soft clay, low bearing capacity and excessive settlement, the ground improvement technique using deep cement soil mixing is one of the most suitable methods to overcome this problem. The sole purpose of deep cement soil mixing is to improve shear strength of soil by in situ mixing the soil with cement grout.

KEY WORDS

Wonogiri reservoir, sedimentation closure dyke, deep cement soil mixing

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CLIMATE CHANGE IMPACT ON SURFACE WATER RESOURCES AND HYDROPOWER GENERATION IN THE DEZ DAM BASIN, IRAN*

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1. BACKGROUND AND OBJECTIVES

Due to of human activities greenhouses gases increased in the atmosphere and the impacts was very strong as climate change is a major challenge of 21st century. Considering the interactions of atmosphere-Earth system, climate change alters hydrological processes. Owing the importance of Dez River Basin regarding water resources management and energy generation through Dez and Bakhtiari dams, changes in the inflows of two reservoirs and the potential of hydropower generation is assessed under climate change.

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* *ENQUÊTE SUR L'IMPACT DU CHANGEMENT CLIMATIQUE SUR LES RESSOURCES EN EAU DE SURFACE ET LA GÉNÉRATION D'HYDROÉLECTRICITÉ DANS LE BASSIN DE DEZ DAM, EN IRAN*

2. MATERIALS AND METHODS

First, employing LARS-WG, ECHAM5-OM and HadCM3 general circulation models and three SRES scenarios (A1B, A2 and B1), future temperature and precipitation were downscaled for 2020’s, 2050’s and 2080’s time horizons. Afterwards, the HBV-light hydrologic model was forced with the downscaled datasets. Finally, the simulated flow fed to the two reservoirs system that was developed in Vensim and hydropower generation potential were simulated.

3. RESULTS

Based on the results, temperature increases dramatically (up to 4°C in 2080’s) and precipitation significantly changes between -26 and 13.1%. Also, the Inflow to the Bakhtiari and Dez reservoirs is mostly projected to be decreased by up to 20.5 and 14.3%, respectively. Investigation of changes in the potential of energy generation shows decreasing electricity production for Bakhtiari and a slight increase in case of Dez. Contrasting results of changes of inflow to Dez and its energy generation is mainly due to low capacity of the reservoir (2.7 Bm3) compared to its inflow (8 Bm3), hydropower plant’s limits as well as different flow regime in future time horizons leading to less spills. Table 1 represents future changes in inflow to the reservoirs as well as hydropower generation potential.

Tab. 1 Percentage of changes in Inflow (I) and Electricity generation (E) under climate change

Scenario-Period	GCM1: ECHAM5-OM				Scenario-Period	GCM2: HadCM3			
	$I_{(B)}$[1]	$E_{(B)}$	$I_{(D)}$[2]	$E_{(D)}$		$I_{(B)}$	$E_{(B)}$	$I_{(D)}$	$E_{(D)}$
A1B- 2020	-7	-6.8	-4.7	2.4	A1B- 2020	-13.6	-15	-6.8	1.5
A1B- 2050	-14.9	-16.9	-8.3	2.5	A1B- 2050	-8.2	-8.4	-3.5	2.4
A1B- 2080	-19.9	-22.7	-11.5	2.3	A1B- 2080	-10.4	-11.1	-3.7	2.6
A2- 2020	-7.7	-7.6	-5.4	2.4	A2- 2020	-10.1	-10.4	-8.2	2.2
A2- 2050	-14	-16.8	-10	2.4	A2- 2050	-9.5	-10	-4.8	2.5
A2- 2080	-20.5	-23.6	-10.7	2.3	A2- 2080	-6.5	-5.8	2.5	2.2
B1- 2020	-5.9	-5.3	-3.2	2.1	B1- 2020	-10.7	-11	-9.6	2.1
B1- 2050	-15.3	-17.2	-12	2.2	B1- 2050	-1.7	-0.9	3.2	2
B1- 2080	-20.8	-24.1	-14.3	2	B1- 2080	-3.1	-2.1	3.6	1.9

[1]B: Bakhtiari dam; [2]D: Dez dam

Keywords: Climate Change, Hydrology, Hydropower, Dez Dam, Bakhtiari Dam

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SEDIMENTATION MANAGEMENT OF THE PATRIND HYDRO POWER PROJECT USING OHDS TECHNIQUE

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1. INTRODUCTION

Fossil resource depletion and climate change have raised the interest of renewable energy around the world. Among them, the development of hydropower utilizing water resources is considered to be an effective way to prepare for electricity shortages. However, the development and operation of hydropower generation facilities should be greatly influenced by hydrological and topographical conditions. In particular, sedimentation in the upstream of a dam causes reservoir volume reductions and generator abrasions. Therefore, a proper management technique for sedimentation is needed for hydropower plant projects.

Currently, K-water(Stockholder) and SHPL (SPC) are operating the Patrind hydropower project in Pakistan. The Patrind project has a capacity of 150MW, and the watershed area is about 2,400 ㎢. It is a run-of-river generation type and the project location is near the Himalayan Mountains and the City of Muzaffarabad, about 120 kilometers north of Islamabad, which is capital of the Pakistan.

2. SANDTRAP DESIGN

Initially, this project was planned to have an underground sand trap to settle above 0.2s of sedimentation in which the annual average quantity is approx. 4.4Mt. The plan, however, was changed to an above ground sand trap due to the lack of foundation supporting force at the design stage. A numerical analysis, however, showed that a reduction in the efficiency of the trap is expected due to sediment deposits forming in front of the intake. Therefore, OHDS(Optimal Hybrid DeSander) technique was considered. This method consists of a bypass tunnel and a natural sand trap. The bypass tunnel connects the reservoir of the upper cofferdam and downstream of the weir to prevent sedimentation from flowing into the modified pool. Approx. 59% of the total sedimentation was removed using this tunnel and some of the suspended sediments that inflow to the modified pool have settled in the modified pool. The modified pool has a function as a natural sand trap.

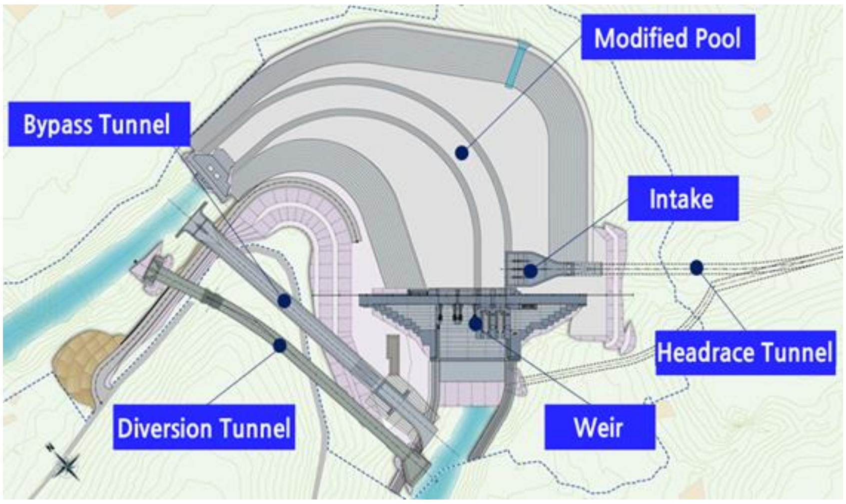

Fig
Layout of the Weir Site(Detail design, 2015)

Numerical analyses and physical modeling investigations were performed to review the performance of the sand trap (trap and flushing efficiency). As a result, the sand trap was found to have met the target sediment management standard. We will verify the appropriateness of the technique by carrying out observations of sediment inflow and deposition in the reservoir and modified pool during the operation phase. After the adequacy of the technique has been confirmed, we will apply the OHDS technique to the hydropower project that has similar sedimentation conditions.

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**ADVANTAGES OF DRY DAM AS FLOOD CONTROL
IN JAKARTA'S URBAN AREA**

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ABSTRACT

Jakarta as the Special Capital Region of Indonesia has an area of approximately 661.52 km². The problem of Jakarta during the rainy season is flooding in several places in the Ciliwung river basin. Based on the masterplan of flood control in Jakarta, planned to be built Ciawi Dam and Sukamahi Dam which will be useful as flood control, these dams are located in the upper Ciliwung river.

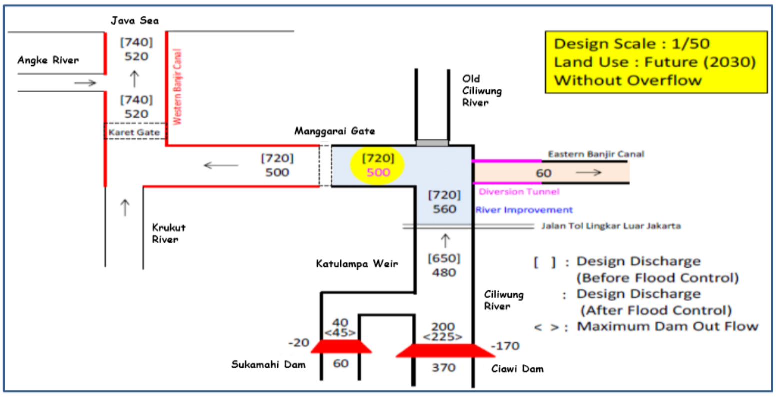

Fig. 1 The Masterplan Of Flood Control In Ciliwung River

The current status of these dams are progressing with site preparation, land acquisition, etc, with schedule of construction commencing in the month of, November, 2017 and plan of completion in 2019.

Advantages of this type of dam (Dry Dam) are not only the lack of sedimentation in the reservoir, but also the water quality of the river either upstream or downstream of the natural dam and the supply of the upstream part of the river. Besides, the maintenance of river ecosystem by not inhibiting migration of fish. It can still move from upstream to downstream Ciliwung river and back to the initial habitat.

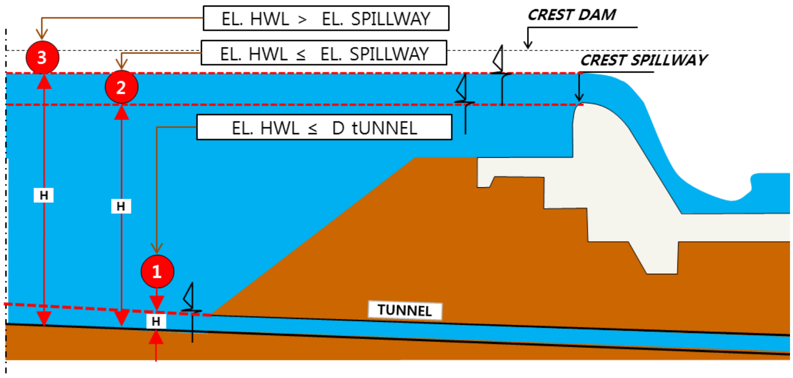

Fig. 2 The Concept of Dry Dam

The main advantage in flood control with dry dam is effective for flood control in the urban area, because with small storage and small resettlement it can delay the peak of flood discharge. The dry dam has a low operating cost and easy to operate because there is no water level in the reservoir so it can work without operating the gate. With the above reasons, technical operation is performed, which at the beginning of the rainy season, the water level of the reservoir is set to a low elevation so that at the beginning of the flood, the flood discharge flows freely through the tunnel.

Keywords: Dry Dam, Flood Control, Small Resettlement

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GREEN DAM RESERVIOUR: A NEXUS CONCEPT FOR SAFE OPERATION AND MAINTENANCE OF DAMS IN IRAN

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IRAN

1. INTRODUCTION

Many dams have been recently constructed in Iran with different purposes, from storing water for agriculture and industrial usages, to household uses for hundreds of years in Persian culture historically [1]. Hydroelectric dams, additionally, act as an alternative to non-renewable energy resources that constitute the majority of the world's energy [2]. However, dams may have drastic damaging effects on the environment and on the populations that live near dams and thus, have become the subject of great scrutiny, with organizations concerned with environmental health such as Iranian Environmental Organization. In a worldwide perspective, Out of the 38,000 large-scale dams, registered by the International Commission on Large Dams (ICOLD), an international organization that sets the standards for dams, 50 percent of dams are used for irrigation, 18 percent for hydropower, 12 percent for water supply and 10 percent for flood control and the rest for other functions [3]. As such, external effects such as environmental issues are of a huge consideration for any nation.

2. METHODOLOGY

This research strives to present an innovative approach called "Green Dam Reservoir" or GDR that helps minimize environmental effects and maximize dam and reservoir green operation. In order to achieve this goal, a framework is proposed. First, the common polluting sources in dam reservoirs are determined and then, they will be categorized and each group analyzed. In the implementation phase of the GDR, a specific remediation action is proposed for each group of polluting source (e.g. chemical source, wastewater source, external source). Combination of remediation actions will result in an integrated remediation approach in which upon approval of the dam owner, can be applied in the construction as well as the operation phases of dam projects. In order to demonstrate the robustness of the proposed approach, a dam case study in Iran is used to elaborate how the GDR concept can be implemented successfully.

3. CONCLUSIONS

There is a great hope that by applying the GDR approach, not only the near-by communities have better life quality but also, reservoirs operate in safer mode both in physical and technical aspects. This research significantly contributes to the provision of more sustainable operation and maintenance of under operation dams. A new era of dam industry in Iran is recently demanding more focus on the environmental issues. This research is a right attempt in a right direction and in a right timing to address these issues and ultimately, make sure these remarkable national and vital investments have lower damaging effects as well as longer life span for current and next generations.

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KEYWORDS

Environment, Green Development, Dam Project, Operation, Management

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DAM SAFETY EMERGENCY RESPONSE PLAN: SHARING EXPERIENCE ON ENGAGEMENT WITH LOCAL AGENCIES FOR TNB HYDROPOWER DAM IN MALAYSIA

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1. INTRODUCTION

Dams are often referred to as monolithic hydraulic structures. Made of adequately impermeable materials, dams arebuilt to create a storage compartment known as reservoir at the upstream to store water for various purposes. These hydraulic structures supply raw water to water treatment plants. In Malaysia, dams contribute to irrigation and flood control mechanisms, on top of its predominant role in generating/ producing hydroelectric energy power source for local consumption.

Despite the aforementioned benefits, dams can also impose risks to the public. In line with current global awareness of water security, the aspect of dam safety has drawn increasing attention from the public as it constitutes the element of a country’s national security. The consequences of dam failure may involve substantial downstream injury and property damage as well as catastrophic and long-lasting environmental effects [1]. In Malaysia, Tenaga Nasional Berhad

(TNB) is the owner of most of the larger dams in Malaysia. In fulfilling its corporate responsibility, and also as a responsible dam owner and operator, TNB has embarked a comprehensive research program to study the dam break analysis and assess its impact downstream in terms of social, economic and environmental for all its operating dams since the year 2003.

The dam break simulation results were translated into Emergency Response Plan and quantification of impacts downstream indicating the procedures to be taken in the case of such unfortunate event and the foreseeable loss of all aspects in monetary term. In view of this, TNB has decided to expand the implementation of Emergency Response Plan (ERP) by developing Dam Safety Emergency Response Plan (DSERP) for various TNB power stations to suit both local agencies and TNB station personnel. The DSERP developed to suit the Malaysian Government's management of national disasters, outlined in the Directive No. 20, Policy and Mechanism on National Disaster Management and Relief (In 1997 by National Security Council). The Directive covers all aspects of the management of natural disasters in Malaysia including preparedness, mitigation, response, recovery and rehabilitation.

Potential risks associated with the failure or disruption of these assets could result in significant destruction including loss of life (LOL), massive property damage, and severe long-term consequences [2]. The drill and tabletop exercises prepared the dam personnel in the early detection of the emergency conditions which could endanger the integrity of the dams, provide prescribed procedures for mitigating the emergency condition and timely notification to relevant emergency management agencies. The tabletop exercise helped to ensure timely warning and evacuation of the population at risk by the local agencies. With the SJSIP DSERP manual in place, it will help prevent or minimize the negative impact to the lives and property under the dam failure condition, thus putting corporate image of TNB to greater height.

The implementation of SJSIP DSERP manual through drill and tabletop exercise has successfully highlighted the importance emergency preparedness among dam personnel and also local agencies in minimizing the impact to the society and environment due to dam failure.

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KEYWORDS: DAM FAILURE, EMERGENCY PLAN, FLOOD WARNING, SAFETY OF DAMS

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DEVELOPMENT AND ASSESSMENT OF DAM INFLOW DEFICIT INDEX FOR COPING WITH A DROUGHT

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1. INTRODUCTION

Drought is a natural disaster that causes widespread damage to the ecosystem and human society. In addition, it can result in severe economic, social, and environmental costs (Wilhite, 2006). Sheffield et al. (2012) indicated that climate change has affected the frequency and magnitude of drought in a way that is very likely to result in increased drought regularity in the near future. Modern water management system is mainly based on the water that stored in reservoirs, so indicator that appropriately monitors dam inflow shortage is of great importance. Although many drought indices have been developed, there is no index adequately monitoring dam inflow shortage. Therefore, this study suggested and assessed Dam Inflow Deficit Index (DIDI) focused on Chungju Dam in Korea considering the criteria for reduction in water supply related to dam operation

2. METHOD AND RESULTS

Fig. 1 shows procedure for calculating DIDI. Where, I_C is the critical inflow, DI is the difference between critical inflow and observed inflow, CDI is accumulation of DI, and TH is a upper limit of CDI. I_C can calculate using a criterion for reducing water supply, and the planned amount for water supply. The optimal TH is determined as the TH value when the ROC value is greatest by performing the ROC analysis repeatedly, and the DIDI can be obtained from the optimal TH value.

Fig.2 and 3 show comparison with DIDI and SWSI and SPI12. It can be seen that DIDI reproduces water shortage better than SPI and SWSI.

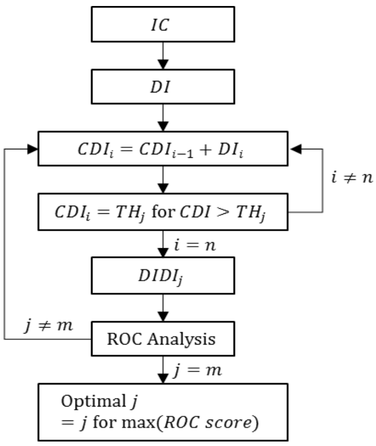

Fig. 1 Procedure for caculating DIDI

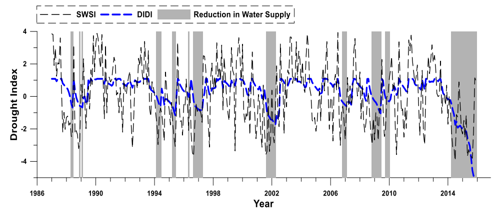

Fig. 2 Comparison with DIDI and SWSI

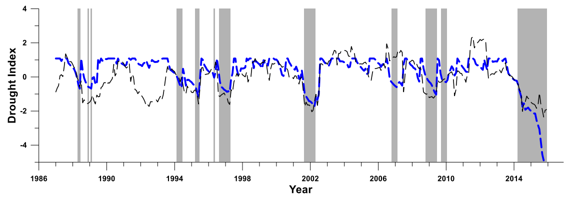

Fig. 3 Comparison with DIDI and SPI12

3. CONCLUSIONS

DIDI is excellent in the ability to reproduce the lack of inflow that causes a water shortage in the dam. The DIDI is useful for monitoring and responding the drought of dam inflow, and its application could help to mitigate drought damages.

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ADAPTED OPERATION OF TROPICAL GLACIAR RESERVOIRS DUE TO CLIMATE CHANGE

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AUSTRIA

Throughout history, there have been a series of catastrophic events in the Cordillera Blanca generated by mudflows coming from glacier reservoirs. This omnipresent hazard in the Cordillera Blanca together with the increasing mean temperature due to climate change effects, which are most visible in the tropical glacier regions with an overall glacier loss of 46% between 1930 and 2016, lead to the necessity to know the risks and the possible effects when operating reservoirs in this area of Peru. In the present paper, the potential risk of 18 ice blocks falling into a reservoir with a volume of 29 Mio m^3 and a maximum depth of 90 m is presented. The results from a 2D simulation showed overtopping heights between 1 and 19 m in function of impact heights between 300 and 1’600 m as well volumes between 18’000 and 526’500 m^3. To prevent overtopping at the dam, the water level in the lagoon has to be reduced between 2 and 40 m. Correspondingly, the actual water volume of the lagoon

(29 Mio.m^3) is reduced down to 5 Mio.m^3, which represents a reduction of 82 %. Overtopping wave heights become more important when the ice block starts to have a significant volume compared to the reservoir volume – threshold of the ice block volume regarding overtopping is in the order of 50’000 m^3 for the investigated situation. A reduction of about 40 to 50 meters results to be ineffective regarding the prevention of overtopping. This is also the case, if the volume of the ice block reaches 6 – 10 % of the remaining reservoir volume (Fig. 1). Prevention of overtopping by reducing the FSL becomes ineffective when impact momentum reaches 45 GNs. Even with the initial conditions of the lagoon (without dam), there would be a risk of overflow (wave heights approx. 8 m), as it would be necessary to reduce the level of Lagoon by 35.0 m, far below the level of the former moraine.

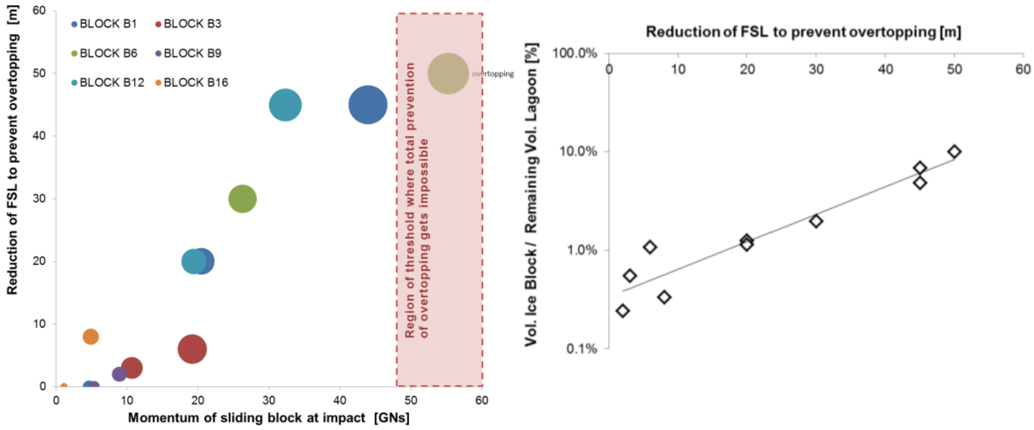

Fig. 1

Analyses of impact momentum and required reduction of reservoir water level to prevent overtopping (left) and relation of ice block to remaining reservoir volume in function of required reduction of the FSL (right)

As there are many other lagoons in the Cordillera Blanca with similar conditions, the risk of a GLOF event in the sub-tropical glaciers becomes more evident taking also into consideration the effect of climate change, which already can be observed in the Andean Glaciers in the last decades. Obtained results serve as additional basic data for the risk assessment of ice avalanches and the operation of reservoirs within the environment of tropical glaciers affected by climate change. To assure a safe operation of these reservoirs in the future as well as the security of people living downstream, permanent observation of the glacier by the means of images (satellite and direct photography) might be realized to enable fast reaction in case of an event. This also would improve the still poor database, which nowadays exists in the Andean region with respect of GLOF risk assessment.

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STUDY ON SOIL EROSION OF MAHAWELI RIVER UPPER BASIN UNDER CLIMATE CHANGE USING SWAT MODEL(*)

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SRI LANKA

1. BACKGROUND

Many countries developing their water resources are facing the severe issue of reservoir sedimentation. Meanwhile, high intensity rainfalls due to climate change has the potential of exacerbating soil erosion in reservoir catchments causing rapid reservoir sedimentation. Sri Lanka also has got many multi-purpose reservoirs and four of them namely, Kothmale, Victoria, Randenigala and Rantambe (1,756.3 million m3 & 582 MW in total) are in the Mahaweli River Upper Basin (MRUB). The Mahaweli is the longest river in the country and MRUB consists of steep slopes conducive to soil erosion, where 39.9% of the area consists of slopes above 30%. Therefore, aforementioned reservoirs in the MRUB are also under the threat of sedimentation. It is important to estimate the rate of sediment yield in the area and check whether it has got any increasing trend due to climate change in order to take possible measures to mitigate soil erosion.

(*) *Étude sur l'érosion de la rivière Mahaweli bassin supérieur en vertu de changements climatiques à l'aide du modèle SWAT*

2. METHODOLOGY

Soil Water Assessment Tool (SWAT), a continuous simulation hydrological model was used to analyze the soil erosion above Victoria reservoir in the MRUB (1,865.52 km^2). Main inputs to the model were digital elevation model, land-use map, soil map, rainfall and temperature. Unavailable climatic data; solar radiation, wind speed and relative humidity were generated by the model itself. Annual sediment yields of the area were estimated for the period from 1960 to 2016 and plotted to check whether there is any trend. In addition, average sediment yield of each sub basin created by the model was also calculated.

3. FINDINGS

The highest annual sediment yield in MRUB has been 1,022,717.31 Ton as reported in 2013. The average yield for the period (1960-2016) has been 48.55 Ton/km^2/year. Time series of annual sediment yields denote a strong upward trend. At sub basin level average sediment yields indicates a considerable spatial variation.

4. CONCLUSIONS AND RECOMMENDATIONS

At present, sediment yield rate of the MRUB is at an alarming rate with an increasing trend due to climate change. Erosion rates differ much within the basin at sub basin level. All the reservoirs in the cascade system of the river basin are under the threat of sedimentation. Therefore, proper basin management is compulsory for retarding soil erosion. It is required to adopt suitable soil conservation methods in areas where erosion is excessive. In addition, bare lands can be used for afforestation. Formulating new policies and regulations to prevent soil erosion form possible developments, which may take place in future to cater demands of increasing population, is also important.

ACKNOWLEGEMENTS

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A USEFUL TECHNOLOGY TO SOLVE OR MITIGATE ARTIFICIAL RESERVOIR SEDIMENTATION

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ITALY

Reduction of sediment flow generated by dam construction leads to erosion on downstream riverbed and on coastal areas; the lack of coarse sediment (sand, gravel) generated channel riverbed deepening and relevant effects on bridge foundation structures, and on other infrastructure affected by water bodies, meanwhile the lack of fine sediment (silt, clay, nutrients) can have serious effects on balance of downstream ecosystems, reducing water turbidity and affecting water temperature.

Loss of reservoir capacity caused by sedimentation can greatly impact reservoir management because it generates a reduction of water availability for several uses (energy generation, irrigation, drinking water). Most recent studies estimated global gross storage capacity at 6,000 km^3 and annual reservoir sedimentation rates at 31 km^3. According to this growing trend, global reservoir storage capacity will be reduced by 50% on 2100.

Both accumulation of sediments in dams and the lack of these in downstream areas have negative effects on the performance and conditions of the infrastructures, on the coastline stability, already endangered by sea level rise (greenhouse effect), therefore actual handling of these sediments is of paramount importance for long term management of artificial reservoirs.

Several possible solutions can be taken into consideration:

- sediment by-passing into the downstream area;

- drawdown routing involves discharging high flows through the dam during periods of high inflows to allow sediment to be transported through the reservoir minimizing sedimentation;
- drawdown flushing, opposite to sluicing, focuses on scouring and re-suspending deposited sediment and transporting it downstream. It involves the complete emptying of the reservoir through low-level gates;
- turbidity current venting can be done when inflowing water with high sediment concentrations forms a higher density current that flows along the bottom of the reservoir without mixing with the lower density clear waters;
- dredging with specialized equipment to remove the sediments from the dam.

In the last years, sedimentation in artificial reservoirs became more and more important, especially in reservoirs where their catchment basin is affected by important surface erosion rates due to poor vegetation coverage (degradation of the vegetation by human action), or to the presence of heavy rains in very short periods (flash floods).

Climate change has increased the frequency of flash floods, therefore sedimentation in artificial reservoirs is one of the most important challenges of Public/Private Authorities responsible for artificial reservoir management. Sedimentation is really important because there are situations, all around the world, where original reservoir capacity has been dramatically reduced by 30/50%, generating important losses in terms of electricity production, reduction of water for irrigation and human use.

This paper deals with the positive experience happened in an artificial reservoir located in the eastern part of the Italian Alps (Ambiesta reservoir) managed by A2A, that is one of the most important energy supplier in Italy. Few years ago, A2A launched a tender to select a Contractor able to propose a cost-effective technology to remove about 23,000 m^3 of sediments settled near the water intake structure located on the right flank of the valley close to the dam, affecting dam bottom outlet, and water intake for hydroelectric purposes.

The tender has been awarded to THETIS COSTRUZIONI & DRAGFLOW which designed, supplied, installed, tested and managed a dredging system which allowed to complete the activity required by A2A fulfilling contractual time and very stringent environmental constraints established by River Tagliamento Authority. In the following pages the reader will find in detail reference data used to dredging system design, characteristics of the dredging system itself, on site activity and monitoring plan during dredging, and finally the conclusions.

Dredging activity has been concluded fulfilling the total time allowed by the Client, taking into consideration supply and installation of the equipment, preparation of the jobsite area, assembling and testing of the dredging system, maintenance of equipment, and finally the disassembly of the equipment, and the restoration of the jobsite area to the original situation.

Selection of the dredging system demonstrated its validity to fulfil Client's requirements, and maintenance activity was really reduced, demonstrating that DRAGFLOW pumps are really a good and cost-effective solution for slurry dredging. For security reasons a stock pump has been located at the job site just in case, because the respect of the total time (100 days) was mandatory, but this pump has been never used.

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ASSESSMENT OF TEMPERATURE AND PRECIPITATION CHANGES TREND EFFECTS ON THE DAM INFLOW

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IRAN

1. INTRODUCTION

The principle of climate change, as a problem, despite of its various angles being discovered worldwide is still discussed by researchers, engineers and managers of related sectors. The importance of climate change issue becomes greatly apparent when this discussion develops issues related to water resource management and flow classification into various sectors of drinking, industry, agriculture and the environment (Cacho et al., 2008).

2. GENERAL LAYOUT

Climate change (temperature and precipitation) affects different parts of the ecosystem of a region such as water resources, plant and animal species, the environment, agriculture and community health. Climate change (global warming), by shifting precipitation from cold seasons to warm seasons and vice versa, or changing the pattern of seasonal precipitation from snow to rain, obligate all water resource management components to be reviewed. Changing the precipitation pattern, discussed in this study also reduces the snow storm and the displacement of the rivers' regeneration regime. In this way, river basic discharge and dams' adjustment capacity are lowered and the supply and demand balance of the water system is impaired. On the other hand, changes in the precipitation pattern will increase the uncertainty in supplying the plant's water requirements with effective precipitation in the cultivation season. The first effect of these uncertainties is to increase the reliability coefficients used in supplying the water needs of the agricultural sector and thus increasing the need for water extraction. Investigating Taleghan Basin data during 1959-2012, indicates that significant changes have occurred in some of the hydrological parameters of the area. The most important results from the calculations are:

The issue of the effect of temperature change and precipitation pattern on water resources of Taleghan basin is definite.

No trend in precipitation series is observed on the annual and monthly scale of precipitation. This confirms other previous researches before referred to in the introduction. Meanwhile, the increasing trend of temperature in the Taleghan basin is in line with the results of the research in other regions of Iran.

Due to the lack of trend in runoff, the annual scale is not a suitable scale for study of hydrological changes in rivers with a snow-rainy regime.

In discharge time series, an incremental trend is observed during the months of March and April (around 7%), and a decreasing trend in May and June (about 10%). This means that the spring runoff has declined sharply, and instead of winter runoff, increased over these periods. This factor stems from the increase in winter temperature, which is due to the decrease in snowfall during recent years, indicating a change in precipitation pattern in the basin and precipitation change from snow to rain.

As changes in the region are actually changes in precipitation pattern from snow to rain, which leads to changing the time of overflowing and dehydration periods as well as floods of Shahroud River, management of Taleghan reservoir dam needs to be reviewed.

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RAPID SCREENING OF SEDIMENT MANAGEMENT TECHNIQUES FOR MORAGOLLA HPP WITH RESCON-2

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JAPAN

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CENTRAL ELECTRICITY BOARD

SRI LANKA

INTRODUCTION

Moragolla HPP project involves the implementation of a run-of-river Hydropower scheme on Mahaweli River in the central highlands of Sri Lanka. The installed capacity will be 30.2 MW and the expected mean annual energy generation 97.6 GWh. The Moragolla HPP will be the latest and presumably the last entry in the upper Mahaweli Complex, which is a cascade of five reservoirs serving for hydropower generation and supply of irrigation water.

The general layout of the Moragolla HPP scheme comprises a reservoir with pre-impoundment gross storage capacity of approximately 4.7 million m^3 which will be created by a 37 m high concrete gravity dam equipped with an overflow gated spillway with stilling basin. The power waterway consists of a low pressure concrete lined tunnel, a surge shaft and penstock. The surface powerhouse will accommodate two Francis turbines.

The reservoir storage will be used for daily hydropower peaking operation and therefore the time path of the reservoir storage can affect significantly the long-term economic performance of the HPP scheme. The study which is presented in this paper investigated the service lifetime of the reservoir under different sediment management scenarios. The purpose of the study was the selection of the optimum, technically feasible and environmentally friendly sediment management technique after the necessary tailoring onto the project specific needs.

The analysis was performed with the software Reservoir Conservation (RESCON-2) which has been recently developed by FICHTNER for the World Bank Group. The application of the software allowed a rapid assessment of the state-of-the-art sediment management techniques including sediment inflow reduction through implementation of a check dam upstream of the reservoir, flushing, dredging, hydrosuction removal (HSRS), sluicing, by-pass and density current venting.

The RESCON-2 analysis indicated that the expected service lifetime of the reservoir for the no-action scenario, i.e. no sediment management intervention, will be approximately 40 years. The construction of a check-dam upstream of the reservoir will create a small sediment retention pond, which if maintained regularly by means of sand mining, will retain the coarser part of the sediment inflow. This will have as result a prolongation of the service lifetime from 40 to 60 years. Furthermore, the sedimentation rate of the active storage will be lower, since the finer grain size sediment has different spatial deposition pattern. Regular sand mining will mainly result in positive social and some minor negative environmental impacts.

Although, in the first years of operation, density current venting and sluicing will not be technically feasible, in the mid-term however, RESCON-2 indicated that this technique will also become attractive due to the propagation of the headwater deltaic sediment deposits. On these grounds, the implementation of an additional reservoir release structure, such as bottom outlet at the concrete gravity dam is fully justified. It will not only contribute for the dam safety by allowing lowering of the reservoir levels but it will also allow the venting of density currents if they appear in the future. Both density current venting and sluicing are not associated with adverse environmental impacts, since they facilitate the routing of sediment laden flows through the reservoir, following thus the ambient seasonal pattern.

The RESCON-2 results on the development of reservoir storage for the aforementioned sediment management techniques were compared to the results of a widely used one-dimensional numerical model and a very good overall agreement is obtained. This is why the model can be recommended for further use in similar applications.

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SUSTAINABLE DEVELOPMENT IN HYDROPOWER PROJECT

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PAKISTAN

1. INTRODUCTION

Korea Energy (KOEN) is a state owned company of Republic of Korea with 10,329MW of generation capacity of Korea. To comply with its “Vision 2025”, KOEN acquired Mira Power Limited to develop 102 MW Gulpur hydropower project.

Original Environmental Social Impact Assessment (ESIA) of Gulpur Hydro Power Project was put on hold due to declaration of Poonch river as National Park, coupled the same with availability of critically endangered Kashmir Catfish and endangered Golden Mahaseer following challenges were the challenges to meet:

1. Minimizing the impact of resettlement from 128 households
2. To plan to achieve “Betterment of Park” as per AJ&K Wildlife legislation
3. To meet with the requirements of “Net environmental gain” of ADB and IFC

2. METHODS & RESULTS

The project design was changed and studies/ assessments relating to critical habitat, integrated ecological flow of Gulpur HPP site and Biodiversity Action Plan (BAP) demonstrating the net environmental gain were carried out. Based upon the changed design, the relocation decreased to almost zero from 128 households. After reviewing of the studies and assessments, EPA and Wildlife Department gave approval for (1) Preparation and implementation of Biodiversity Action Plan for achieving protection targets of Enhanced Protection Scenario at basin level protection; and (2) Concept of ‘net gain’ in biodiversity in National Park

MPL carried out Ecological Flow Assessment, Socioeconomic Surveys, ESIA update & Integration and Climate Change Risk. The lenders conditionally approved the revised reports and ESIA as asked for feasibility assessment of achieving net gain, plans for monitoring & evaluation of biodiversity and ecological flow management, program for hatchery design and restocking and road map for NPMP.

3. CONCLUSION

Land acquisition completed without any significant relocation. The initial results after implementation of plans developed for sustainability are very encouraging whereas hatcheries for critically endangered Kashmir Catfish & endangered Mahaseer are under construction whereby a significant ‘net gain’ in the population of these species is expected. We expect that the concept of net gain shall be the best solution and standard for various other projects not only on Poonch River rather other rivers as well. This will set an international standard that how development and environmental protection can work together for sustainable development.

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DISASTER COMPETENCE NETWORK AUSTRIA

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AUSTRIA

1. INTRODUCTION

The Disaster Competence Network Austria (DCNA) is a cooperation platform of universities and research institutions in the field of security and disaster research. The aim of the initiative is to transfer scientific knowledge into practice, through cooperative research and education activities carried out in collaboration with various stakeholders, as well as the provision of decision-relevant information in the event of a disaster.

2. ABOUT THE ASSOCIATION

The basic idea behind the DCNA initiative is to bundle scientific expertise in Austria in the field of disaster prevention and disaster research. The association acts as a networking platform and coordinating body for scientific institutions, companies and disaster management authorities at all levels. It is organized as a non-profit and open association under university management and distinguishes three different types of memberships. Ordinary members are all Austrian institutions in the field of scientific security and disaster research. Associate members are all Austrian institutions that are interested in DCNA activities and their support, but do not carry out any scientific research themselves. To further anchor disaster research across multiple institutions, there are strategic partnerships. These can be met with ministries, local authorities and international institutions that will pursue a common goal with DCNA. Meanwhile, the network has been expanded to include major players in disaster prevention and management (see figure 1).

Fig. 1 Current DCNA members

The common denominator of all participating institutions is disaster prevention and appropriate preparation to potential emergencies. This large clip is drawn by DCNA in order to be equally available to the research and academia as well as stakeholders from the public and private sector.

Organizational structure of DCNA includes the Board Members from the founding universities such as University of Technology Graz and University of Natural Resources and Life Sciences Vienna, with their rectors holding the Chairmanship. A General Assembly is bringing together all network members and partners. In addition to the management, the implementation-oriented and scientific activities are carried out in five different working groups as follows:

- Mass Movements and Earthquakes
- Floods
- Extreme-Weather-Events
- Critical Infrastructure and Industrial Hazards
- Socio-Economic Disaster Aspects

Within these scientific working groups, specific research and technology fields form the corresponding connection for research coordination and common orientation. These are: Modelling & Simulation, Remote Sensing & Geoinformation & Navigation, Sensors & Sensor Carriers, Statistics & Actuarial Science, Artificial Intelligence & Information and Communication Technology, Training & Operation.

3. CONCLUSION

The Disaster Competence Network Austria is combining scientific expertise in the field of disaster research and prevention in order to establish a closer cooperation between knowledge carriers and their stakeholders. The aim of the non-profit association is to transfer scientific knowledge into practice through cooperative research and educational activities carried out in conjunction with a wide range of stakeholders, as well as the provision of information and advice to decision-makers in the event of a disaster.

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PERMANENT SAFETY ASSESSMENT OF DAMS, LEVEES, RESERVOIRS, WATERWAYS WITH FIBER OPTIC DISTRIBUTED SENSING

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SMARTEC SA

SWITZERLAND

1. EARLY DETECTION AS A KEY FOR SAFETY MANAGEMENT

The growing demand of safety awareness, cost effective operations and effective maintenance has rapidly stimulated, in the last decade, the development of smart monitoring techniques capable of detecting early-stage events, thus preventing structures from major failures and leading to a better knowledge of the structure itself. In this publication, the aim is to concentrate on long-term, large-scale field applications on dams, dikes and levees, based on the presented distributed technology and sensors.

2. FIBER OPTIC DISTRIBUTING SENSING

2.1. TECHNOLOGY

The most developed technologies of distributed fiber optic sensors are based on Raman and Brillouin scattering. The system can therefore provide a calibrated strain or temperature reading at every meter along the sensing cable.

2.2. DATA MANAGEMENT

Direct data analysis based on distributed temperature or strain data has limitations and does not provides real-time data to the operator that often becomes overwhelmed by the amount of data he receives. It is therefore necessary to automate the data management and analysis process. The developed software displays measurement profiles, status maps of temperature or strain, evolution of the structure and events automatically recognized and logged by the monitoring system. All measurements are imported and stored into a single database and data is processed to apply calibrations and select zones of interest. Alarms are generated automatically, based on complex criteria (e.g. for leak detection).

2.3. BENEFITS

Traditional instrumentation based on localized point sensor is not sufficient to guarantee the detection of early signs of damage and localization of unknown events. Distributed fiber optic sensing allows the early detection, localization and sizing of defects and degradations such as seepages, leakages, settlements, shearing, cracks, abnormal joint movements, intentional tampering and over-flooding.

3. CONCLUSION

Fiber optic distributed sensing is a recognized technology in dams engineering and meets todays goals of asset management. It overcomes limited capability of conventional sensors with reduction of maintenance expenses. Distributed sensing is often combined with fiber optic point sensors (temperature, piezometers) and data communications are fully compatible with plant DCS or SCADA system.

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EXPERIMENTAL INVESTIGATION OF STEPPED SPILLWAY PERFORMANCE OF UPPER CISOKAN DAM IN INDONESIA

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1. INTRODUCTION

Nowadays, the stepped spillway design has been widely used in many countries in the world due to rapid development of RCC (Roller Compacted Concrete) dam which gives both structural and economical benefits. This type of spillway also applied in Upper Cisokan Dam in Indonesia. However, since this type of spillway is still new and has not been designed in Indonesia before, the implementation can be challenging especially when it comes to the scouring problem. The aim of this study is to have a proper design of stepped spillway which can be a good reference for further implementation of stepped spillway. The experiments were conducted inside hydraulic laboratory and the model covering the upstream reservoir, approach channel upstream apron of the spillway, dam, spillway and appurtenance structures with the geometric scale of 1:40 (See Figure 1a).

Fig. 1 (a) Stepped spillway model , (b) stone riprap for downstream protection

The following items received attention: Prevailing flow regime, location of inception point, pressure head measurements, the cavitation performance and downstream scouring.

2. RESULTS

2.1. MODEL PERFORMANCE

On this experiment, the result shows that the location of the inception point started to shifted more downstream in regards of increased discharge from nappe to skimming regime. Moreover, the highest water pressure was shown at the middle of the spillway and at the end of the energy dissipator. Also there are relatively deep local scour occurred at the downstream of stilling basin, the deepest local scour reaches 3 meter. Based on the simulation, riprap protection (See Figure 1b) on the downstream on the spillway are effective to reduce the impact of the scouring. However, the shape and material of the riprap also needs to be determined to get the optimum design. Therefore, number of model series were done in the experiment by modifying the length of the riprap and boulder material is preferably chosen because of the availability of the material on site.

2.2. ACKNOWLEDGEMENTS

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REMOTE INSPECTION OF SMALL DAMS AND LEVEES*

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CANADA

1. INTRODUCTION

Inspections of small dams can present challenges that hinder comprehensive condition assessment. These can include health and safety of personnel, limited access to the inspection area, and water conditions. Each project brings unique complexities, so is important to assess and consider a range of technology and equipment. In this paper, we will review a project where methodology was amended to suit site conditions.

2. METHODS

The original proposed solution to complete this specific dam inspection was to utilize an inspection vessel equipped with sonar systems for data collection. However, as water levels were discovered to be too low for vessel operations, an alternative solution was required. Therefore, a comparative study of technology and equipment suitable for the project was analyzed. In the end, the project involved design and fabrication of an unmanned surface vessel (USV), which was identified as the safest and most adaptable platform for site conditions.

3. RESULTS

The result was an inspection that provided high-resolution georeferenced bathymetry expressed as point cloud data, crack detection, and spall crack size.

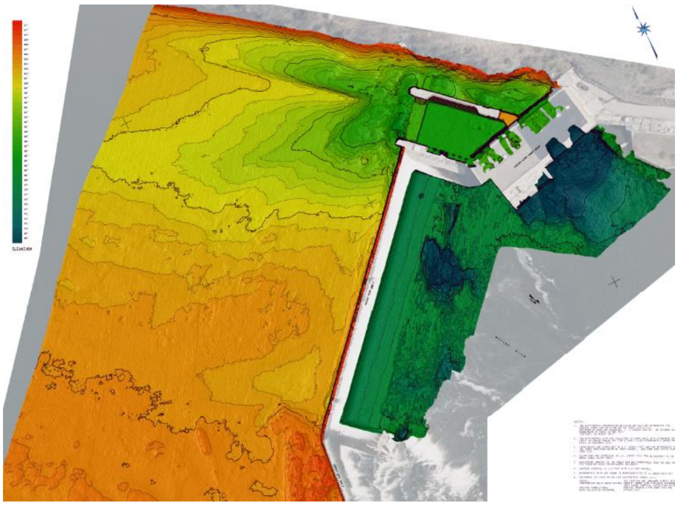

Fig 1. Bathymetric Contour Map of Dam Reservoir and Spillway

4. CONCLUSION

Underwater survey sites can present unique challenges, especially near dams where water level conditions can change dramatically. In the case of unforseen low water, access to key shallow areas can become impossible using manned vessels or even ROVs, both of which require sufficient draft to manouver. In the case of personnel on the water, safety is of course the primary concern. Shallow water is still dangerous. Work vessels can strike rocks or become grounded. It only takes about 20 cm of swift moving water to knock someone off their feet. Cold water only adds to the dangers. Additionally, sensors need to be deployed as close as is practicable to the water surface, and ROVs and the underwater portion of the hull of manned boats would partially block the sensor field. This would require additional manouvering to ensure coverage of shadow areas.

The USV solved these problems firstly by removing most of the danger to human life. Shoreside safety precautions were no less important, but overall the field aspects of this program was far safer and more efficient. Additionally, data collection was done more efficiently and to a higher consistent standard.

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HOW TO DEAL WITH AGING PRESTRESSED ANCHORS IN DAMS: A NORTH AMERICAN PERSPECTIVE *

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1. INTRODUCTION

Prestressed rock anchors have been used since 1934 to stabilize dams and appurtenant structures, while their history dates from 1964 in North America. Concepts and practices have continually evolved during this period, especially with respect to the protection of the tendon against corrosion. However, a large proportion of the anchors installed prior to 1996 in North America have corrosion protection details which would now not be regarded as representing an acceptable standard of care. Further, for various reasons, it is typically not possible to directly evaluate the residual load in these tendons or to establish the severity of corrosion, while no non-destructive, indirect method has yet been developed for these purposes. This is a problem facing dam owners and regulators worldwide.

2. METHODS

The authors have acted as Principal Investigators for an intensive State of Practice survey of all North American dam anchoring projects, and have established a database of well over 400 case histories.

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The evolution of concepts and practices has been traced from a study of these projects, together with an analysis of the successive phases of the Anchor “Recommendations” documents produced by the Post-Tensioning Institute between 1974 and 2014. Interviews have also been conducted with dam owners and regulators to confirm these findings and to gain insight into current philosophies and concerns.

3. RESULTS

Rock anchor construction for dam stabilization has generally attracted a high standard of care and quality. However, philosophies towards corrosion and corrosion protection have rapidly evolved, especially since 1996. As a consequence, a large proportion of the anchors installed prior to that time would now be regarded as having unacceptable corrosion protection details, and so their reliability is questionable in the long term. The problem is compounded by the fact that direct (lift-off) testing is often impossible and may in fact cause damage to the tendon. Further, there is no reliable non-destructive method currently available with which to conduct a condition assessment. These factors are expanded upon in the paper.

4. CONCLUSION

Given this very challenging problem – the ramifications of which to dam safety can be very severe – the authors provide a step-by-step process for conducting a Screening Portfolio Risk Assessment program which will aid owners and regulators to better judge the risks inherent in each project. This will therefore provide a logical basis for deciding if anchor systems need to be replaced, or whether there is sufficient confidence that the aging anchors in question are still reliable.

KEYWORDS

Aging, anchorage, concrete dam, inspection, prestressing, risk assessment.

Vieillissement, ancrage, barrage en béton, visite, précontrainte, analyse de risque.

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DAM SAFETY MONITORING IN EXTRMELY CONDITIONS

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1. OVERTOPPING EMERGENCY MONITORING

Floods, insufficient discharge, malfunction of gates, blocks on spillway may lead dam overtopping. Inspection should be focused on spillway, gates, and unstable slopes around spillway. Unmanned aerial vehicle (UAV) may be applied.

Table 1
Emergency monitoring items for flood overtopping

Number	Monitoring item	Grade			
		Ⅰ	Ⅱ	Ⅲ	Ⅳ
1	Inspection	●	●	●	●
2	Water level	●	●	●	●
3	Rainfalls	●	●	●	●
4	Inflow and outflow discharge	●	●	●	●
5	Superficial deformation	●	●	●	○
6	Seepage pressure	●	●	●	○
7	Seepage discharge	●	●	●	○
8	Discharge flood pulverization	○	○	○	○

Notes：● mandatory item, ○ optional item

2. ABNORMAL SEEPAGE AND STRUCTURAL INSTABILITY EMERGENCY MONITORING

Variation of tendency should be more concerned during inspection and monitoring. Monitoring data should be analyzed in time.

Table 2

Emergency monitoring items for abnormal seepage and structural instability

Number	Monitoring item	Grade			
		Ⅰ	Ⅱ	Ⅲ	Ⅳ
1	Inspection	●	●	●	●
2	Water level	●	●	●	●
3	Rainfalls	●	●	●	●
4	Seepage pressure	●	●	●	●
5	Seepage discharge	●	●	●	●
6	Surface deformation	●	●	●	●
7	Cracks	●	●	●	●
8	Underground water level	●	●	○	○

3. EARTHQUAKE EMERGENCY MONITORING

The damages caused by earthquake are related with earthquake magnitude and distance from epicenter. Crack, leakage, structural deformation and landslide are the major seismic hazards.

Table 3

Emergency monitoring items following earthquake

Number	Monitoring item	Grade			
		Ⅰ	Ⅱ	Ⅲ	Ⅳ
1	Seismic acceleration	●	●	●	○
2	Inspection	●	●	●	●
3	Upstream and downstream water level	●	●	●	●
4	Rainfalls	●	●	●	●
5	Vertical and horizontal displacement	●	●	●	●
6	Crack	●	●	●	●
7	Landslide	●	●	●	○
8	Seepage discharge	●	●	●	○
9	Seepage pressure	●	●	●	○

4. ACKNOWLEDGEMENTS

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GROUND VIBRATION CHARACTERISTICS INDUCED BY FLOOD DISCHARGE OF A HIGH DAM: AN EXPERIMENTAL INVESTIGATION

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1. INTRODUCTION

Upstream and downstream vibrations generated by large volumes of flood water discharging from a high dam can potentially damage buildings and impact on the normal life of local populations. Modelling vibrations created by overflow conditions has enabled improvements for the traditional physical model, and the establishment of a correlation system by combining the model with prototype observations. In addition, the factors influencing vibration intensities, were investigated.

2. EXPERIMENTAL PRINCIPLES AND METHODS

The hydroelastic experiment simulation of flow-induced vibrations simulates the fluid-structure interaction vibration system combined with "structure - water - foundation - dynamic load". According to the principle that the hydraulic similarity conditions is compatible with the structural dynamic similarity conditions, the hydroelastic model must adhere to the conditions of large density ($\lambda_\rho = 1$), a low elasticity modulus ($\lambda_E=\lambda_L$), an equal damping ratio ($\lambda_\xi = 1$), and an equal Poisson's ratio ($\lambda_v = 1$) [11].

The foundation plain fill was excavated and replaced, and a vibration isolation channel was created to reduce the influence of background vibration and vibrations caused by the water pump. The upstream or downstream sections were connected using a rubber belt to form a flexible connection. The location of the waterfall was also placed 7 m from the end of the downstream section of the hydroelastic model. A hydroelastic model of Xiangjiaba hydropower station with energy dissipation via a hydraulic jump was built on the test platform. The geometry scale of the model was 1:80, and the simulation context included the overflow section of the dam, two stilling pools and a section of its foundation.

3. RESULTS AND DISCUSSION

The results show that establishing a hydroelastic model with vibration isolation and damping measures can simulate flood discharging conditions and accurately reflect ground vibrations through linear prediction. Findings from our investigation show that orifice open and upstream and downstream water levels were the major influences on ground vibration intensity, thus controlling these factors and regulating the discharge modes from a high dam will control the intensity of these vibrations.

4. KEY WORDS

Hydraulic model test, flow fluctuation load, discharge regulation, vibration, Xiangjiaba dam

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EXPERIMENTAL STUDY ON THE GLOBAL STABILITY OF THE XIAOWAN ARCH DAM USING A 3D GEO-MECHANICAL MODEL TEST

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1. INTRODUCTION

This study constructed a three-dimensional (3D) geo-mechanical model for the Xiaowan high arch dam, which simulated the topographical and geological features, the distribution of weak structural planes, the shallow relaxation unloading phenomena, and the dam reinforcement scheme. During the test, traditional model materials were used to simulate the dam body, the concrete reinforcement plug, and the mail rock mass of the abutment and foundation, whereas temperature-analogue materials were used to simulate faults F_{11}, F_{10}, F_5, F_{12}, F_{19}, and F_{20}. A small specially prepared rhombic block and thin block were used to simulate the shallow layer of the unloading rock body. The failure test was performed using the comprehensive method, which considers both the overloading and strength-reduction techniques.

2. METHODS

The combined overloading and strength reduction methods were applied in this test. The model failure test procedure is as follows. First, the model was pre-loaded and then the normal load level was applied. Afterward, the shear strength of the abutment rock faults, such as F11, F10, and F5, were reduced by approximately 20% by heating up the model materials. Finally, the overloading test was implemented until the dam instability caused the destruction of the dam abutment. The loads were applied successively in the following order as factors of the normal working load, P0: 1.2, 1.4, 1.6, 1.8, 2.0, 2.2, 2.4, 2.6, 2.8, 3.0, 3.3, and 3.5.

3. RESULTS

The asymmetry of the two-bank terrain and the geological condition of the dam abutments created an asymmetric trend of the displacement of the dam body. In the overloading stage, with an increase in overloading multiples, the displacement of the dam body continuously increased and had an asymmetric trend, which indicates that the displacement of the right arch abutment was slightly larger than that of the left arch abutment.

Under normal working conditions, the surface displacement of the abutments and resistance blocks of both the left and right banks was minimal, and there was no abnormal phenomenon. After K_p was increased to over 3.0, the surface displacements of both abutments increased rapidly and the change amplitude of the displacement curve increased. Furthermore, the measuring points near and around the arch abutment and at the fault outcropped points had abruptly increasing displacement and fluctuating displacement curves.

The primary reasons for the failure of the arch dam and foundation plane are as follows: in the later portion of the overload period, especially when the overloading coefficient K_p was over 3.0, the load born by the arch dam was large, and the geological condition of the two abutments had a large asymmetrical phenomenon. Furthermore, the resistance bodies of the two abutments had inhomogeneous deformation, and the width height of the river valley in the dam area was large. The beam direction effect of the arch dam was large, which caused fissures in the dam body and foundation plane.

Based on the analysis of the experimental data and results, the strength reserve coefficient K_1 is 1.2 and the overloading safety factor $K_2$was estimated to be 3.3-3.5, respectively, that is,

$$K_C = K_1 \times K_2 = 1.2 \times (3.3 \sim 3.5) = 3.96 \sim 4.2$$

Thus, the global safety factor K_C for the Xiaowan Arch Dam and foundation should be 3.96-4.2, which meets the present design requirement.

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JUSTIFICATION FOR SELECTING A FACTOR OF SAFETY FOR DAMS

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NORWAY

1. INTRODUCTION

This paper presents a study carried out to identify how different variables affect the estimated safety for dams. To do so, a series of calculations has been carried out to understand how the FoS is affected for a wide range of variables and assumptions.

2. METHOD

The calculations have been carried out by combining a computing tool for stability calculations with a script that runs the calculations. This method has proved to produce a very powerful and flexible tool for computing stability with varying assumptions. In total, the report is based on approximately 7000 separate calculations with different variables.

The result of the stability calculation of each parameter is presented graphically, where the resulting FoS is plotted against the varying parameters for each dam height. Variation in the FoS are shown for both sliding and overturning. This paper only presents a sample of the results that has been produced.

3. RESULTS

The following table summarizes the suggested safety factor for each variable as discussed in this paper. Multiplying the different factors is assumed to represent the overall FoS.

Table 5.
Total FoS as a product of the individual safety factors.

Variable	FoS - Sliding		FoS - Overturning	
	Design	Accident	Design	Accident
Friction	1,0	1,0	Not relevant	
Water level	1,0	1,0	1,0	1,0
Self-weight	1,08	1,08	1,04	1,04
Pore pressure	1,40	1,00	1,20	1,00
SUM	1,51	1,08	1,25	1,04
Current FoS in Norway	1,5	1,1	Not applicable	

4. CONCLUSIONS

Knowledge about how different parameters affect the dam stability is essential in order to identify which parameters that are most important for stability of a dam. This knowledge is of particular interest in assessing exiting dams. By gaining more knowledge about different parameters it is possible to reduce the uncertainty connected to these parameters, and thereby reducing the overall uncertainty. This knowledge can thereby be used to reduce the calculated FoS without affecting the safety level of the dam.

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This article is based on a study documented in a report by EnergiNorge in Norwegian. When this article was written, the report was not published. The report will in time available on: https://www.energinorge.no/publikasjoner

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DETERMINING ALIGNEMENT PATTERN OF TECHNOLOGY STRATEGY WITH POWER PLANTS DEVELOPMENT STRATEGY - CASE STUDY OF KARKHEH DAM *

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IRAN

1. INTRODUCTION

Organizations have no choice but to use technology as a strategic resource to achieve their strategic goals, and it's where the concept of strategic alignment of development and technology makes sense. Undoubtedly, the most important component in the progress of organizations in today's world is technology. The lack of a development strategy to manage technology transfer is one of the problems for companies. In this study, first, effective indicators for determining strategy development have been identified, and then, by assessing the quality of technology, the strengths and weaknesses of the company in each technology are determined and, while presenting the proposed solution, the performed

* *Karkheh Dam is one of the largest dams in the world and the largest earth dam in Iran and the Middle East. Karkheh dam is the biggest dam of Iranian history.*

phases of the SWOT analysis (Matrix of Technology) and Grounded theory (Model Alignment) are expressed briefly.

2. RESEARCH METHODOLOGY

2.1. DETERMINATION OF TECHNICAL CHARACTERISTICS AND DRAWING TECHNOLOGY MAP

The purpose of drawing the technology map for the technologies of designing and building a power plant in the Karkheh Dam Power Company is to demonstrate the technological status of the company in each technology (the strengths and weaknesses), identify key technologies and determine the competitive position of each technology in comparison with other technologies considered (opportunities and threats). After determining these, we can adopt a suitable development strategy for the development and acquisition of each technology in the company [1].

2.2. REPRESENTATION OF THE ALIGNMENT PATTERN FROM THE GROUNDED THEORY METHOD

In order to clarify the criteria and sub-criteria of the process of technology strategy alignment with the development strategy, the method of content analysis and theoretical coding technique was derived from the data – based theory. in this paper, a new approach to developing alignment pattern of technology and development strategy was introduced using swat matrix technique and grounded theory analysis, which is considered a scientific innovation. for this purpose, development strategy analysis indicators were extracted and then an algorithm was developed for creating a development strategy aligned with technology (the proposed model) [2].

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A COMPARISON BETWEEN HYDROSTATIC-TIME-SEASON AND BAYESIAN DYNAMIC LINEAR MODELS FOR MONITORING BEHAVIOR OF DAMS*

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CANADA

ABSTRACT

Monitoring the long-term behavior of dams is key for addressing safety and serviceability issues. One challenge is to enable the detection of changes in the baseline response of the structure (i.e. anomalies) in real time, while mitigating false alarms.

The most popular data interpretation method for monitoring the long-term behavior of dams is the Hydrostatic-Season-Time model (HST; [1]). The HST performs a regression analysis to decompose a time series into three sub-components related to the hydrostatic effects (H), the thermal effects (S), and the baseline response of the dam (T). The main drawback of HST models, is that they are not dynamic; it means that once the model is built using a training dataset, it stops evolving as new data are collected over time. This is a limitation because the main objective of dam instrumentation/auscultation is to interpret non-stationary (i.e. abnormal) behavior in the baseline response. Moreover, the

* Comparaison entre les modèles Hydrostatique-Saison-Temps et les modèles Bayésiens Linéaires Dynamiques pour le suivi temporel du comportement des barrages

detection of anomalies typically depends on hypothesis testing or threshold-based procedures, which are prone to false alarms.

Bayesian Dynamic Linear Models (BDLMs) are a class of state-space models which are well suited for sequential inference [2]. BDLMs are capable to decompose time series into a set of sub-components, as HST does. In contrast with the HST technique, the behavior of the sub-components can vary with time, without the need to retrain the model. Recent applications have demonstrated the potential of BDLMs to track time-varying baseline responses of civil infrastructures from real dataset [3], and to detect anomalies [4].

This paper compares the HST and BDLMs techniques for the long-term monitoring of dams. This study presents a specific class of BDLMs based on the switching Kalman filter (BDLM-SKF). Two examples of application based on real displacement data recorded on a dam in Canada and simulated data show that BDLM-SKF is robust towards false alarms, and enable to interpret non-stationary time series. One feature of BDLM-SKF is its capacity to interpret the baseline after an anomaly occurs (i.e. when the dam returns to its normal behavior), without retraining the model. In contrast, HST model is prone to false alarms, and is unable to provide information about when an anomaly stops.

This study demonstrates that Bayesian Dynamic Linear models (BDLMs) outperform Hydrostatic-Time-Season (HST) modelling for monitoring the long-term behavior of dams, while providing the same level of interpretability. The main advantages of BDLM over HST model is its ability to interpret non-stationary time series and to detect change in the baseline response of the dam (i.e. anomalies) without being prone to false alarms.

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INCREASE CONCRETE QUALITY IN DAM CONSTRUCTION DURING DESIGN AND EXECUTION PHASE

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DOKA GMBH

AUSTRIA

1. INTRODUCTION

The durability and service life of a dam structure is designed in an early stage of the planning phase. In order to achieve the planned target of concrete quality, monitoring during execution is one of the keys of quality management. For instance in case of mass concrete structures one of the most important aspects is the monitoring of the temperature gradient and appropriate actions on site to avoid cracking and simply guarantee the concrete quality already during construction.

The ambition is to emphasize the importance how to optimize the combination of formwork expertise with superior material technology enabling a well-defined construction sequence between all relevant parties. Resulting in increased quality management and enhanced durability of the designated concrete structure.

2. THE METHOD

Based on numerous of examples it has been proven that the optimization of quality assurance and quality control during design and execution phase will have a leverage on the costs of the final building.

UNDERSTANDING – CONCRETE

Already in the project tendering and work preparation phase, the early strength development of individual concrete mixtures with different performance will be simulated with respective calibration and temperature assumptions with the real-time monitoring system Concremote (= 'Concremote Value Engineering Methodology'). A temperature simulation of the critical structural members shows the temperature gradient of various points in the current pouring section and also the influence to the following building parts (= 'scenario gaming').

In the construction phase, the monitoring of the temperature and strength development by Concremote sensors takes place in each critical concreting section. A systematic analysis shows whether the selected concrete mixture matches the requirements or any adjustments has to be made. This ensures compliance with the desired cycle time and concrete costs.

UNDERSTANDING – FORMWORK

Understanding the building and job site requirements is the basis to achieve an optimized working solution. A formwork solution can be influenced by the geometry of the structure, the construction method as well as the construction schedule. Vice versa a formwork design can influence the geometry of the structure (increased block size) resulting in less construction and block joints, improve the construction method and construction schedule to increase productivity and reduce the construction costs.

Just the 'big picture', considering the impact from the formwork and the superior material technology, is providing the possibility to optimize the construction method resulting in **increased concrete quality in dam constructions**.

3. ADVANTAGES FOR CONSTRUCTION COMPANIES AND INVESTORS

Amidst the different options in power plant construction, there is one goal at the top of the list: producing energy as quickly as possible. Although the objective is formulated with utmost simplicity, the solutions for getting there are no less challenging. The combination of formwork experience and concrete expertise of Doka allows the customer a 'scenario gaming' in the design phase of a construction project. During execution phase the 'Concremote Value Engineering Methodology' offers the possibility to use the most economic concrete mixture and to monitor the evolution of the temperature gradients in the concrete. The resulting benefits are a higher productivity during construction, higher concrete quality and financial savings during execution and the service life of a dam structure.

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VISUAL DOCUMENTATION AND INSPECTION OF DAM SURFACES USING STATE-OF-THE-ART TOTAL STATIONS

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AUSTRIA

1. INTRODUCTION

Visual inspections constitute an essential component for dam safety assessment. Today, dam engineers perform these inspections on-site in regular intervals to document the current state with photos, manual sketches and notes (Fig. 1). As the downstream side of the dam is not easily accessible, the documentation is often inaccurate or subjective.

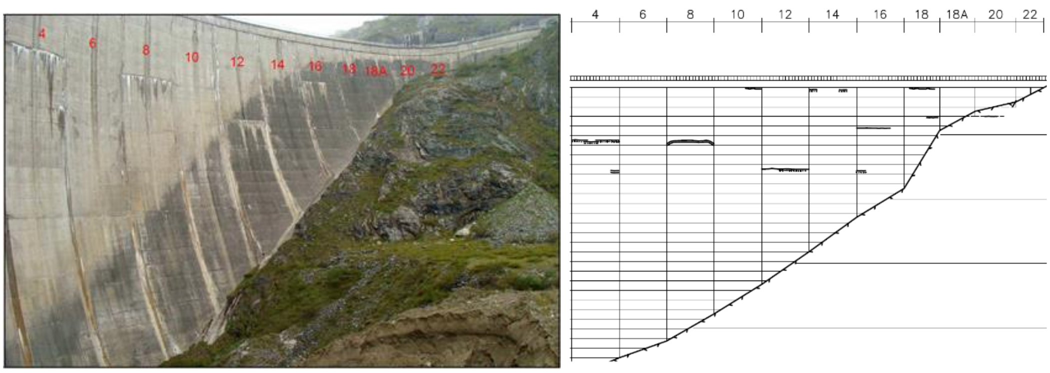
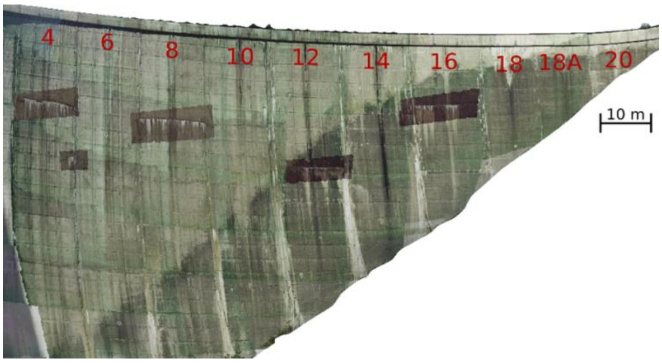


Fig. 1:
Typical documentation of the downstream side of an arch dam, photograph from an accessible viewpoint (left), CAD drawing showing defect locations (right), source: Verbund Hydro Power GmbH

2. METHODS AND RESULTS

In the ICOLD Bulletin 158, the potential of laser scanning and digital imagery for visual inspection is emphasized. However, acquisition and evaluation of data gathered with laser scanners and cameras mounted on drones is sophisticated and requires significant investments of money and time. Hence, we propose a method for surface documentation with a sensor, commonly used in dam monitoring: total stations. We use the laser scan and image data acquired with a modern total station to derive a textured 3D surface model of the dam's downstream side. With the metric information, it is possible to perform measurements on the surface without needing direct access, e.g. of the defect size and position. Moreover, we demonstrate the potential of a visual surface monitoring solution by using the total station capabilities and image processing techniques.

Fig. 2:
Derived 3D surface model of the downstream side (same area as in Fig. 1)



The resulting textured 3D surface models (Fig. 2) and ortho images achieve a comprehensive documentation of the downstream side of the dam. Detect or already known defects are acquired with high-resolution automatically. The location (coordinates) and appearance (photos) of the defects are documented and thus changes on the concrete surface are automatically identified and quantified.

3. CONCLUSION

In this paper, we demonstrate that modern total stations are valuable not just for deformation monitoring but also for assisting visual inspections. The advantage of total stations over other sensors (e.g. laser scanners and cameras) is that it is easy to use for dam operators and well suited for monitoring visual changes on the dam's surface. This can improve the overall assessment of the visual inspections.

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PARAMETRIC ANALYSIS OF THE INFLUENCE OF FLEXURAL, SHEAR DEFORMATION AND INERTIAL ROTATION EFFECTS ON GRAVITY DAMS NATURAL FREQUENCIES*

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BRAZIL

1. INTRODUCTION

Dams can cause enormous worries because of the possibility of eventual collapse. In the literature, there are few researches that contemplate the effects of shear deformation and rotational inertia effects, introduced by Timoshenko beam theory, on the dynamic analysis of dams. This paper presents an exploratory analysis of the influence of considering such effects in the case of gravity dams. It follows insights given in Anderson [1], Herzog [2], Silva [4].

2. ANALYTICAL AND NUMERICAL PAARAMETRIC ANALYSIS

A parametric analytical study, based on Pedroso [3], is developed admitting a simply supported homogenous beam, providing a preliminary evaluation on the matter. Then, numerical models of clamped homogenous beams, with constant cross sections and different width/length ratios are analyzed in Ansys v18 [5], via the elements BEAM4 and BEAM182, which consider the Euler-Bernoulli Theory and Tymoshenko Theory respectively. The results in Fig. [1] are presented as the

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Analyse Paramétrique de l'influence des effets flexuraux, deformation de cisallement et de rotation inertielle sur des barrage de poids en béton ratio between the frequencies considering shear deformation and rotational inertia effects and the frequencies considering classical flexural effects, for the first five modes.

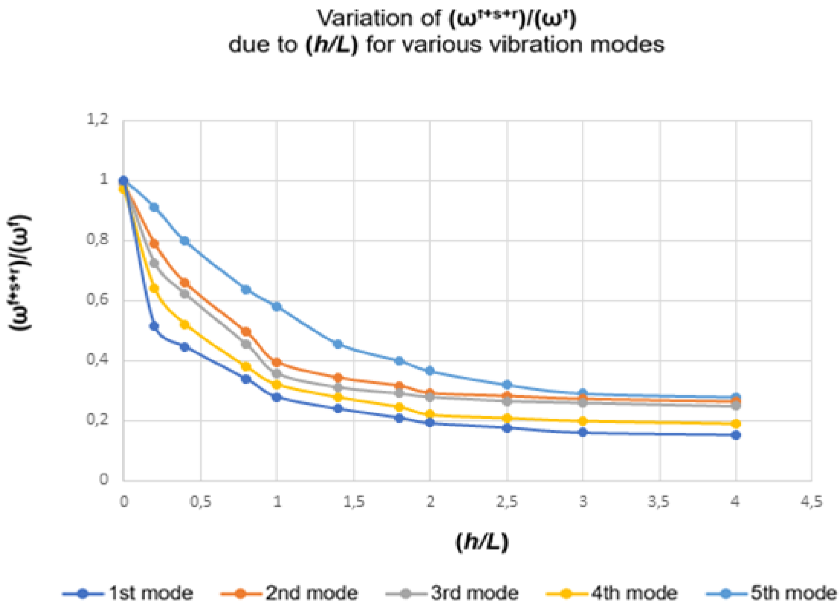

Fig 1. Results from the numerical models in Ansys, for various h / L and vibration modes.

3. CONCLUSION

This work presents an exploratory analysis of the effects of considering shear deformation and rotational inertia on the dynamic analysis of gravity dams. The ratio height/section width influence lowering the natural frequencies.

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TIME-SPACE COLLISION ANALYSIS AND ADJUSTMENT METHOD FOR HIGH ARCH DAM SURFACE CONSTRUCTION

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CHINA

1. INTRODUCTION

The high arch dams are usually located in the narrow valley with steep terrain. The construction space of the storehouse is limited, the construction process is complicated, the construction methods are complex and the operations cross each other. which makes diffcult to layout construction equipments, and reduce work efficiency, and even generate security risks. Therefore, how to scientifically formulate construction plans, avoid collisions and rework, and achieve efficient and safe construction of storehouse are the focuses by all parties.

To solve the above problems, the time-space evolution model of storehouse entities is established firstly.time-space storehouse, Then analyzes the mechanism, classification and effect of the collision of storehouse construction entity. The time-space collision simulation and detection analysis model for the storehouse based on the pouring behavior simulation model is built.The results shows that this moedel can provide a scientific basis for the analysis and optimization of storehouse.

In order to make the construction process efficient and safe to implement, this paper takes the construction process of the storehouses as the main line, simulates the operation of the construction equipment in the pouring activities as the basic unit in the virtual scene, and analyzes the process collision detection and effect in the simulation process. Finally, the simulation results was recorded to analysis and optimize the construction process.

A project is located in the southwest of China. The max dam height is 285.5m. The dam body is divided into more than 2000 storehouses. One of a construction storehouse is taken to simulate the process. The block located in 7# section layer 38, height 512.0m~518.0m. The volume is 3069 m^3, area is about 1023m^2. In initial plan, 5 cable cranes, 5 lateral unloading cars, 2 scrapers and 2 vibrators is assigned. The scene as shown in Fig.1.

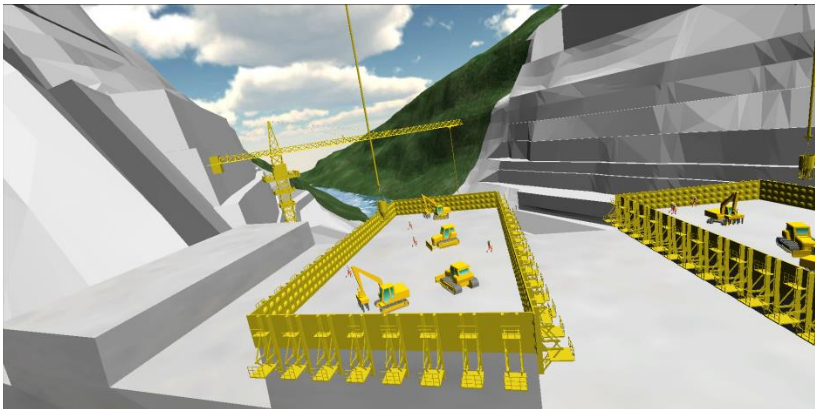

Fig. 1
A construction surface scene

After deduction of scene simulation, the total pouring time is 26.2h. The operation parameters of every cable crane is counted. The statistic results demonstrate that collisions are mainly caused by cable crane, which also reduce the efficiency. By analysis the layout of cable crane, crane 2#~4# are located upward of block, crane 1# and 5# may effect by middle cranes. Thus, a new plan is carried out by reducing the cable crane number, and simulate again. And the total pouring time reduced to 23.23h.

In this paper, according to the collision problem in high arch dam construction process, the model of time-space evolution model for entities in the storehouse is established first. Then, the type and effect of the collision are analyzed and the collision detection and adjustment mechanism was established. At the same time, a dynamic adjustment and optimization model of the construction scheme was established. At last, a case study was carried out according to a real practice, and the results shows that the method proposed in this paper can effectively provide a scientific basis for decision-making of construction projects.

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EXTERNAL DEFORMATION MONITORING OF NINETEEN ROCKFILL DAMS USING SATELLITE SAR DATA

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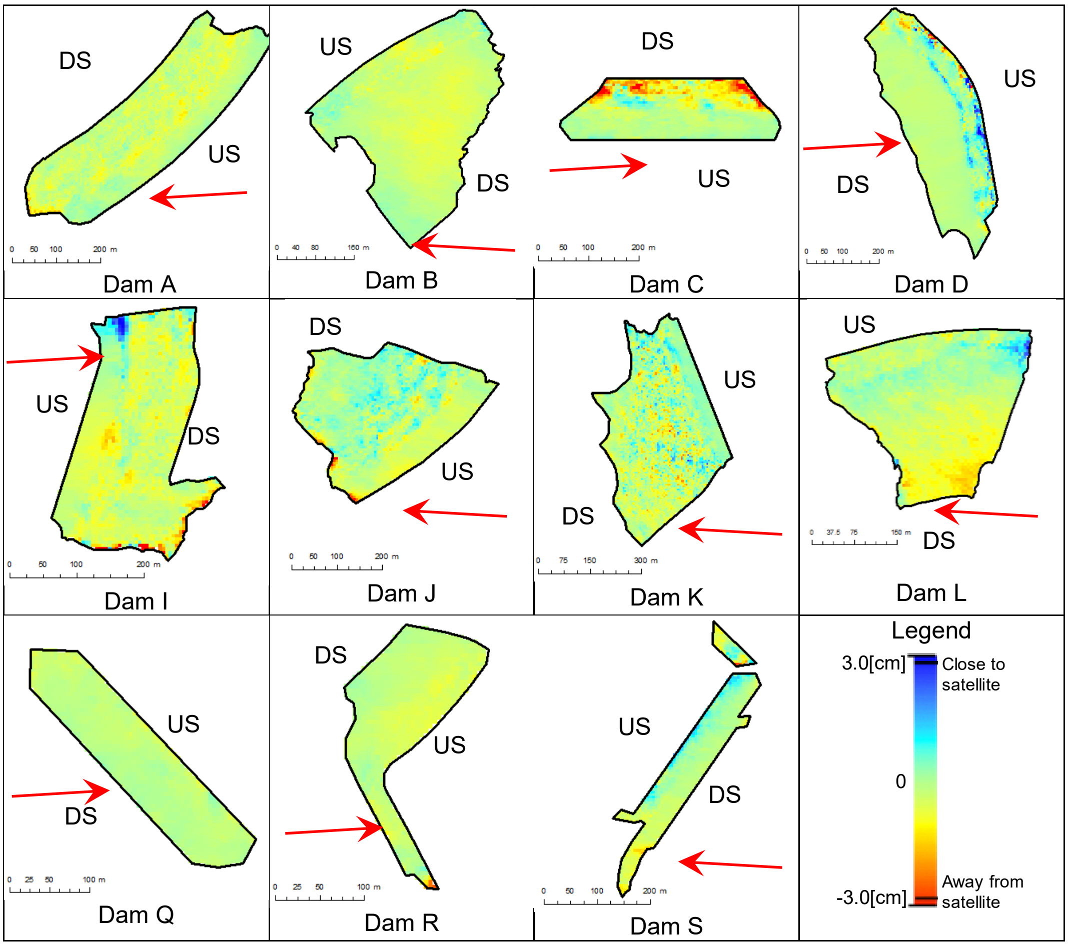
JAPAN

INTRODUCTION

It is important to research new methods of conducting effective measurements of the external deformation of embankment dams. In this paper, based on data collected by Synthetic Aperture Radar (SAR) satellite, a basic examination was carried out regarding the applicability of SAR to the external deformation measurement of rockfill dams. Because no measurement facilities on the dam surfaces are needed for SAR, SAR technique will lead to cost reduction for external deformation measurements of embankment dams. This paper reports the results of satellite SAR based external deformation monitoring of nineteen rockfill dams in Japan in about two years from late 2014 to early 2016 shown in Fig.1. The results of external deformations using satellite SAR data were compared with those by GPS or electro-optical survey data. We found that the results of external deformations using satellite SAR data agreed well with those by existing geodetic data and the average error of the external deformations between SAR and existing geodetic survey was about five millimeters.



US : Upstream Side, DS : Downstream Side
Red arrows show line of sight directions of satellite SAR.

Fig. 1
Some examples of external deformations of rockfill dams using satellite SAR data

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BEHAVIOUR OF THE BACKFILLED RIGHT BANK OF THE MAVČIČE DAM

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SLOVENIA

The Mavčiče concrete gravity dam, part of the corresponding hydro-power plant, was built on the Sava River, in Slovenia, in 1986. It has a maximum structural height of 38.5 m, and the dam crest has a length of 149 m. The dam structure consists of an erection bay, a machine hall, and two spillways, followed by an embankment dam. Most of the dam is founded on permeable Quaternary conglomerate bedrock, so that a cut-off grout curtain had to be constructed to a depth of up to 60 m below the ground surface, where a layer of impermeable Oligocene marine clay occurs. However, the erection bay, which is located on the right bank of the dam, is founded on a layer of gravel backfill, up to about 25 m thick, which lies on top of the conglomerate bedrock. Long-term technical monitoring of the behaviour of the dam began in 1986. In general, the results of measurements and visual inspections did not show any abnormalities. However, this was not the case for the erection bay located on the top of the backfilled right bank of the dam, where the results of measurements of vertical displacements showed increasing settlements. By 1999, i.e. over a period of 12 years, these settlements had increased to 22 mm. The results of investigations, by drilling three research boreholes in 1993, and another six such boreholes in 1996, indicated that the settlements were the consequence of the secondary consolidation of the backfill, and probable also due to scouring of fine material from the backfill. Due to the resulting differential settlements, the crane rail which connects the erection bay to the machine hall, as well as the crane rail which is

located along the crest of the dam, became non-functional, and needed height corrections. For this reason rehabilitation works of the backfill and of the substratum of the right bank of the dam were performed in 1999 - 2000, using 50 m long grouted boreholes. This grouting was performed using a combination of water reactive polyurethane and a cement-bentonite mixture. Measurements performed since than have shown that the settlement rate has slowed down slightly (by 2017, i.e. over the last 17 years, the settlements had increased by up to 8 mm), but from the point of view of the operation of the two crane rails the settlement process needed to be stopped. Additional investigations, involving the drilling of two research boreholes, as well as appropriate laboratory and field measurements, were performed in 2015 - 2016. According to the results of these most recent investigations, the newer settlements were the consequence of additional scouring of fine material from the backfill. In order to achieve a final solution to the problem of the subsidence of the erection bay, additional rehabilitation works of the backfill and substratum of the right bank of the dam, by grouting the permeable zones, would be needed in order to stop both the scouring of fine material from the backfill, as well as any internal erosion of the cavernous conglomerate at the base of the backfill. The latter concerns the long-term stability of the right bank of the dam with potentially serious results.

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AIR DEMAND OF BOTTOM OUTLETS: INSIGHTS FROM SCALE MODEL TESTS AND PROTOTYPE MEASUREMENTS *

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SWITZERLAND

Bottom outlets (BOs) are a key safety feature of high-head dams. Their main purpose is the regulation and – if required – a fast drawdown of the reservoir water level in case of e.g. floods, structural damage of the dam or maintenance works. The high energy heads at the gate result in high-speed free-surface flows in the BO tunnel. This leads to considerable air entrainment and air transport, possibly resulting in negative pressures in the bottom outlet. Subsequent problems like gate vibrations, cavitation and flow chocking can be mitigated by sufficient air supply via an air vent. Despite the importance of BOs, design recommendations regarding the required normalized air demand $\beta = Q_a/Q_w$, with Q_a = air discharge and Q_w = water discharge, are surprisingly scarce and the existing design equations show a large scatter (Fig. 1).

In this research project, hydraulic model tests and prototype measurements are used to develop improved design guidelines for BOs. The hydraulic model features a maximum energy head at the gate of H_E = 30 m w.c. at a discharge of $Q_W \approx$ 600 l/s, and allows to investigate the effect of H_E, gate opening a, air vent loss coefficient ζ, tunnel length L and slope S on air demand. The data indicate that the air demand not only increases with increasing Froude number at the vena contracta F_c, but also with decreasing ζ and increasing tunnel length L. A detailed analysis of the model data will be given in the full paper.

Air demand data from prototypes that also include parameters like e.g. ζ are scarce. To close this gap, we installed instruments to measure the air demand, air pressure and temperature at Luzzone (H_E = 210 m w.c.) and

* *Aération des vidanges de fond: Résultats des essais sur modèle à échelle réduite et des mesures de prototype*

Malvaglia (H_E = 90 m w.c.) arch dams in Switzerland. The first measurements during the yearly function tests of the old and new BO of the Malvaglia dam show a moderate to high air demand compared to existing data and design equations (Fig. 1). For the new BO the transition from free surface flow to spray flow leads to a major increase in air demand. The old BO with a different geometry exhibits a similar air demand for all tested gate openings *a*, and all measurements are in the spray flow region. These data, together with further measurements in autumn 2017 and spring 2018, will be used to validate the findings from the model tests and propose improved design recommendations.

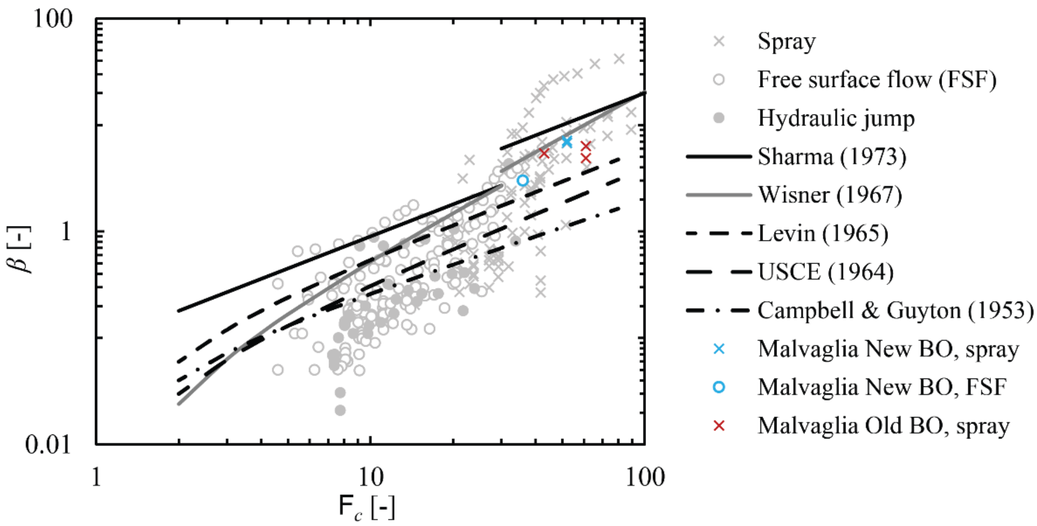

Fig. 1 Comparison of new prototype air demand measurements with existing data and equations. Comparaison des nouvelles mesures de la demande d'air en prototype avec des données existantes et des équations.

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TECHNICAL STAGE TO PLUG THE LARGE SIZE DIVERSION TUNNEL OF JATIGEDE DAM AT WEST JAVA, REPUBLIC OF INDONESIA, 2017

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INDONESIA

1. ABSTRACT

Jatigede Dam is a rock fill dam located on Cimanuk river, West Java province, Republic of Indonesia which is one of Multipurpose dam and second biggest in Indonesia with 114 m height and about 980 Mcm of reservoir volume. To perform the initial filling of the reservoir, the inlet of the diversion tunnel must be closed and followed by plugging work. Systematically, Jatigede Dam diversion structure with a diameter of 10 m, starting from Inlet Diversion Conduit along

61.454 m connected with Tunnel along 546,221m and Outlet tunnel ends at Plunge pool.

There are two types of plugging done that is Primary plugging along the 17,74 m the starting position of the conduit and Main plugging along the 41 m at the core of the dam.

Immediately after closing of closure gate on August 31, 2015, Engineer will confirm the area where is in the right bank of Plunge Pool up to front of Tunnel Outlet is satisfied to use for access and material loading area from above. After closure gate, lining concrete of tunnel at position grout stopper shall be cut by using electric grinder to make groove for fixing of the Steel Galvanized Plate. After the completion of the installation of Steel Galvanized Plate, so Grout Pipes, including Riser Pipes, Backfill pipes, and T-type Socket are installation and fixed firmly by U-bolts at 10 cm center to center at the correct position from Grout Pipe. Drainage pipe is installed at the bottom of tunnel before 1st stage of concrete placing then Shut-off gate, tied with a wire rope of 12 mm diameter, is installed at the upstream end drainage pipe.

Forms are installed and firmly fixed together by using wooden timbers, anchor bars tension bars to avoid displacement or deformation. All supports wooden timbers and anchor bars at upstream of forms for all lift (up to 5th layer of A1 Block) shall be installed and firmly fixed prior to the placing concrete. Cooling pipe was constructed for each Block. All cooling pipes are tested for the leakage under the pressure of 3.5 kg/cm2. The cooling water will be continuously provided by pump through the cooling pipes from the time of placing concrete until the concrete temperature comes down to 26oC. The discharge of water shall be controlled not to exceed 50oC of the concrete temperature. If necessary the water temperature shall be controlled by ice.

KEYWORDS

Large Diversion tunnel, Primary plug, Main plug, control the concrete temperature

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AN INTEGRATED GEOPHYSICAL INVESTIGATION FOR THE EARTHEN DAM INSPECTION: ELECTRICAL RESISTIVITY IMAGING, MULTICHANNEL ANALYSIS OF SURFACE WAVE AND GROUND PENETRATING RADAR

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THAILAND

1. ABSTRACT

Royal Irrigation Department (RID) announces that an integrated geophysical investigation can provide useful information for the earthen dam inspection. Nondestructive geophysical techniques; Electrical Resistivity Imaging (ERI), Multichannel Analysis of Surface Wave (MASW), and Ground Penetrating Radar (GPR) have a great potential in identifying subsurface deficiencies and the results are intuitively acceptable.

In relation to these activities, subsurface characteristics of particular interest must be inferred from the physical properties of clay core. Low or high resistivity range means relative moisture in embankment material and implies the homogeneousness of impervious clay core. The shear wave velocity measured by MASW can be numerically converted to undrained shear strength, implying the bearing capacity of compacted clay. The GPR image clearly reveals partial settlement of freeboard zone at the upper part of the old earthen dam as well as the area covered by filled material, if there was any treatment in the past.

Integrated interpretation of the three results together with several field evidences can help verifying the current condition of the old earthen dam. The applicable techniques are applied to twenty six earthen dams of RID for a five-year research project, and finally, exhibit a flowchart for the old earthen dam inspection by using integrated geophysical techniques. Solutions and recommendations from the research lead to big changes in maintenance and/or retreatment program of the RID dams in the present day.

Keywords— Dam inspection, GPR, MASW, Resistivity.

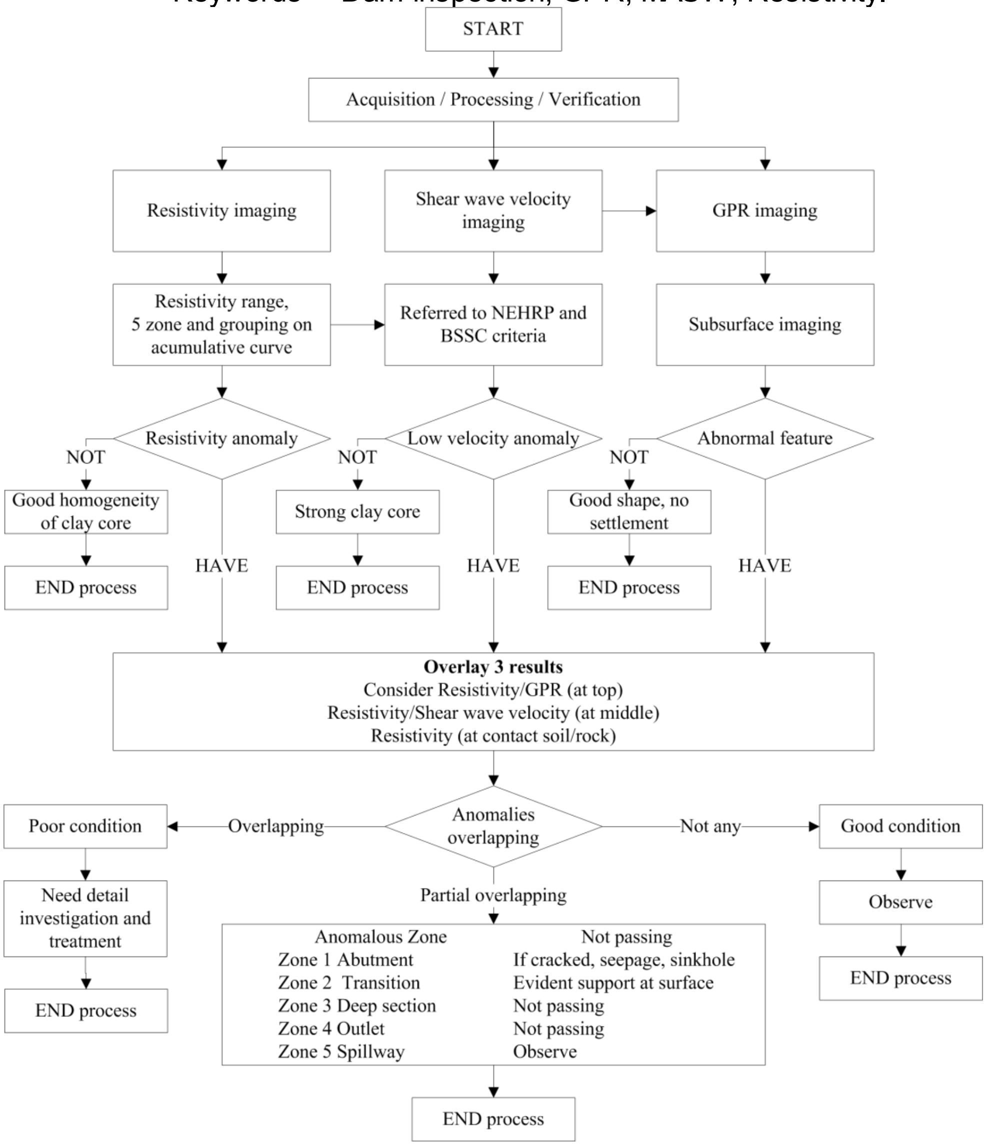

Fig. 1
Flow chart showing criteria of dam inspection, using geophysics. Note: at least resistivity, shear wave velocity and GPR play key technique in this account

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HOW PROBABILISTIC APPROACH CAN IMPROVE CMD DESIGNINGS

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IRAN

1. INTRODUCTION

Although CMD allows both the construction of admirable gravity dam bodies on weak rock foundations and the employment of low specific materials as aggregates for the dam body, it has more uncertainties than conventional RCC and CVC regarding design. Performance-Based Design (PBD) using a probabilistic approach could be a proper strategy for this type of dam. In this paper, the advantages of this method are described. Three CMDs, currently being constructed under the supervision of ABFAN consulting engineers in Iran, are used in the case study for the proposed probabilistic approaches.

2. USING THE PROBABILISTIC METHOD

Using this method in these aspects are discussed in the paper:

- Controlling the variations of aggregates.
- Weak rocks with uncertain engineering parameters.
- Effect of simplicity in construction on dam body behavior.

- Finding optimum characteristic compressive strength of Hardfill to minimize the total cement usage.

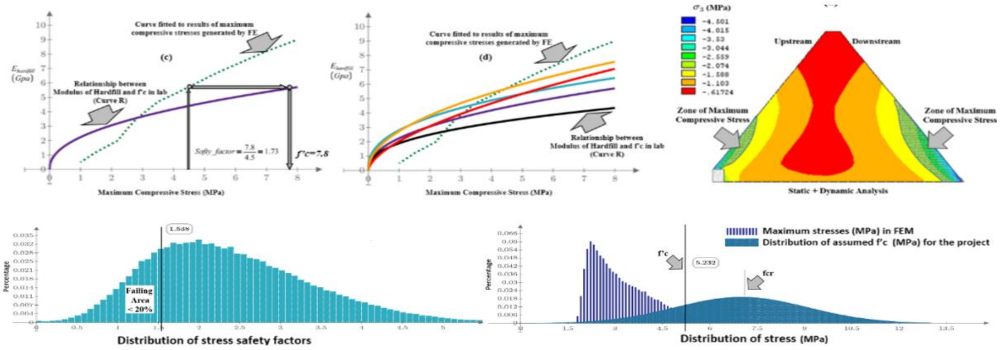

Fig. 1: Dasht-e-Palang dam probabilistic analysis results

3. CONCLUSIONS

In this paper, using a probabilistic approach in the designing process of three CMDs described. The main benefits were as follows:

1. Minimizing the variations of aggregates in the Hardfill using an optimal method for screening and fractioning without any crushing.
2. More authentic estimation of the effect of weak rock parameters on the sliding safety factors of the dam body.
3. Better estimation of the layered properties of the CMD body.
4. Using less cementitious material by optimizing f’c.

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EFFECT OF DILATANCY ANGLE ON THE RELIABILITY ANALYSIS OF BEARING CAPACITY OF DAM FOUNDATION USING MONTE CARLO SIMULATION

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1. INTRODUCTION

Analysis and design of geotechnical structures continue to face many uncertainties which make it difficult to choose the appropriate design parameters. Reliability analysis method makes it possible to quantify the uncertainties involved in the problem. It also determines safety factor according to the degree of uncertainty and acceptable risk. Reliability analysis can be considered as an alternative to the definitive methods and makes engineering judgment easier [1]. In this study, the reliability analysis of the bearing capacity of dam foundations was carried out via Monte Carlo simulation with the focus on the uncertainty associated with the friction angle. To do so, the upper-bound limit analysis was employed assuming the deterministic friction angle. The formulation and the general computational procedure were kept exactly as the one introduced by Michalowski (1997)[2]. As it is obvious, the non-associativity of plastic deformation of soils is a significant factor in limit load problems. In the current study, the substantial influence of the dilatancy angle on N_γ was also examined. As a conclusion, appropriate safety factors based on reliability analysis are suggested leading to economical advantage of the design of geotechnical structures.

2. CALCULATION OF THE BEARING CAPACITY OF DAM FOUNDATION USING MONTE CARLO SIMULATION METHOD

In this method, the foundation bearing capacity can be analyzed for various performance levels and soil bearing capacity is calculated depending on the desired level of confidence. Probabilistic analysis for bearing capacity of dam foundations using Monte Carlo simulation and uncertainty parameters is calculated. Among input variables, the friction angle is considered as random variables and (ψ), (γ) and (B) are constant. The number of iterations to simulate is set to 200,000 times, also the coefficient of variation of soil friction angle is considered 15% [3, 4].

3. NUMERICAL ANALYSIS

In the example a foundation with a width of 2 meters and granular soil with the unit weight of 19 $\mathrm{kN/m^3}$ are considered. Also The average of dilation angle (ψ) is assumed to be 6°. In calculating the definitive bearing capacity, the average friction angle is considered 25 degree. Safety factor in different iterations is calculated and the frequency graph of ultimate bearing capacity is shown in Figure 1. As can be observed the curve is continuous and follows the log-normal probability distribution function. In Figure 2 the procedure of calculating allowable bearing capacity with a confidence level of 90% are illustrated.

Ultimate bearing capacity of foundation using Michalowski method is obtained 92.5 kN for smooth foundations. If the dam foundation with the assumed specifications is analyzed using Monte Carlo method, the cumulative distribution graph of bearing capacity could be as Figure 1. To select the allowable bearing capacity of foundation, regarding the desired confidence level, cumulative distribution graph of bearing capacity can be selected. it can be concluded that the confidence level required for structures is about 90 to 98%.

According to Figure 2 allowable bearing capacity of smooth foundation due to the 90 percent of confidence level equals to 48.2 kN. By comparing the allowable values and ultimate bearing capacity regarding confidence level of 90%, it can be pointed out that safety factors for smooth foundations are obtained 1.92. According to the above explanation, it can be stated that the method of reliability analysis to calculate the bearing capacity of foundations is more reliable that certain methods, because in addition to reducing construction costs, this method handles the uncertainties that are also quantified.

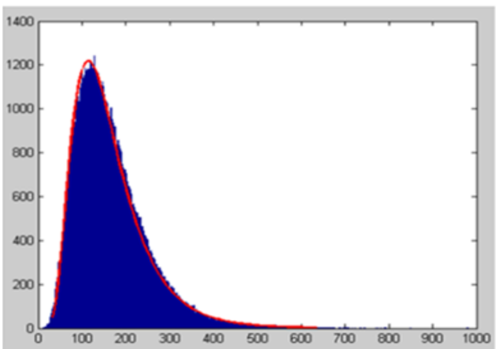

Figure1: Frequency diagram of ultimate bearing capacity of smooth foundation

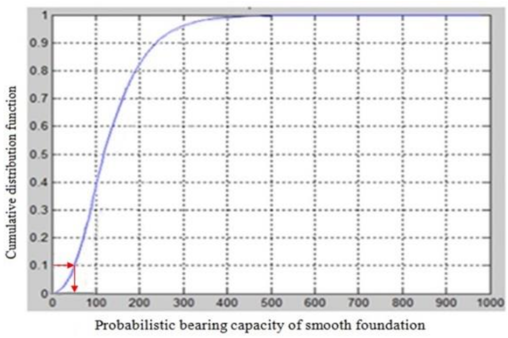

Figure2: Probabilistic bearing capacity of smooth foundation

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SPILLWAY HYDRAULIC MODEL TEST OF CIPANUNDAN DAM, WEST JAVA, INDONESIA[1)]

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INDONESIA

ABSTRACT

Primary purpose of water resources development in Indonesia is water supply for various needs. Therefore, various efforts are made by the government to solve the problem. One of the efforts in planning stage, is water resources infrastructure development of Cipanundan Dam at Cirebon District.

The spillway prototipe of Cipanundan Dam is made on scale of 1 : 20, several scenarios of discharge flow carry out based on design flood Q_2, Q_{25}, Q_{100}, Q_{1000}, and Q_{PMF}.

Design flood discharge on spillway prototipe of Cipanundan Dam is expected to provide parameters of hydraulic test results in laboratory that will

determine optimal dimension of spillway and appurtenance structure, so that it will be used as a starting point for next calculation step.

KEYWORDS

Cipanundan Dam, model test, hydraulic parameters

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MAE SUAI DAM SAFETY

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Worawut PINTABUTR, SAMART ENGINEERING CONSULTANTS CO.LTD

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THAILAND

ABSTRACT

Mae Suai is the second RCC dam in Thailand which is situated in Chaing Rai province, in the northern region as shown in Figure 1. It was constructed on the Mae Suai river during 1999 and 2002 for irrigation. The storage capacity is 73 Million cubic meter. The dam is a composite dam consisting of the RCC dam in the middle part of the dam to be the spillway and the earth dam on the both abutments as shown in Figure 2. The maximum height of dam is about 59 m. There are RCC blocks on the crest of earth dam at the downstream side. The differential settlement between the RCC spillway and the earth dam is occurred causing the cracks and gaps at the RCC blocks. In the first filling, the water overtopped the spillway and flow through the cracks and gaps. The leakage was observed at the downstream crest near the contact area between the RCC part and the earth zone part. They are repaired by the impervious membrane covering at the upstream surface of RCC blocks, the leakage is reducing but stilling. The downstream population worried about the safety of the Mae Suai dam especially in case of earthquake.

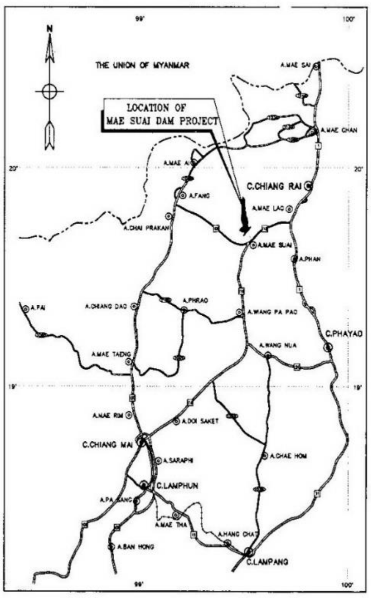


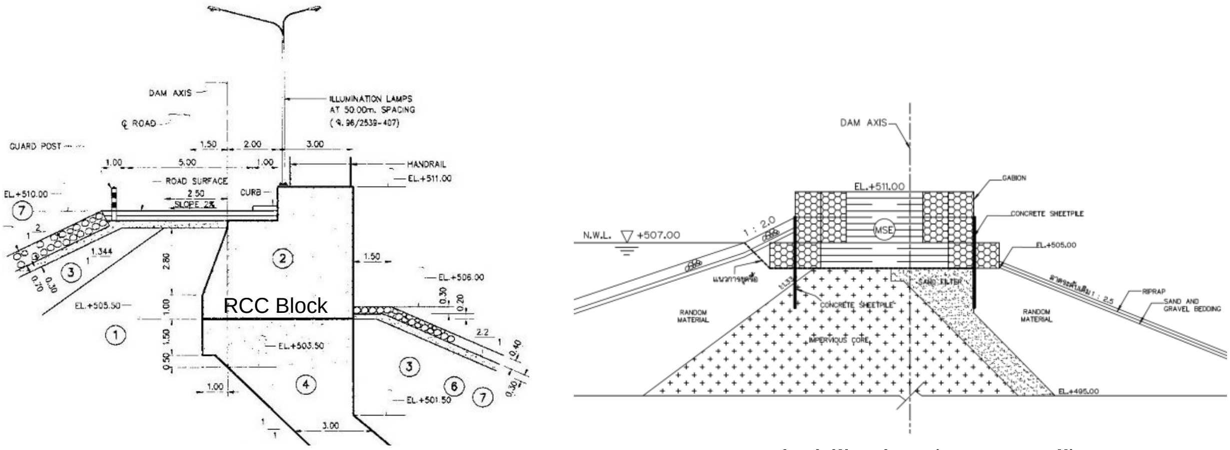
Fig. 1 Location of Mae Suai Dam Project

Fig. 2 View of Mae Suai Dam

Fears of an earthquake have deepened after 6.3 magnitude earthquake hit the province in May of 2014. The epicenter to the dam site is 18 km. The maximum PGA at the dam site is 0.33g. Fortunately, the seismic force did not affect the Mae Suai Dam. Officers inspected the dam conditions immediately after the earthquake and no abnormality was found.

However, people at the dam downstream still worried over the incident. Besides, there was not any study, plan, prevention measures or risk surveillance in terms of surplus discharge and dam break, which caused faster flood and more damage to life and property. Then, the Royal Irrigation Department had studied the dam break of Mae Suai Reservoir Project in terms of surplus discharge, causes of damage of dam and appurtenant structures which may cause flood and flood severity and characteristics, as well as to complete action plan to cope with the dam break.

Moreover, the dam rehabilitation will be done in two parts. First, the RCC blocks on the earth dam crest will be removed and replaced by the flexible and vibration resistance structure. The GRS wall with the cutoff sheet pile will be used as shown in Figure 3.And the second is to build the 3 m diameter tunnel as the additional outlet to control the water level for flood management.



Existing

Rehabilitation (GRS Wall)

Fig. 3 Dam Crest Rehabilitation Detail

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SAFETY ASSESSMENT AND MAINTENANCE OF RELIABLE OPERATION OF DAMS IN RUSSIA

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RUSSIA

1. INTRODUCTION

The report includes information on the state policy of Russia in the sphere of the safety and reliability of dams, on other laws and standard legal acts and on organization of surveillance of dams.

2. SAFETY MAINTENANCE OF DAMS IN RUSSIA

In Russia one of the basic laws in the sphere of safety and reliability of hydraulic structures is the Federal Law "On the safety of hydraulic structures" [1], which was adopted 20 years ago. According to this law, maintenance of safety of a hydraulic structures includes development and implementation of measures aimed to prevent possible failure.

Russia adopted the system of maintenance of safety and reliability of dams on every stage of their lifespan (design, operation, preservation and rehabilitation). According to this system, safe and reliable operation of hydraulic structures is the duty of their owner or operator, which is supervised by federal executive authorities. The report includes case studies which demonstrate how the system works. It also includes estimation of reliability, failure risk assessment and analysis, assessment of ability of the operator to localize and eliminate possible emergency situations. According to legislature of Russia, one of the basic results of state supervision includes the issue of operation permit. The aims, issues and types of state supervision of dams in Russia are described in the report.

The principal issue in development of dam surveillance is includes organization and management of hydraulic structures' safety and reliability provision system. This issue is solved by design and implementation of the system of legislative, economic, technical, organizational and social measures aimed to prevent possible failures of dams, localization and termination of their consequences, which is demonstrated in the report on the hydraulic structures operated by RusHydro PLC.

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DAM DEFORMATION MONITORING MODEL AND FORECAST BASED ON PCA-RBF NEURAL NETWORK*

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CHINA

ABSTRACT

Dam safety assessment has received much attention since the end of the last century. The safety assessment of a gravity dam requires a wide range of information that is acquired from monitoring systems. Usually, there are many instruments equipped in the dam and its surroundings for monitoring the water level, temperature, deformation and other aspects. Now, with the progress of monitoring technology, the current measurement technology has advantages of high precision, good stability and strong sensitivity. But the response of dam structural behavior is the result of multi-factor synergies. So it’s necessary to extract the main factors, which influence the dam performance, and in the meantime analyze their development trend.

In this paper, a monitoring model based on principal component analysis (PCA) and radial basis function (RBF) neural network is put forward to analyze the displacement trend of the concrete dam. The method of principal component is used to reduce the dimension of the dataset and simplify the multi-correlation of the components. On the basis, the in-situ monitoring displacement and the extracted

components is taken as the input of the RBF neural network to build the forecasting model. An example analysis based on the proposed monitoring model is performed on a prototype concrete dam, and the results show that the proposed model is reasonable and practical.

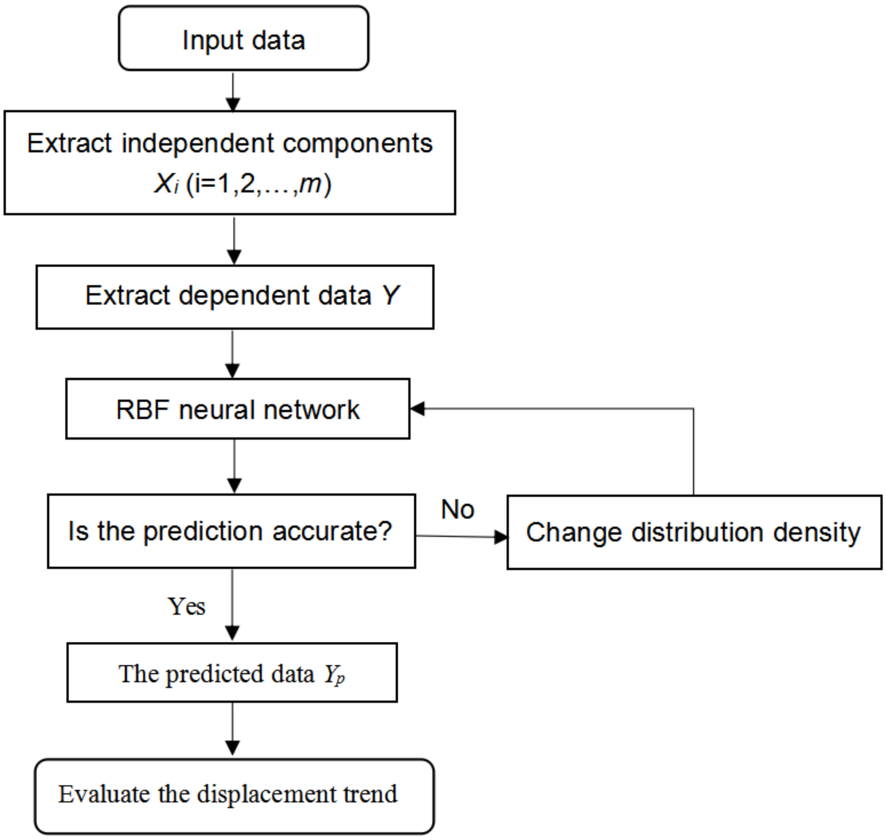

Fig. 1: Process of PCA-RBF neural network

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SAFETY ASSESSMENT FOR LARGE RESERVOIR CONSTRUCTED FOR DOMESTIC WATER NEAR URBAN AREAS AND A CASE STUDY

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TURKEY

1. INTRODUCTION

Earthquake safety is one of important task of total safety assessment for the structures, at where are constructed on the seismically active regions in the world. There are some metropolitan provinces, which are under threatening of earthquakes. One of them is Izmir Metropolitan Area with five million people. Major earthquakes with the potential of threatening life and property occur frequently here. There are six large dams for providing domestic water for Izmir province. These are namely Alacatlı Kutlu Aktas, Balcova, Gordes, Guzelhisar, Tahtalı and Urkmez dams. The investigation area is structurally cut by numerous faults, which are resulted by horst-graben system in west Anatolia.

2. EVALUATION

For this study, the dams providing domestic water for Izmir Metropolitan Area were considered for case study. The physical properties of these dams are given in Tab. 1. The study of seismic activity is generally performed by means of deterministic and probabilistic seismic hazard analyses. The deterministic seismic hazard analyses indicate that peak ground acceleration changes within a wide range (0.116g and 0.442 g) for the six dam sites within the Izmir Metropolitan Area.

Tab 2. shows the results of seismic analyses. There are various methods to quantify the total risk factor of a dam. In this study ICOLD and Bureau methods are used. Tab. 3 introduces the results of total risk analyses.

Tab 1. Physical properties of dams considered for this study.

No	Dam	River	Height from river bed (m)	Completed Year	Volume of embankment (hm^3)	Volume of reservoir (hm3)
1	A.Kutlu Aktaş	Hirsiz	20.3	1997	0.28	16.61
2	Balcova	Ilica	73.3	1980	1.25	7.76
3	Gordes	Gordes	82.9	2010	4.54	448.46
4	Guzelhisar	Guzelhisar	89.0	1982	3.21	158.00
5	Tahtali	Tahtalı	60.5	1999	3.37	306.65
6	Urkmez	Urkmez	43.5	1990	3.50	72.02

Tab 2. The results of seismic analyses

No	Dam	Deterministic Method *			
		Maximum earthquake M_{max}	Minimum distance, R_{min}	Mean PGA + 50 %	Mean PGA + 84 %
1	A.Kutlu Aktaş	6.1	19.7	0.116	0.189
2	Balcova	6.1	4.3	0.288	0.450
3	Gordes	6.7	1.1	0.442	0.702
4	Guzelhisar	6.7	3.1	0.409	0.642
5	Tahtali	5.7	2.9	0.277	0.431
6	Urkmez	5.7	1.7	0.310	0.482

Tab 3. Total risk of dams considered for this study.

No	Dam	Hazard Analysis		Total Risk (ICOLD,1989)			Total Risk (Bureau, 2003)		
		Class	Hazard Ratio	Risk factor	Risk class	Risk ratio	Risk factor	Risk class	Risk ratio
1	A.Kutlu Aktaş	II	Moderate	30	III	High	163.4	III	High
2	Balcova	IV	Very high	34	IV	Very high	187.6	III	High
3	Gordes	IV	Very high	36	IV	Very high	155.6	III	High
4	Guzelhisar	IV	Very high	36	IV	Very high	158.3	III	High
5	Tahtali	IV	Very high	36	IV	Very high	186.6	III	High
6	Urkmez	IV	Very high	32	IV	Very high	188.5	III	High

3. CONCLUSIONS

The seismic hazard analyses have indicated that peak ground acceleration changes within a wide range (0.116 g and 0.442 g) for the six dam sites of this area. The total risk analyses depending on the seismic hazard rating of dam site and risk rating of the structure have concluded that most of these large dams have high-risk class in the metropolitan area. This study indicates that some dams must be analyzed and redesigned to provide public safety for people, who are living in the Izmir Metropolitan area.

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LABORATORY STUDY OF THE EFFECT OF RECYCLED FILLERS FROM COKING AND IRON CONCENTRATE FACTORIES ON THE ROLLER COMPACTED CONCRETE PROPERTIES IN DAMS*

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IRAN

ABSTRACT

This study presents mechanical and durability aspects of using different waste fillers including Iron powder, Iron concentrate, Coal and Coke Powder, which cannot be reused at industry process. (samples from different parts of the Jalalabad Iron Ore Concentrate Plant and Zarand Coking Plant, Kerman, Iran) as well as mineral powder filler as a control sample to replace 3% and 6% of coarse and fine natural aggregates content in RCC combination. Absorption, compressive strength, workability and non-segregation of grains investigated for the concrete specimens. The experimental results showed that RCCs of iron ore-

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* *Roller Compacted Concrete Dams (RCC Dams)*

powder filler contents with 6% of the weight of coarse and fine natural aggregates had higher values of 28 days compressive strength and minimum 24-hour water absorption about 2.22%. Generally, the fillers of iron ore concentrate factory including iron ore filler and concentrate filler have better results in improving the mechanical and transitional properties of roller concrete, due to rounding of aggregates, comparing by the case of carbonaceous compounds extracted from the coking plant, including Coke and coal fillers. In addition to that, using this type of waste in concrete may has more environmentally efficient, because this helps to remove some parts of wastes and protects the environment.

Keywords: Roller Compacted Concrete (RCC), Slump, Mix design, Compression strength, Water absorption

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OPERATION AND MAINTENANCE OF SABALAN DAM

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IRAN

ABSTRACT

Inspection and Monitoring of dams as well as data analysis and interpretation has a critical role in the field of dam safety. Surveillance and Monitoring programs on dams provide information for evaluating the dam`s performance with respect to design intent and expected behavior.

Sabalan dam is an 89 m high rock-fill embankment with central clay core constructed in the north west of Iran and has been operated since 2006.

The dam instrumentation system comprises variety of piezometers, total stress cells, settlement meters and inclinometers that are installed along 5 cross sections. In this paper, instrumentation scheme of Sabalan dam are described. Then the safety of the dam during operation is evaluated through the surveillance reports which have been prepared from records of the whole monitoring system.

The results indicated that the stability of the dam satisfies the safety requirements. The percentage of settlement is within the reasonable range and also stress and pore water pressure graphs indicate safety of the dam. Detailed results of the study are demonstrated through the text.

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STUDY ON DESIGN AND RESEARCH OF RESERVOIR EMPTYING OF HIGH DAMS IN CHINA

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CHINA

1. PRESENT EMPTYING ABILITY OF LARGE HYDRAULIC RESERVOIRS IN CHINA

Emptying facilities were set up in most of high dams in China to lower water level in case of emergency or dam damage. Most reservoirs can be discharged more than half water head and 70% capacity which is mainly affected by hydrologic conditions, reservoir topography, dam height and design of emptying facilities.

2. KEY TECHNOLOGIES OF LOWER DISCHARGE FACILITIES

The most effective measure to emptying reservoirs is via lower discharge facilities, the key technologies of which are an important breakthrough of emptying design, including enhance emptying ability, shorten emptying time, routine maintenance, hydraulic problems and downstream protection.

3. SUBJECTS NEED TO BE FURTHER RESEARCHED ABOUT EMPTYING DESIGN OF HIGH DAMS

The emptying requirements and process are much complex and some factors should be considered in the emptying design, including the relationships and requirements of integral safety degree and the water level for overhaul, hydrologic characteristics and downstream area flood control, arrangement conditions and sizes of emptying facilities as well as reservoirs slope stabilities when emptying. Through comprehensive and thematic analysis, a proper emptying ending water level and emptying facilities scale should be chosen to satisfy the dam overhaul requirements, ensure dam safety risk acceptable and prevent dam failures or other secondary disasters.

SUMMARY

Based on summarizing of present design status of reservoir emptying, the key technology problems of lower discharge facilities are analyzed in this paper, and then some subjects need to be further researched are discussed.

(1) Reservoir emptying is to discharge the reservoir to a proper water level in order to keep the dam stability instead of discharging the entire reservoir.

(2) It is very important and effective to set emptying facilities to lower down the water level in emergency. Characteristics of reservoir and projects as well as hydrologic conditions should all be considered when emptying design to help choosing a reasonable emptying scale and depth.

(3) The key technologies of lower discharge facilities should be further researched in the future to break though the limited factors.

(4) The basin cascade dispatching and forewarning, manage systems of dams safety adapting to construction and economic level, as well as dams lifecycle safety management and risk distinction system suited to national conditions, should all be established and improved in order to minimize risk of basin cascading dams failure.

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VISUAL INSPECTION AND ASSESSMENT OF OPERATING DEVICES IN IR. H. DJUANDA DAM - INDONESIA

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INDONESIA

Ir. H. Djuanda Dam is one of the largest dams and the first multipurpose dam in Indonesia. The dam with an area of 8,300 ha was built by the French franchise contractor Compagnie francaise d'entreprise in 1957 and completed in 1967, with a water potential of approximately 12.9 billion m3 / year. The capacity of this dam is 2.44 billion m3.

Visual inspection of large dams Ir. H. Djuanda is a routine activity undertaken in the context of monitoring activities on dam safety. Visual inspection is done periodically and continuously to get the latest visual data about the condition of Dam Ir. H. Djuanda. Visual inspection is important because not all changes in the condition and behavior of the dam can be described from the measurement or reading of the instrument. This visual inspection is done twice a year i.e May - June at high water level and November - December when the water level is low.

Visual inspection activities consist of a series of inspection activities on dam bodies, complementary buildings, hilltop, rim (roving) reservoirs and the surrounding dam environment. Matters inspected during the visual inspection of the dam include leakage, basement, springs, evaporator, erosion eruption, surface erosion, scouring, abrasion, excessive plant growth, top straightness, protrusion or subsidence of slopes, animals, deterioration of rip-rap quality as well as other slope protective materials. As for the concrete buildings are examined for cracks, crushing, dissolving, leaking, indication of deterioration of quality or chemical reaction and or damage due to erosion and cavitation, the stability of construction joints.

The method of inspection implementation is divided into 2 types: visual inspection and underwater inspection. Visual inspection is a visual inspection of the ground and water inspection objects, such as dam surfaces, auxiliary buildings, ridges and reservoir cliffs, hydro mechanical equipment and so on.

Based on the results of visual inspection and observation of the dam body, main spillway towers, access galleries, saddle dam bodies, reservoir reefs and complementary buildings that are generally in relatively good condition and normal.

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EVENT TREE CONCEPT FOR DESCRIBING THE RELIABILITY OF GATED WEIRS AND SPILLWAYS

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AUSTRIA

ABSTRACT

The safety and reliability of dams and weirs depend – among other things – on the functionality and reliability of the gates, which are used to control the flow. Various design approaches exist in different countries. In Germany and Austria and numerous other countries, the so called (n-1) condition has to be met when designing the gates of dams and weirs [1]. This deterministic design concept aims at a safe discharge of the design flood, assuming one gate is out of operation. The probabilistic approach behind this concept is that the coincidence of a blockage of two or more gates with a design flood is very unlikely.

A new design approach, that could replace the (n-1) condition, is under investigation at the moment. It is based on the idea, that the required level of safety is determined at the beginning of the design process. For example, it is accepted, that the maximum water level is exceeded with a probability of 0,001 each year (return period of 1 in 1000 years). The design has to take into account four variables: the number of gates, the total capacity of the weir respectively the spillway of the dam, the duration of ‘critical works’, where the gates or their drive systems are under revision and not available for flood discharge and the probability of the malfunction of one gate. Empirical values for the letter two

variables have to be found, based on data gained from literature and experiences of gate operators.

The paper will explain the design approach in detail and give examples of the actual design process.

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KEY WORDS

Safety Of Dams, Gates

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VEGETATION EFFECT ON RELIABILITY ANALYSIS OF SLOPE STABILITY USING MONTE CARLO SIMULATION

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IRAN

1. INTRODUCTION

As an inevitable consequence in dam construction, unnatural slopes around dam body are formed and usually devoid of vegetation. Translational failure is defined as linear movement along a bedding plane or a soil layer lying near to the surface. Such movements are normally shallow and parallel to the surface [1]. Vegetation affects mechanical properties of soils related to slope stability and shallow landslide triggering [2]. The aim of this study is evaluation of increased landslide resistance of a slope due to vegetation considering uncertainty of related parameters.

2. METHOD AND ANALYSIS

The stability of slopes is governed by the load, which is the driving force that causes failure, and the resistance, which is the strength of the soil-root system [3]. Main influences of vegetation on the stability of the slope segment are from enhanced soil cohesion due to soil reinforcement by roots and tensile root force acting at the base of the slip plane [4]. Considering the equation of safety factor and uncertainty of four parameters, i.e. angle of friction, unit weight of soil and both mentioned parameters due to vegetation effect, reliability analysis based on Monte Carlo simulation using a developed Python code was carried out.

3. RESULTS AND CONCLUSION

Cumulative distribution functions (CDF) of safety factor (FOS) for slope with and without vegetation are depicted in Fig.1.

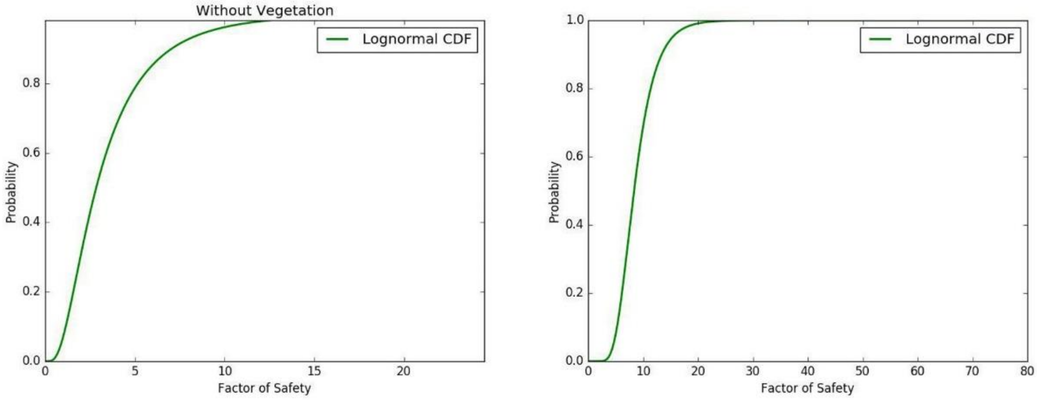

Fig. 1: Cumulative distribution function

Comparing these diagrams, it is conspicuous that taking vegetation into account, FOS significantly increases. The overall results indicate that vegetation roots have a considerable stabilizing effect on the slope, limited to the rooting depth. It is appeared that through a matrix of tensile fibers, enhanced soil cohesion has a significant effect on slope stabilizing.

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Keywords: Slope stability, Vegetation, Statistical method, Safety factor

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PERMISSION PROCEDURES OF DAM CONSTRUCTION AND MANAGEMENT IN INDONESIA

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INDONESIA

1. INTRODUCTION

In order to manage the safety of dams from planning, construction, initial impounding, operation and maintenance, until the dam closure, Indonesia has regulations governing the approval procedure in questions, or commonly known as certification. First, design certification that can be submitted together with the construction certification. Second, the initial impounding certification with a complete review of the construction. Third, operation and maintenance certification by completing the initial impounding datas. Fourth, dam closure certification with no more benefits or failure that endanger the downstream. Other than those fourth certification, there are dam design changes and design rehabilitation certifications from the Minister of Public Works and Public Housing through the Commission of

Dams Safety. All regulations stipulated in the ministerial regulation of public works and housing number 27 in 2015 about dams.

2. DAM DEVELOPMENT IN INDONESIA

In accordance with Minister Regulation No. 27 / PRT / M / 2015 on Dams, dam safety role is intended to realize the orderly development and utilization of dams so be worthy of a technical or non-technical aspects from the design, construction, operation, decommissioning stages in order to prevent or reduce the potential failure risk of the dams construction.

Many dams in Indonesia are very old. It was built before Mid 80's, some dams were even built before 1950, during the colonial time. Based on Minister Regulation No. 27 / PRT / M / 2015 on Dams, Indonesia has 214 dams are categorized as large dam until 2017.

3. CONCLUSION

The idea of dam safety concept is best provided when due consideration is given to the following tenets:

- Structural safety, safety against structural, hydraulic, and seepage failure;
- Operation, maintenance and monitoring; and
- Emergency action plan.

In order to review the safety of the dams, the dams construction in Indonesia must obtain a license or approval, including:

1. Design.
2. The construction in preparation for reservoir initial impounding.
3. The reservoir initial impounding in preparation for the dam operation.
4. Decommissioning of the dam functions.

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INTERNAL EROSION RISKS IN RIGHT ABUTMENT OF AHMADBEIGLU STORAGE DAM IN IRAN

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EXTENDED ABSTRACT

Stability in embankment dams is one of the significant issues where dam failure involving loss of life and property can occur. Foundation behavior especially soil foundations can significantly affect the stability of this kind of dams. Internal erosion /piping through the soil foundation or along dam body-foundation is one of the leading causes of embankment failure that should be considered in design and during impounding.

This paper summarizes the internal erosion risk assessment process for right abutment of Ahmadbeiglu Storage Dam, earth fill dam that located in North-west of Iran with 65 m height from clay core foundation and 27.4 million cubic meter reservoir volume.

Ahmadbeiglu Dam Site is located at the upstream of several villages with more than 1000 population and failure of this dam will result in loss of human life, extensive property damage to homes and other structures, thus, Ahmadbeiglu Dam is high risk.

According to the geology and geotechnical studies, the results of field and laboratory tests and the dam site investigation, the right abutment of this dam site has been considered as layered soil foundation. The foundation soil is often in CL classification; soils with classification of SC, SM, and ML have been observed as layer between soils with CL classification and these layers are approximately continues layer. In addition, the plasticity index (PI) of these layer is less than 7.0 (PI<7).

The risk analysis process consists of a) Identification of failure modes b) Estimation of probability of dam failure due to each failure modes c) Dam failure consequence d) Risk prioritization and risk control.

The failure of embankment dams by internal erosion or piping has been evaluated in three different modes including piping through embankment, piping through foundation and piping from embankment into foundation. All failure modes due to internal erosion are broken down in two four phases; initiation of erosion, continuation of erosion, progression of erosion, detection and finally breach.

The probability of dam failure due to the backward erosion in the layered soil foundation (PF1), from embankment into layered soil foundation(PF2) and through embankment (PF3) have been estimated as 1.1e-7, 1.35 e -8 and 5.4e-9 by considering that the reservoir is in normal operation.

In order to categorize the internal erosion risk, f-N event chart has been used. On the f-N chart, f and N represent the annualized failure probability and the estimated life loss associated with an individual failure mode, respectively.

According to the f-N chart, the most critical risk comes from erosion through layered soil foundation (PF1), but all the risks of dam failure by erosion in right abutment of Ahmadbeiglu dam is in Priority C that indicate a reduced justification for risk reduction action related to these failure modes.

For increasing safety, in addition to the instruments of dam body and foundation in right abutment, instruments such open standpipe piezometers and observation wells for evaluation excess pore water pressure and ground water level at the downstream and right abutment have been installed.

Key words: Abutment, Internal erosion, Risk assessment, Stability, Ahmadbeiglu Storage Dam

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THE ECOLOGICAL RISK, THE PROTECTION MEASURES TAKEN AND ACHIEVEMENTSIN THEYANGTZE RIVER BASIN

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ABSTRACT

The Yangtze River is the third long river in the world with 6300km, there are unique and complex habitats and ecosystems including rivers and lakes, form the original to estuary the drop is over 5400m.There are over 400 species in the Yangtze River basin, of which 350 species are pure freshwater fish and 156 species are endemic species. The Yangtze River system contains unique and diverse species, and provides us with abundant aquatic products, which are the products of floods. Although the flood is disaster for human being, they can provide us with valuable hydropower resources, on the one hand, we try to control flood in the middle and lower reaches, as well as for the excessive demand for water and electricity; on the other hand, resulted in tens of thousands of dams in the Upper Yangtze River.

Human activities such as water projects, reclaimation projects have led to the change of habitats on which aquatic life depends, which will affect the reproduction of aquatic organisms; The destruction of aquatic communities, in turn, affects the environment on which humans depend. Compared with the historical literatures, aquatic biodiversity of the Yangtze River basin has decreased obviously, and its outstanding characteristics are the species decrease and population structure change. Now, the Yangtze River basin of the main ecological problems and risks include loss of aquatic biodiversity, part of the loss of habitat environment conditions, showed a trend of increase, river connectivity to reduce water pollution. The decline of biodiversity is

manifested mainly in the decrease of species number, shrinkage of population, miniaturization and lower age of individuals, and degradation of germplasm resources. For the sake of deteriorations of natural fishery of Middle and Lower Yangtze River, the connectivity of Yangtze River had played significant negative impacts on fish resources, which resulted in the decrease of the wild fish diversity in the lakes, despite having heated it up by overfishing.

To resolve the aquatic ecological problems and risks in the Yangtze River basin, China has legislated nine laws on ecological environmental protection, 15 laws and more than 660 regulations on the natural resources protection. It has also increased its efforts to protect the nature consercation, such as strengthening the construction of protected areas, carrying out artificial breeding and releasing, and restricting fishing and construction of fishing facilities. However, with the development of the Yangtze River basin increasing, the existing measures may not be enough to delay or reverse the trend of the Yangtze River aquatic ecological decline, and the protection measures still need time to be checked.

Key words : Hydraulic-projects; Ecological Risk; Ecological problems; Aquatic ecological protection measures

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ANALYSIS AND INTERPRETATION OF THE BAIXO SABOR DAM'S BEHAVIOUR DURING THE FIRST FILLING OF THE RESERVOIR

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PORTUGAL

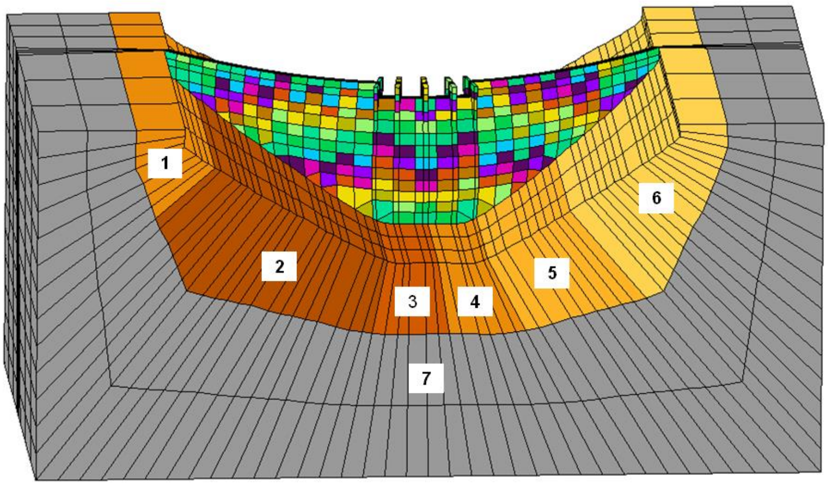
1. STRUCTURAL MODEL

The paper presents some relevant results of the structural behaviour analysis and interpretation of Baixo Sabor dam, a double curvature arch dam with 123.00 m high, during the first filling of its reservoir, considering the monitoring data and the results of a 3D finite element model of the dam and its foundation (Fig. 1). The first filling of the reservoir lasted about 28 months, between December 2013 and April 2016.

The viscoelastic behaviour of the concrete was considered. Actions due to water pressure and thermal variations were discretized fortnightly.

2. SOME RESULTS

In Fig. 2 the horizontal displacements observed over time for the central plumb-line at elevation 233.10 m and the correspondent computed horizontal displacements are represented. The great influence of the thermal variations on the structural response and the very good agreement obtained between observed and calculated displacements should be pointed out.



Rock mass foundation (Young modulus):

E_{f1} = 20 GPa

E_{f2} = 30 GPa

E_{f3} = 25 GPa

E_{f4} = 20 GPa

E_{f5} = 15 GPa

E_{f6} = 10 GPa

E_{f7} = 40 GPa

Creep law of concrete:

$$J(t,t_0)=\frac{1}{40.0}\left(1+3.2(t_0^{-0.35}+0.05)(t-t_0)^{0.12}\right) \qquad (\text{GPa}^{-1})$$

Fig. 1

Dam-foundation finite element mesh considered in structural analysis

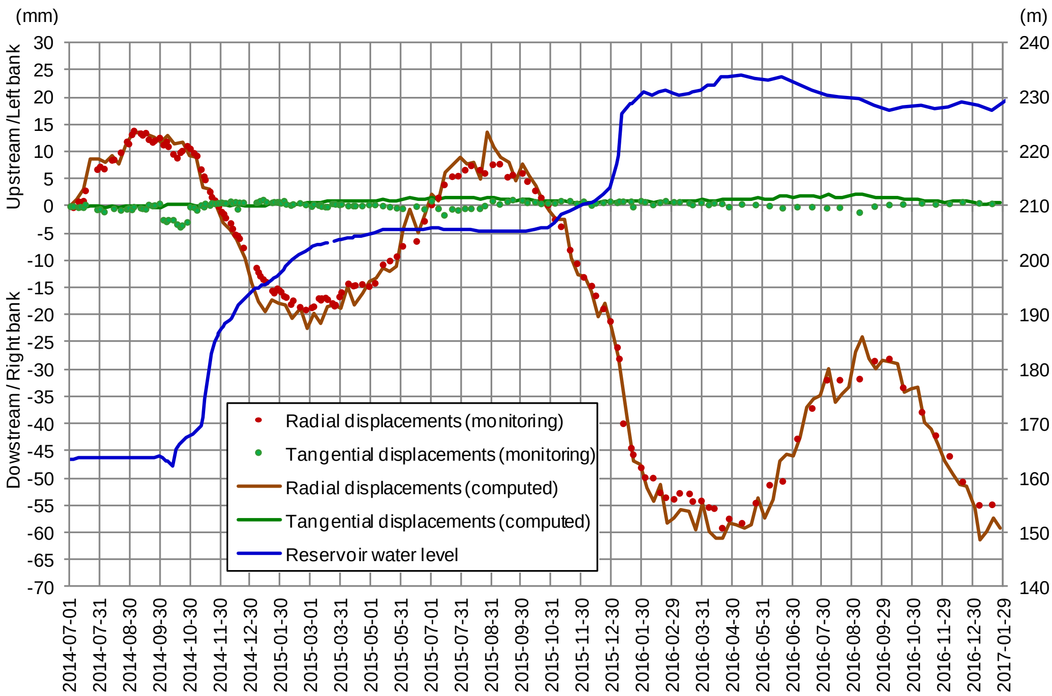


Fig. 2

Central block 17-18 horizontal displacements at 233.1 m elevation, measured on the plumb line and computed from July 2014 to January 2017

The data from other types of measuring instruments also presents good agreement with the computational results, demonstrating the good performance of the dam and the adequacy of the models considered for the analysis and interpretation of the observed behaviour during this important lifetime stage of the dam.

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SCOUR ESTIMATION FOR NAM THEUN 1 SPILLWAY PLUNGE POOL

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THAILAND AND SWITZERLAND

1. INTRODUCTION

Nam Theun 1 is a hydropower plant under construction in Lao PDR, located about 170 km east of Vientiane. The scheme comprises a 180 m high RCC gravity dam. The flood release structures including the plunge pool at the dam toe need to be designed to withstand the high dynamic loads and is one of the major hydraulic design issues. In order to reduce the scour depth, the spillway flip buckets will be equipped with baffle blocks that will spread the jet and improve its aeration.

In addition, the presumable scour depth and the required pre-excavation are important design parameters both with regard to the powerhouse tailwater conditions and the dam safety. Several methods were used to estimate the presumable scour depth for different return periods and to design the plunge pool pre-excavation for the 100-year design flood.

2. METHODS

A practical methodology for design of Nam Theun 1 pre-excavated plunge pool has been applied.

At first classical scour formulae were applied. Second a physical model was built at AIT in Bangkok. This was used to investigate the behavior of a movable gravel bed, mainly in order to compare the effect of the above mentioned scour reduction measures, as well as to investigate the pressure fluctuations in the pre-excavated area.

In the next step, the pre-excavated plunge pool was designed for a flood frequency referring to the serviceability of the powerhouse. Then, the dynamic pressures on the plunge pool invert and berms were recorded and the according dynamic pressure coefficients were calculated.

The pressure data was analyzed in terms of the mean dynamic, RMS, maximum and minimum pressure coefficients at the proposed pre-excavation invert and berms. The jet characteristics just before impacting the plunge pool water cushion surface were determined. These results were used to evaluate the residual energy and scouring potential at the plunge pool invert and berms. The chosen approach containing empiric formulae combined with physical model testing allows for as suitable design of the challenging flood evacuation system of the Nam Theun 1 hydropower scheme.

3. RESULTS

Comparing the range of the pressure coefficients for Nam Theun 1 plunge pool case with those available in the literature shows that the Nam Theun 1 proposed pre-excavated plunge pool shall be deep enough to not be eroded in an extensive area deeper than the proposed invert level of 105.0 m asl by its design flood jet.

The calculations also show that the spillway jets for all range of floods shall be fully developed before impacting the plunge pool surface which will reduce the erosive power of the plunging jets. Provision of the dents on flip buckets, which are not embedded in the disintegration length relationships, shall further improve the jets disintegration and aeration.

KEYWORDS: EXCAVATION, FLIP BUCKET, HYDRAULIC MODEL TEST, PLUNGE POOL, SCOURING.

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A DEVELOPMENT OF HYDROLOGIC RISK ANALYSIS MODEL FOR SMALL RESERVOIRS BASED ON BAYESIAN NETWORK *

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1. ABSTRACT

Typhoon-induced storm surge along with heavy rainfall has been recognized as the most frequently reported hazards for water-related hazards in South Korea. Moreover, it has been widely acknowledged that the frequency and intensity of typhoons (or abnormal low-pressure system) are likely to increase over time due to the potential impact of climate change. There are 14,000 small reservoirs in South Korea and various issues related to the reservoir safety. A hydrologic reservoir risk analysis requires a systematic process to ensure dependency relationships among key hydrologic variables (e.g. precipitation,

* *A DEVELOPMENT OF HYDRAULIC-HYDROLOGIC RISK ANALYSIS MODEL FOR SMALL RESERVOIRS BASED ON BAYESIAN NETWORK*

discharge and water surface level). However, the existing reservoir risk approach showed a limitation in assessing the interdependencies across the variables. In this context, this study proposed a Bayesian network based reservoir risk analysis. Based on the basic information of reservoir, various failure modes was first identified and the failure modes are then translated into nodes in the Bayesian network framework. The failure probabilities of the each node were estimated quantitatively by integrating limit state equations, which are composed of a set of random variables. Moreover, we investigated an integrated Bayesian network model to estimate overtopping risk from water surface level rise informed by climate change scenarios. A further discussion on the role of the uncertainty for overall risk is provided. This proposed procedure will help to effectively introduce the risk analysis for reservoirs safety in Korea.

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EXPERIMENTAL STUDY ON DIRECT SHEAR BETWEEN FRP - CONCRETE IN TERFACE BASED ON DIC

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1. INTRODUCTION

This experiment measures the surface deformation of FRP plate with the assistance of relevant advanced digital image technologies and can overcome some limitations of above tests quite well, thus eliminating some disadvantages of strain gauges. Besides, this experiment analyzes the stress transmission in different de-bonding stages through careful observations of FRP-concrete de-bonding process, thus establishing the de-bonding law of FRP-concrete interface and providing technical instructions for the disposal of FRP-concrete bonding interface in real hazard elimination and reinforcement projects.

2. METHODS

This experiment adopts optical measurement technique to measure the deformation of FRP plate surface. In order to acquire speckles for optical measurement, two colors-black and white, are sprayed on the surface to be measured respectively. Connect the data line of optical measurement camera with the computer, observe the computer screen, and adjust the height and focal length of camera until the speckles on FRP plate can be clearly seen. Set the photograph frequency as five pics per second. Place the installed testing equipment fixed with FRP plate-concrete specimen on the 10t testing machine. Adopt monotonic loading mode under displacement control, the tensile speed is 0.03mm/min.

3. RESULTS

(1) The strain distribution law of FRP plate of each specimen is consistent.

(2) The maximum strains of specimen SS-120 and specimen SS-180 are relatively small for influence of clamping chuck of testing machine.

(3) Apart from some factors that influence the test results, and combined with the analysis of FRP-concrete specimen of each plate length, we can predict that: the maximum strain of each specimen under extreme load increases as the bonding length of FRP plate increases; the strain distribution law curve along the length direction of plate extends outwards as the bonding length of FRP plate increases.

4. CONCLUSION

(1) The shear strain stress of FRP plate and concrete interface is not evenly distributed, the de-bonding starts from the load end and presents itself as brittle failure.

(2) The strain-plate length distribution of FRP plate indirectly reflects the bonded quality of specimen and corresponds to the strength error reflected by the calculation outcome of Chen-Teng formula.

(3) The effective bonding length of FRP plate is estimated by analyzed the surface strain distribution of FRP plate along the length direction. The determination of effective bonding length of FRP plate in project applications means a lot for reducing reinforcement costs and construction work load.

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COMBINING NUMERICAL AND PHYSICAL MODELS FOR COST EFFECTIVE DESIGN OF IRREGULAR SPILLWAYS

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ABSTRACT

Regular dam safety evaluations are performed on Swedish dams according to the voluntary Dam-Safety Guidelines (RIDAS). Implementation of the updated guidelines has raised the demands on the existing dams and deficiencies are regularly discovered during dam safety revisions.

In the case of the Swedish dams Långströmmen and Ramsele, deficiencies in structural and hydraulic performance were discovered and dam safety upgrades were enacted timely.

For Långströmmen, the challenges were several. Prior to the dam safety upgrades, the capacity of the spillway had been 1670 m3/s , while the updated design flood added another 50% or close to 2500 m3/s. Inspections also uncovered damages in the bedrock and concrete adjacent to the rock downstream of the spillway. Diving inspection found bedrock to be jacked up and washed away during previous flood episodes downstream the ski jump.

Downstream of Ramsele's left spillway chute, extensive rock erosion has occurred even though the spillways are rarely used. This due to the fact that the original design did not include energy dissipation, even though the hydraulic conditions were non-favorable. There were also reasons for concern with regard to backward erosion under the existing spillway chute as even occasional, shorter spills caused visible erosion damage.

For both dams, feasibility studies led to the selection of new spillway designs which necessitated a physical model. These models were designed, constructed and tested.

In the case of Ramsele, the model was constructed with the main objective to attain optimal design of the prolongated spillway chute. However, during the testing phase, an alternative design was proposed: a shorter prolongation with a ski-jump at the end. The design change was chiefly motivated by cost reduction, as the construction length could be decreased by 30% to about 35 m.

Långströmmens' model was completed as planned and the project went into the construction phase following the selected design. During this executive phase, the design needed to be revised due to issues such as poorer rock quality than expected as well as to excavate additional rock from the stilling basin to supply material for the reinforcement of the embankment dams.

As the physical model no longer existed, Computational Fluid Dynamics (CFD) was used to evaluate impacts of proposed changes designs. The CFD-model was only used for qualitative comparisons of results from different designs.

After the completed construction of the planned measures, discharge tests are carried out according to accepted international guidelines. The prototype verification of hydraulic performance at Ramsele has been completed. This was used to generate a topographic model, which, can be updated by repeating the procedure after larger floods in the future. The two models can then be compared for evaluating erosion propagation.

A similar verification is planned for Långströmmen following the completion of the project.

The paper illustrates the benefits, in both economic and engineering aspects, of having physical models constructed. In the case of Långströmmen, it also shows a way to benefit from the model even after it has been removed.

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THE BEHAVIOR OF THE SPILLWAY-STRUCTURE OF THE DJUANDA DAM JATILUHUR INDONESIA *

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INDONESIA

1. ABSTRACT

Djuanda Dam is the largest dam built in Citarum River, located about 80 km toward southeast from Jakarta the capital city of Indonesia.

Djuanda Dam Jatiluhur is a multipurpose dam with a design-capacity volume of 3 billion m3, and based on the latest bathymetri measurement results has a storage capacity of approximately 2.5 billion m3.

This dam has a concrete cylindrical-shaped spillway called morning glory with a diameter of 90 meters and a height of 105 meters. The maximum capacity of this spillway is 3,000 m3 and also equipped with two irrigation outlets of which capable to release 195 m3/s water on normal water level.

This spillway is integrated with the powerhouse and connected with the access galery and tailrace tunnel, and make it as the only infrastructure to

* *LE COMPORTEMENT DE LA STRUCTURE DE DÉVERSEMENT DE DJUANDA DAM JATILUHUR INDONÉSIE*

release water from this dam so that the operation and maintenance of this spillway structure is very important.

The shift of the dam body construction toward the upstream than the planned has shifted the center of gravity of the dam causing the concrete fracture connecting the spillway-structure with the access gallery. This cracks then named as join 0. The water leakage from this cracks are collected and channeled into the drainage channel to monitor the quantity and the quality of leakage. The leakage monitoring activity conducted every two weeks.

There are 37 points of surface marker installed in this morning glory spillway-structure, 3 points placed on the top floor of the morning glory spillway-structure, 3 points on the floor in the powerhouse. While on the wall of the powerhouse is placed 31 points of surface marker, 11 mounted on the inside wall named interior circle, and 20 others mounted on the outside wall named exterior circle. The monitoring activity by measuring the movement of these surface markers conducted every month.

The measurement of the spillway-crest on 14 spillway-windows has conducted twice, on August 2001 and on October 2017.

Based on surface-marker monitoring results, this spillway has experienced movement and the monitoring data record shown the average cummulative settlement is 11 cm, and the largest cummulative settlement reached 15 centimeters at the point of window number 12, with elevation 106,8438 meters above sea level.

The movement of this spillway is influenced by the elevation of the reservoir water level (RWL), when the elevation of the RWL reach the normal elevation the spillway-structure moves down, and vice versa.

The movement of the spillway-structure also impact to the leakage at join 0. The leak is still monitored until now and it shown the largest discharge of 190 ml per second. The water quality of the leakage is monitored and did not indicate it carry the embankment material, visually it looks clear and clean.

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PHYSICAL MODELLING OF THE JIRKOV DAM BELL-MOUTH SPILLWAY

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CZECH REPUBLIC

1. ABSTRACT

Jirkov Dam is located in the North-west part of the Czech Republic. It was constructed between 1960 and 1965. It is a rockfill dam sealed by the impervious clay core. The dam is equipped with the bell-mouth spillway structure at the upstream toe of the dam that is combined with two bottom outlets and three water abstraction intakes at different levels. Water from the bell-mouth spillway and the bottom outlets is conveyed to the outlet tunnel that ends at the downstream toe of the dam. The upper part of the tunnel structure forms an access to the bottom outlets.

Perpendicular to the tunnel is the injection gallery that goes along the whole dam at the foundations level. In recent years a grout curtain was constructed from the injection gallery in order to seal the seepage that had been observed.

The unusual spillway intake setup led to the research that was carried out by the Civil Engineering Faculty of the Czech Technical University in 2015

and 2016. The aim of the research was to assess the existing layout and propose optimized design.

Physical model was used to derive the rating curve of the spillway and particularly to find the flow at which the undesirable hydraulic effects occur. It was also used to design and verify suitable modifications to the intake of the bell-mouth spillway, to the bottom end of the vertical shaft and to join of the bottom outlets to the spillway tunnel.

This paper presents proposed design features as well as the results of the physical modelling. The research derived rating curve for the existing spillway design, for the spillway without the overflow piers and for the rounded bottom end of the vertical shaft. Proposed layout showed an improvement over the original design with lower risk of blocking the shaft by debris. The original capacity of the Jirkov Dam spillway prior reaching the undesired hydraulic conditions was assessed to be 95 m^3/s, while the improved design capacity is 124,6 m^3/s. This capacity is higher than 1 in 10 000 years flow which meets the Czech national standards for dam safety.

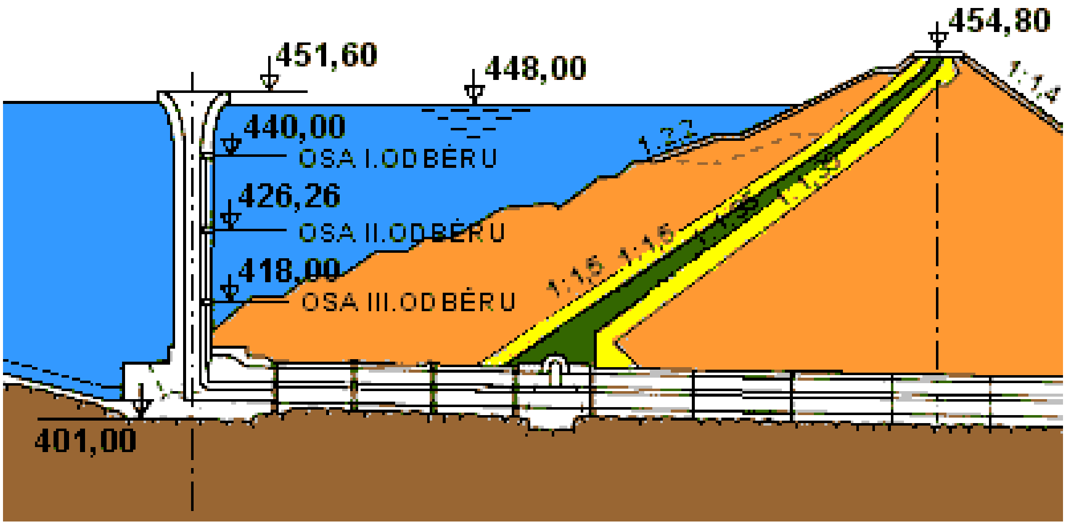

Fig. 1 Jirkov Dam bell-mouth spillway

Keywords: Jirkov Dam, dam, design, spillway

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THE AUTOMATED DATA ACQUISITION SYSTEM FOR THE SAFETY CONTROL OF BAIXO SABOR DAM

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ABSTRACT

This paper presents the main characteristics of the automated structural monitoring system of Baixo Sabor dam and addresses a proposal for the definition of triggers for the physical quantities measured through the use of an automated data acquisition systems (ADAS).

Baixo Sabor is 123 m high concrete arch dam, and 505 m long at the crest, designed, constructed and explored by EDP, located in the northeast of Portugal in Sabor river (a tributary of Douro river). The first filling of its reservoir, with a volume of about 1095 hm^3, took place between December 2013 and April 2016.

The defined triggers for the physical quantities will be linked to an Internal Early Warning Control System of the dam, allowing the early identification and

notification of potential abnormal situations to the entities responsible for the dam safety.

In operation since August 2016, the ADAS of the Baixo Sabor dam defined by EDP allows the measurement of several quantities used for the safety control, analysis and interpretation of the dam behaviour, such as: horizontal and vertical displacements, movements of joints, strain, uplift pressure, foundation displacements, seepage, concrete and air temperatures, and reservoir water level, among others.

The measurements, obtained through the use of the ADAS developed and installed by Prointega Ingeneria, are sent to the gestBarragens system, which is the LNEC and EDP data processing and management system used for monitoring, diagnosis and safety control of dams.

Fig. 1 Baixo Sabor Dam

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SEISMIC HAZARD ANALYSIS FOR GAMBIRI DIVERSION DAM

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IRAN

1. INTRODUCTION

The Gambiri diversion dam is located at east of Kunar province, near the Asadabad city on the Kunar river, eastern Afghanistan. This project falls within a region of very high seismicity, in the eastern sector of Alpine- Himalaya orogenic belt. In order to estimate the ground motion parameters a comprehensive seismic hazard analysis was performed. This paper gives first a brief overview of the seismo-tectonics of the region and the seismicity. The methodology followed to obtain the peak ground acceleration, response spectra and design accelerograms for different design levels is then described together with selected results.

1.1. PROBABILISTIC SEISMIC HAZARD ANALYSIS (PSHA)

This model better fits the many line sources (faults). It can be treated by the well-known software SEISRISK III [1]. For estimating the seismic potential (maximum magnitude) of a fault the Wells & Coppersmith relationship was used which is based on worldwide data [2]. Calculations were carried out for return periods between 100 and 2500 years. In order to obtain a weighted average of the results calculated with the three attenuation laws, a logic tree approach with three branches was applied. Selected results are shown in “Table 1”.

Table 1
Values of PGA obtained from PSHA using line source model

Design level	Return period (year)	Dam site	
		Peak ground acceleration (g)	
		horizontal	vertical
OBL (84th percentile)	200	0.30	0.18
DBL (84th percentile)	500	0.394	0.245
MDL (84th percentile)	2500	0.455	0.290
MCL (84th percentile)	Deterministic	0.64	0.53

2. CONCLUSION

The dams and relevant structures are designed for the median (84th percentile) of the maximum credible level (MCL). This yields peak ground acceleration of 0.64 g in the horizontal and of 0.53 g in the vertical direction. Response spectra were produced for the design of concrete structures and acceleration-time histories, compatible with the design site-specific response spectrum, for the design of the dams and slopes.

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KEY WORDS

Analysis, earthfill dam, finite elements method, slope stability

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IN-DEPTH SAFETY ASSESSMENT OF LARGE RUN-OF-RIVER HYDROPOWER PLANTS IN SWITZERLAND

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SUMMARY

Among the 1200 dams classified in Switzerland, 167 are large dams according to ICOLD standards. The Swiss Federal Office of Energy (SFOE) is entrusted with the overall supervision of the enforcement of the legislation, which comprises the development of the safety concept and dam safety requirements published in form of Guidelines. The SFOE is also entrusted with the direct safety supervision of the 217 largest dams in view of their impounding head, storage capacity and hazard potential for the population in the area downstream of the dam. These are categorized into 124 concrete dams, 66 embankment dams and 27 run-of-river hydropower plants. The latter are deemed to be in the interest of public safety mainly for their relevant storage capacity.

With the new Dam Safety Legislation in Switzerland (2012), large run-of-river hydropower plants along main rivers became subjected to in-depth safety assessments under the direct supervisory authority of the SFOE based on the specific Enforcement Guideline of the Dam Safety Legislation (2015). The Swiss dam safety concept, apart from continuous surveillance, maintenance and emergency planning also entails such periodic in-depth safety assessments. This consists in a review of hydraulic and structural actions (static, flood and seismic) for all water-retaining structures and safety-critical appurtenant components of such an installation, including lateral embankments or dams within the storage area. Present structural, hydraulic, hydrogeological, geological, steel-structural and process control technology state of all above components require an assessment, as well as implemented surveillance and maintenance practices. If necessary, based on actual scientific and technical state of knowledge, improvements are recommended and may be set into practice.

Two case studies are presented in this paper. The two plants dispose of continuous surveillance (regular function tests of all safety-critical installations and equipment and yearly inspections by external experienced engineer), continuous update of an archive with relevant documents, continuous structural maintenance, adequate monitoring instrumentation and redundant control technology. Further, as all operational and hazardous load cases meet the requirements, it is allowed to conclude that safety of both plants is guaranteed in accordance to the Swiss Dam Legislation. A team of experts (civil, mechanical and electrical engineers and geologists) can perform straightforwardly a total in-depth safety review of such hydropower plants within a reasonable timeframe.

KEYWORDS: Safety of Dams, Run-Of-River Hydropower Plants, Inspection and Assessment

CLEARANCES AND COPYRIGHT

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ASPECTS CONCERNING AGEING OF EMBANKMENT DAMS

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1. INTRODUCTION

Ageing defines the timely change of the behaviour of embankments. These changes are caused by biogenic, geogenic, anthropological or climate factors. The ageing processes may occur periodically, temporarily, steadily, or even suddenly. These ageing processes can cause harm and can initiate failure processes.

Different definitions of ageing are available, and were developed within the different engineering faculties. Generally, ageing depicts a deterioration process and, frequently, is treated hand in hand with the long-term behaviour of dam structures.

Particularly, embankment dams, which were designed without safety margin or show design deficits, are sensitive to long-term deterioration effects. Ageing affects all materials and all parts of embankment dams. Research and science frequently focus on single processes such as the behaviour of dispersive clays, but those single processes are rarely put into an overall context such as life cycle considerations. Life cycle considerations may support risk management approaches as well as may shed light on the obligations of the owner during the different life cycles (Fig. 1).

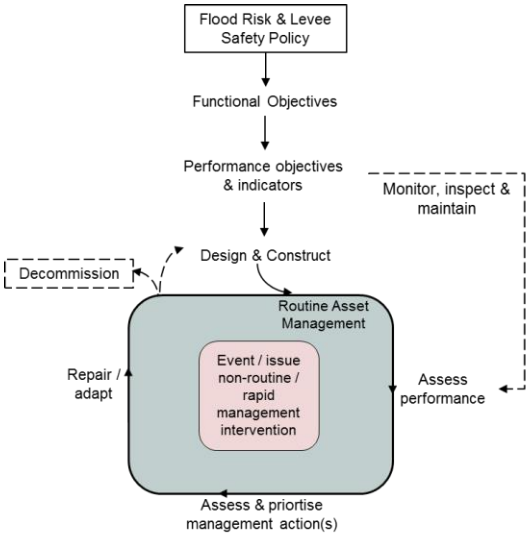

Fig. 1 Life Cycle Management of Levees

2. DEFINITION/GENERAL ASPECTS

“For the purposes of this therefore, ageing is defined as a class of deterioration associated with time-related changes in the properties of the materials of which the structure and its foundation is constructed. Excluded are the effects if exceptional events. Under normal conditions during the operation of structures ageing will usually affect the performance requirements, and then later affect the safety if corrective measures are not taken.” (ICOLD 93) Generally ageing depicts a time-dependent alteration and deterioration of material characteristics and/or the complete dam structure.

In modern dam management life cycle considerations are state of the art starting with the design phase.

The ageing of typical materials, such as clay, geotextiles, concrete, etc. is an important aspect to assess the ageing of complete structures. The long-term behaviour of soils and the underground is more difficult to assess or to predict than the behaviour of artificial materials such as concrete and geosynthetics. For latter materials ageing was investigated in the past precisely.

A safety margin should be considered within the design phase in the context with stability analysis and serviceability aspects. The sooner negative ageing effects are detected, the earlier countermeasures can be taken. Early measures are generally cheaper and more efficient than trying to rehabilitate a severely damaged embankment. Measures reach from easy works which can be handled during maintenance routines to a complete demolition and re-construction of the embankment dam.

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HYDRAULIC ANALYSIS OF TEMPORARY FLOOD HAZARD TO SUPPORT THE PLANNING OF THE CONSTRUCTION PHASES OF HYDROPOWER PLANTS

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SLOVENIA

1. INTRODUCTION

In the planning stage of the interventions in water space and riparian areas hydraulic model research of runoff regime is an established tool in the search of the final solution, which in addition to providing the functionality provides the preservation or mitigation of flood and erosion hazard. To support construction, stepwise planning of temporary structures and measures, etc., is crucial as well. The importance of analysing the runoff regime in a particular intermediate phase of the construction is mainly reflected in siting of an extensive and complex intervention, the construction of which takes place a long time, with changing environmental and hydraulic conditions. During the period of intermediate phase of construction the temporary state in the area could have a significantly more adverse effect on the runoff regime than a final design state.

2. METHODS

In hydraulic research hybrid hydraulic modelling was used, which applies the manner of modelling (physical/numerical) that is the most relevant in a particular case [1]. We applied conventional and distorted physical models for flood areas and various structures, while for the numerical analyses of runoff conditions during the individual construction phases fully-2D modelling was applied.

3. RESULTS

Based on the calculations, the impact of the intermediate conditions during the construction was determined by comparing the water levels in the characteristic points and velocity fields, as a difference between the situation during the implementation of the individual phases and the condition prior to the start of construction. By comparing intermediate situations and the results of the conditions prior to and upon completion of construction works it was possible to determine and evaluate the potential deterioration in the individual phases of construction or changes in space, so that the HPP design engineer could predict different construction phases of the individual structures or propose and justify an additional set of (temporary) measures to remedy increased hazard and risk.

4. CONCLUSION

Temporary flood hazard hydraulic analysis in the planning of construction phases is presented on the case of siting interventions according to the national spatial plan of HPP Brežice, to identify potential intermediate increase of hazard and risk, higher than that predicted for the HPP under full operation.

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KEYWORDS

Power Plant, Construction Phase, Flood Control, Numerical Model, Physical Model

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THE APPLICATION OF MATURITY MATRIX IN DAMS SAFETY PROGRAM IN BENGAWAN SOLO RIVER BASIN ORGANIZATION (RBO)

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Safety of dams can be successfully achieved through prudent implementation of a solid dam safety program. The safety assessment of the dam was carried out based on the strategy and policy prepared by national government. The implementation program of the dam safety is prepared by concerned RBO. To implement the program the RBO establish Dam Management Unit (DMU).

To support DMU in the preparation and monitoring of the dam safety program, monitoring needs to be done to all activities related to the dam safety program. The DMU activities involve technical and non-technical aspects from regulatory, human resources, facilities and procedures. The maturity level of each DMU can be measured by using several methods, one of those is Maturity Matrices.

The Maturity Matrices was introduced by the World Bank in cooperation with Damwatch from New Zealand. This method is a tool for DMU in measuring its performance or level of its maturity through self-assessment. The matrices consist of master matrix with 10 components, and sub-matrices that contain sub-

component or activities. Other than for measuring the maturity level of the DMU, the matrices can also be used by the DMU for the planning purposes.

The government of Indonesia is considering to use this Maturity Matrices in each RBO in Indonesia. The Bengawan Solo RBO has recently piloted the Maturity Matrix in their organization. This paper discuss the initial results of this pilot. Self-assessment using maturity matrices has been conducted in some DMUs to evaluate the implementation of dam safety program as a result of 2 workshops. Among the assessment result done by DMUs, DMU of Bengawan Solo RBO showing an interesting result to be studied. The following figures are the result of the DMU, scoring of the matrices mostly fall at a good practice level except for Information Management and Dam Safety Training and Education components which are at the elementary levels and Reservoir Operations at the very good practice level. Yet the objective of such assessment has to be achieved, to expedite the objective, validation to the assessment result need to be done by the independent facilitator.

Components of the Maturity Matrix		Maturity Level				
		Level 1 Needing Development	Level 2 Elementary	Level 3 Good Practice	Level 4 Very Good Practice	Level 5 Best Practices
1	Governance	1	2	3	4	5
2	Information Management	1	2	3	4	5
3	Dam Safety Training and Education	1	2	3	4	5
4	Surveillance	1	2	3	4	5
5	Spilway and Outlet Equipment	1	2	3	4	5
6	Reservoir Operation	1	2	3	4	5
7	Dams and Spilway Maintenance	1	2	3	4	5
8	Audit and Review	1	2	3	4	5
9	Managing Dam Safety Problems	1	2	3	4	5
10	Emergency Preparedness	1	2	3	4	5

Fig. 1
Results of the assessment of the DMU Bengawan Solo RBO

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FULL WAVE BASED DAMAGE IDENTIFICATION IN DAMS

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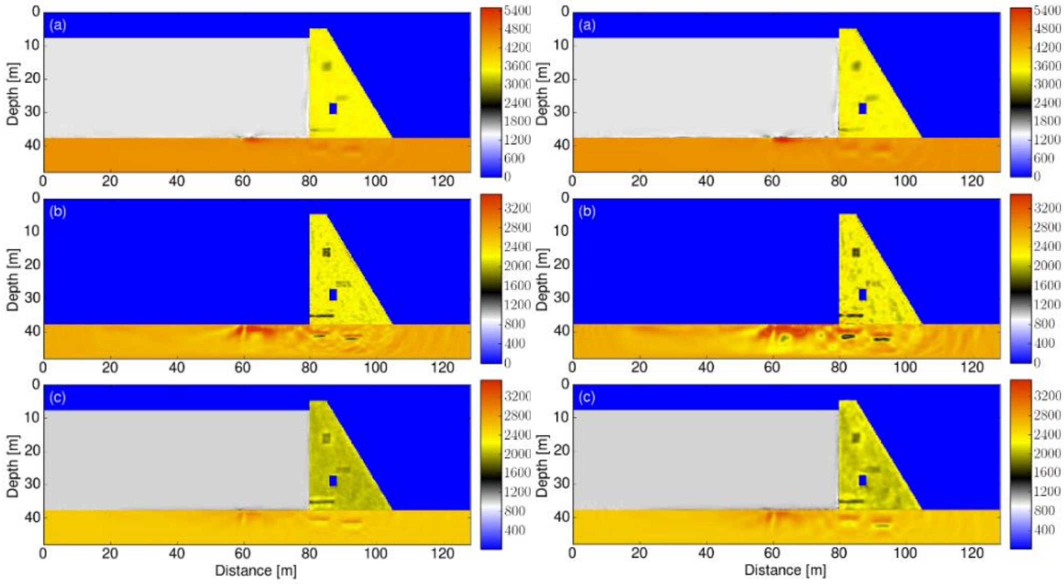
EXTENDED SUMMARY

To quickly and efficiently identify the deterioration in the structural integrity of dams we propose the application of numerical methods and inverse analysis. Drawing inspiration from the successful application of Full Waveform Inversion (FWI) in geotechnical exploration and non-destructive testing (NDT), this paper explores the application of seismic body waves identify damages in dams.

Full waveform inversion (FWI), initially proposed by [1, 2] and further developed in the last decades, is regarded as the modern seismic imaging technique which utilizes a comprehensive representation of the interaction between wave physics and subsurface properties. Here information on the material properties are obtained by ‘fitting’ a numerical model (here the wave equation) to the data field data obtained by propagating seismic body waves in the said material (the dam). The numerical model is usually a function of the material properties being searched for and the fitting/inverse analysis is carried out using various optimization strategies.

For the FWI, two acquisition setups were considered. Setup 1 consists on sensors placed both on the dam structure and the foundation. Setup 2 differs with fewer sensors on the foundation and a 20m distance between the source and closest sensor. The true dam model used had damaged regions both in the dam structure and the foundation. To start the FWI, dam material properties at construction was used.



(a) Setup 1 (b) Setup 2

Fig. 1 FWI model comparison for acquisition setup 1 and 2.

From the results obtained in Fig. 1, it can be observed that the proposed method is capable of identifying most of the damages in the dam. More so, the resolution of damages identified in setup 2 was higher. Thus, an acquisition setup with sensors placed closer to regions of (expected) critical damage is recommended for an optimal identification process.

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SELF-PROTECTED UNDERWATER CONCRETE IN REHABILITATION OF HYDRAULIC STRUCTURES

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CHINA

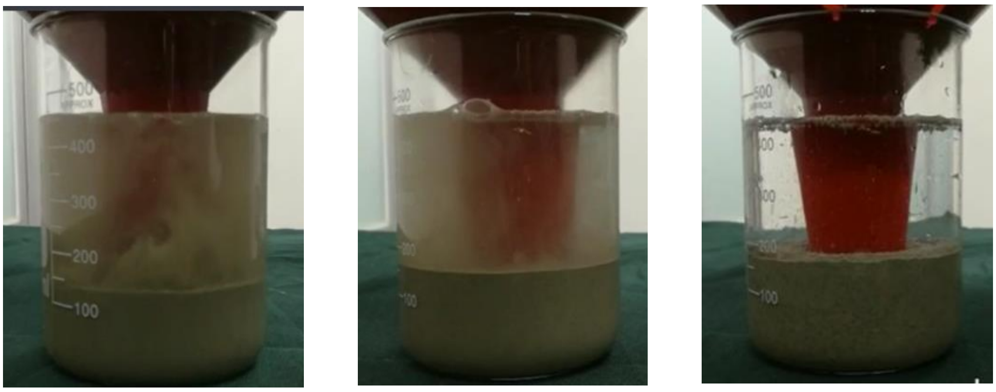
ABSTRACT

In rehabilitation projects of hydraulic structures, underwater concrete technology can be adopted without reservoir emptying. It should have a very economic advantage in many cases, although the unit price of underwater concrete may be higher than that of ordinary concrete. Most underwater concrete, or underwater undispersed concrete, has employed flocculent to improve the scouring resistance of concrete during pouring process in the water. Meanwhile much more superplasticizer have to be used to assure the workability of the concrete. The price of concrete increases due to the large consuming of the admixtures. Although the flocculent retain most cement in concrete, there are still a few cement diffusing into the water body during the underwater concrete pouring. The diffusing of cement induced not only cement waste, but also pollution of water body.

Self-Protected Underwater Concrete （SPUC） is an innovative concrete technology for underwater construction invented by Tsinghua University and Sinoconfix company in China. Before concrete pouring, a small amount of innocuous protective agent is pouring into water body. The water in the vicinity of pouring concrete becomes into a dilute solution of the protective agent, for example,

the concentration could be 0.01%. Due to the exclude effect of the solution, no cements will diffuse into the water body.

To illustrate the difference among the ordinary, undispersed and self-protected technology, three demos were conducted, shown in Fig.1. The ordinary and dispersed cases indicate the motor without and with flocculent, respectively. The self-protected case indicates the motor without flocculent but protective agent in the water. All the mortars were poured into the water via a funnel. Water remain lucid and no cement diffusion was observed in the self-protected case.



(a) Ordinary (b) Undispersed (c)Self-Protected

Fig. 1 Comparison among ordinary, undispersed and self-pretected technology

To validate the SPUC technology, an in-situ test was conducted in Tanjiang bridge, Guangdong Province, China. A pit was digged and paved with plastic sheet with color bands, as shown in Fig. 2. Then water filled and UPA was poured into the water. Concrete had been poured until the pit filled with SPUC.

(a) commencement of pouring (b) process of pouring (c) drill core

Fig 2. Field test of SPUC

After concrete harden, the difference of elevation between the cast point and 5 m away is only 60 mm. The average compress strength of drill cores is 36.8 MPa, where design compress strength is only 25 MPa. The bottom concrete of the piers in this huge bridge was decided to pour by using SPUC technology.

Some practical engineering application in projects are also introduced in this manuscript, for example, a rehabilitation project of gravity dam, an underwater concrete poured foundation and a bridge underwater pier. These success applications exhibit the broad prospect of SPUC technology.

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VIBRATIONS IN LARGE DAMS. MONITORING AND MODELLING*

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PORTUGAL

1. INTRODUCTION

In the scope of dam safety control, knowledge regarding the dynamic behavior of dams must be continuously updated and improved, relying on the combined use of advanced vibrations monitoring systems for measuring accelerations, which must include quality data acquisition technologies (e.g. accelerometers, data concentrators, etc.) and sophisticated modal identification software for automatic data analysis/management, and accurate numerical models of dam-reservoir-foundation (DRF) systems [1].

2. METHODS AND RESULTS

The case study is Cabril arch dam (132 m high). A continuous dynamic vibrations monitoring system is installed in the dam, which includes cutting-edge

* *Vibrations dans les grands barrages. Auscultation et modélisation*

software for automatic and interactive data analysis and management (*Modal_ID2.0* and *Modal_ID_auto2.0*), based on frequency domain modal identification techniques. Cabril dam's dynamic behavior is simulated using a recently developed 3D FE numerical program (*DamDySSA2.0*), for dynamic state space analysis of arch dam-reservoir-foundation systems.

A comparative study between modal identification outputs and numerical modelling results is presented, namely in terms of the dam's natural frequencies and vibration mode shapes, for different reservoir water levels.

3. CONCLUSIONS

The excellent agreement achieved between experimental and numerical results demonstrates the value of Cabril dam's monitoring system and associated software (*Modal_ID_auto2.0* and *Modal_ID2.0*), and simultaneously proves the reliability of the state space formulation implemented in *DamDySSa2.0.* Thus, this work proves the importance of vibrations monitoring systems (and the associated hardware and software) in the scope of dam safety control, as well as the potential of their combined use with numerical models of dam-reservoir-foundation systems.

ACKNOWLEDGEMNTS

The authors wish to acknowledge the funding association – FCT, Portugal - for supporting the installation of the monitoring system in Cabril dam (REEQ/815/ECM/2005) and for the PhD grant SFRH/BD/116417/2016.

KEYWORDS

Vibrations; Monitoring; Modelling; Cabril arch dam.

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SEEPAGE AND SLOPE STABILITY ANALYSIS OF EARTH DAMS

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ABSTRACT

Earth dams' failure may occur due to different reasons such as structural instability conditions, hydraulic conditions, seepage through the dam body and/or rapid drawdown. The determination of factor of safety for the dam slope stability, under different cases of operations, is vital to ascertain the dam overall safety. In this work, Finite Element modeling is employed for simulating seepage and stress analysis of earth dam problems via GeoStudio software. Thus, phreatic seepage surface, pore water pressure distribution and total hydraulic head variation of an earth dam are analyzed. The model is verified, then it is employed to analyze seepage and stability of Mandali Dam (Iraq). For three different cases of operation, four major analytical methods are used to verify the stability of the dam side slopes. Benchmark safety regulation criteria (USACE and BDS) are obeyed. The results confirm the safety of Mandali dam against combined seepage and slope instability under all cases of operation. The case of rapid drawdown is the most critical operating case; compared to other cases of operation.

KEY WORDS

Earth dams, Seepage, Stability of slopes, Finite element modeling, Mandali Dam.

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IMPROVING MODIFIED ICOLD METHOD WITH LOSS OF LIFE INDEX FOR DAM SAFETY RISK ASSESEMENT IN INDONESIA BY USING RASTER METHOD

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INDONESIA

1. INTRODUCTION

Indonesia is one of many countries that have the highest number of dams in the world. Related to climate change in the world with so many dams in Indonesia (286 dams) needs to be assessed, the risk assessment action plan is very important to be done. Modified ICOLD Method (MIM), is a risk assessment model that is often used in Indonesia. However, this method has the disadvantage that only provides data on the number of people at risk (PAR) not to the point Loss of Life (LoL). According to the downstream dam area where dominated by densely populated areas and economic centers in Indonesia, which makes the risk level of dam is high or even extreme, the aspect of LoL shall be a priority for concerned. Although considered to be a lot of uncertainty, further study of PAR is the prediction of the number of LoL at least a measurable picture for various efforts to reduce the amount of LoL.

2. METHODS

Because this paper only discusses PAR in the innundation area then some conditions, such as PAR who are in the dam and LoL due to traffic accidents due to drift on the highway when disaster does not take into account. Basically, this method involves basic map preparation, parameters affecting the amount of LoL in the innundation area, the development of interaction matrix, coding on the matrix, parameter classification, rasterization, potential risk assessment of LoL, making of risk maps and simulating the reduction of the amount of LoL. Raster method is a method that describes the relationship between risk determinant parameters to a threat in each sub unit of the inundation area. The total number of LoL predictions of the raster method will be calibrated by the empirical equations of regression results from the number of catastrophic collapse events in Indonesia and the world. If the results are not significantly different, then the prediction of the amount of LoL can be considered close to and can be an additional reference in risk assessment in the MIM.

3. RESULTS

To know the interaction of all parameters with each other, semi-quantitative method is used with 5 categories with range 0 to 4 with categories: No Interaction (0), Weak Interaction (1), Medium Interaction (2), Strong Interaction (3)) and Critical Interaction (4). Based on results with Semi Quantitative Method, it is known that anticipating factors related to natural disasters (32,59 %) , especially the disaster of dam collapse (17,78%), are the dominant parameters that influence the modification effort of dam security risk assessment. The prediction of the amount of LoL itself depends heavily on these two factors. Meanwhile, two other factors that are balanced but interrelated is the information factor predicting the flood flow (14,81%) that will occur with the PAR preparedness factor facing the disaster related evacuation action (13,33%) and evacuation site plus post disaster handling (8,15%). The information (8,89%) and prediction of PAR (4,44%) factor has the lowest weight compared to other parameters.

4. CONCLUSIONS

Although the prediction of the LoL amount, has the smallest weight but the prediction of the amount of LoL is considered to provide a new argument for efforts to reduce the level of security risks of dams in Indonesia. Dams that with the downstream conditions of densely settled values of extreme or high conditions can be lowered risk level if the downstream preparedness of the disaster is considered good. One of the assessment factors is if it has been able to apply well to the risk reduction effort of LoL with short term anticipation (evacuation preparedness) and long term (preparation of disaster-based spatial design)

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NEAR-FAULT SEISMIC VULNERABILITY OF GRAVITY DAMS

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IRAN

Near-fault ground motions recorded close to a ruptured fault can be significantly different than those observed further away from the seismic source. The near-fault zone is dependent on the earthquake magnitude. In the near-fault area, depending on the rupture mechanism and slip direction relative to the site, the ground motion may exhibit a unique characteristic known as directivity effects. There is also another property resulted by the permanent ground displacement at the site which is called fling-step. These special aspects of near-fault ground motions should be accounted for in the analysis and design of structures in near-fault areas. The directivity effects, in particular, would lead to high specific pulses in the velocity time-history of the record in the direction perpendicular to the fault rupture. It has been observed that pulse-like motions have larger elastic spectral acceleration values at moderate to long periods.

Seismic vulnerability is commonly assessed by estimating the probability distribution of EDP for a given IM, EDP|IM. The complementary cumulative distribution function of EDP|IM is used to compute the probability that EDP exceeds a certain level edp, given that IM = im. This estimation can be combined with a ground motion haza14rd hIM (im), to compute the mean annual rate of exceeding the EDP level edp.

In this study, a set of seventy-five pulse-like near-field ground motions collected by Baker [1] is utilized. The pulse in this set has been identified using a wavelet analysis. Sixty non-pulse-like (ordinary) near-field ground motions with no velocity pulse are also used for comparison with the pulse-like record set. Using large number of earthquake records implies an aleatory uncertainty due to record-to-record variability. All ground motions were recorded on firm soil or rock sites.

The selected dam model is the tallest non-overflow monolith of Pine Flat gravity dam. It is modeled along with its full reservoir using the finite element method. The water-structure dynamic interaction is taken into account employing Eulerian-Lagrangian formulation. The nonlinear behavior of dam concrete is modeled using plastic-damage method. The concrete properties are: mass density of 2400 kg/m3, initial elastic modulus of 30 GPa, Poisson's ratio of 0.2, and tensile strength of 2.9 MPa. The water has density of 1000 kg/m3 and Bulk modulus of 2.07 GPa. The model is first loaded statically under the self-weight of the dam and the hydrostatic pressure of the full reservoir. Then, it is dynamically analyzed under the selected earthquake ground motions.

The dam-reservoir coupled system is analyzed under the selected pulse-like and non-pulse-like records, and the EDP values are computed. An important parameter of pulse-like motions that affects the structural response is the ratio of the pulse period to the fundamental period of the structure Tp /T1. The results show that as the ratio of Tp/T1 increases, approximately, lower response values are observed specifically for the damage dissipated energy which is a global measure of the imposed cracking damage. This trend is somewhat observed for the base local damage index, but it is not so clear for the neck damage index. No all of pulse-like motions would result in Λ n, i.e. neck cracking; this parameter is observed for motions with Tp/T1 < 22 for only 49 out of 75 records. For the larger period ratios, the pulse period is so much high that it cannot excite the lower main vibration modes of the dam which cause large movements and neck cracking.

Because Sv (T1,5%) and Sd (T1,5%) was shown as good predictors of dam's structural response under both pulse-like and non-pulse-like records, the conditional probability of failure is computed using these two parameter as IM. The failure threshold of Dc, Λb and Λn are assumed as 2cm, 30% and 5%, respectively. Although these thresholds are subjective, but they have illustratively used to compare the fragility curves. The probability of failure is higher for the pulse-like records than the non-pulse-like records; however, the fragility curves are very close for Dc and Λn. But, the probability of base cracking is much higher under the pulse-like records with respect to non-pulse-like records. The probability of cracking of 30% of the dam's base length under the near-field records with Sv(T1,5%) = 20cm/sec is 45% and 85% for the non-pulse-like and the pulse-like records, respectively.

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EFFECTS OF FOUNDATION FLEXIBILITY ON THE FAILURE PROBABILITY OF KARUN IV ARCH CONCRETE DAM IN SEISMIC CONDITION

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IRAN

1. INTRODUCTION

Water supply techniques have always been the most important part of the human needs in all of the era. Concrete arch dams are among the main structures in today industrial life. They are built for various purposes such as hydroelectric power generation, water storage for agricultural, industrial, flood control, and preparation of drinking water. It is of particular importance to achieve an adequate safety of dams against earthquakes, because many large dams are constructed in seismic regions.

2. METHOD

In this study, Response Surface Method (RSM) is used for calculate the Limit State Function (LSF) of drift failure mode of KARUN IV arch concrete dam. A three-dimensional model of dam-foundation-reservoir of the dam is created by ABAQUS 6.11 FEM software and the ratio of foundation modulus to dam modulus (Ef/Ed) is considered as the random variable. Material properties of dam and foundation are defined in linear domain and the water is modeled using equations of state (EOS).

Interaction between water and solid areas is considered as frictionless and LAYZMER boundary condition is considered for the free end of the lake. Sliding of the dam heel and abutments is neglected because of being small (2). USBR code is also employed for calculation of the dead, seismic, uplift, hydrostatic and hydrodynamic loads.

3. RESULTS

Five LSFs of drift failure mode for KARUN IV arch concrete dam under earthquakes loading have been extracted by RSM. The functions have been analyzed with six approaches and the $\hat{p}_f$ of dam is presented. RSM is adjusted in polynomial mode. The LSF then obtained by considering the failure drift and the performance of dam (i.e. $g(\boldsymbol{x} = E_f/E_d) = 0.0025 - Drift$). Obtained results by six mentioned approaches are presented.

4. CONCLUSION

It is concluded that CHI-CHI earthquake has the most impact on dam failure and the failure probability is much more than the other earthquakes, considering the foundation flexibility as a random variable. It is also concluded that Subset Simulation method has the best performance in terms of standard deviation of answers and it's results are very close to MCS. Importance Sampling can be also employed for reliability analysis of dam because it is able to find the approximate (near to MCS) failure probability with a few number of function calls.

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UPGRADING THE PERFORMANCE OF POORLY COMPACTED EMBANKMENT FOUNDED ON SOFT CLAY USING SECANT AND STABILITY PILES SYSTEM*

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1. INTRODUCTION

In the present work, a stabilizing system of an embankment of one of the major canals north of Egypt was monitored and the collected data are discussed. The soil properties, the embankment cross-section, and the design concept of the proposed upgrading system were pointed out by [1]. The Atlas pile type is used in constructing both seepage control and stability improvement systems. The cast insitu screw piles with very rough shaft (Atlas type) proved to be the most suitable pile type to handle the presence of deep soft clay deposits. The suggested secant-pile wall consisted of reinforced concrete piles with a diameter of 60 cm spaced at 90 cm from center to center intersected with bentonite piles with a diameter of 60 cm and the over lapping distance is not less than 15 cm. Piles P52 and P54 were instrumented with vibrating wire strain gages (s.g) on the reinforcing steel bars at various levels. In addition, P54 was provided with inclinometer casings and magnetic rings of sondex system. Pile P53 (the bentonite pile) was instrumented with an inclinometer casing and magnetic rings of sondex system. Furthermore, three piezometers were installed to monitor the variation of water level. The overall performance of the embankment mass was monitored through inclinometer I2 in the berm at the canal side, inclinometer I5 in the berm at the road side and inclinometer I8 at the center line of the road.

** Amelioration De La Performance D'un Embanchage Mal Comprime Fondu Sur Un Argile Moyen Au Moyen D'un Systeme De Piles Secondaire Et De Stabilite*

2. RESULTS

The piezometer readings were collected before the beginning of the secant-pile wall construction, during wall construction, after the end of wall construction, and during the loading stages. The difference between the reading of the piezometer in the canal side of the wall and the piezometer in the roadside was increasing with time until eleven days after the end of loading activities where monitoring activities stopped.

The collected data of the lateral displacement of the bentonite pile P53 show that the maximum displacement experienced during the different loading and construction activities does not exceed 30 mm, the end toe approximately experienced no lateral displacement. The analysis of the lateral and vertical displacements (movements) of P53 and P54 reflects the ability of the designed monitoring system in tracing the performance of the secant-pile wall. The monitoring system was able to reflect the difference in installation time among its components, and what took place during the construction and the loading stages. The monitoring system was also able to reflect the effect of the presence of different soil lenses within the soft clay layer on the experienced movements especially during the installation and construction stages. The bending moment, calculated based on the measured strains, reflects high concentration moments at the upper silty sand and the lower very soft clay lenses within the soft clay layer. These sand and clay deposits controlled the pile movements especially during the construction stage, which resulted in concentration of stresses.

3. CONCLUSIONS

The readings of the piezometers embedded in the embankment proved the high efficiency of the secant-pile wall in controlling the seepage through the tested section of the canal embankment. The readings of the inclinometers embedded in the bentonite piles indicated its high flexibility because of the heave action of the pile after each construction or loading activities. The monitoring system succeeded in reflecting the effect of the presence of hard and/or very soft soil deposit lenses within the soft clay layer on the developed strains and stresses. Monitoring of the reinforced concrete piles showed that they experienced small stresses compared with its ultimate capacity.

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PUBLIC SAFETY AROUND DAM: SUTAMI DAM EXPERIENCE

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INDONESIA

1. INTRODUCTION

Dams are critical in terms of population life support and ensuring sustainable economic development. Dams not only for flood control but also provide water for some mutipurpose activities such as hydropower, irrigation water supply, domestic consumption, industrial water use, tourism aquaculture, navigation, etc. Sutami dam is one of the large dams located in Brantas River Basin. Sutami dam (locally named as Karangkates dam) located at Brantas River Basin in Indonesia. The dam is a multifunction dam, which is used for flood control (with the capacity of 1,650 m^3/sec), providing irrigation water supply for 34,000 hectares, and also to generate hydro power plant with installed capacity of 3 x 35 mW. Sutami dam has 180 million m^3 storage capacity (based on 2016 bathimetry survey) and 1,500 hectaresreservoir surface area. The public safety around dam issues surrounding the safety concerns for Sutami dam existed from its beginning of operation because of its critical water storage capacity, structures and massive human acitivities surrounding it. This paper addreses some of those public safety requirements throughout the facility and more specifically following the more recent safety risk assessments and mitigation strategies implemented to meet the anticipated safety requirements nowadays.

KEY WORDS

Dams, Public Safety, Risk Assessment, Sutami Dam

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SUMMARY

Dams are critical in terms of population life support and ensuring sustainable economic development. Dams not only for flood control but also provide water for some mutipurpose activities such as hydropower, irrigation water supply, domestic consumption, industrial water use, tourism, aquaculture, navigation, etc. Sutami dam is one of the large dams located in Brantas River Basin. Sutami dam (locally named as Karangkates dam) located at Brantas River Basin in Indonesia. The dam is a multifunction dam, which is used for flood control (with the capacity of 1,650 m3/sec), providing irrigation water supply for 34,000 hectares, and also to generate hydro power plant with installed capacity of 3 x 35 mW. Sutami dam has 180 million m3 storage capacity (based on 2016 bathimetry survey) and 1,500 hectares reservoir surface area. The public safety around dam issues surrounding the safety concerns for Sutami dam existed from its beginning of operation because of its critical water storage capacity, structures and massive human activities' surrounding it.

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RISK BASED APPROACH AT THE DAM SAFETY ASSESSMENT DURING ITS RECONSTRUCTION

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1. INTRODUCTION

Due to the more strict requirements on the hydraulic safety of the dams in the Czech Republic lot of hydrological and dam safety assessment studies and also extensive remedial works at numerous dams are in progress. The reconstructions concern namely improvement of spillway capacity, adjusting of the dam crest and also clayey core elevation to withstand the check flood according present regulations. As the construction activities often call for provisional reduction of the dam crest elevation and opening of the spillway profile, the dam safety during the civil works has to be carefully analyzed. Usually, considerable drawdown of reservoir water level during the construction period is essential. This however may significantly interfere with main purposes of the dam and may also harm subsidiary effects of the scheme. In the paper the risk based approach is proposed and demonstrated at the safety analysis of the dams in the Czech Republic. The results of the analysis also give guidance for the optimal sequence of works at the site.

This work was supported by the TACR TH03030182 project “Protection of hydraulic structures against action caused by oscillatory wind waves” and No. LO1408 AdMaS UP – Advanced Materials, Structures and Technologies.

2. THE DEGREE OF DAM SAFETY DURING ITS RECONSTRUCTION

The safety issues during the reconstruction of the dam concern two aspects:

- the protection of the construction site during the flood;
- the safety of the dam against its rupture.

The protection of the construction site concerns individual workplaces like spillway, chute, stilling basin, upstream slope lining, dam crest etc. In a view of safety rate these structural parts should be assessed individually. Some of them like repair of the dam crest or spillway may directly relate to overall dam safety.

For other structures not influencing overall safety of the dam cost-benefit analysis has to be performed in case of the threat of significant losses, terms of construction site insurance against floods should be taken into account. Generally, guideline applied in the Czech Republic recommends the return period *N* of the flood for the site protection:

$$N = T + 1, \quad [1]$$

where *T* is duration of the construction in years.

The safety of the dam against its collapse should be assessed considering:

- current dam safety;
- potential material losses due to dam break flood;
- potential loss of life.

Usually, it is not reasonable to provide dam safety during construction exceeding the dam safety before the reconstruction.

The material losses should contain losses at the dam itself, benefit losses (water supply, power generation, recreation, fish and wildlife), remedial costs and indirect economic consequences like water shortage, labor reduction, loss of tourism, etc. The dam break flood extent modelling and hazard mapping is performed by contemporary hydraulic models combined with GIS tools. The census data serve for the assessment of direct losses. Usually it is necessary to specify reservoir water level drawdown and corresponding losses caused to environment, fish population, recreation, etc. due to drawdown. The cost benefit analysis should be applied as an appropriate tool for the balancing of material consequences.

The estimated number of fatalities is related to the probability of dam failure which many times corresponds to the probability of the arrival of given flood wave during the reconstruction period. The appropriate tools for the assessment are the F-N curves and ALARP methodology.

The risk based procedure gives the guidance for the determination of appropriate probability of the flood for the dam safety assessment during the reconstruction. The specified probability has to be adapted to the hazardous construction periods like decreasing of the dam crest level, dismantling the spillway, etc.

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MASTER PLAN FOR SAFETY OF MAJOR HYDRAULIC STRUCTURES IN EGYPT

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Major hydraulic structures in Egypt are dams, barrages, regulators, and weirs with/ without navigation locks or hydropower plants. This infrastructure represents the means of control of water discharges and levels for accurate distribution of the water for different purposes in the Nile valley and delta region. The control structures are thousands, but the major ones are limited to about 150 structures.

Most of these structures were built more than 100 years ago; and they have been subjected to functioning problems, weathering, wearing and/ or material deterioration. The authority holding the jurisdiction of these structures faces the problem of planning the required remedy works and allocating its resources in the best way in order to minimize the risks of failure or malfunctioning of these structures.

In order to assure safety of these structures, the authority aims at planning future rehabilitation/ replacement plans up to 2050. The authority included 150 structures in a master plan study which concept was to inspect all of these structures to assess their current conditions, evaluate their safety and functionality, assess the risk, define the remedy measures, establish a multi criteria decision making system to define priority of actions, and finally conclude 5-year plans till 2050.

The scoring and weighting technique was adopted through an expert system that defined factors and parameters of the technique. Depending on that technique, a multi criteria decision analysis model was developed and used to plan the best plan till the year 2050. This paper spots the light on each of these activities, the objective of each, how they were carried out, and what were the findings of them.

As a conclusion, the study provided the required tool to the authority for dynamic planning with the innovation of basic criteria for prioritizing actions required to control risks of the structures. It would be important to mention that such system/tool supports better water use efficiency as another target as per the National Water Resources Plan. The same study methodology and activities are recommended to be applied to different infrastructures in order to have master plans for these vital structures.

Key words: Master Plan – Hydraulic structures – Inspection - Rehabilitation – Safety – Multi criteria decision analysis – Expert system

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FORMAL INVESTIGATION OF LAHOR DAM, INDONESIA

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INDONESIA

1. INTRODUCTION

Lahor dam is located in Malang Regency, East Java Province of Indonesia. It is one of the dams in Brantas watershed on the tributary of the Lahor River. Lahor dam was constructed in 1972 for adding capacity of Sutami hydropower. Not only provides great benefits, dam also creates a potential risk to neighboring populations, property, and the natural environment. Therefore, assessment and monitoring of the dam have to be carried out comprehensively and periodically. Formal investigation of Lahor dam aim to evaluate the dam condition during design and construction compare to recent. It is also including visual inspection, instrumentation and slope stability analysis, hydrology and geology condition, and sedimentation analysis. Based on those parameters, the condition of the Lahor dam was ready to be operated.

2. METHOD

Formal investigation of Lahor dam consist of two stages: preliminary stage and advance stage. The former aims to collect all of the information about dam design, construction document, and dam record book (operating and maintenance). While there is an anomaly on the preliminary study, advance study must be carried out that are including re-evaluation of design document, construction method and material type, analysis of operation and maintenance document, and engineering analysis.

3. RESULT AND DISCUSSION

3.1. VISUAL INSPECTION

Visual inspection activities include dam body and complementary building, water quality analysis in laboratory, monitoring of dam instrumentation, hydro mechanical equipment, and concrete structure condition on spillway and access tunnel. The water quality was monitored on BOD (biochemical oxygen demand), COD (chemical oxygen demand) and DO (dissolved oxygen) parameters from 2013 to 2017. Those BOD, COD, and DO parameters met the standard.

3.2. HYDROLOGY

Spillway design of Lahor dam based on design flood with 1000 years time period and resulted inflow debit 790 m^3/second with spillway capacity 399 m^3/second. Flood routing with initial elevation of water table +272,70 m obtained maximum flood elevation +274,11 m for 1000 years time period (Q_{1000}) and +277,09 m for Q_{PMF}. The elevation of parapet is +279,00 m.

3.3. INSTRUMENTATION

Some instruments (pore pressure meter, V-Notch, and observation well) was installed in Lahor dam. The pore water pressure at each location is always up and down as the reservoir water level changes. Based on the monitoring results of the seepage discharge shows normal conditions, no significant fluctuations occur, the magnitude is still below the maximum threshold. The amount of seepage discharge depends on reservoir water level and rainfall. The maximum of seepage discharge on toe dam is 1,105.20 liter/minute, the maximum seepage discharge that occured in toe dam is 896,99 liter / min (April 25, 2017) at water level +273,21 m with seepage water condition looks clear. The amount of spring water discharge at the right bank and left bank (including on the rail way) was fluctuated, because it was influenced by rainfall that occurs. The ground water level conditions also fluctuate along with the water level of the reservoir

3.4. SEDIMENTATION

Based on echo sounding measurement that was carried out in 2016, the dead storage capacity of Lahor reservoir is 3.38 million m^3 or 50.45% of the initial dead storage capacity (6.70 million m^3). The effective capacity is 28.73 million m^3 or 97.72% of the initial effective storage capacity (29.40 million m^3) and the total storage capacity is 32.11 million m^3 or 88.95% of the initial total storage capacity (36.10 million m^3). Sedimentation rates in the Lahor Reservoir from 1977 to 2017 is ± 99,750 m^3/year or 0.623 mm/year.

3.5. GEOLOGY

Geological structure (unconformity and fault) around the dam caused several problems during construction. There are agglomeratic tuff as the rock basement, grey clay layer at the middle, and tuffaceous loam as overburden. Those condition lead to land slide around the reservoir. Therefore, in the foundation was carried out rim grouting along the dam axis (433 m). This method could solve the probem effectively.

4. CONCLUSION

Based on formal investigation result in Lahor dam can be concluded that its condition was normal and ready to be operated. There is no anomaly on each inspection parameter.

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FLEXIBLE PROTECTION MEASURES FOR ADAPTATION WITH SEA- LEVEL RISE ON THE NILE DELTA

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EGYPT

1. INTRODUCTION

The Nile Delta in Egypt is one the most venerable areas in the world to sea level rise which could cause devastating damages to water resources, agriculture land, people and properties if occurred. Therefore, adaptation measures must be carried out on the ground to protect inhabitants, properties and infrastructure in the Nile Delta. These measures need to be low cost and environmental friendly in order to protect the Delta and preserve the environment in a cost effective way. Therefore, the Government of Egypt, among its efforts to adapt to Climate Change in different sectors, the Global Environmental Facility (GEF) and the UNDP have jointly funded the Adaptation to Climate Change in the Nile Delta through ICZM project (ACCNDP). The ACCNDP [1] has piloted and assessed the performance of Flexible (soft) techniques to protect the Nile Delta from the anticipated inundation impacts of sea level rise and consequently improve the livelihood of the local population. This extended abstract and also an accompanying paper provide a detailed description of those adaptation options aiming at sharing such experience so they can be up-scaled at local, regional and international scales in similar environments. They also present the assessment results of suck work.

2. ADAPTATION OPTIONS AND RESULTS

Based on the work undertaken by Egyptian researchers at the Coastal Research Institute (CoRI), practitioners at the Shore Protection Authority (SPA) and indigenous people in the Nile Delta, the ACCNDP constructed a number of flexible (soft) dike options that are mainly built from local material to protect the Nile Delta such as sand fences to capture sand blown by wind to accumulate and build sand dunes and dikes with clay and geo-tube cores (Fig. 1). The performance of the above options was assessed during the winters of 2016, 2017 and part of 2018. A number of extreme events occurred during those winters but no damages were observed on the dikes and they remained intact.

a) Sand fences dike b) Clay core dike c) Geo-tube core dike

Fig. 1
Dike options

3. CONCLUSION

Low cost and environmental friendly adaptation options have been constructed in Egypt. Assessments of those options against extreme events shows that they provide protection against sea inundation.

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KEYWORDS

Egypt, Nile Delta, Sea level rise, inundation, water scarcity, flexible protections and dikes.

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AN INTELLIGENT COOLING CONTROL METHOD AND SYSTEM FOR XILUODU ARCH DAM CONSTRUCTION

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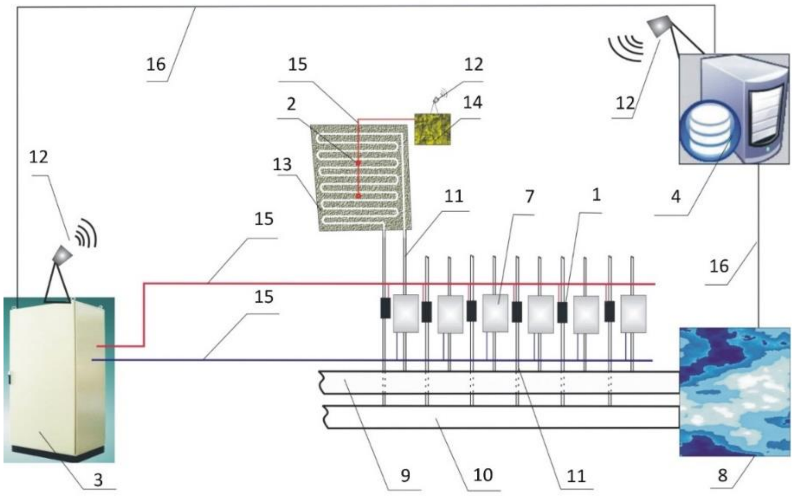
CHINA

1. INTRODUCTION

A real-time, online and personalized intelligent cooling control method and system for a mass concrete structure(ICCS) is developed in this paper, the proposed method is an important engineering measure to prevent the mass concrete structure from cracking during the construction period.

2. INTELLIGENT COOLING CONTROL SYSTEM

The system includes devices for heat exchange, control device, devices of dam data acquisition and auxiliary device for heat exchange. Its main features include: The digital temperature sensors are installed in the new pouring mass concrete blocks for real-time measurement of temperature change; One flow, temperature opening measuring and feedback controlling device is installed in the inlet and outlet of cooling pipe; And then, according the design control curve, an average reduction of concrete temperature is obtained online through calculating the cooling temperature difference(the analog PID control method); Thus, the real-time water flow is determined for cooling, thereby reducing the concrete tensile stress to achieve purpose of pouring non-cracking concrete dam.



1 interpolated digital temperature measuring device; 2 pre-embedded digital temperature sensor; 3 control cabinet; 4 sever of control; 5 two-way intelligent control valve; 6 flow meter; 7 integrated control device of temperature and flow; 8 pump; 9 main inlet pipe; 10 main outlet pipe; 11 branch inlet pipe; 12 wireless transmitting bridge; 13 mobile multi-point device of displacement acquisition; 14 concrete section; 15 connecting cable of flow and temperature collection; 16 optical fiber cable

Fig. 1

The schematic of intelligence cooling control system in multiple placement blocks

3. CASE OF XILUODU ARCH DAM

The indoor experiment (at Tsinghua university) and field test (at Xiluodu arch dam) are conducted to debug the system. After the pre-test, the system was initially applied on a large scale at Xiluodu Site. No harmful cracks are identified during the construction and the dam is shown to perform as desired till now.

4. CONCLUSIONS

The proposed controlling system were successfully used to guide the temperature controlling of Xiluodu arch dam construction. The proposed novel method will be beneficial to the design and construction of the similar projects for controlling thermal stress of mass concrete structure.

KEY WORDS

CONTROL METHOD; COOLING; TEMPERATURE; DAM;

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KEY CONSTRUCTION TECHNOLOGY OF 300M HIGH CORE WALL ROCK-FILL DAM

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ABSTRACT

As the high rock-fill dam being constructed to 300m, the dam anti-seepage safety attracts much more attention. For the high rock-fill dam constructed at the place where the overburden is deep and the river valley is steep and narrow, the construction quality of foundation treatment, ant-seepage system and dam body filling becomes particularly important. The dam of Changheba Power Station is gravel soil core-wall rock-filling dam, which is construction on the deep overburden, with the dam height of 240m. The height of overburden and dam is 293m in total. The seismic intensity reaches 9 degree. For the above reasons, the control of dam deformation stability and seepage stability is very difficult and it requires high design index and construction quality standard. The deep scientific research was carried out for this project and it made plentiful achievements. This article briefly introduces the engineering characteristics and construction difficulties of

Changheba Power Station dam and describes the key technology adopted during the dam filling works, which has a reference value on the construction of similar projects.

CONCLUSION

The application of the new technologies and new techniques in Chang-he Dam project efficiently guarantees the construction quality. The dam was filled to the crest on 10th September, 2016, which is 4 months ahead of the contract construction period. After 13 times quality inspection carried out by quality monitoring station, it shows that the dam filling is totally under control and the quality is well received by experts. At present the dam seepage controlling and deformation both meet the design requirement and the dam is in good operation condition.

The systematical construction and quality controlling technology developed from the research on Chang-he Dam construction key technology and engineering practices, the engineering problems in 300m high core wall rock fill dam constructed on thick overburden have been solved and the engineering quality and anti-seepage safety have also been guaranteed. 3 industrial standards are formed, more than 50 national patents are obtained and many national and provincial-level construction methods are also formed. The relevant technologies have been applied in some large-scaled hydropower projects, such as the Lianghekou project and the Shuangjiangkou project. It brings remarkable economic and social and environmental benefits and has wide application prospect.

KEY WORDS

Core wall rock-fill dam; construction; key technology; new process

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ON-LINE STRUCTURAL HEALTH MONITORING OF REHABILITATED DAMS

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INDIA

For control and mitigation of disastrous consequences caused by the failure of an ageing dam, it is essential not only to take preemptive corrective action at the site by strengthening and rehabilitating it but also by implementing a good monitoring and forewarning system. The latter is vital for identification of hazardous conditions or developments well before a catastrophic failure takes place and alert personnel with authority to take remedial measures, as early as possible. This paper describes advanced instrumentation for dam safety monitoring comprising of field-proven and rugged geotechnical instruments, advanced automatic surveying techniques and public cloud-based web database management system.

The field sensors for measuring parameters such as surface and subsurface deformations, porewater pressure, anchor load, rainfall etc. could be connected to the field dataloggers through an SDI-12 bus thus minimizing the cabling costs and increasing system's reliability. Data transmission through Radio Frequency (RF) is also possible whereby instruments or group of instruments are connected to nearby nodes which in turn communicate with the Gateway using RF. Gateway, equipped with GSM/GPRS modem further transmits the data collected by the nodes over the cellular network to the web-based data monitoring service. It further reduces the cabling and makes the system flexible and reliable further.

Deployment of the robotic total station to automatically monitor 3D prisms at critical locations adds to the comprehensiveness of the data collected and system's integrity. Data collection at frequencies which are much higher than what is achievable by traditional survey techniques is possible. The data collected by the robotic total station's control box is transmitted using the cellular network.

In all of the above systems, data is readily available in real time to the different stakeholders, who may be located in any part of the world. Automatic notification of alarm conditions through e-mail or SMS is also realized by the system.

The dam safety monitoring network is cost-effective thanks to the emerging technologies described in the paper and in monetary terms, it is just a small fraction of what is spent later on for repair and rehabilitation.

Fig.1 Dam monitoring instruments on an SDI-12 network

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THE OPERATIONAL AND MAINTENANCE OF KEULILING RESERVOIR AS THE FIRST DAM IN ACEH PROVINCE - INDONESIA

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AUSTRIA

1. INTRODUCTION

Keuliling Reservoir most well known as the first dam in Aceh Province has been serving nearly 10 years. The operation and its maintenance controlled under surveillance of River Basin Organization Sumatera I - the Ministry of Public Works and Housing of Indonesia. Dam Operation Unit (DOU) is a unit in River Basin Organization Sumatera I which conducting the dam monitoring works in every week, month and year. Three outline duties and responsibilities of DOU; firstly, arranging water reservoir through intake gate in accordance with the needs of water users and operating patterns of Keuliling Reservoir; secondly, supervising the dam instrumentation and hydro-mechanical equipment; and third, maintaining and controlling the dam structure from human activities or animal behavior that may caused a trigger to dam damage.

The first five years inspection of dam surveillance done by Dam Safety Committee shows the dam can serve as its main function. The committee evaluated the dam structure, stability, and its operation system and management. Several recommendations issued for the dam safety and other for dam maintenance. One significant proportion is the human activities surrounding dam area. Hence, the River Basin Organization improving dam safety regulation for Keuliling Dam and the other next dam project.

2. BACKGROUND

The reservoir can cause tremendous flash floods, which will result in many casualties, property, public facilities and severe environmental damage due to dam failure state beside its positive benefits. In preventing such calamities, the dam should be monitored and maintained properly. The success of Keuliling Dam monitoring supported by routine, periodic and large inspections.

In year 2013, River Basin Organization of Sumatera - I had conducted the first large inspection of Keuliling Dam in pursuance of preserving the dam security. It is hoped that. it will be able to capture as early as possible signs of abnormalities in the dam. The result shows that the dam had a good performance without any abnormalities.

The recent periodic dam monitoring conducted in November 2017 where it is the third investigation in one year. It is found in saddle dam 5 and saddle dam 6 have been scoursing on the dam body of saddle dam 5 and rock pairs of saddle dam 6 due to the illegal water connections made by the society around (*Dam Operation Unit BWS –SI Report,* 2017*) (see Fig.1).*

Fig. 1. The Water siphoning activities by the local communities

It is proposed that there should be re-emphasized to ban illegal connections (water suction) from River Basin Organization Sumatera I.

Keywords: Operation, Maintenance, Dam Inspection, Dam Regulation.

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AN ANALYSIS ON THE BEHAVIORS OF A DAM FOR THE EARTHQUAKE IN SOUTH KOREA

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1. ABSTRACT

Dam Structure have always influenced by various internal and external forces such as various load, original ground motion, change of reservoir water level and so on. Therefore, it is important for dam structure to measure the physical behavior by comparing a presently measured data for the behavior of a dam with the past measured data in order to properly operate and maintain the dam facility.

In 2016**,** Gyeongju region in South Korea experienced the largest earthquake since seismological observation of South Korea, 1978. Before this occurred, Most People in South Korea have recognized that Korea is safe for earthquake. However, they realized that Korea is no longer safe for earthquake after that.

Moreover, Earthquake that has similar magnitude to Gyeongju recently occurred in Pohang region. This region is not far from Gyeongju, and some buildings and facilities were damaged by earthquake.

Korea Infrastructure Safety & Technology Corporation (KISTEC) performed urgent inspection and the behavior analysis of a dam located near seismic epicenter in Gyeongju. Because main infrastructure such as dams might have been affected by these earthquakes.

The behaviors of a dam were analyzed by comparing with the real-time measuring data on displacement of dam structure and change of quantity or quality of leakage water for before and after occurring earthquake in Gyeongju.

This paper shows the results for this analysis and presents comprehensive conclusions for inspection of a dam.

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DAM SAFETY REGULATION IN SOUTH AFRICA: 32 YEARS DOWN THE LINE*

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SOUTH AFRICA

1. INTRODUCTION

South Africa is the 30th driest country in the world. This is due to low levels of rainfall (relative to the world average) and high variability (60% of river flow arises from only 20% of the land area) as well as high levels of evaporation. Of the total mean annual runoff of 49 000 million m^3 per year, only 10 000 million m^3 is annually available as assured yield (98% assurance) [1]. As a result, South Africa has been one of the major dam building countries in the world. It is the country with the seventh most large dams (more than15 m high) on the ICOLD register of dams [2] but also of small dams (less than 15 m high).

Of the total available water resources 67% is currently allocated for irrigation while the rest is made up of domestic and industrial use (22%), mining (5%), afforestation (3%) and power generation (mainly thermal power) and transfers between catchment basins (3%) [1].

This paper not only summarize the history of Dam Safety implementation in South Africa from its earliest humble beginnings in the 1970s to the implementation of legislation in 1980s [3] and the update of the relevant regulations in 2012 [4] but

* *titre de l'article complet*

also provide insight into the required regulatory processes during the lifespan of a dam.

A summary is provided of the lessons learnt in the implementation of the legislation including the positive influence of effective dam safety legislation and the fact that it takes time and significant resources to implement a dam safety regulatory system. It is also important to note that these lessons learnt were used to help some other African countries starting with the implementation of Dam Safety regulatory systems in their countries [5][6].

From the lessons learnt from the implementation of dam safety legislation in South Africa the following is of importance:

- It is of prime importance to convince political decisions makers about the necessity for Dam Safety implementation including the necessary legislative and regulatory environment.
- It takes time and significant resources to successful implement a dam safety regulatory system – for example after more than 30 years existing dams are still being registered in South Africa. It also takes time and effort to classify the dams as well as establish regulatory compliance;
- Dam Safety legislation, enforced by dedicated and experienced officials (in the DSO), has a positive correlation with the decrease in the number of incidents and failures of dams built since promulgation of dam safety legislation in South Africa. This has also ensured the formal recording of incidents and failures. Not all incidents and failure of especially small dams are however reported to the DSO as required.

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BEHAVIOUR OF ASPHALT CONCRETE CORE EMBANKMENT DAMS (ACED) AND SHEAR ZONE DEVELOPMENT

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AUSTRIA

1. INTRODUCTION

Asphalt concrete core dams provide a cost-effective and flexible solution for dams. The highly deformable asphalt concrete core which is used as an inner water barrier is able to withstand extensive deformations caused by settlements of the shell zones without cracking. For the design and the specification of asphalt concrete core dams, the knowledge about the deformation behaviour of the dam and the core is crucial. Compared to conventional embankment dams, the stress distribution and the deformation behaviour of asphalt concrete core dams depends on the dam zoning, material stiffness and shear strength. Therefore, the zoning and dam designs are important factors to control and distribute the stresses between the dam shoulders and the core. Measurements of asphalt concrete core dams in Austria have shown a specific deformation behaviour indicating the development of shear zones in the upstream dam shell. The location and distribution of those zones governs the deformation behaviour of the core and the adjacent zones. Until now, general knowledge about those shear zones is rare and the effect on the core stability was not theoretically explored in detail. This paper presents fundamental aspects on the stress distribution and the deformation behaviour of ACED dams particularly with regard to shear zone development.

The measurement data from two different dams (Feistritzbach Dam and Finstertal Dam) is analyzed with regard to the interaction between the asphalt concrete core and the adjacent upstream zones. Both dams are well instrumented and have been intensively monitored during construction and impounding. The 85 m high Feistritzbach Dam is designed with a 70 - 50 cm thick vertical asphalt concrete core, slightly inclined in the upper part while the Finsterdal Dam is designed with a 96 m high inclined core (1H:4V) with a thickness of 70 cm at the bottom and 50 cm at the top. The measurements showed that the horizontal core deformation to the downstream side induced shear zones during impounding and mobilized a sliding wedge in the upstream dam shoulder.

Until now, the cause of this shear zone development and the effect on the core's stability has not previously been examined in research. In this contribution fundamental theoretical considerations about the stress paths in the dam body and the core are presented. For a verification of the theoretical considerations and the measurements an intense numerical study on a typical ACRD dam was performed. The numerical results confirmed the theoretical analyses and showed a good agreement with the monitoring data from Feistritzbach Dam and Finstertal Dam.

2. CONCLUSION

Theoretical considerations about the typical behaviour of AC dams during impounding showed clearly that the core deformation during the first impounding leads to a mobilization of an upstream wedge. The mobilized wedge closes the joint between the core and the adjacent upstream zone which develop due to the horizontal core deformation. It could also be demonstrated that this mobilized wedge stabilizes the core when the reservoir level decreases and the horizontal support from the water pressure is lost. The results from the numerical analysis as well as the measurements confirm the theoretical considerations and show a comprehensive picture about the stress paths and changes in the dam during different load cases. The presented theoretical principles should lead to a better understanding of the behaviour of asphalt concrete core dams.

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EJECTOR POWER PLANT – VERTICAL KAPLAN

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AUSTRIA

1. INTRODUCTION

In order to contribute to the transition from fossil to renewable energy sources, it is necessary to focus also on power generation from small scale Hydropower plants. The main aspect in this context should be to maximize the exploitation of hydro power. One possibility in this regard is the utilization of the ejector effect in low head schemes.

The research project (EJVK) has been carried out by ZT-Fritsch GmbH / Steyr in collaboration with the Institute HFM - Graz University of Technology.

From this research, scientifically based norms for dimensioning for the special ejector plant in different conditions have been determined.

2. MAIN PROJECT FEATURES

The paper describes a specific type of Ejector power plant in a run-off-river hydro power layout, equipped with a Vertical Kaplan Turbine. The bent draft tube, leads downstreams under an overlapped specially designed ejector ramp. In case of excess water flow the ejector will be activated by opening an ejector gate at the upper side of the ramp. Downside the ramp the energy of the access flow helps to lower the pressure in area of suction tube outlet and so to increase the useable head for the vertical Kaplan Turbine.

As described in Fig. 1 and Fig. 2 the main components of a typical ejector power plant are:

(1) vertical Kaplan Turbine
(2) bent suction tube
(3) intake with horizontal screen
(4) ejector gate
(5) ejector ramp
(6) turbine outlet

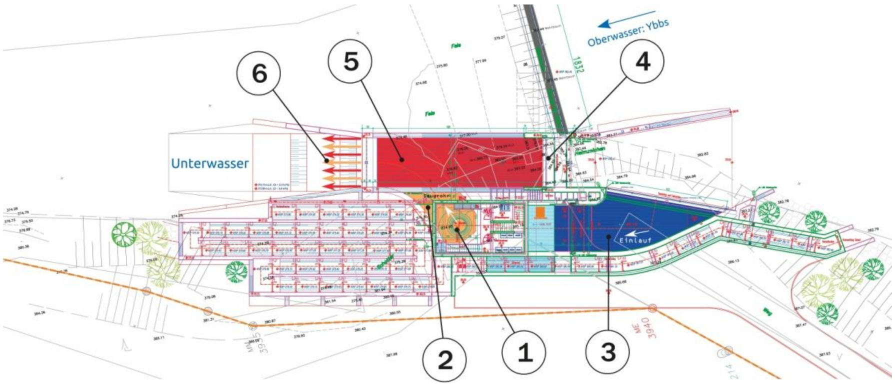

Fig. 1: plan view of a typical ejector power plant

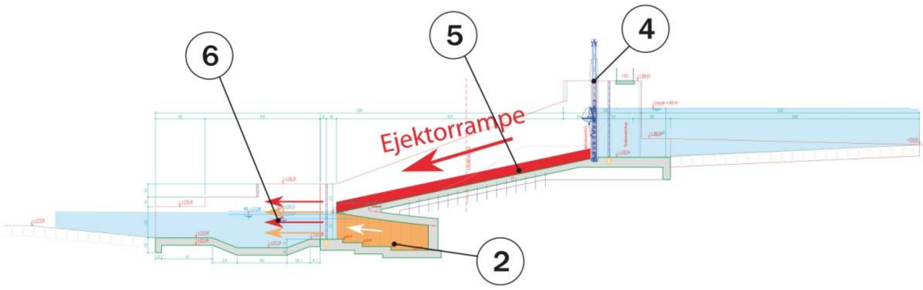

Fig. 2: section of ejector ramp

3. RESULTS AND CONCLUSION

In case of surplus water the increase of head results in a significant increase of power and energy production in operation at full load supplementary by utilization of run off.

In the meanwhile three projects could be realized and the outcome confirms the positive effectiveness without cost increase.

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FEATURES OF MONITORING TEMPERATURE OF AN RCC DAM DURING CONSTRUCTION BASED ON DATA MINING

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1. ABSTRACT

A deep understanding of concrete temperature varying in large concrete dams is of importance for improvement of construction technology. A large number of temperature sensors are installed in the dam blocks as concrete pouring. The temperature of the dam concrete, which increases due to hydration heat in the early stage and decreases when employing water-cooling system, is measured and massive temperature data is stored. The monitoring temperature history varies as time and its changes are affected by many factors, such as the hydration heat temperature rise, the amount and velocity of water flows in the cooling system, environmental temperature, etc. Features of the monitoring temperature may provide insight into possible prevention of temperature-induced cracks in concrete dams.

In this paper, the features of the monitoring temperature data of a roller compacted concrete (RCC) dam (height 203 m), under construction in Yunnan

Province of China, is recognized based on data mining. The raw measured temperature data always contains missing values and outliers. Processing of the missing values and outliers is required before analysis of the data. The density-based spatial clustering of applications with noise method is employed to detect and delete the outliers and the the k-nearest neighbor algorithm is used to estimate and substitute the missing data. The K-means clustering with dynamic time warping algorithm is applied to classified the temperature time series and to find their features.

Four types of temperature series are recognized. Fig. 1 shows the four types of temperature history curves determined by the K-means clustering algorithm. There is a significant difference in the temperature variation between the different types. Type I exhibits a rapid increase due to hydration heat and a decrease as cooling water flows within 20 days after concrete pouring, followed by a gradually increase in the next 3 months. Comparing with Type I, Type II has a stable curve after its drop due to water-cooling. Type III is a approximately horizontal curve, and the hydration heat induced increase and the water-cooling induced drop of temperature are possibly missing. Fluctuation is observed in the later stage of the temperature curve of Type IV, while it is smooth in the other three types, implying that temperature of Type IV is measured near the surface of the dam where the environmental temperature has significant influence and the other three types monitored inside the mass concrete.

This study presents a preliminary analysis of features of monitoring temperature of the RCC dam during construction. Further study based on the big data mining and numerical simulation is needed to understand the cause of the difference between the features and the effect of different features on the concrete dam behavior.

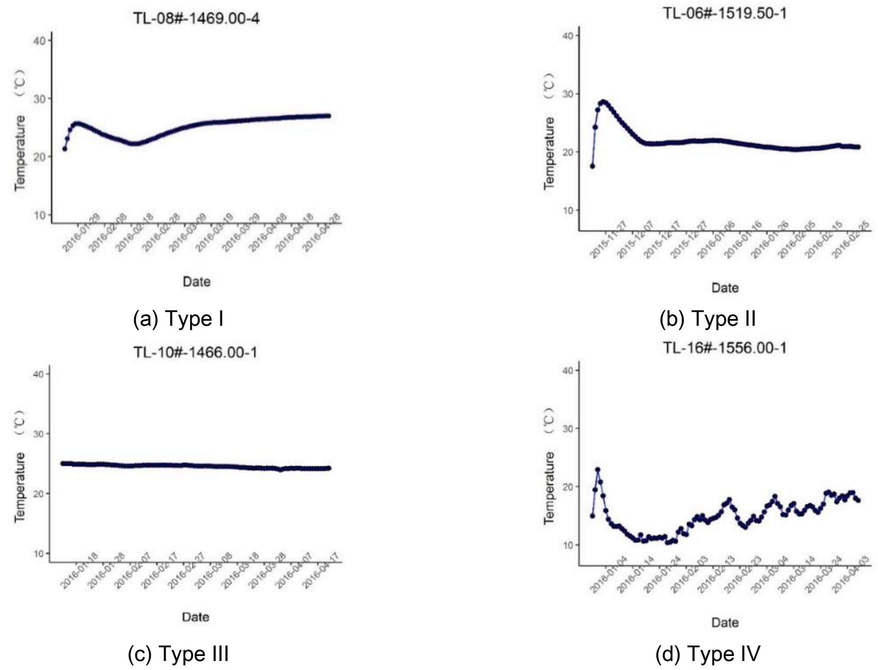

Fig. 1 Types of the monitoring temperatures time series

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RUBBER DAM CONSTRUCTION WITH NAVIGATION LOCKS

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AUSTRIA

1. INTRODUCTION

Gomti River is a main river in India and he is passing the main capital Lucknow in the Indian State Uttar Pradesh. The State Irrigation Department developed a river rejuvenation program with the following topics:

- Upgrading of the existing Gomti Weir downstream of the Gomti Barrage
- Improvement of the flood safety by structuring of the river banks
- Creating a water surface with a reservoir with app. 400.000 m³
- Improvement of water quality in the river stretch
- Enabling river boating in the reservoir and passing of boats.

2. METHODS AND MAIN PROJECT FEATURES

Alternative Studies carried out came to the solution that a flexible rubber dam with a water filled regulation system meets the requirements as it bests to reach the outlined targets and the economic feasibility. The rubber dam system on the weir is added by navigation locks on both river banks for passing of boats. In the navigation locks there are also moveable rubber dams installed.

The dam system has a length of in total about 256.20 meter and is consisting of 4 sections, each 54 m long with inflatable rubber dams and navigation channels on right and left river bank. The height of the rubber dam in the main sections is 3.00 m.

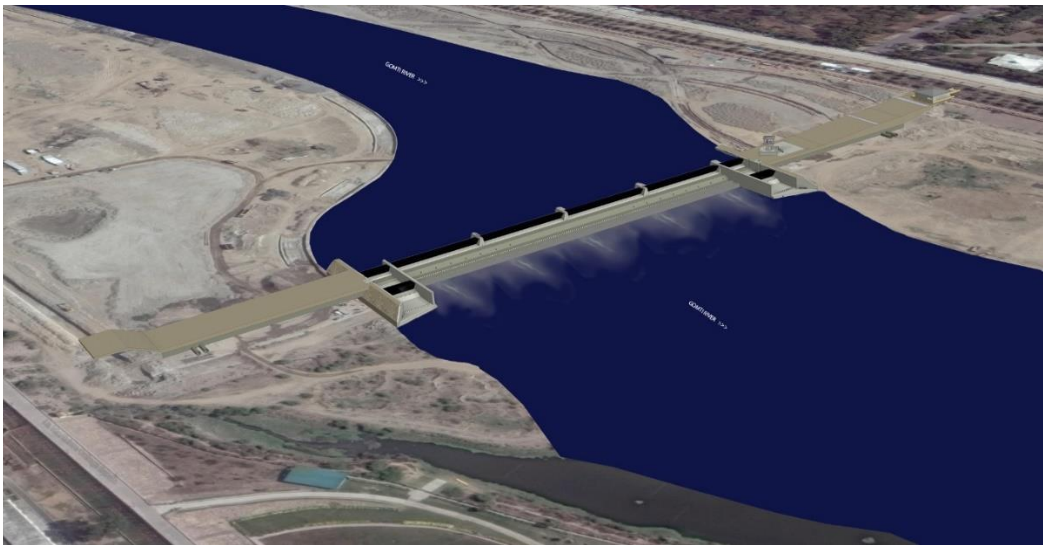

Fig. 1 General view to the new Gomti River Weir

3. RESULTS AND CONCLUSION

Rubber Dams are known worldwide for applications creating reservoirs in wide rivers for spans up to 100 m and heights up to 4.5 m. Main advantage is the flexible structure for full automatic reservoir level control allowing discharge of sediments, debris and ice in Nordic conditions. Numerous applications for reservoir control, spillway gates, irrigation purposes and hydroelectric power generation were realized in the last decade. Several rubber dam projects are under operation in India now.

The said main advantages were the reason why a rubber dam system was selected by the Main Client Government of Uttar Pradesh, Irrigation Department to meet the targets for the Upgrading of the Gomti River weir structure in India. For the Gomti Project a water filled system with his advantage for regulation of the reservoir level was selected.

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EVALUATION OF SLOPE STABILITY CONSIDERING EXISTENCE OF THE SPILLWAY CHANNEL TRENCH AT THE RIGHT AND LEFT ABUTMENTS OF GELEVARD DAM

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IRAN

1. INTRODUCTION

Glevard Dam project is located in Mazandaran Province and constructed on Neka River, and its middle point situated on the coordination of 36.59 N and 53.61 E. The type of dam is CFRD and maximum height of the dam from riverbed is 103 m and from bedrock is 113 m. Dam crest elevation is 739 m.a.s.l. with the dam crest length of 250 m and width of 10 m.

Based on the geological report of the project, left and right abutments of dam consist of white limestone (Lw) and grey limestone (Lg). Material of riverbed includes flood plain and alluvium on top following by gray limestone, Shemshak Formation and Gorgan metamorphic rocks at the bottom, respectively. Selection of the grout curtain and grout boreholes shall be in a way that their direction has the optimum status in relation with the dip and dip direction of discontinuities.

2. ASSUMPTIONS AND CALCULATION PROCEDURE

Calculations have been carried out based on the mechanical and geo-mechanical parameters provided in table 1, limestone properties and drilling section and also based on the specifications of layers in each borehole and its height conditions, which include three analysis sections at the right abutment and two at the left. In other words, the section belonging to borehole BH-22, which is located at elevation 772 m.a.s.l, due to its more height, is more critical than other sections, and this is the fact shown in calculations, too. Calculations have been performed based on the Geo-Slope V5.16 mathematical model, Mohr-Culomb model of discontinuity and also according to the above-mentioned descriptions and assumptions and for each analytical state, calculations in earthquake conditions with 0.15 factor have also been taken into consideration. Mathematical model of excavation in soil and trench has been provided in figure 1, which has been prepared in Geo-Lope software program.

3. CONCLUSION

With regards to pressure meter and other in-situ and laboratory test results in addition to the numerical analysis following design for stable slope was proposed: excavation with 1H: 1.5V slope in the first 15 m height with a 4m berm, at El. 738 m.a.s.l. following by a 8m berm at El. 745 m.a.s.l. and then excavation with a slope of 2H : 1V. For the surface soil, instead of initial design (using geogrid to support top soil) in order to prevent erosion using biological methods such as plantation is recommended. Indeed, the biological methods suggeted as the properties of the surface humos soil are instable and can flow down due to rainfall and this support is necessary to prevent erosion and flow of the mud. To support the toe of initial berm gabion is recommended as a facing. References

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ANALYSIS ON THERMAL FIELD EVOLUTION OF WUDONGDE ARCH DAM CONSTRUCTION SITE BASE OF DISTRIBUTED OPTICAL FIBER MONITORING

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1. INTRODUCTION

With the rapid development of optical fiber sensing technology, the application of distributed optical fiber temperature measurement technology has been widely used in mass concrete temperature monitoring.

The low-heat cement used in Wudongde dam can improve the crack resistance of mass concrete. However, the early strength development of low-heat cement concrete is slow and it is also the first time for the large-scale use of full-dam in China. It is hard to make sure the evolution of the true temperature field inside the low-heat mass concrete. Therefore, using the distributed optical fiber for concrete temperature monitoring is very significant.

2. DISTRIBUTED OPTICAL FIBER INTELLIGENT TEMPERATURE MONITORING SYSTEM

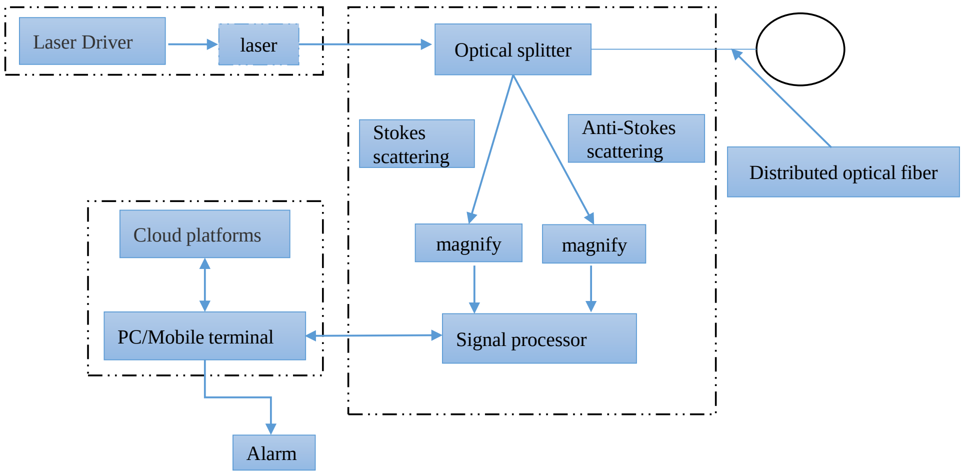

Fig.1 Distributed optical fiber intelligent temperature monitoring system

The basic principle(Fig.1.) of DTS is to make use of the principle of optical time domain reflectometer (OTDR) and the temperature effect of Raman backscattering of fiber. The thermal expansion coefficient of optical fiber can modulate the phase of the laser to reflect the temperature information.

3. THE CONSTRUCTION OF DISTRIBUTED OPTICAL FIBER

Wudongde dam is divided into 15 sections. The distributed optical fiber is buried in the 7 # section. The optical fiber is approximately the same elevation as the buried thermometer during the construction period along the river. The vertical optical fibers at the upstream and downstream surfaces are both 1m away from the upstream and downstream surfaces. The optical fibers below 871m in elevation are laid along the "Z" shape in the 7 # dam section. The optical fibers with an elevation of 871m - 988m are laid along the center line of the concrete block.

4. CONCLUSION

At present, the monitoring results show that the internal temperature of low-heat cement concrete increases obviously under hydration action after placement without effect of cooling water. Then the temperature increases with the age at a steady rate under the control of cooling water. After it reaches the highest level (the temperature is controlled at less than 27 C°), the temperature gradually decreases with the age and finally becomes stable under the cooling rate of less than 0.5 C° / d. The temperature distribution of the concrete will tend to be uniform.

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OPERATION OF SMALL AGRICULTURAL DAMS IN BULGARIA – STATE-OF-THE-ART

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EXTENDED SUMMARY

There are more than 2000 small dams in Bulgaria according to the definition of ICOLD. They were built predominantly in the 1960s and 1970s serving most of all agricultural purposes – local irrigation and stock farming.

After the fundamental political change in 1989 in Bulgaria, all cooperative farms and so-called agricultural-industrial complexes were liquidated. Many small dams owned previously by cooperative farms and societies were sold. All responsibilities for the further operation of all remaining small dams were administratively transferred to the local municipalities. On the one hand, they had neither the qualified personnel nor the financial resources to perform proper maintenance of the dams and their facilities. On the other hand, due to the collapse of national agriculture and the steady evacuation of the land population, there is in fact almost no need for the water from these small reservoirs. As a result, the technical maintenance of the small dams as an inherent operation component was disregarded for many years with all related consequences.

Currently, there are almost 40 acts and subordinated legislative documents which regulate all aspects of the operation of the dams in Bulgaria.

The following main issues can be formulated as identified in the operation and maintenance of small dams:

- Many municipalities let the dams for rent. In most cases, the operator used the dam reservoir as a fish farm and installed meshes at the spillway for preventing the fish to escape.
- During the liquidation of the cooperative farms, many dams were sold by tenders. Later on, it became obvious in many cases that the legal owner of the dam didn't have in fact anything more since the land below the reservoir was returned to its previous owners.
- The lack of resources for technical maintenance of the dams and their structures brought some dam owners to the necessity either to keep the corresponding reservoir permanently empty or to cut the dam body and thus to prevent any further impounding.

The following issues due to the lack or even absence of technical maintenance can be formulated with respect to the small dams performance:

- In general, there has been no technical maintenance of the dams and their facilities. Usually, there is no documentation, either.
- Damaged or clogged bottom outlet.
- Non-maintained dam slopes with developed dense plant and tree cover.

After the summarizing above presentation of the main operation problems of the small dams in Bulgaria, the following recommendations can be formulated:

- The necessary administrative work has to be done for overcoming of the separation in the operational management of the small dams between the dam with its structures and the water reservoir. Careful and justified distribution of the activities and responsibilities, respectively, has to be carried out.
- The performance of the facilities under so-called overload conditions for the particular class of importance has to be regulated.
- The property issues related to the small dams need urgent solution.
- Highest priority has to be assigned to the repair of dams with damages of the dam body and of the safety-related structures.
- It is a matter of state policy that dam owners have a chance to obtain the resources needed for proper maintenance of the dams.

From the performed short analysis, the following conclusions can be drawn. The small dams are essential component of the national water resources management infrastructure at lowest structural level. Hence, their operation and technical maintenance should be subject to strategic national policy in this field.

We are glad to find that currently, there is the general expert and administrative will in Bulgaria for solving the problems with the status and operation of the small dams.

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COMPARISON OF SELECTED SOFTWARE FOR 3D FLOW MODELING AT THE DAM SPILLWAY

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CZECH REPUBLIC

This paper deals with the application of numerical modeling on the spillways of selected case study dams in the Czech Republic. The main purpose is primarily to describe the application of selected software (Flow-3D, OpenFOAM and Ansys Fluent), for solving tasks on the same object. Advantages and disadvantages are discussed. The result is a description of the work with each software, the comparison of results, solution speed, stability and other important parameters for all users.

With continuously increasing level of spatial visualization and numerical modeling, it is possible to easily apply these methods for dam spillway design. It is valuable to observe the assumed behavior of 3D flow in perspective and different angles of view. It can help not only a general public, but also for specialists for their better understanding of fluid dynamics. Last but not least, numerical modeling can serve not only to design new structures, but also to assess and verification of existing works, rehabilitations, examining more options for reconstruction and other.

Thanks to advanced computer technologies is numerical simulation in 3D a relatively common matter. Constantly expanding offer of virtual resources may become tempting. Therefore, it is necessary to verify the selected software or to compare it with programs with each other. There is also great way, how to complete this numerical solution. It is the verification of numerical model with a physical model. The numerical model might be sometimes less accurate than the physical model due to some simplifications. However, there is always a necessity to set boundaries, how far the model can be simplified. It is not an intent to simplify the model too much; so, it could lose the properties of the real process. Nowadays, it is inefficient to construct prototypes of objects or complicated physical models because of financial and time reasons. Especially for larger waterworks is this solution often problematic.

There could be a little distrust of the models. Although computer technology is relatively developed, it is always desirable to rely on the empirical experience and good drawing documentation. If the input setting would be incorrect, it is not possible to get the correct results. The paper deals with all mentioned above, showing that there are many ways how to model with expensive or free software, but the correct results can be obtained with all of them.

SUMMARY

The main result of numerical simulation is the movement of flowing water in side channel spillway. The level of water surface from all software products is pretty similar, even for the same STL format geometry data. But the STL input must be modified/changed for every solver. Thus, from the beginning are all three processes completely different. They have all their pros and cons and it is delicate question which is better to use. Same desktop computer, similar settings, similar outputs. Today, the numerical modelling is a perfect way how to perform 3D simulation of water flow on water structures. Of course, the difference makes always the price of the software license. All tested software proven to be worth using for some reasons and some users.

ACKNOWLEDMENTS

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INVESTIGATION OF THE PROBABILITY OF FAILURE OF A GRAVITY DAM

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1. INTRODUCTION

The analysis of failure probabilities is an important element of risk assessment in dam management. This investigation is illustrating probability of failure calculations of the Eder dam, an old gravity dam in Germany, by means of a parameterized and fully nonlinear 3D-finite element model of the dam and the foundation (see Fig. 1). The model is calibrated based on measurements (thermal, hydraulic and mechanical) with the software optiSLang®. Therefore, sensitivity analysis with stochastic latin hypercube sampling is performed using a total of 200 designs (parameter combinations) with varying material parameters of the dam and the foundation. For the stochastic analysis of the dam, distribution functions for all relevant effects and resistances, e.g. flood events, are defined. After all, the evaluation of the stochastic analysis is done again with optiSLang®, which is capable to directly yield the failure probability P_f for the specified assessment criteria. Additionally, input parameters influencing the failure probability the most can be indicated quantitatively and qualitatively. A total of five reliability analyses by means of probabilities of failure are carried out. To determine the exceedance probabilities, an adaptive response surface method (ARSM) was used in combination with the First Order Reliability Method (FORM) with several hundred simulations each. As a result of the analyses, it can be stated that all failure probabilities are below the value of $P_f = 10^{-5}$, corresponding to reliability indexes above $\beta = 4.27$ (Reference period of 100 years). Thus, by using probabilistic analyses and procedures described in the report, a sufficient stability of the Eder dam can be confirmed and the safety margins beyond are quantified.

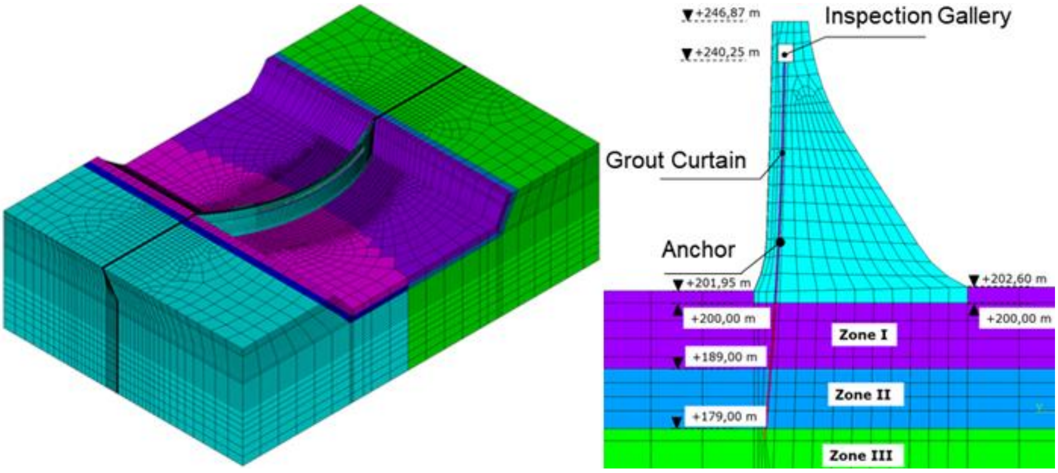

Fig. 1 Nonlinear 3D model of the dam and the foundation

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CHALLENGES OF DAMS CONTRUCTION AND MANAGEMENT IN INDONESIA

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INDONESIA

Indonesian Archipelago, which is situated in tropical zone, doesn't benefit much its climatic condition from the hydrological point of view. With existence of dry season and rainy season, the rainfall depth is only concentrated in certain months of the year (mostly on November, December, January and February), thereby varying from region to region and from island to island. Such as situation has caused people to look for means of storing up as much as possible water for future use in the dry season when rain is scarce or if it's of not non-existent. One answer to this problem is the construction of dams capable of storing up water in large quantities.

Ministry of Public Works and Housing, who responsible for infrastructure, will construct 65 dams across the region, From 2013 until 2019. It will provide totally 6.5 billion m^3 reservoir and irrigated 460,382 Ha and in 2022, it expected that all of 65 dams, will be finished. From 65 dams, 49 are new dams, the other 16 dams still on going. All of them are were owned by the government with 6.5 billion m^3 reservoir capacity, not included of those from all other dam stakeholders. So for next 5 years later, Indonesia will have over 270 large dams accros the nation.

This paper will attempt to present some issues and solution regarding to challenges of dams construction and management in Indonesia.

Keywords : land acquitition, human resources, Indonesia

CONCLUSION

As a tropical country and largest archipelago which has abundant water potential, Indonesia plan to build more dam in the future. Building a dam, is the same as we build a dangerous structures. Therefore, Indonesia needs a lot of competent dam engineers to escort this plan to be done. Unfortunately, increasing the number of dams in Indonesia is unbalance with the availability of competent human resources in dam engineering.

Nevertheless, the government realized, they need some breakthrough to solve this issues. Some breakthrough among them is to conduct training and continuously based on the need.

In terms of non-technical issues, land acquisition, handling social impact and budget provision for dam construction must be solve immediately. All those factors should be organized very well, government as a leader, cooperate with other stakeholder and communities with more normative and human approach.

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SEISMIC STABILITY ANALYSIS OF CONCRETE GRAVITY DAM

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1. ABSTRACT

The prediction of the actual response of a gravity dam subjected to earthquake is a very complicated phenomena. The added mass increases the natural vibrations period of the dam, and affects inertial forces created due to earthquake action. The interface of the dam with the impounded water is an important boundary where the static and hydrodynamic forces are applied to the dam structure. These forces provide a significant contribution to seismic response analysis and design of dams. Specific concrete properties used in the design of concrete gravity dams include unit weight, compressive, tensile, and shear strengths, modulus of elasticity, creep, Poisson's ratio, coefficient of thermal expansion, thermal conductivity, specific heat, and diffusivity. Seismic dam response depends on several factors such as dam-foundation interaction, dam-water interaction, material model used and the mathematical model employed. In fluid-structure interaction one of the main problems is the identification of the hydrodynamic pressure applied on the dam body during earthquake excitation. When such system is subjected to an earthquake, hydrodynamic pressures are developed on upstream face of the dam due to the vibration of the dam and reservoir water. Consequently, the prediction of the dynamic response of dam to earthquake loadings is a complicated problem and depends on several factors, such as interaction of the dam with rock foundation and reservoir, the computer modeling and material properties used in the analysis. For the structure on the rigid foundation, the input seismic acceleration gives rise to an overturning moment and transverse base shear. As the rock is very stiff, these two stress resultants will not lead to any (additional) deformation or rocking motion at the base. For the structure founded on flexible soil, the motion of the base of the structure will be different from the free-field motion because of the coupling of the structure-soil system. This process, in which the response of the soil influences the motion of the structure and response of the structure influences the motion of the soil, is referred to as soil-structure interaction. Different ground motions can induce similar values of peak stresses in the dam section but the potential consequences of these input motions could be very different regarding crack initiation and propagation. Time-history analyses provide the analyst with valuable insight and information in the analysis progression. They represent a very useful tool that not only can provide significant information regarding the main characteristics of the dynamic response of the dam but also can be used to yield qualitative damage estimates. The paper discusses the seismic design criteria for concrete dam projects, methods of dynamic analysis for strong ground shaking. An extensive review of case histories of concrete gravity dam behavior during earthquake is undertaken in this study.

KEYWORDS

Concrete gravity dams, Seismic response, hydrodynamics, dam-reservoir-foundation interaction, modal analysis, time history.

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3D BLOCK ERODIBILITY: REAL-TIME MONITORING IN AN UNLINED SPILLWAY CHANNEL

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1. ABSTRACT

Scour of rock foundations and spillways during normal and extreme flood events poses an important concern for dam safety. The challenge of making direct observations during a spill event has limited the understanding of the mechanisms driving the break-up of the rock mass when subject to hydrodynamic loading. Historically, methods for scour prediction have been derived from scaled laboratory studies often using simplified rock geometries and flow hydraulics. We present real-time observations of block removal captured using an instrumented block during a flood event in an unlined rock spillway of a dam in northern California. Particle image velocimetry (PIV) from digital video footage provides information on flow characteristics near the time of removal, while pressure and displacement sensors installed on the block faces provide measurements of hydrodynamic loads and block displacement leading up to failure/removal.

2. ACKNOWLEDGEMENTS

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SUMMARY

Scour of rock foundations and spillways during normal and extreme flood events poses an important concern for dam safety. The challenge of making direct observations during a spill event has limited the understanding of the mechanisms driving the break-up of the rock mass when subject to hydrodynamic loading. Historically, methods for scour prediction have been derived from scaled laboratory studies often using simplified rock geometries and flow hydraulics. We present real-time observations of block removal captured using an instrumented block during a flood event in an unlined rock spillway of a dam in northern California. Particle image velocimetry (PIV) from digital video footage provides information on flow characteristics near the time of removal, while pressure and displacement sensors installed on the block faces provide measurements of hydrodynamic loads and block displacement leading up to failure/removal.

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KEY NOTES ON QUALITY CONTROL OF ROLLER COMPACTED CONCRETE DAMS

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ABSTRACT

Roller compacted concrete dam (RCC) construction, including preparation of RCC materials, construction procedures and testing during construction is put into the framework of quality concepts. When put into this framework, the designer and contractor can see the integrated nature of both design and construction processes to achieve project quality objectives that result in safe and cost effective dam construction.

Quality concepts, particularly quality assurance (QA) and quality control (QC) are defined as follows:

Quality assurance (QA) is a program covering activities necessary to provide quality in work, and to ensure that activities that require good quality are being performed effectively. QA specifies actions necessary to provide enough confidence that the project will satisfy the given requirements as established in e.g. design criteria and performance specifications.

Quality control (QC) is the specific implementation of the QA program and includes the monitoring and evaluation of processes and outcome against the requirements and specifications. QC has to facilitate the immediate application of actions to the outcome, thus, allowing the engineer to exert direct influence on the outcome.

All the documents related to Quality Control works such as logbooks of concrete placements, shift reports, Quality Control reports, technical specifications etc. are controlled documents. During construction, a system of checklists are developed and adopted at the work site. This is an important document containing approvals of day-to-day construction activities. Every inspection and test is recorded and all the test results are regularly entered in the computer for statistical analysis. A comprehensive Quality Control report is prepared for each construction season listing all test results, their statistical analysis with any recommendations.

The purpose of RCC quality control is to maintain uniformity (minimizing variation) of all constituents and operations entering into the final product such that the final product will have predictable properties and behavior, and will satisfy the design requirements. Thus, quality assurance and quality control (QA/QC) systems for RCC dams need to be established in the preconstruction phase and rigorously continued during the dam construction.

In this paper, quality control of RCC dams during construction are discussed along with corresponding quality control (QC) programs, QC tests and acceptance criteria.

KEY WORDS: Quality Control, Roller Compacted Concrete, Construction, Material

MOTS CLES: Controle de Qualite, Beton Compacte au Rouleau, Construction, Materiau

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AN EVALUATION SYSTEM OF HYDROPOWER SUSTAINABLE DEVELOPMENT

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The 13th Five-Year "hydropower development planning (2016-2020)" clearly stated that we must "Make the development of hydropower an important strategic measure of energy supply side structural reforms, so as to ensure energy security and promote the construction of ecological civilization. Sustainable hydropower is an effective way by which to comprehensively understand the social, economic and ecological benefits of hydropower, comprehensively measure the benefits and impacts of hydropower, and coordinate hydropower development and watershed/regional development.

As China's administrative department of energy industry, the State Energy Bureau attaches great importance to the long-term development of hydropower. It has proposed that the concept of sustainable hydropower being established through the innovation of ideas, so as to solve practical problems in the development and management of hydropower industry. The global greenhouse gas emission reduction and China's demand for the prevention and control of smog have given China a new connotation of sustainable hydropower development. China has drawn lessons from international experience, and established a sustainable technology evaluation method for hydropower in China, which is consistent with international standards, in line with the national energy development strategy, and of great significance for promoting sustainable development of the hydropower industry, thereby achieving national emission reduction targets, and promoting the development of green power.

Hydropower development, while generating enormous social benefits, also has an important impact on local immigrants, society and ecological environment. Xie Qingsheng (2013) pointed out that large-scale hydropower development has resulted in the situation of "reservoirs of rivers and rivers, ecological fragmentation, interest group formation and overall inefficiency" of some of the main tributaries in the upper reaches of the Yangtze River. China's sustainable hydropower is different from the green hydropower of Switzerland and the low-impact hydropower of the United States.

In order to assess and provide guidance on the protection of the ecological environment during the construction of hydropower projects, the Swiss Federal Institute of Water Science and Technology (EAWAG) proposed the certification procedures and standards for green hydropower stations in operation in 2001. The US proposed the implementation of a low-impact hydropower station certification system. German International Cooperation (GIZ) compiled a handbook of watershed ecosystems in hydropower development. In 2000, the World Commission on Dams (WCD), a joint initiative of the World Conservation Union (IUCN) and the World Bank (WB) published a paper entitled Dams and Development - The New Decision Framework and Development: A New Framework for Decision-Making)". The International Commission for the Protection of the Danube River (ICPDR) explicitly sets forth the development of sustainable hydropower in the "Sustainable Hydropower Development in the Danube Basin Guiding Principles".

At present, the relevant evaluation of hydropower projects in China mainly focuses on the planning, preparatory stage and implementation stages, while the operational stage is relatively inadequate, especially in terms of environment and immigration. Relevant policies, standards and norms concerning planning, preparation, implementation and operation of hydropower station, are issued to identify stakeholders in China. Sustainable development issues should be addressed, and specific recommendations and supporting policies should be given to promote the sustainable development of hydropower.

China's large and medium-sized hydropower project, has led the local economy, improved the environment, and enrich the social responsibility of immigration. Subsequent research on hydropower development sustainability evaluation has to be combined with other systems, such as negative listing system and ecological compensation system to improve the ecological environmental benefits of hydropower projects. And it’s helpful to treat immigration in addition to reservoir anti-poverty policies as well as engineering benefit sharing mechanisms.

The issue of sustainable development of hydropower in China is not only a policy issue, but also a technical issue. Many problems occurred in the process of hydropower development, which affected its positive development and system in the status and in turn. In the future, we must seize the opportunity of power system reform and study-related supporting policies regarding sustainable development of hydropower from the aspects of finance, taxation, electricity price and financial subsidies. We must also establish an incentive mechanism to alleviate the contradictions between local governments and businesses, and achieve a win-win situation.

Keywords: hydropower sustainability, evaluation system, international projects, Belt and Road Initiative

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DAM PROTECTION GATES – ARE WE SOFT ON RISK?

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1. INTRODUCTION

At the simplest level, risks associated with dam protection gates can be classified into two headings, namely Hard and Soft. Hard risks are those that have defining factors and a great deal of statistical data. They include machinery failure, power failure and storm events. They are generally quantifiable, analytical and can be stated within statistical limits.

Soft risks are often people-related and include factors which are difficult to analyse. They include, without limit, ethos and culture, leadership and incentives, communications, human psychology, change and complexity. Such risks are often difficult to identify and quantify. As Engineers, do we under-estimate these risks because we are naturally disposed towards analysis and it is easier to operate where numbers are available?

This paper explores the source of soft risks and attempts to learn lessons by reference to previous studies into fields such as finance, corporate governance and accident investigations. As such, it explores "Human Factors" relating to individuals, groups and organisations.

2. METHODS

The paper reviews various previous works on human and associated soft risks. It sets out the issues in respect of human frailties and seeks to relate these to the "dam" environment.

3. RESULTS

The paper lists the problems and possible solutions in respect of managing soft risks

4. CONCLUSION

The presence of soft risks and the need to control them does not in any way diminish the importance of reliability analysis relating to hard risks. The need is to find ways of addressing and minimizing both.

This paper explores at a high-level the frailties and quirks of the human condition and shows how these can be embraced in a way that can reduce risk and thereby improve safety.

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HYDRAULIC ASSESSMENT OF TUNNELS

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ABSTRACT

Increasing urban population and the pace of industrial and other developments led to increase in water demand. Many of metropolitan and urban cities are facing acute shortage of water for domestic and industrial purposes. To reduce the stress on water supply infrastructure, existing water sources are utilized to fullest and new sources are continuously added to augment the water supply. Major problems in design of tunnel for water flow are flow conditions in approach to tunnels, in tunnel and downstream of tunnel. Even though art of tunneling is very old and well documented, new challenges in design and construction in difficult situations are added over the years. In this paper various hydraulic aspects related to tunnel interlinking rivers are described. Major head loss in tunnel flow is due to friction. Detailed information on investigation by various researchers related to friction factor is attached in Annexure A.

Key Words: Discharge, Diversion Tunnel, Explicit Equation, Friction Factor.


Fig. 1 Prototype photograph showing exposed reinforcement inside Tunnel due to cavitations

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OPERATIONAL MODES MONITORING FOR PREVENTION OF FAILURE OF DAMS WITHIN THE DESIGN ENVELOPE

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ABSTRACT

Monitoring and surveillance of dams have provided the first line of defence in dam safety management practices for many years, and in doing so have been central to the management of risks from dams since long before the emergence of contemporary risk-informed dam safety management practices. Historically, monitoring and surveillance have focused on determining, by means of observation, measurement and data analysis, if the observed structural functioning of dam, appurtenant structures and foundation conform to the design expectation under the conditions expected normally to occur in the life of the structure. Importantly, simple deformation and leakage monitoring, two of the fundamental elements of effective monitoring and surveillance of dams can be established and implemented in an informative way based on a rudimentary understanding of the basic functional modes of a dam and in the absence of knowledge of the design expectation or theoretical performance analysis from first principles of physics. Monitoring and surveillance, which includes testing is also essential for understanding the adequacy of the operational functionality of dams, and flow control gates in particular. These activities also inform the maintenance activities that should be carried out.

Appropriate data management systems for recording and classifying monitoring and surveillance information can be readily established and used for managing dam safety activities including prioritising obviously needed

maintenance and repair activities. Monitoring and surveillance data also provide the essential triggers for implementing interim risk management measures to control structural and operational deterioration, and for emergency planning and response. Viewed in this way, monitoring and surveillance activities provide the basis for a sound, if not sophisticated dam safety management system that can be applied even if information on the design basis and intent, the expected performance and past performance of the dam and the operational characteristics of the system are not well understood at the outset. Such a dam safety management system can be enhanced by including, by means of data and records searches and back analysis as a means of establishing the design basis and intent, the expected performance of the dam and its structural vulnerabilities, and its operational modes, expectations and functional vulnerabilities. Such enhancement of the scope of the management system, based on long established engineering principles and modern safety management practices can be expected to bring additional demands for monitoring, surveillance, testing, and data analysis. Further enhancement of the management system can then be introduced involving analysis of functional modes of operation followed by consideration of associated failure modes first qualitatively and ultimately quantitatively in terms of probabilistic risk modelling and analysis.

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STUDY ON THE HARMFUL IMPACT OF SLIT-TYPE ENERGY DISSIPATER WATER WINGS

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1. INTRODUCTION

Slit-type energy dissipater (STED) as an efficient device to dissipate energy of flow, is widely used in hydraulic projects of high water head, large discharge, and narrow river valley. However, the water wing caused by the shock waves in the contraction section of STED, may bring about harmful effects, which has been hardly attached enough importance.

2. METHODS

This paper revealed the internal relation of the shock waves and the water wing in STED through physical model experiments and theoretical analysis.

3. RESULTS

Simplified formulas to calculate the shock wave angle and the water wing area were theoretically derived. The scope of the water wing could be estimated from the values of L_M and T_M.

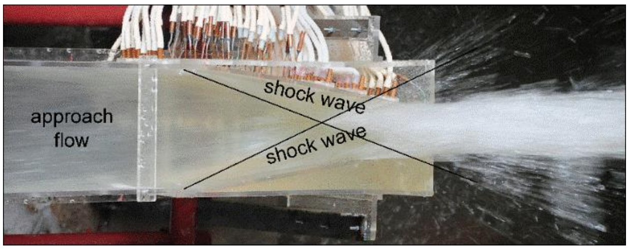

Fig. 1 Flow regime in the STED contraction section

4. CONCLUSION

The calculation results were compared to the experimentally determined area of the rainfall caused by water wings. Results show that they are accurate enough to estimate the scope of the water wings.

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6. KEYWORDS

Slit-type energy dissipater; Flow shock wave; Water wing; Hydraulic modeling

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SEISMIC ANALYSIS OF MIJARAN EARTH DAM AND OPTIMIZATION OF ITS PARAMETERS USING PSO

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ABSTRACT

In this paper the dynamic behavior of the Mijaran earth dam (Iran), considering dam-foundation interaction, under normalized Manjil earthquake as input motion has been studied. In order to assess the effect of the dam heights and the foundation widths, in the finite element model on the earthquake response, various dam-foundation coupled models are analyzed by Plaxis, a finite element package for solving geotechnical problems. In this research, the dam heights and the foundation widths has been chosen optimally using particle swarm optimization (PSO) method. The simulation results indicate considerable differences in the seismic responses.

KEYWORDS: Dynamic analysis, Mijaran earth dam, Manjil Earthquake, foundation width, dam height, particle swarm optimization

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REFERENCE PRESSURE CELL, AN EFFECTIVE SOLUTION FOR A CHALLENGING MATTER OF DAM MONITORING

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1. ABSTRACT

Design, construction and sustainable operation of embankment dams have always to do with geotechnical monitoring. Two most important categories of geotechnical monitoring by instrumentation are the measurement of pressure and displacement. In many instances of measurement technologies, these two physical parameters help each other to measure a quantity of them. Besides the displacement of soil mass is a source of inconsistent total pressure data. This issue is a challenging matter in geotechnical monitoring of embankment structures, which experience a considerable displacement during construction and consolidation phases.

In case of rotation of total pressure cell without knowledge of the final inclination, correction of measured values through the theoretical assumptions is either impossible or not completely reliable.

A total pressure cell installed in the body of an earth-fill, e.g. in the clay core of an embankment dam, must be capable to measure the total stress in a special

direction. In many instances, the position of pressure cell changes continuously due to the development of displacements and functionally changes the value of measured pressure. This is the most important reason for the inconsistent total pressure data and uncertainty of monitoring results of embankment structures. This uncertainty can cause some misunderstanding of pressure data and related pressure ratios – such as Arching Ratio - and following mistakes of monitoring.

The potential for rotation of the total pressure cells in the soil material during compaction of an embankment is very likely. Therefore, the analysis of pressure data in an embankment without knowledge of final inclination of the pressure cell is a challenging matter, which sometimes causes resign form installation of total pressure cell.

There are some methods, which try to overcome these uncertainties either by some technical considerations during manufacturing, installation or by some recalculating of measured stress values. However, the practical methods are limited to the installation point in a large soil or rockfill mass and do not definitely warrant an on-site consistent measurement of total pressure.

On the other hand, the theoretic recalculations and back analyses are based on many assumptions. There are some methods, which are a combination of both practical and theoretical methods for reducing the negative physical effects and increasing the accuracy of theoretical calculations. These methods have certainly some limitations and disadvantages.

It is to be noticed that there is a considerable quantity of the embankment structures, especially embankment dams, in which projects the designer has preferred to resign the stress monitoring by total pressure cells. The current technical and academic literatures implicate that this attitude is becoming rapidly as an accepted design method of instrumentation of embankment structures. In that case the only remaining solution for approximating the pressure ratios is evaluating a pressure value by the average density of overburden materials regardless of unequal layer compaction and arching phenomenon.

This paper describes an innovative outcome of a R&D project for developing a new measuring instrument, which solve the above-mentioned problem, increase the reliability of monitoring data and reduce the errors and the costs of instrumentation. The important critical success factor of this measuring system is an optimal mechanical and electrical integration of an inclination sensor and a pressure insert in a tight heavy-duty housing. This type of total pressure cell is capable to measure the inclination in two axes up to 90°.

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THE APPLICATION OF PERFORMANCE ASSESSMENT OF EMBANKMENT DAM MODEL BY USING KNOWLEDGE-BASED SYSTEM

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EXTENDED ABSTRACT

The performance assessment of embankment dams in respect to main deterioration mechanisms is the major challenge for managers in charge of their security. To cope with them, we build assessment models linked with vegetation and behavior dam using the knowledge-based system as it responds well to the constraints of the problem: visual observations can be used, and these can be combined with different types of information such as construction and monitoring data, visual observations, etc. The structure has double assessment scale for all the indicators: an ordinal scale characterized by the ordering of categories as a function of an intensity criterion linked to a scale of intervals that allows working on continuous numerical magnitudes (Fig.1) and the specific indicator.

Figure 1. Ordinal Scale of the double assessment chosen for assessing the performance of dams

The result of the study is assessment models that will permit assessing the performance of dams regarding other possible deterioration mechanisms. In Table

1, present the specific indicator, formalization grid for assessing the indicator "Diameter of the tree trunk from with the scoring scale.

Table 1. Specific indicator for formalization grid - the status indicator "Diameter of tree trunk."

Name	Density of individuals
Definition	Primary look at the diameter of a tree trunk for indicator and root typology is taproot. Typology: vertical, horizontal, short root. Never allow any vegetation larger, especially eucalyptus tree roots can cause the core to crack resulting in the failure of the dam.
Scale	10 (good at very good): Without taproot 5-4 (poor): Diameter tree trunk < 5 cm 1-0 (unacceptable): Diameter taproot > 5 cm
Temporal characteristics	Measure is carried out during a visual examination focused on the characterization of vegetation on dam

Applying of this indicator using this indicator is carry out at the Juanda Dam. Based on the results of the latest visual inspection, the scale of assessment is good. On the downstream slope of Juanda Dam is not found any hard trees. The downstream part of the dam body is covered by grass as a protector from rain water splashing, also serves as an indicator when there is a wet area on the downstream slope. In the Fig. 1, looks a hard tree, all of which is in the original land, and there is no visible hard tree growing on the dam body.

a. The downstream of Juanda Dam

b. Upstream toward downstream

Fig 1. Upstream and downstream Juanda Dam
(Source: Jasa Tirta II Public Corporation)

Keywords: embankment dam; vegetation; performance; knowledge-based system

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REMEDIAL GROUTING OF EXISTING EMBANKMENT DAM *FOUNDATIONS: LESSONS LEARNED (AND IGNORED)

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1. BACKGROUND

During the last 20 years in the United States, there has been a technological revolution in drilling and grouting processes associated with the remediation of existing embankment dam foundations. The details of this revolution have been widely published in the technical press and presented at conferences. However, the authors believe that many of the "lessons learned" in that period have not been fully or correctly applied or, in some cases, have been ignored.

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* *INJECTION RÉPARATEUR DES FONDATONS DE BARRRAGES EN REMBLAI EXISTANTES: LEÇONS APPRISES (ET IGNORÉES)*

2. METHODS AND RESULTS

Practical guidance is provided on several processes critical to the efficient, effective and safe implementation of a remedial grout curtain. These processes are:

- Drilling techniques for overburden and rock, highlighting the use of rotary vibratory and dry duplex methods for overburden, and the use of water-powered down-the-hole hammers for rock.
- Design and testing of grout mixes, emphasizing the necessity to assess key fluid properties such as apparent viscosity, bleed stability and pressure filtration coefficient.
- Placement and sealing of standpipes and MPSP's in the embankment materials: this is a critical aspect for dam safety and good progress of the works, and is becoming a victim of over-conservatism on the part of some Owners.
- Data management systems, which are a vital part of contemporary grouting projects and whose challenges are often overlooked by the Contractors.
- Refusal and closure, two terms which are often confused.
- Allowable safe injection pressures: this is often a source of controversy and concern, but which can be resolved with thoughtful use of computer-aided and controlled injection systems.
- Joint Instrumentation Monitoring Plans are essential to develop between Owners and Contractors before the project begins. This is also limited to long-term performance monitoring schemes.

3. CONCLUSION

High quality, durable and effective grout curtains are now being regularly installed under major dams in the U.S., particularly in karstic terrains. The authors believe that the current high standards being exhibited can be maintained, but only if the "lessons learned" over the past 20 years or so are not allowed to be forgotten or ignored.

KEYWORDS

Automated monitoring, boring, construction, cutoff, embankment dam, foundation treatment, grout curtain, grouting, karst, quality control.

Ausculation automatique, forage, construction, barrage en remblai, traitement des fondations, écran d'injection, injection, karst, control de qualité.

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SEEPAGE CUTOFFS FOR DAMS AND LEVEES: LESSONS LEARNED FROM 40 YEARS OF REMEDIAL CONSTRUCTION IN NORTH AMERICA *

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1. INTRODUCTION

Potentially soluble and erodible rock underlies about 40% of the 48 contiguous states in the U.S. These materials form the foundations of dams in the principal river basins such as the Mississippi-Missouri, Tennessee and Ohio River systems. Beginning in 1975, a program of seepage remediation using "excavate and replace" cutoff walls [1] has been implemented, with a particularly high level of activity from 2012 to 2017.

2. METHODS

The author has analyzed the details of 27 major remedial cutoffs installed over the past 43 years in North America [2]. These projects, the contractors who built them, and the techniques used, are presented in chronological order. "Lessons learned" are synthesized under the following headings:

Design Considerations, including:

- Geological and Geotechnical Site Characterization

* *MURS PARAFOUILLES POUR DES BARRAGES ET DES LEVÉES : LES LEÇONS ONT APPRIS DE 40 ANS DE CONSTRUCTION RÉPARATRICE EN AMÉRIQUE DU NORD*

- Geotechnical Reports
- General Principles of Cutoff Wall Design
- Risk and Performance Considerations
- Durability

Construction
QA/QC Verification
Instrumentation and Performance Monitoring
Development of Contract Documents and Contractual Arrangements

3. CONCLUSION

The analysis provides guidance to owners, designers, and contractors as to what may be regarded as the best of the U.S. practice in this field. While the intensity of construction witnessed over the last decade may not be repeated, there is no doubt that some level of activity will continue both in North America and elsewhere in the world. Attention to the “lessons learned” will help ensure that the current high standards of design, construction and dam safety are maintained in the future.

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KEYWORDS

Construction method, core wall, cutoff wall, diaphragm wall, embankment dam, foundation, internal erosion, karst, leakage, piping, rehabilitation.

Methode de construction, écran interne, mur parafouille, paroi moulée, barrage en remblai, fondation, erosion iterne, karst, fuite, renard, rehabiitation.

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THE SEEPAGE ANALYSIS OF THE EMBANKMENT DAMS OF A FLOOD RETENTION BASIN IN POLAND

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1. INTRODUCTION

All kind of embankment fill dams are faced with seepage body during impoundment and during operation. Therefore, seepage control plays an important role at the design stage to prevent uplift pressures, instability of the downstream slope, piping through the embankment and/or foundation and potential suffusion and erosion processes. In order to guarantee safe seepage conditions for the anticipated load cases, the seepage control design should comprise sealings, dam body specifications, special drainage elements, and their characteristics.

The paper provides the main information and results of the seepage and stability analysis of a case study and aspects considering potential suffusion and erosion processes.

2. RESULTS

The steady-state seepage analysis is carried out to determine the pore water pressure, the total head and the amount of seepage through the embankment dam and the foundation. The slope stability analysis is performed to determine the factor of safety only for the downstream embankment slope (see Fig. 1).

As a last step, a process depending assessment for the erosion and suffusion risk was carried out in order to evaluate the potential suffusion and erosion processes. As confirmed by the performed analyses, the dam design shows critical drawbacks concerning some of the analyzed load cases. In most of the load cases, the seepage shows an unfiltered exit which can cause backward erosion.

The sealing system does not reach to the crest level. Therefore, a considerable seepage flow may occur in the unsaturated zone, bypassing the sealing in the crest area. Especially, for high water levels this shows an adverse effect.

The applied gravel columns show a minor effect on the underground seepage conditions. The gravel columns increase the seepage flow amount, pressure head and seepage line also when the sealing system is working in full sealing conditions.

Concluding, the performance of sealing system plays an important role on the seepage conditions. As soon as load cases are considered which analyze the malfunction of the upstream sealing or the downstream toe, the dam shows an unsatisfactory behavior. The design does not comply with modern dam design criteria and modern European dam safety philosophy.

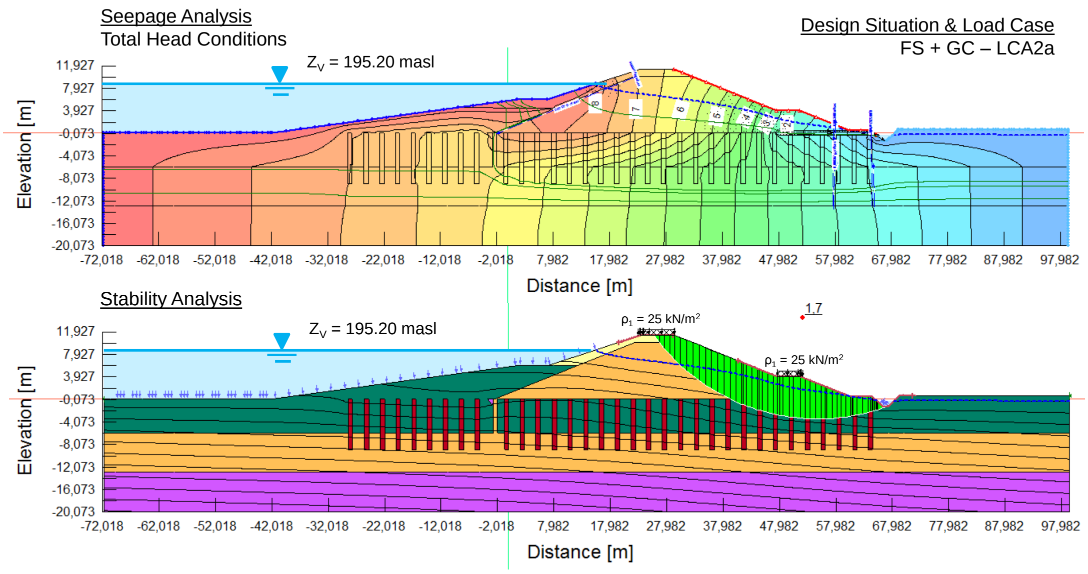

Fig. 1
Exemplary results of the stability and seepage analyses

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GROUT CURTAIN PERFORMANCE PARTICULARITIES IN THE COMPLEX GEOLOGICAL CONDITIONS ENCOUNTERED AT GURA APELOR CLAY CORE ROCKFILL DAM

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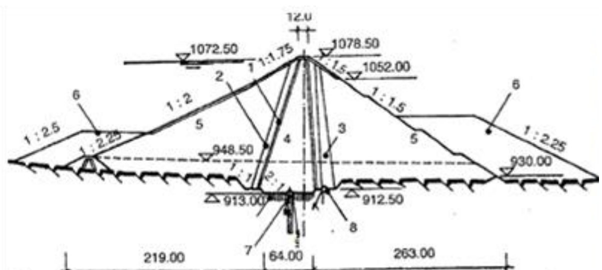
ROMANIA

1. GURA APELOR DAM

Gura Apelor dam is a clay core rockfill dam 168 m high, that provides a 230 mil. m^3 storage for the 335 MW Retezat power plant. It is the tallest dam in Romania. The crest length is 480 m and total fill volume is 11.2 mil. m^3. The core is moderate thick, 64 m at the dam base. The grouting and drainage gallery is located along the clay core – foundation rock contact, in the mid axis of the core. A second gallery is provided downstream of the grouting gallery, inside the downstream filter, in order to collect the water seepage escaped through the clay core or percolating the grout curtain.



1-clay core;2-US filter; 3-DS filter; 4-clay; 5-rockfill; 6-stability prism; 7-grout curtain; 8-seepage collecting gallery; grouting gallery

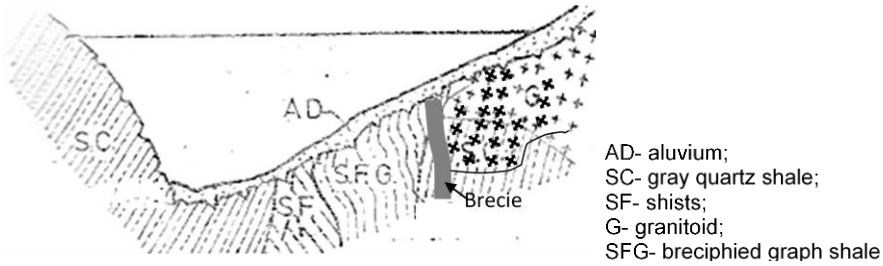


Fig.1
Gura Apelor Dam – cross section, geology and downstream view

The foundation rock is made up of a complex of crystal shale and granite gneiss. The right slope, the river bed and the left slope below about 950 mASL consist in gray quartz shale with greenish chlorine-sericitous bands. The left slope below elevation 1,030 mASL and down to about 950 mASL is made up of tectonised, breciphied graph shale. Above the 1030 mASL the right bank is made of granitoid rock mass.

2. GROUT CURTAIN EFFICIENCY

The grout curtain was designed based on lugeon values and consists in two rows of grouting holes, with a depth of 60 … 80 m, performed from the grouting gallery. On the upper part of the left abutment, above the elevation 985 mASL the control drillings have shown very large water absorptions. The difficulties encountered during the grouting process due to complex geological conditions has imposed the temporary stopping of the grout curtain performance. Consequently, the reservoir water level was severely restricted. After 10 years of studies and analyses it was decided to complete the grout curtain. At the end of the process the criteria based on lugeon specific absorption were only partly fulfilled.

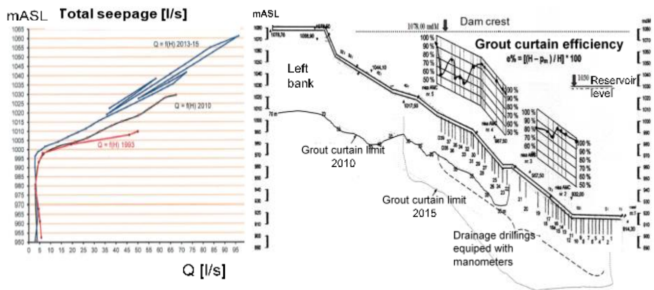


Fig.2
Grout curtain efficiency in terms of total seepage and pressure drop

However, the total seepage collected by the monitoring system have shown significant decrease of the seepage values. The grout curtain efficiency was defined based on the measured pressures upstream and downstream the grout curtain. On the average, the efficiency was above 80% but two local zones where the efficiency was 65 … 70%.

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MONITORING AND EVALUATION OF VARIED ANTI-SEEPAGE MEASURES IN DEEP GRAVEL FOUNDATION FOR AN EMBANKMENT DAM - A CASE STUDY

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CHINA

1. GENERAL SITUATION OF THE DAM

The dam is a homogenous embankment dam with length of 2222m and maximum height of 24m. The bedrock is overburdened by Quaternary alluvial and diluvial layer, which includes three permeable layer composed by sand and gravel and two impervious layer composed by clay. Seepage control prevention measures of the dam include cut-off wall in section from 0+700 to 1+250 and jet grouting in the section from 1+250 to 1+750. The axial geological formation of the dam is shown in Fig. 1.

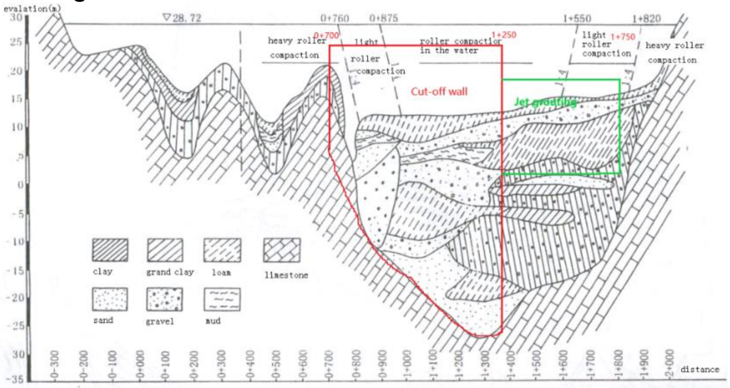

Fig.1
Theaxial-section geological formation of the dam

2. EVALUATION OF SEEPAGE CONTROL EFFECT

Seepage observation points are distributed in the cross sections of 0+500, 0+850, 1+130, 1+300 and 1+650. Observation points of dam body and foundation are distributed in front and back of seepage control measures.

Two dam foundation observation points of section 0+850are located at the back of cut-off wall, and their average potential percent is 25% and their seepage pressures have a poor correlation with water level. The potentials at the back of cut-off wall of section 1+130 reduce about 55% respectively compared with those points at the front of cut-off wall.

The potentials of observation points of section 1+300 keep near 40% and their seepage pressures have a poor correlation with water level. There is small loss of water head and high permeability of dam foundation, which means that the joint area of cut-off wall and jet grouting shows a poor anti-seepage effect.

The potentials at the back of jet grouting of section 1+650 reduce about 20% respectively compared with those points at the front of jet grouting， with remaining potentials of 70% and 60%. Besides, the correlation coefficients between their seepage pressures with water level exceed 0.9. Grouting aims to make the materials denser and form an impervious barrier in dam by using a thin mixture of sand, water, and cement or lime, which is only suitable for the low water head embankment dam. Cut-off wall is a technique used to build reinforced concrete walls in dam body or foundation. Its integrity is good and anti-seepage effect is remarkable, which makes it more applicable.

3. CONCLUSION

Anti-seepage effect of jet grouting is significantly influenced by the condition of the soil layer and it is only suitable for the low water head embankment dam. Cut-off wall presents a bigger safety and reliability in aspects of foundations' cutoff fin deep overlying strata and it is more applicable. As shown in the case, for an embankment dam with a deep gravel foundation, cut-off wall is more efficient of seepage prevention than jet grouting.

4. ACKNOWLEDGEMENTS

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ASSESSMENT OF HYDRO TASMANIA'S CONCRETE DAMS AND IMPACT OF UPLIFT

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AUSTRALIA

1. INTRODUCTION

Hydro Tasmania is the State-owned generation company for the island of Tasmania in Australia. Hydro Tasmania's power system includes 55 large dams, 30 hydropower stations and two major wind farms and has a total installed capacity of over 2000 MW of hydropower and 300 MW of wind. Hydro Tasmania's portfolio of dams covers a wide range of dam types, with a total of 12 concrete gravity dams ranging in height from 6 m to 49 m.

The portfolio of dams is ageing, with more than 30 of the dams now more than 50 years old. As a result there has been increased effort to understand the risks associated with this ageing portfolio of dams. Hydro Tasmania has had an active dam safety program since the early 1970s. This program was initially structured around dam surveillance activities; however, in the past two decades risk assessment has become the framework for the program. A full portfolio risk assessment was completed in 2006, which forms the basis for risk-based decisions in relation to dam management.

As part of the dam portfolio risk assessment a key risk identified for the concrete gravity dams was the unknown uplift pressures under the concrete gravity dams, which directly influence the stability due to both sliding and overturning. This was because there was no pressure monitoring, drainage holes were of small diameter and drain cleaning was not undertaken routinely.

2. METHOD

The risk associated with the unknown uplift pressure on these concrete gravity dams was considered unacceptable. This resulted in Hydro Tasmania undertaking a program of works on its large concrete gravity dams. This program of works consisted of the following five steps:

(1) Installing piezometers
(2) Measuring pressures within the foundation prior to drain cleaning
(3) Cleaning of the drains and in some cases increasing the diameter of the drain holes
(4) Ongoing measurement of uplift pressures following drain cleaning
(5) Ensure that there was a link between O&M manuals for the dams and the uplift monitoring.

3. RESULTS

An important part of the process undertaken was the measurement of foundation pressures before and after foundation drain upgrades/maintenance to quantify the state before and after and the impact of the drainage. This enabled an assessment of the effectiveness of the upgraded drainage system.

This paper provides some details on two of these dams, namely Trevallyn Dam and Clark Dam. These case studies provide some summary data on uplift pressures before and after foundation drain upgrades, and compares actual uplift pressures against the design assumptions. An upgraded drain size of 75 mm was adopted in both case studies with varying results.

4. CONCLUSION

The foundation drainage upgrade at Clark Dam was noted to be more effective than at Trevallyn Dam. This could be due to the smaller initial drain size at Clark Dam (32 mm diameter) compared to Trevallyn Dam (50 mm diameter) or drain cleaning at Clark Dam being less frequent previously than at Trevallyn Dam. The data provided in this paper is considered to be of value to the wider dam engineering industry.

KEY WORDS

CONCRETE DAM, DRAINAGE GALLERY, DRAINAGE HOLE, GRAVITY DAM, PIEZOMETER, PORE PRESSURE, RISK ASSESSMENT, STABILITY, UPLIFT

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RESEARCH AND APPLICATION OF NEW-TYPE MATERIAL IN WUDONGDE AND BAIHETAN 300M ULTRA-HIGH ARCH DAM KEY TECH OF CHARACTERISTICS AND APPLICATION ON LOW-HEAT CEMENT CONCRETE*

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ABSTRACT

300m ultra-high arch dams have higher stress level and higher requirements of concrete dam body in integrity, safety and durability. It also requires that the dam concrete must have higher strength ($C_{180}30$~$C_{180}40$), impermeability ($W_{90}10$~$W_{9}016$), frost resistance($F_{90}200$~$F_{90}300$) and crack resistance. A specific low heat Portland cement (P.LH) suitable for ultra-high arch dam concrete has been developed in this study. For this new type of cement, suitable contents of its four major mineral components were determined by considering the comprehensive effects of cement mineral composition on strength and hydration heat. C_2S content in P.LH is controlled between 40%~50%, C_3S content is controlled in 30%~40%, C_3A content is controlled not greater than 4% and C_4AF content is controlled in 15%~19%. MgO content is controlled in 4.0%~5.0% to compensate thermal shrinkage during concrete temperature drop. And its specific surface area was limited not greater than 340 m^2/kg to reduce cement hydration rate at early age. Meanwhile, it is helpful energy-saving, emission-reduction and production cost. Furthermore, for the improvement of quality of P.LH and its stability, the technical requirements have been elaborated in the enterprise standard of China Three Gorges Corporation(Q/CTG 13-2015), named as *Technical Requirements and Testing of* Low Heat Portland Cement for Arch Dams issued in this study. Meanwhile, two difficulties while adopting traditional calcing technology to produce P·LH with higher content of C2S have been sovled, they are the stability of β crystalline belite compound (β-C2S) and the hydration activity of belite compound whereas its early strength at room temperature is very lower. After a long-term study of scientific experiments and multiple projects application, the specific P.LH was decided to wholly used in Wudongde and Baihetan ultra-high arch dam with height of 300m. Site application and research results are shown that P.LH concrete have lower unit water consumption only in 79kg/m3~ 83kg/m3 compared with moderate heat Portland cement (P.MH) while mixed with maximum size aggregate of 150mm; P.LH concrete have higher compressive strength in late age, the compressive strength is nearly the same as or even a slightly greater than P.MH concrete at 90d, but 180d compressive strength is greater than P.MH concrete; P.LH concrete have lower adiabatic temperature rise, its 28d adiabatic temperature rise is nearly 3℃° lower than P.MH concrete; P.LH concrete has stronger comprehensive crack resistance than P.MH. In addition, the construction process of P.LH concrete have been formed with comprehensive study of construction technology including concrete transportation, pavement ,vibration, rinse and forms removal etc. Although the strength of P.LH concrete in early age is lower, rinse and forms removal duration will be 1~2 days lagged, but it is still in the allowed interval, there is no effect on the construction schedule through reasonable organization. The temperature control measures have adopted such as concrete pre-cooled, intelligent water supply and surface heat preservation etc, for the implementation of intelligent temperature control in the whole process. The concrete temperature at outlet of the batching system, placing temperature, cooling water temperature and water flow can be more easily controlled than adoption of P.MH concrete. So far ,the fresh concrete performance can meet the construction requirements. Various performance of P.LH concrete technical index can meet the design requirements in Wudongde and Baihetan ultra-high arch dams. The concrete core sample has tight appearance, smooth distribution of aggregate and good quality. The maximum temperature of concrete has been controlled in the design requirements with a certain amount of surplus. The temperature crack have not been found till now, P.LH concrete have obtained good application.

KEYWORDS

P·LH cement, dam concrete, temperature control and crack resistance, duration of forms removal, rinsing duration, ultra high arch dam

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REHABILITATION OF THE CENTER HILL EMBANKMENT DAM

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1. INTRODUCTION

In the US, the US Army Corps of Engineers (USACE) is amongst others responsible for the surveilling and maintaining of dams. One of these structures is the Center Hill Dam in Tennessee. It was built in the 1940ies as a combination of a concrete gravity dam and a connected embankment dam. The structure is used for flood control of the Caney Fork River up to the town of Nashville and to generate electricity with a connected power station.

The subsoil mainly consists of karstified limestone. The karstification resulted in water conductivity below the dam soon after the filling. Several grouting measures were not able to permanently seal these permeabilities. At the beginning of this century, not only damp spots occurred at the embankment dam but also major sinkholes at the left abutment.

Subsequent examinations led to the decision to install a permanent concrete cutoff wall as a sealing-barrier in the until then coreless fill dam and to permanently tie this cutoff wall to the existing concrete gravity dam. Due to dam safety reasons, an encasement wall for temporary use was specified to prevent uncontrolled trench collapse in case of sudden slurry loss during execution of the cutoff wall. Within this encasement wall, the permanent barrier wall was installed.

2. METHODS

2.1. CONCRETE CUTOFF WALLS

Two combined diaphragm walls were executed during 2013 and 2014 at the partially filled reservoir in two phases. Phase 1, the encasement wall, to protect the earthen embankment dam during the construction works and Phase 2, the barrier wall, to install the permanent cut-off wall deep down to non-karstified limestone layers. The depth of the barrier wall reached down to a maximum of 96 m.

2.2. CONNECTION TO THE CONCRETE DAM

Apart from safety and environmental aspects, a special task was to finally and permanently connect the cut-off wall to the existing concrete dam. Water conductivity between the two structures had to be durably eliminated.

3. RESULTS

All tasks were executed as specified and the dam resumed its full operation.

4. CONCLUSION

With available foundation engineering techniques, experienced specialist contractors are able to install durable concrete cutoff walls in embankment dams at impounded reservoirs. At combined dams, i.e. embankment dam connected to a concrete gravity dam, the cutoff wall will be executed tying into the concrete dam, sealing the interface between the two dam types.

5. KEYWORDS

Cutoff Wall, Concrete Dam, Diaphragm Wall, Embankment Dam, Tie-In

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REMEDIAL GROUTING FOR EMBANKMENT DAM CORE SEALING – 10 YEARS EXPERIENCES

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1. INTRODUCTION

Remediation grouting for sealing of aging embankment dam cores has been known as effective, however, no standardization is at present and publication of case histories are rare. For remedial grouting of embankment dam cores, a different design concept is required comparing to typical dam foundation or coffer dam grouting. It should satisfy the opposite conditions, which are the prevention of hydraulic fracturing as well as the maximization of filling of voids and deteriorated areas. In this paper, low pressure remediation grouting techniques applied for two large dams over past 10 years are analyzed in detail.

2. DAM INCIDENTS AND REMEDIAL GROUTING

After apparent incidents derived from deteriorated clay cores, carefully designed remediation grouting technique was applied for two earth-cored embankment dams (WM and AG dam) in Korea.

WM dam is a 55m high earth-cored rockfill dam and exhibited distinct deterioration by observing three sinkholes near dam crest over six months during normal dam operation. Before any remediation, dam seepage measured at the downstream toe increased up to about 2,340 m^3/day at Normal High Water Level (NHWL). After in-depth diagnosis, compaction grouting was partially performed (length of 80m out of 407m) on the dam crest as the first choice of remediation measure. After compaction grouting, the total seepage reduced down to 860 m^3/day near NHWL. However, after 2 and a half years later, seepage increased up to 1,007 m^3/day and another in-depth diagnosis revealed diversified flow paths within the embankment, which required remediation measure over the whole length of the dam. The ultimate remediation was conducted using low-pressure permeation grouting.

AG dam also indicated a distinct symptom of core deterioration after first impounding. The dam embankment had very low stiffness of earthfill and the core material contained relatively large portion of sandy soil with fines. Various areas of wet-zones were found on the downstream surface and remedial grouting applications were performed four times without any technical consideration of the state of embankment. Consequently, heavy rainfall induced large downstream slope sliding occurred in 200). After immediate emergency measure to rehabilitate the slope, permanent remediation was taken with the application of permeation grouting.

As empirical guidelines for the two dams, permeation grouting of two- or three-rows layout was successful with a grout column spacing of 2m in dam axis direction and 1m in stream direction on the crest. Remedial grouting sequence at least 8m spacing in an interpolation method was accompanied. Main grout material was composed of ordinary Portland cement and micro-cement. Bentonite mix with a mixture less than 5% mass quantity was effective as an additive material. Empirically proven recipe of permeation remedial grouting encompasses the maximum fluid pressure (kPa) given as 2 × 10 (kPa/m) × depth (m) × 0.75.

Seepage rate measured on the center of downstream toe after remediation grouting remarkably decreased for WM and AG dam, which indicated the successful effect of permeation remedial grouting.

Empirical case study in this paper is believed to be an important hazard mitigation technology in the field of aging dam rehabilitation project.

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THE EFFECT OF THE GROUNDWATER FLOW VELOCITY AND SEDIMENT DISCHARGE ON INTERNAL EROSION OF RIVERS*

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1. ABSTRACT

Rivers play an important and life-sustaining role in human societies and provide many critical advantages to human civilizations such as water transport, habitat, economical support, transportation, etc. Degradation of rivers due to the natural occurrences such as flooding or human's interferences like constructions would inevitably lead to undesired environmental and economical situations. Therefore, river engineers have always attempted to monitor the river/coast interactions and control the potential failures which might take place in rivers. Erosion and sedimentation are two key parameters which needs to be closely monitored in rivers in order to prevent unfavorable consequences. In this study, internal erosion as one of the main mechanisms for the river degradation and bank erosion has been experimentally investigated and the effect of the groundwater flow velocity and sediment discharge on the internal erosion was evaluated.

The results of extensive experimentations showed that the parameters such as the length of internal erosion in sandy layer, hydraulic gradient, sediment transport parameters, and Reynolds number are significantly influenced by river bank slope. Also, an empirical correlation was proposed to predict the length of internal erosion. Results of the present study were found to be in good agreement with the previous measured data and other empirical equations.

KEY WORDS

Internal Erosion, River Bank Slope, Alluvial Layer Slope, Sediment Discharge, Experimental model

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DESIGN OF DEEP SOIL MIXING WALLS AND THEIR ADVANTAGES OVER CONVENTIONAL SEALING FOR EMBANKMENT DAMS

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GERMANY

1. ABSTRACT

Sealing elements control the seepage in embankment dams and dikes/levees. In some cases, the sealing has to have also a static function. Common sealing elements such as sheet piles or bore piles that are able to take over static loads are expensive. Cut-off walls using earth concrete represent a cost-efficient alternative. Different methods for the realization of earth concrete walls are available such as the mixed-in-place (MIP) or the deep soil mixing (DSM) methods.

The paper discusses a case study project comparing earth concrete walls with sheet piles. Due to the favourable structural behaviour of earth concrete walls the deformation behaviour is considered to be favourable compared to sheet piles which enables to design the sealing with less embedment length. This also allows placing groundwater flow windows within the underground in order not to affect the groundwater conditions.

The case study project is located in the southwest of Germany at the Neckar River. The existing levees show woody vegetation that is nature protected. Furthermore, the levees show partly deficits considering the height so that the degree of flood protection cannot be guaranteed anymore. Hence, static sealing elements are designed for both, the heightening of the structure and the stabilization of the dam body.

For the case study, project DSM and MIP type cut off walls are compared with sheet piles in consideration of the deformation and static performance as designed for the levee rehabilitation and refurbishment.

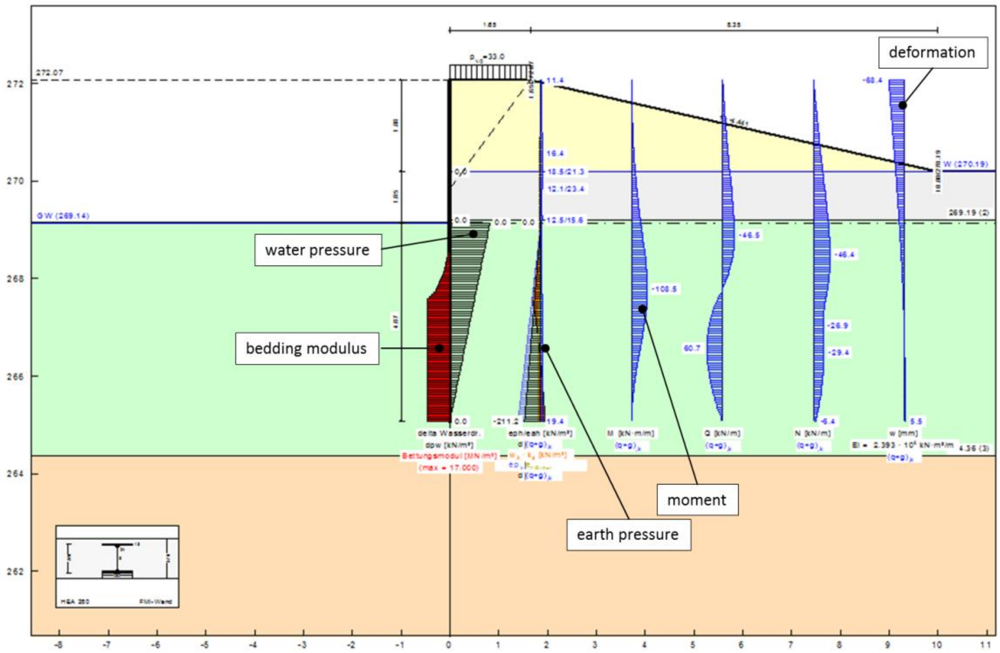

Fig. 1
Results of a MIP wall design

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FIGHTING CRITICAL UPLIFT AT ATATURK DAM *

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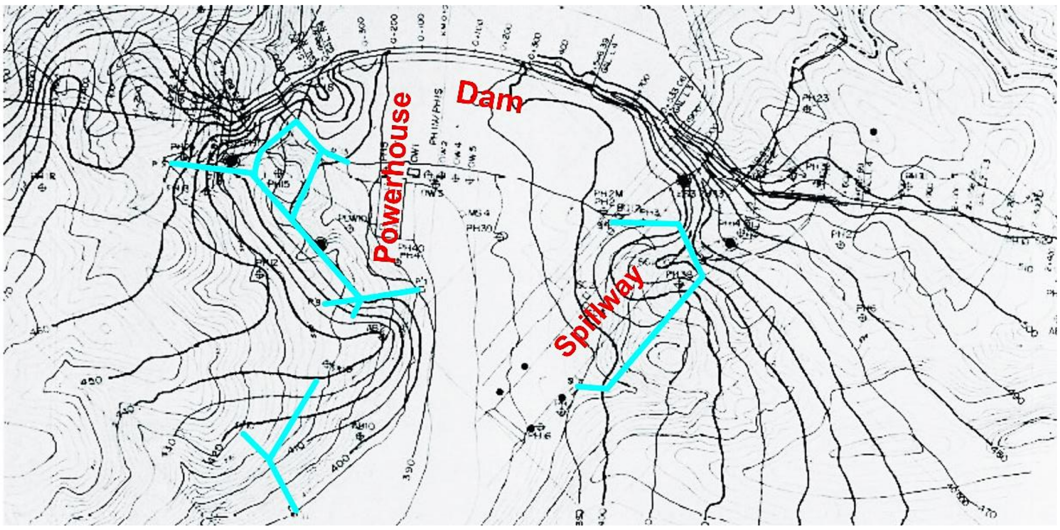
A sequence of carbonate sediments – limestone, marl, dolomite – forms the foundation of the Ataturk dam on the Euphrates River in Turkey. Exploratory drilling and especially galleries identified important karstification and, in consequence, the design included an extensive grout curtain (1.2 km² area) and provided drainage systems for the spillway and the powerhouse. Nevertheless, with the variation in hydrogeological properties and complexity of the hydrogeological regime in a folded and faulted rock mass, substantial uncertainty in the prediction of the development of seepage and uplift had to be admitted.



*Lutte contre sous-pressions critiques à Atatürk Barrage

Fig. 1

Dam site, contours for phreatic aquifer, location of drainage galleries in the valley flanks Site du barrage, contours de la nappe phréatique, emplacement des galeries de drainage dans les appuis

To contain the risks potentially associated with this uncertainty, a hydrogeological monitoring system was installed and, concurrent with the progress of construction of the grout curtain and with the reservoir filling, the collected data were evaluated for implications related to the performance of the curtain and the building of uplift pressures. Important seepage and particularly artesian pressures caused concern.

Options for remedial action were: further extension of the grout curtain and boosting of the drainage system. Significant extension of the grout curtain met with the limits of technical feasibility and, as a respective evaluation indicated, was economically not justified. Accordingly, action on the grout curtain focused on local strengthening, as implied by the efficiency assessed from piezometric monitoring, and chiefly on enhancing the drainage system driving additional drainage galleries in both valley flanks.

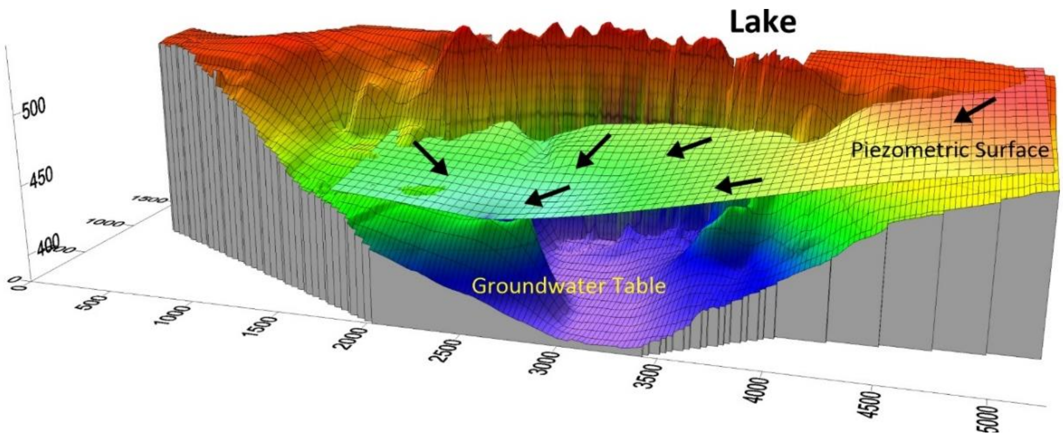


Fig. 2

3D models of groundwater table and piezometric surface downstream of Ataturk grout curtain Modèles 3D de la nappe phréatique et de la surface piézométrique en aval du voile d' injection

The optimized combination of the two actions achieved acceptable uplift conditions without excessively raising the seepage discharge. Whereas extrapolations and model simulations carried out in the initial stages of construction had predicted a seepage flow of about 20 m³/s, the measurements during reservoir filling stayed below 12 m³/s, owing to balanced work on improving the grout curtain and enhancing the drainage system.

A set of criteria was developed to be applied to the monitoring data for managing the risk of the complex foundations for this monumental project.

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WATER TIGHTENING OF RESERVOIR BED AND UPSTREAM FACE OF DAM IN PERSIAN GULF MARTYRS (CHITGAR) LAKE - A CASE STUDY

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IRAN

1. ABSTRACT

Chitgar (Persian Gulf Martyrs) Artificial Lake of Tehran was recently developed for recreational purposes and has significantly changed the landscape of the Iran's Capital. Design and Construction of the lake involved many technical challenges. Shortage of water supply from the nearby river, a four-month impounding constraint and significant surficial evaporation made water tightening at the reservoir bed and the surface of the upstream earth fill dam inevitable. Several solutions were initially considered for the purpose of water tightening among which use of clay blanket, concrete protection layer, injection in alluvium, protective hydraulic asphalt and finally Geomembrane were notable. After carrying out comprehensive technical and economic studies and also considering the time frame of construction, use of Geo-synthetic material was ultimately selected as the best option. In this paper, challenges and lessons learned during construction and installation of Geomembrane for the 130 hectare Chitgar Lake were discussed. In this paper is discussed about main below headlines:

1. Necessity of Water tightening for Chitgar Lake
2. Lake Water tightening Alternatives

3. Finding the Best Solution by Comparison between Water tightening Alternatives
4. Geomembrane Installation on Lake Bed and on Upstream Slope of Dam and Perimeter Dykes
5. Quality Control: Short-term Tests and Long-term Tests
6. Construction Difficulties

This project has set records in use and installation of Geo-synthetic materials for an artificial Lake in Iran and also the Middle East Region. Installation of nearly 133 hectares of Geomembrane and 265 hectares of Geotextile while fulfilling latest standards of practice requirements was a great achievement for the Engineering industry and the project has proven to successfully serve the nature, residents and tourists of the Iran’s Capital.

Authors hope that information provided herein can be used and applied to many similar projects and help toward improving technical knowledge and successful completion of large scale water tightening projects around the world.

Fig. 1:
Preparation and Installation Stages for Water tightening of the Chitgar Lake bed

2. ACKNOWLEDGMENT

It is highly appreciated to have constant guide and direction from Tehran Municipality and having their kind supervision as well as providing necessary information regarding this article. We are very grateful for their support in completing the article.

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EXPERIENCE ON GROUTING CURTAIN OF EMBANKMENT DAMS WITH MODERATE HEIGHT IN TURKEY

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TURKEY

1. INTRODUCTION

Dam designers believe the fact that grouting curtain is one of most effective techniques used to control seepage and leakage quantity under embankment dams. The efficiency of a grout curtain is directly related with its depth. The empirical equations have been developed to explain the relationships between dam height and curtain depth, and then adapted as design criteria in specifications. In this study a back analysis was performed on grout curtain activities of thirty-two embankment dams, which pose a height of 50 to 100 m in Turkey. The foundation units of these dams are completely igneous and metamorphic rocks and their sedimentary products. The dams having soluble rock units were also considered for this study. The depth of grout curtains ranges from 25 to 60 m for the moderate height dams. Dams considered for this study were selected from different regions of Turkey and their heights from river basin range from 44 to 87 m. Their construction was completed between 1984 and 2013.

2. EVALUATION

The depth of grout curtain is a critical issue for performance of dam structures. In USBR standard, it can extend to a depth below the surface of the rock equal to about 0.5 to 1.0 times the reservoir head, which lies above the surface of the rock. However, an empirical criterion is generally used as guideline which are based on practice (D= 0.3333xH + C). In this formula D is depth of grout curtain, H is the height of the dam (the final head of water) and C is a coefficient ranging from 7.5 to 22.5 in m. In Turkish design practice, it is a common way to design grout curtain by the simple USBR equation for the dams.

Figure 1 shows the relationship of curtain depth with water head in reservoir for three separate series. This figure indicates that the relationship between two parameters are very changeable for soluble sedimentary rocks (red color). There is a more acceptable relationship between curtain depth and water head in reservoir for the series including igneous and metamorphic rocks as based on the cases considered for this study (blue color). The series about non soluble sedimentary rocks conforms the relationship belonging to igneous and metamorphic rocks (green color).

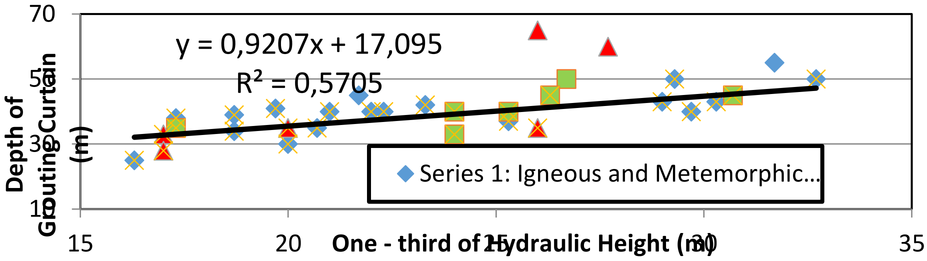

Figure 1. Direct relationship between gout curtain and hydraulic height for three different series

A simple equation is suggested to relate depth of grout curtain and hydraulic height for non-soluble sedimentary, igneous and metamorphic rocks for the dams having a structural height of 50 and 100 m (eq.1).

$$D = 0.307x\ H + C_c$$

In this equation D is depth of grout curtain, H is head in reservoir water and Cc is the corrected coefficient for grout curtain, which averages to 17.01.

3. CONCLUSIONS

The results of this study show that the Turkish design practice for grout curtains of embankment dams generally conform the USBR’s approximation for the dams having a height of 50 to 100 m from foundations. A new empirical equation relating depth of grout curtain with hydraulic height of dam and a guideline on depth of grout curtains as based on rock types are suggested for the dam having moderate height as based on the Turkish practice. However, use of this equation for soluble sedimentary rocks is questionable.

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STUDY ON THE LONG-TERM EFFECT OF INFILTRATION DEFORMATION ON THE DISTRIBUTION OF UPLIFT PRESSURE IN EARTH-ROCK JOINT AREA OF EARTH DAM

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CHINA

1. SUMMERY

The earth-rock joint area is generally existed in some earth dams, such as the combination area of dam body with concrete dam, Spillway, dam culvert and other structures. The soil in these areas is susceptible to infiltration failure due to seepage and soil properties, and this kind of damage phenomenon will further affect the distribution of uplift pressure in earth-rock contact surface. In order to study the transformation of the uplift pressure distribution, a contact scouring experiment which is based on the normal stress controlling by the pressure of contact surface is proposed in this paper. The experiment can simulate the seepage failure of soil-rock joint area and reveal the basic law of stress, seepage and soil loss. Based on the experimental results, a mathematical model of contact mechanical state of contact area is established, and the seepage failure in the contact area is simulated using finite element. In conclusions, the evolution

process of the uplift pressure/pore water pressure in the contact area of soil and stone is simulated while taking in to account the aging factors.

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ASSESSMENT OF WATER FLOW MEASUREMENT IN A ZONED DAM USING ARTIFICIAL NEURAL NETWORK MODELS

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PORTUGAL

This paper concerns about the assessment of the hydraulic behavior of a 50 m height zoned dam used for industry water supply, located in Alentejo region, in Portugal. The original draining system of the embankment is composed of a sub-vertical filter, located downstream of the central core, and by a drainage blanket placed over the foundation, in the deeper area of the valley, which, in turn, discharges to a downstream drainage toe. After first filling of the reservoir, resurgences and artesian pressures in the terrain at downstream of the dam body were identified in the left bank. Following that abnormal behavior, the reservoir water level was restricted, and an inverted filter was built over the affected area, to limit occurrence of internal erosion and heave. Additionally, to monitor the hydraulic behavior of the dam and of the inverted filter, several piezometers and a few flowmeters were installed. In this work, the usefulness of neural network models to predict the hydraulic behaviour of such complex dam site was evaluated. In particular, we correlate the monitoring data from one of the additional piezometers with the data from the closest flowmeter, and confirm that the prediction from the artificial neural network model is more accurate than that from a multiple linear regression model.

The data used corresponds to a period between March 2003 and August 2018, resulting in more than 120 observations per variable. The time evolution of the reservoir water level, the uplift pressure in the P30, P31 and P17 piezometers, and the seepage in the drain MC4, are presented in Fig. 1. The samples were collected every month.

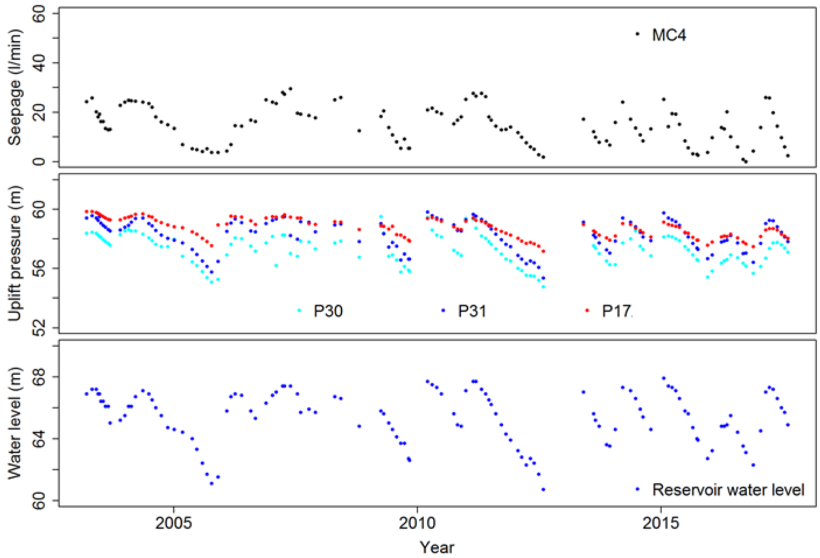

Fig. 1 - Seepage, uplift pressure and water level measured between 2003 and 2017

The artificial neural network (ANN) model (a multilayer perceptron feed forward neural networks trained by back-propagation) used in this case study consists of an input layer with 3 input parameters (the reservoir water level and the uplift pressures measures in the piezometer P31 and P17), an output layer (to represent the seepage measured in the MC4) and one hidden layer.

The used ANN architecture has shown the best results, considering all the tested networks, from 3 until 30 neurons, at the hidden layer. To find the optimum result, 5 initializations of random weights and a maximum of 5000 iterations were performed on each ANN architecture.

Figure 2 shows the evolution of the seepage at the drain MC4 (black colour), and the predicted values from the Multiple Linear Regression (MLR) model (green colour) and the ANN model (red colour).

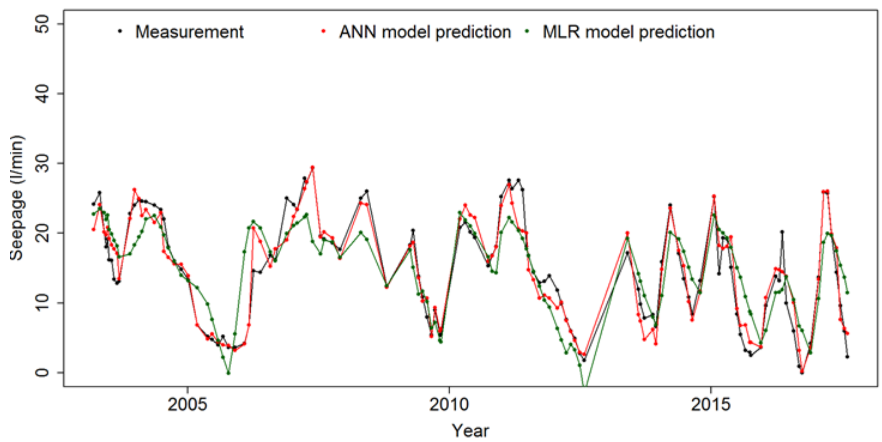

Fig. 2 - Measurements, ANN prediction and MLR prediction along time

The results of this study show that ANN models can be a useful tool for the prediction of the flow rate measured in the flowmeters.

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APPLICATION OF GEOMEMBRANE AS THE UPSTREAM IMPERVIOUS LAYER OF KAHIR RCC DAM

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IRAN

1. INTRODUCTION

Application of geomembrane as the upstream impervious layer of dams, especially of Roller Compacted Concrete Dams, has been increasing worldwide due to its better performance and easier process.

A reinforced concrete slab was in the design phase supposed to be used for waterproofing of Kahir dam but within construction phase, it was changed to geomembrane due to some technical and economic reasons.

According to special regional conditions and to prevent any construction stop caused by implementation of waterproofing system, combination of three methods used in upstream part of the dam including exposed geomembrane in lower levels, geomembrane covered with precast concrete panels in middle part and geomembrane attached to the precast concrete panels (known as Winchester method) in upper levels.

It is noteworthy that Kahir dam is the first concrete dam of Iran that uses geomembrane as the waterproofing element and now, the design and construction method have been finalized and the abovementioned system is under construction. The dam height is 54.5 m, crest length is 382 m, spillway length is 120 m, RCC volume is 485.000 m^3 and CVC volume is 179.000 m^3.

2. DAM WATERPROOFING SYSTEM

According to the contract drawings, a 60 cm-thick reinforced concrete layer was supposed to be used for waterproofing of Kahir dam that implemented after completion of dam body to lessen the tensions on concrete layer induced by settlement. On the other hand, geomembrane is technically more flexible than concrete and eliminates concerns about concrete cracking. Additionally, Using geomembrane shorten the duration of the project due to simultaneous construction of dam body and impermeable system. Therefore, geomembrane waterproofing system was designed as mentioned below:

- Expose part from elevation +16 to +42; which is always under water after first impounding.
- Covered part with precast concrete panels over geocomposite from elevation +45 to +50.
- Winchester part (geocomposite attached to precast concrete panels).

From cost aspect, both concrete slab and geomembrane system have almost had the same expenditure in this project but as mentioned before, the shorter the time of construction, the less the costs of project.

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Keywords: Dam, Impervious Material, Roller Compacted Concrete, Sealing Work, Kahir Fshd

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A STUDY ON CAUSE OF PERFORMANCE DEGRADATION OF SEEPAGE MEASURING FACILITY IN OLD DAM

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KOREA

1. INTRODUCTION

This study intends to find out the possibility of recovering the original function of the dam by analyzing the cause of functional degradation of the seepage measurement facility that may occur in old dams. The dam concerned is the upper dam of Cheongpyeong Pumped Storage Power Plant constructed in 1980 and it was not possible to measure the leakage except during the period of localized heavy rain as the water was not collected in the facility.

2. FIELD INVESTIGATION

Various field investigations were conducted to find the cause of functional degradation of the seepage measuring facility. According to the result of naked eye investigation, the facility did not have significant probems. Two points on both banks of the collecting wall were excavated to confirm the groundwater leakage. it confirmed the leakage of groundwater in the foundation of the collecting wall in the right bank area of the dam. The result of strength measurement to confirm the soundness of the concrete of the collecting wall indicated that the condition of the wall is acceptable. In addition, a boring investigation was carried out to determine the geology of the foundation ground, and the Lugeon test, which was conducted to determine the permeability through the collecting wall and foundation soil, showed the sections with high lugeon values.

3. CONCLUSION

The comprehensive analysis of the investigation results showed various paths through which the leaking water flowed instead of being collected in the collecting wall and came to the following conclusions. First, the foundation of the wall is located above the soft rock layer. The quality of this soft rock layer is poor with the developments of cracks and joints and this layer displays 3Lu or greater permeabilty in all sections, which identifies the soft rock layer as the major seepage pathway. Second, the investigation found the leakage of groundwater noticeable by the naked eye in the contact area between the foundation of the water-collecting wall and the bedrock and identified the leakage in the contact area as another major cause. Third, the condition of the concrete of the collecting wall was relatively acceptable. However, the Lugeon test showed that the lugeon value exceeded 3Lu in some sections and it is deemed that the leakage occurs through the wall as well.

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LONG TERM BEHAVIOR AND PERFORMANCE OF CORE ZONE AGAINST UPLIFT DISTRIBUTION OF MAE NGAD SOMBOON CHON DAM, CHIANG MAI, THAILAND

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THAILAND

ABSTRACT

Mae Ngad Somboon Chon Dam is a zone embankment with impervious clay core located in Chiang Mai province, northern part of Thailand, completed construction in 1985. The dam body is 69 m height; 9 m crest width and 1,950 m length. Dam instrumentations such as electrical piezometers, surface settlements, inclinometers, and observation wells have been installed to monitor the dam. Seepage behavior during the period of 1985-1987 (66% degree of consolidation) are used to assess with data from 2014 to 2017 (approach 100% degree of consolidation) at station 0+180 depth section. After reservoir operation

following rule curve from 1985 to 2017, average pore pressure on bottom of cutoff trench of upstream side reduces to 77.72%, average pore pressure of downstream bottom of cutoff trench falls to 83.42%, hydraulic gradient decreases to 61.40%. The ratio of critical velocity to seepage velocity increases to 161.56%. Factor of safety against uplift at contact clay core of bottom of cutoff trench rises from 6.01 to 25.22 or 319.63%, since increment of consolidation from two thirds to approximately full degree of consolidation. Thus, stability against particle migration of contact clay core is increased with degree of consolidation. Long term seepage performance index of core layer at two thirds of consolidation compared with approached full degree consolidation is (L_{hi}) as shown Equation 1.

$$L_{h_i} = a_{h_i}.b_{h_i}.c_{h_i}.d_{h_i}.e_{h_i}$$

Where,

a_{h_i}= ratio of average pore pressure at upstream core layer h_i

b_{h_i}= ratio of average pore pressure of downstream core layer h_i

c_{h_i}= ratio of average seepage gradient of core layer h_i

d_{h_i} = ratio of average seepage velocity of core layer h_i

e_{h_i} = ratio of factor of safety against buoyance of core layer h_i

a_{h_i}, b_{h_i}, c_{h_i}, d_{h_i}, and e_{h_i} are dimensionless ratio between two thirds and full degree of consolidation. Subsequently, Mae Ngad Somboon Chon Dam, at bottom of cutoff trench clay contact, $L_{h_{i=0}}$= 0.790. For the core zone is characterized by Equation 2.

$$L_{avg_{h_i}} = -22273.739h_i^6 + 49838.747h_i^5 - 40452.909h_i^4 + 15444.748h_i^3 - 2925.149h_i^2 + 265.718h_i + 0.790$$

$$R^2 = 0.9967$$

Where,

H = core zone height

h = height of considered core zone layer from bottom of cutoff trench (m)

$$h_i = \frac{h}{H}$$

This index can be used to assess performance of core layers advantage to long term dam safety management

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DAM AND FOUNDATION SEEPAGE CONTROL IMPROVEMENT BY CEMENT-CHEMICAL GROUTING UNDER STORAGE CONDITION OF MAE THI DAM, LAMPHUN, THAILAND

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THAILAND

ABSTRACT

Mae Thi Dam is an earth dam with impervious clay as a core material located in Lamphun province in the northern part of Thailand. The reservoir storage is at 4.5 million-cubic meter have the construction completed in 1987 and improved to 6.0 million-cubic meter by increasing normal pool elevation by 1.00 m. in 2009. Excessive seepage problem appear at the right abutment of the dam more than 28 liter per second. The dam body is 25.60 m in height; have an 8 m crest width, and 437 m length. Chemical grouting using sodium silicate and sodium bicarbonate was carried out at a changing of Km.0+020 to 0+060 m. while cement grouting was carried out between reach of Km.0+00 to 0+090 m on crests, toe and right abutment of the dam. As the dam-reservoir stays under storage condition, grouting has to take into account of uplift and pressure distribution during the sealing work. For rock foundation, high pressures cement grouting processes with quick setting condition. Areas with high uplift pressure, cement grouting carried out in discrete steps allowing setting time for grout. For chemical grouting in clay portion, high pressure could not be applied during grouting thus, laboratory experiment was carried out with mixture of water (ml), Silicate (ml) and Bicarbonate (g) in the ratio of 1150:400:40 with the gel-setting time between 1-2 hour and 1000: 400:40 mix with gel setting-time of maximum 1.5 hour. Thus, lower the water ratio decreased the gel-time of the solution and depending upon the uplift pressure, areas with high-pressure second mixture was selected while for normal conditions first mixture was selected. For areas with high uplift pressure, chemical grouting was accomplished in time interval to allow the set time for the gel. The effectiveness of grouting conducted, water pressure test namely lugeon test was carried out which gave result of less than 5 lugeon which proved its efficacy. The apply pressure of chemical grouting varied from 1.50-8.00 kg/cm^2 in this project. Ground Improvement of Mae Thi Dam without excavation and emptying reservoir by using chemical grouting showed the F.S. against uplift greater than the limiting value as per USBR standard. Apparently, foundation sealing by using cement and chemical grouting without excavation and emptying reservoir saved time, cost and utilization excessive man power or material mobilization without hampering the reservoir operation.

Keywords: cement-chemical grouting under storage condition

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FOUNDATION TREATMENT CHALLENGES FOR EARTH AND ROCK FILL DAMS – CASE STUDY OF THE LEFT EMBANKMENT DAM ON ISIMBA

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UNGANDA

ABSTRACT

Uganda will require 8,601MW by 2020, 14,670MW by 2025 and 41,738MW by 2040 as it works toward middle income status. One of the strategies in the National Development Plans is to construct large hydropower plants and thermal power plants through public and private investments, and Isimba Hydro Power Project is being developed with debt financing to a tune of USD 500m. For Isimba Hydro Power Project, the reservoir is retained by concrete structures and two earth-rock fill embankment dams on both sides of the concrete structures.

The design and construction supervision of embankment dams, including considerations for slope stability, seepage control and foundation treatment is indeed of great engineering and construction concern to the employer/ client and the design team of the project. The Left Embankment Dam at Isimba HPP stretches a distance of 375 meters along its longitudinal axis and is designed and constructed on different foundation conditions including highly weathered rock and engineering rock/ sound rock.

Seepage through a permeable foundation, similar to the completely or highly weathered rock foundation for some sections of the Left Embankment Dam at Isimba HPP, can be reduced by constructing a low permeability cut off through the permeable material. There are various seepage cut-off approaches namely; cut-off trench filled with earth fill, slurry trench, and concrete diaphragm wall, contiguous or intersecting bored piles, sheet pile wall, curtain grouting etc. The Left Embankment Dam at Isimba HPP adopted two main ground improvement methodologies as part of foundation treatment, i.e. grouting and construction of concrete cut-off wall, along the longitudinal axis of the dam.

Various challenges have been encountered on the project regarding foundation treatment of the earth rock fill dams namely; the foundation treatment specifications; the client specified 1 Lugeon as the acceptance criteria for grouting works, but some of the supervision team/ experts noted that this was too conservative. The ambiguity around the specification and grouting method cause construction control challenges.

Penetration/ punching of the concrete cut off wall into the clay core were another challenge. The cut-off wall was adopted a part of foundation treatment for sections where the dam was founded on highly-weathered or completely weathered rock. In these sections, according to the EPC Contractor's design, the wall would penetrate at least 2m into the clay core. This created risk for cracking of clay core due to skin friction again the all due to settlement. EPC Contractor was forced to break sections of the wall to reduce penetration. Orientation of the grout holes for curtain grouting works was another challenge. The EPC Contractor adopted vertical grout holes that were not inclined to intercept joints and rock discontinuities as specified in employer requirements. This posed risk of having a grout curtain that is not effective in seepage control. Other challenges include poor quality control of grout materials. The grout mixes adopted by EPC Contractor were considered unstable and thus unsuitable for proper grouting works.

Documentation was also a big challenge. The EPC Contractor could not avail in a timely manner, the as-built drawings for the cut-off wall and grouting works. Furthermore, grouting test procedures, protocols, records and manuals were not well documented and or availed for ease of review and assessment of the grouting works. This posed challenges in approval processes and Quality Control of the foundation treatment works.

These challenges were however overcome with various measures including stoppage of works, doing remedial foundation treatment in some sections of the dam and also conducting comprehensive grouting tests.

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THIRD REMEDIAL GROUTING CAMPAIGN FOR REINFORCEMENT OF IMPERVIOUS CURTAIN TYPE BATHTUB ON THE CAJON DAM *

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HONDURAS, C.A.

1. INTRODUCTION

El Cajón hydroelectric Project is located in limestone geology. The structure is a double curvature concrete arch dam, of 226 m high.

During the life of the project (around 33 years), the monitoring system has detected periodically changes in the followings parameters: infiltration flow and uplift. These variations have been attributed to process of dissolution and deposit erosion of such Karst.

Over the past, few years one of the greatest anomalies was the flow increase in the left abutment of the dam. One of the tasks of the current reinforcement campaign was to seal this infiltration.

* *Traduction en Français (en attente).*

2. SOLUTION

For the final solution, selected size aggregates were pushed without using a concrete pump and intermittent traditional grout mix was used.

At the beginning, of the process one part of the aggregate was pushed out to the exterior, but eventually the repetition of this procedure and the variation of the sizes in each grouting allowed to seal the karstic zone and eliminate the infiltration in the zone.

3. CONCLUSIONS

The project experience taught the project participants the dangers of the piston effect" in the deposits of caverns and joints. The effect was manifested in the short term with the opening of new infiltration sites and in the long term with the erosion process (deposits in caverns and joints) and finally in the increase of in the infiltration flow.

Currently, the infiltration site originally sealed are inactive, even with the high reservoir level reached this year (2017) (maximum operation level of the powerhouse). Which are above the levels registered during the time of the repairs (270 vs. 285 m a.s.l.).

4. KEYWORDS

Abutment, Aggregate, Arch Dam, Erosion, Flow, Foundation Treatment, Grout Curtain, Karst, Seepage, Cajón Dam.

5. MOTS-CLES

Appui, Granulat, Barrage-Voute, Erosion, Debit, Traitement Des Fondations, Ecran D´Injection, Karst, Infiltration, Cajón Barrage.

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NECHRANICE DAM – LONG-TERM MONITORING OF SEALING PERFORMANCE AT THE LONGEST EARTH-FILL DAM IN CENTRAL EUROPE

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1. INTRODUCTION

Nechranice Dam is located on the Ohře River in the North-West of the Czech Republic. It is situated in the geologically unfavorable environment of the brown coal mining area at the base of the Ore Mountains. Nechranice Dam is 47,5 m high and 3280 m long which makes it the longest earth-fill dam in the Czech Republic and Central Europe.

The Nechranice Dam monitoring system comprises of geodetic surveying points, wells and piezometers that monitor vertical and horizontal movements at the foundations level as well as on the face of the dam, piezometric pressures, water table elevation and amount of water drained.

2. METHODS

The paper presents the piezometric pressures in the dam sealing at the foundation level over the 50-year long period of dam operation. Attention is also focused on the one-year long period of significant reservoir water level decrease that occurred in 1969 - 1970.

Process of settlement of the dam crest over the time is presented as well as the vertical movement along the communication tunnel.

3. RESULTS

The water table level is stable with no negative trends. Short-term movements are result of the specific meteorological conditions.

Data of the settlement of the dam crest show continuous progress since the dam construction without any anomalies. The highest settlement of the dam crest is located near the communication tunnel and has steadily grown to the value of 550 mm in 2016.

Vertical movement data along the communication tunnel shows that there has been no significant vertical movement of this structure since 1982.

Despite complicated geological conditions, the Nechranice Dam monitoring has not registered any unexpected behavior.

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SEALING OF AND FOUNDATION ON A 70 M ALLUVIUM LAYER OF ARKUN DAM

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1. INTRODUCTION

The Arkun Dam and HEPP project is located in the North-east of Turkey on the Coruh River. The installed capacity comprises a main powerhouse with 225 MW and an environmental powerhouse with 12 MW. The main dam shows a height of 140 m and is of CFSGD type. The gated spillway is designed for a discharge of 4.701 m³/s. The energy tunnel which is connecting the reservoir with the main powerhouse is 14 km long with a diameter of 6.4 m. The project was commissioned in 2014.

The dam is founded on a deep alluvium layer within the V-shaped valley. The seepage of the concrete face sand-gravel fill dam (CFSGD) is controlled by the concrete face and the articulated plinth which is linked to the maximum 70 m deep two phase cut-off wall. During the construction a seepage analysis, a LEA slope stability analysis and a stress-strain analysis were performed in order to predict the dam's behaviour during construction, first impoundment and for the long-term perspective.

2. RESULTS

A seepage model (Fig. 1), a stress-strain model (Fig. 2), and a LEA slope stability model were prepared in order to investigate the main dam's behaviour in consideration of some issues regarding leakages through the upstream sealing barrier and deformations during the first impoundment.

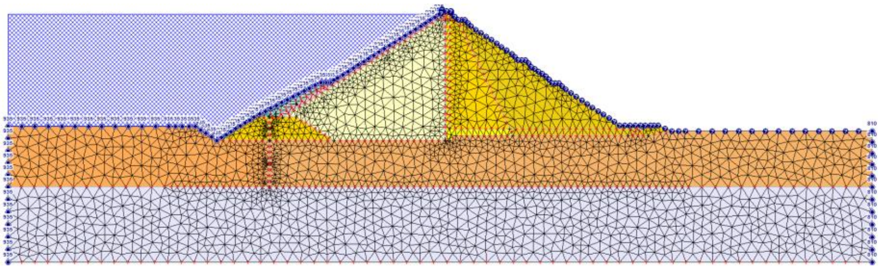

Fig. 1 FE mesh and model for the seepage analysis

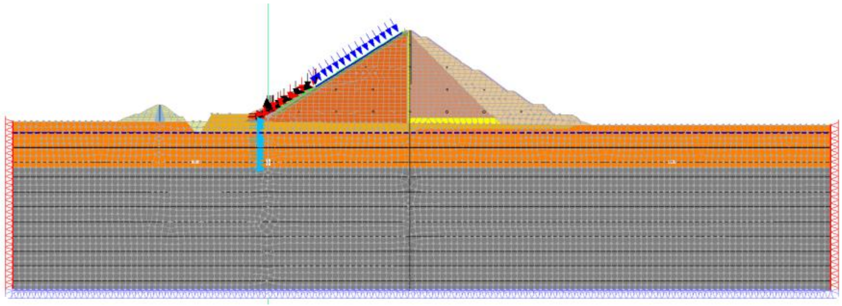

Fig. 2 FE mesh and model for the stress-strain analysis

The seepage analysis showed that the zoning of the dam is able to control the pore water pressures within the dam in spite of a complete malfunction of the complete upstream sealing barrier. Also for these extreme load cases the stability of the slopes showed comfortable factors of safety which was derived from the slope stability LEA.

The stress-strain model resulted in 75 cm total deformation at EoC. During the first impoundment the crest is deforming approximately 30 cm to downstream and the maximum slab deformation shows a value to 45 cm total displacement close to the plinth. Stresses at the cut-off wall are determined being too strong so that cracking is likely to occur during the first impoundment, which is not critical for the overall dam stability as proofed by the seepage analysis.

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FOUNDATION TREATMENT WITH CUT OFF WALL IN TUGU DAM

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1. ABSTRACT

Tugu Dam is an earth fill dam located in Trenggalek district who has a problem with its foundation which is consists of a relatively thick deposit of pervious alluvium. When the dam foundation consists of a relatively thick deposit of pervious alluvium, the designer must decide whether to make a complete cut off wall (diaphragm wall) or allow a certain amount of under seepage to occur under controlled conditions.

To improve the earth fill dam with pervious foundation by cut off wall can be divided into three types: conventional concrete, slurry trench, and plastic concrete wall. Based on the many reasons, Tugu Dam could be proposed using Plastic Concrete Wall as a cut off wall.

Screen grouting under the cut off wall is considered to make sure the water seepage could be protected.

KEY WORDS

Earth Fill Dam, alluvium deposit, plastic concrete wall, screen grouting.

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STRENGTHENING AND SEALING OF GOMAL ZAM RCC ARCH-GRAVITY DAM FOUNDATION IN PAKISTAN

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1. ABSTRACT

Gomal Zam Dam (Multipurpose Project) is situated at Khajuri Kach on Gomal River in South Waziristan Agency. The dam's planned provision is to store water of rivers Gomal, Zhob and Wana Toi ensuring continuous water supply both for irrigation and drinking purposes, flood control, and power generation (17.4 MW) in the second phase.

The maim dam is an RCC arch-gravity structure of 133 m height, 231 m length, and 10 m top width, located in a narrow valley with very steep abutments. Top elevation of dam is 763 masl. The dam foundation consists exclusively of Jurassic limestone with minor intercalation of thinly bedded calcareous marls, marls and fine-sandy claystone/shale. The strata form a wide spanned anticline generally striking perpendicular to the valley dipping with 30° to 70° gently to steeply towards upstream. Obviously, repeated internal folding has caused distinct to heavy tectonization of the thinly to medium bedded limestone.

The presence of karst is disputed since direct signs of karstification such as open channels or cavities are rare and basically limited to particular faults. However several indirect signs such as increased permeabilities (8 Lu to 90 Lu) or perched groundwater at the riverbed exist. At the dam site the main groundwater table was found 28 m to 30 m below the river level.

Various geological investigations have been performed since the beginning to clarify the phenomena, and to apply appropriate treatment measures.

Main geological problems include major faults in the right abutment striking sub-parallel to the river and thus jeopardizing the dam stability, the high permeability of rock mass causing considerable seepage through the foundation, as well as the loosing of the highly tectonized limestone. The geological conditions and their impact on the stability of the arch-gravity dam are discussed. Treatment of the faults in the right abutment comprise the implementation of concrete shear keys with concrete filled shafts and tunnels at several levels. In order to improve and strengthen the jointed rock foundation, deep-extended consolidation grouting with high pressure was carried out over the entire footprint area. To seal the foundation and to prevent considerable seepage beneath the dam, a clay blanket was placed between the upstream face of the main dam towards the clay core of the upstream rock fill cofferdam. Last but not least a deep grout curtain starting from grouting galleries and adits was implemented. The Gomal Zam RCC arch-gravity dam was completed in 2012. Initial reservoir impounding started in March 2011. The actual seepage conditions, as well as proposals for further treatments of the foundation are highlighted.

Keywords: geological investigation, foundation treatment, reservoir watertightness, seepage, sealing work, grouting, upstream blanket

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CASE HISTORIES OF TAILINGS DAM WATERPROOFED WITH A BITUMINOUS GEOMEMBRANE (BGM)

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FRANCE

1. INTRODUCTION

For obtaining permission of opening a mine, a very stringent plan is asked by the authorities to be sure that no pollution could impact quality of soils and aquifer.

2. PRESENTATION OF BGM

The structure of BGM is multi-layered including mainly: a polyester geotextile providing the mechanical resistance and especially the high puncture resistance and a compound with an elastomeric bitumen providing the waterproofing properties and ensuring the proven longevity of the geomembrane. See Fig. 1. The factory located in the North of France.

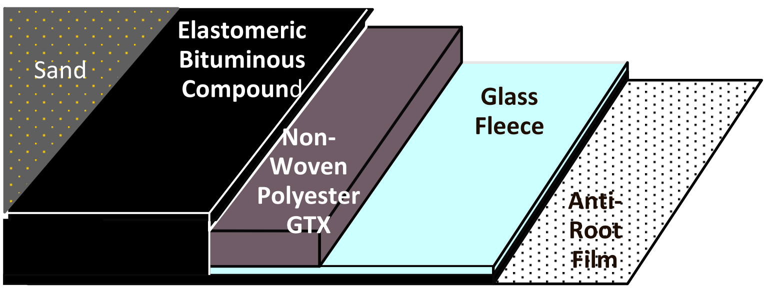

Fig. 1. Typical structure of a bituminous geomembrane

Technical characteristics of BGM are:
Permanent permeability around 10^{-14} m/sec, Darcy law; Does not form wrinkles under sun and temperature variations ; A friction angle from 34° and more following soil in contact ; Can store potable water ; High resistance to earthquake ; Density is larger than 1 ; Manufacturer supplies monitors on site for training local installers: low cost and easy maintenance.

3. SOME CASE STUDY OF BGM IN DAMS AND TAILINGS DAMS CONSTRUCTION

Peru, Cerro Lindo, tailings dam: a 30-m high earth and rock fill dam for the Peruvian mine company Milpo – Toromocho Copper Mine, lies at an altitude of around 4.600 m above sea level – In the copper mine Las Bambas, Chuspiri Dam, was built for the supply of water for the mine.

In North America:
Diavik Diamond Mine (northeast of Yellowknife, Northwest Territories of Canada) – Bloom Lake, Iron Mine: is situated in Labrador extreme North of Quebec.

In Europe, in Finland and in Russia:
Kiitilä Gold Mine: is in northern Finland, lies within the Arctic Region – Kupol Gold Mine (Siberia, Russia) – The Kupol deposit is in the Chukotka Autonomous Okrug. The climate of the region around the site is extremely severe, consisting of long and cold winters (8 months with temperature of -45°C during BGM installation).

4. CONCLUSION

BGM possesses high physical and mechanical properties allowing it to remain exposed, to be installed by very low temperature and able to accept a rough support. This last advantage leads to wide savings of transport of materials and therefore to a huge amount of CO2 savings.

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SEALING PERFORMANCE OF SILVEH EMBANKMENT DAM CUTOFF WALL BASED ON INSTRUMENTATION MEASUREMENTS

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IRAN

1. EXTENDED ABSTRACT

Controlling, measurement and estimation of the amount of water seepage through the body, foundation and abutments of embankment dams are of great importance [1, 2]. In this paper, function of the plastic concrete cutoff wall in one of the zoned embankment dams in Iran, namely Silveh Dam, is evaluated by considering instrumentation measurements. The dam foundation comprises coarse-grained alluvial deposits with maximum of 65 m depth in right bank and limestone or schist rock in left bank. To monitor the short and long terms behavior of the dam body and its foundation, different types of instruments have been installed within the body and foundation of the Silveh dam (e.g., pore pressure gauges in dam body and foundations). To assess the workability of the cutoff wall, recorded pore water pressures at upstream and downstream sides in dam foundation are considered. In this regard, a performance index, *k*, has been defined as presented in Eq.[1]:

$$k = (U_{up} - U_{down}) / (W_r - Z_i) \qquad [1]$$

where U_{up} and U_{down} are the recorded pore water pressures by two semi-elevated pore pressure gauges placed at the upstream and downstream sides of the cutoff wall, respectively, and W_r and Z_i are the reservoir water and pore pressure gauges elevations, respectively [3]. The more value the *k* gained, the more water head lost occurred due to the better performance of the cutoff wall to elongate the seeping streamlines. A sample diagram of changes in *k* v.s time in Sec5-5 of the Silveh dam for two pairs of pore pressure gauges (namely PPF5-1&5-2 and PPF5-3&5-4) is shown in Fig.1 along with the changes in reservoir water and dam body filling elevations. Regarding Fig.1, during construction of the dam body and first impounding, the *k* values have been progressively increased which shows the appropriate function of the constructed cutoff wall to seal the dam foundation and control the water seepage.

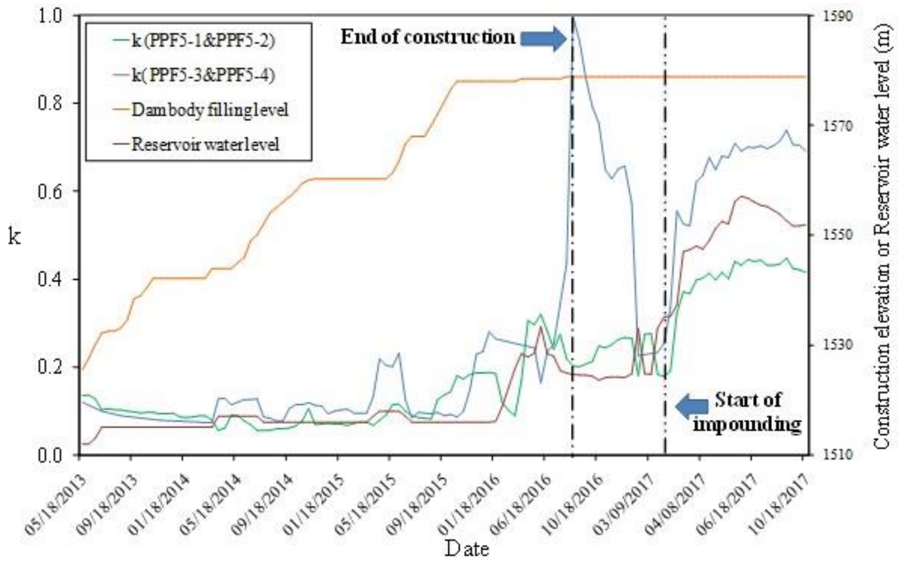

Fig. 1

Changes in *k* values, reservior and body elevations versus time in Sec5-5

Variations des valeurs de k, du réservoir et des élévations du corps en fonction du temps en Sec 5-5

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FOUNDING AND SEALING LARGE DAMS ON VERY WEAK FOUNDATIONS

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1. ABSTRACT

ICOLD guidelines developed over the past several decades form the basis for current design of large dams of all types. Routinely, such dams have been designed and built on foundations deemed sufficiently competent for the selected dam type, be it concrete, RCC, CFRD, AFRD, Geomembrane faced Rockfill, clay core rockfill, earth embankment, etc., However, over the past few decades dams are being designed and built on foundations that are marginal to poor at best as well as over faults and fault zones due to the increasing need to store water for various needs. Since dams need flood evacuation capacity, spillway structures and headworks are normally placed on the more competent foundation part of the dam axis, which has given rise to composite dam design and construction. The flexible part of the dam usually comprises of central core rockfill construction. When such composite dams need to span over fault zones, particularly over extensional fault zones, structures such as grouting galleries need to be provided with sufficient flexibility for future likelihood of extension that may occur during an earthquake. However, assessing the allowance for such extensions remain to be more of guesswork. When composite dams are built in developing countries some additional allowance must also be provided as such countries cannot afford the loss of the dam even in the short term. This paper presents how this uncertainty can be adequately addressed. Further, observations on the design and construction of composite dams including interfacing of the flexible segment with the rigid segment are also presented. In addition, a case is presented for this issue

to be addressed in greater detail to develop basic guidelines for use by Engineers in the future.

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KEYWORDS

Composite Dam, Foundation Treatment, Fault, Grouting Gallery

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RELIEF DRAINAGE SYSTEMS AGAINST HYDRAULIC FAILURE DUE TO UNDERSEEPAGE OF DYKES AND DAMS

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AUSTRIA

1. GENERAL

Many dykes and dams rest on alluvial deposits, which usually grade from fine-grained materials near the ground surface to coarse sediments with high permeability in the lower part of the strata. If dykes or levees do not have a cut-off wall fully penetrating the aquifer, underseepage occurs beneath the earth structure during high river levels. Such seepage may cause an excessive water pressure in the aquifer landside of the embankment dam. Most dangerous situations occur when high hydrostatic pressure acts on the upper soil layers and ground failure develops in the form of uncontrolled boils or uplift of the blanket.

Therefore, design and construction of appropriate measures against uncontrolled hydraulic fracture due to underseepage of dykes or levees require comprehensive knowledge of these failure modes.

Levee underseepage analyses are commonly performed to assess the risk of excessively high pore pressure in the aquifer. These results are used for the assessment of possible failure mechanisms. After today´s practice the hydraulic failure due to underseepage may be prevented mainly by two permanent measures at landside dyke or dam toe by installing pressure relief elements or by placing berms. Especially, relief drainages have proved very successful in Austria during the last excessive floods along the rivers Danube and Morava.

2. RELIEF DRAINAGES

Relief drainages in the form of geotextile wrapped stone columns ("gravel piles") or trenches are highly permeable drainage elements that ensure a defined hydraulic connection with the aquifer. They relieve the hydrostatic pressure beneath the blanket while water discharges freely to the surface. Therefore, the safety factor against hydraulic failure increases significantly. However, until now the existing design criteria for relief drainages were insufficient. Most approaches determine the pressure relief behavior and the discharges only based on assumptions and experience from former projects.

Filter protection of relief drainages is essential and must be provided by using of filter geotextiles. Common filter criteria are from Holtz et al. (1997), Giroud (2003, 2010) and Heibaum et al. (2006). For geotextile filters, four criteria are required: The retention and the permeability criterion as well as the clogging and the roughness criterion have to be considered.

3. EXPERIMENTAL AND NUMERICAL MODELLING OF RELIEF DRAINAGE BEHAVIOUR

Until now, the design of relief measures (drainage columns or trenches) was based on rather insufficient basic principles, strong simplifications and idealizations. For the quantification of the discharge from relief columns as well as for a pressure assessment beneath the blanket only assumptions based on numerical models are in use. These approaches allow indeed comparative calculations of the quantity of seepage through and under the dyke.

Consequently, model tests on dykes including the subgrade (blanket and aquifer) are the best solution to assess the relief behaviour and to quantify the water outflow from relief elements during hydraulic loading. Experimental tests performed under laboratory conditions allow a higher degree of reliability than mere numerical simulations. Based on the results from physical modelling a precise calibration of numerical models can be achieved.

The study of pressure relief behaviour and the estimation of discharge from relief drainages were based on a combined modelling method by using experimental and numerical techniques. First, a small-scale (1:10) dam model on a two-layer strata was used to analyse the influence of main parameters (diameter, embedment length, permeability and number of drainage relief columns) on the relief behaviour of stone columns and trenches. The results of these tests were the basis for calibrating the numerical model and for the large-scale modelling (1:1 scale) as well. Furthermore, this gradual approach allowed parametric studies exceeding the geometric and hydraulic limits of the small-scale model.

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SELECTION OF GROUT CURTAIN IN SPATIAL PLANE BASED ON SET JOINTS AND DIRECTION OF GROUTING GALLERY (GLEVARD DAM, IRAN)

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IRAN

1. INTRODUCTION

Glevard Dam project is located in Mazandaran Province and constructed on Neka River, and its middle point situated on the coordination of 36.59 N and 53.61 E. The type of dam is CFRD and maximum height of the dam from riverbed is 103 m and from bedrock is 113 m. Dam crest elevation is 739 m.a.s.l. with the dam crest length of 250 m and width of 10 m.

The main criteria for selecting optimum status of the dip and dip direction of grouting boreholes at Gleavard dam site to cover predicted curtain plane appropriately is that pay attention to direction of grouting galleries specially in bending parts in the left bank. The direction of the galley in the first 130 m is 7°. Afterwards, two bend; one is located in 24° direction for 40 m, following 40° for the last bend with 52 m length, towards to the dam axis.

2. SPATIAL LAYOUT OF THE GROUT CURTAIN AND TESTING EXPLORATORY GROUT HOLES

Base on the primary site visit of the outcrop of the limestone (LW) in the trench of the access way to the grouting gallery outlet portal, engineering judgment and work experiences, dip and dip direction of discontinuities are such as, 210/74, 104/80, 050/83 and 180/80. This limestone has outcrops in both slopes of the gorge and in the Glevard dam axis; and LW (White Limestone) limestone include milky white, fine-grained, crystallized and dense limestone with average to high compressive strength and high weathered.

Using the approximate method of bisectors, first the appropriate dip of grouting estimated. Bisector of the dip of two joints sets 104 and 50 degree will be in 77-degree direction. Bisector of the dip of two joint sets 180 and 210 degrees is in 195 degrees direction and bisector of 77 and 195 degrees delineated, it will be in 136 degrees direction.

3. CONCLUSION

1. With regard to the results obtained in the surface and underground investigations in the boreholes, the large number of vertical joints and fissures found with two dominant directions. Indeed, it is necessary to drill cross boreholes to have more appropriate and more numerous contacts with discontinuities and more appropriate grout to attain more success in water tightening.

2. For a better understanding, the conditions of boreholes presented in geometrical view, in both vertical curtains with vertical- inclined and inclined - inclined cross borehole systems, as shown in Fig. 1. In the inclined cross borehole system, there are more number of crosses and smaller areas found among the boreholes, which is itself a reason for necessity of carrying out inclined cross boreholes to obtain more success compared to the vertical — inclined cross boreholes.

3. Regarding the effectiveness of the grouting radius, it again pointed out that the rhombic forms among the inclined cross boreholes have areas equal to one-half of the rhombus forms obtained in vertical-inclined boreholes. Penetration of the vertical-inclined grout obtained with smaller penetration radius but in the inclined-inclined cross borehole system, resulting a better overview of the grouting layout and attain more success. In addition, the construction has no additional cost for the inclined-inclined cross boreholes as well as increasing the grout radius and thickness of the curtain. Based on the results, drilling the inclined curtain plane, which will provide the best result in order to cover more joints.

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CASE STUDY: ITUANGO HYDROELECTRIC PROJECT-ADDRESSING GEOLOGICAL AND GEOTECNICAL ISSUES ON THE ROCKFILL-CLAY CORE DAM'S FOUNDATION DESIGN [*]

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COLOMBIA

1. ABSTRACT

The most important hydroelectric project in Colombia's history, located 171 km north of the city of Medellin (Fig. 1), HydroItuango will begin to operate partially in 2018 and with its full capacity in 2026. With 2400 MW of installed capacity distributed in eight Francis turbines, this megaproject icon of the Colombian engineering has presented many challenges before giving its light.

[*] *Étude de cas: Projet hydroélectrique d'Ituango – Relatif aux affaires géologiques et géotechniques dans la conception de la fondation du barrage en enrochement avec cœur d'argile.*

Fig. 1 Hydro-Ituango dam construction process november 2016 photographic taken downstream

HydroItuango features a rockfill-clay core dam of 235 meters high and 965 meters wide, located in the denominated canyon of the Cauca river. This dam has presented multiple difficulties during its construction process, mainly due to the geological condition of the area, which shows the confluence of two fault systems called Mellizo and Tocayo, along the two sides of the river and that have conditioned sensibly the design of the dam, particularly the left abutment, where, in addition to the faults, has a series of discontinuities with high presence of clay material and fractured rock.

In this paper, a solution to prevent that the clay core of the dam suffers from non-permissible differential settlement is presented, integrating the geology features by means of a 3D numerical model (Fig. 2), to evaluate the shear strains in the core, comparing them with the available results of the big scale triaxial tests, verifying the stability of the dam against construction process, full reservoir and seismic conditions.

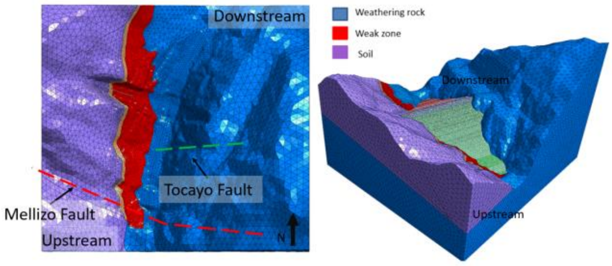

Fig. 2 Finite element numerical model-representation of the dam foundation and rockfill dam.

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COMPARATIVE STUDY ON FOUNDATION TREATMENT TECHNICAL STANDARDS OF HYDROPOWER ENGINEERING BETWEEN CHINA AND AMERICAN*

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CHINA

ABSTRACT

With the implementation of “the Belt and Road” strategy, China’s international hydroelectric engineering business is growing rapidly, but the inadaptation of the related international engineering technical standards, in which the foundation treatment standards play an important role, has been seriously restricting the competitiveness of Chinese enterprises in the international market. In order to solve this problem, the comparation on foundation treatment standards of hydropower engineering from different countries has been studied. Based on the current understanding of the foundation treatment technology with respect to hydroelectric engineering, taking China-America standards as the primary object, foundation treatment measures as the main content, gravity dam, arch dam, earth-rock dam and slope as the key points, and excavation, consolidation grouting, curtain grouting and drainage as the chief route, the design and technical differences of the standards between China’s electric power industry, water conservancy industry and United States Army Corps of Engineers, United States Department of the Interior Bureau Reclamation have been comprehensively and systematically compared. The standards contrast framework between China and the United States is shown in Fig. 1.

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* *Comparative study on foundation treatment technical standards of hydropower engineering between China and American*

The core differences of gravity dam and arch dam lie in the location determination of dam base and the treatment of weak structural face. About the earth-rock dams, Chinese standards divide them into rolled earth-rockfill dams and concrete face rockfill dams and have the design and construction requirements respectively, but American standards just make unit regulations on earth-rock dam's foundation treatment. As for slope's treatment, specialized standards can't be found in American standard system, where relevant standards only introduce the concept of some treatments. However, Chinese standard system includes many slope specifications and provides corresponding detailed regulations.

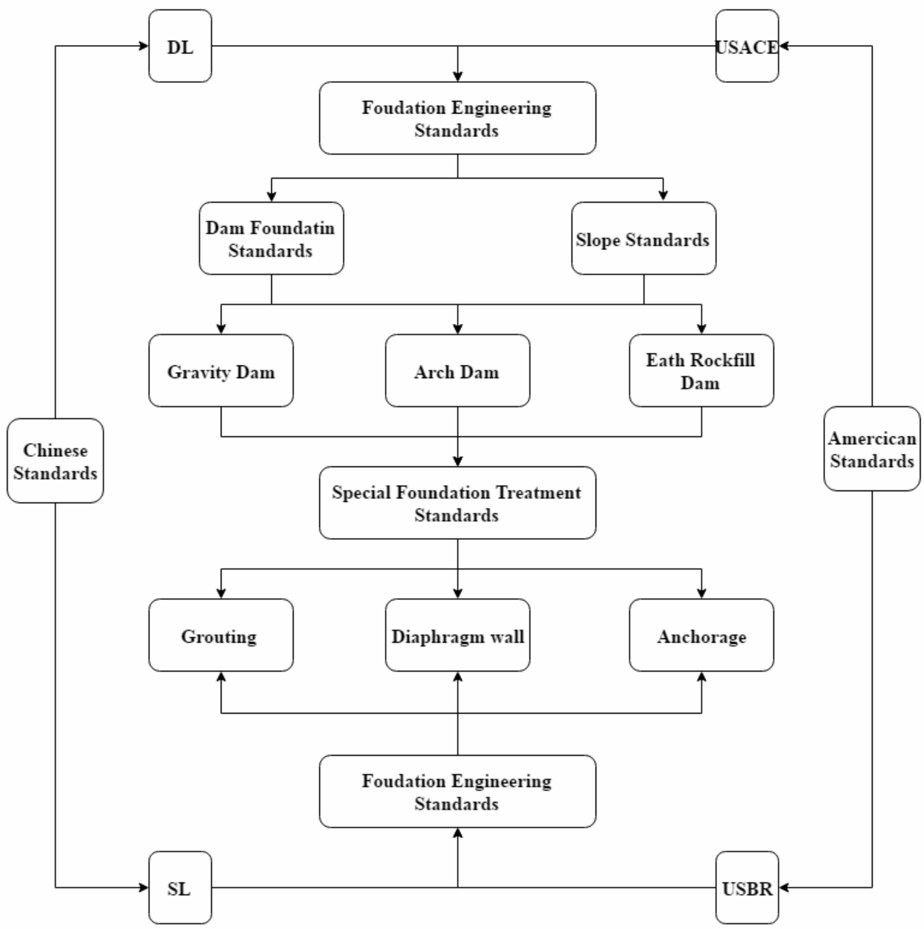

Fig. 1
Standards contrast framework between China and the United States

The comprehensive comparison shows that the overall requirements on foundation treatment of China's hydroelectric industry standards are slightly higher than the American standards, and China's electric power industry a little higher than China's water conservancy industry.

This study will be hepeful to understand the differences of standard on foundation and slope treatment between China and America, and provides technical support for international projects to strengthen the performance capability of international projects.

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Autriche, juillet 2018

SEALING WORKS WITH MICROFINE CEMENT AND SYNTHETIC RESIN AT THE CATHALEEN'S FALL DAM, IRELAND
-
LOW PRESSURE GROUTING OF POROUS MASS CONCRETE

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1. INTRODUCTION

The Cathaleen´s Fall power station is a hydroelectric power plant, located on the river Erne at Ballyshannon in County Donegal, Ireland. It is owned and operated by the ESB (Electricity Supply Board) Group. The construction of the concrete gravity dam started in 1946 and was completed in 1955. The dam is about 256 m long and 10 - 27 m high and has an installed capacity of 45 MW. The associated reservoir has an area of 2 km². The catchment associated with the river is just under 4,350 km². To discharge floods, the dam is equipped with 3 spillway gates, each about 11.0 m long.

Over the life span of around 60 years the mass concrete of the gravity dam became leaky. Especially the construction joints between the casting segments of concreting steps and the sealing joints between the mass concrete and the subsoil became slightly to highly water-permeable. The main leakages were in the inspection gallery inside of the dam and on the downstream surface of the dam near the orographic right bank of river Erne. The inspection gallery and the downstream surface near the orographic left bank of river Erne were in good order. The aim of the commissioned work was to seal the leakages of the dam to restore serviceability and safety against hydrostatic uplift.

2. EXECUTION OF SEALING WORKS

In the year 2014 Züblin Spezialtiefbau was commissioned from the ESB Group to seal the porous mass concrete, the construction joints and the sealing joints to the subsoil with microfine cement and synthetic resin. Low pressure grouting was used to seal the slightly to highly water-permeable joints. Microfine cement was generally used to seal thin and slightly water-permeable joints, synthetic resin was used to seal highly water-permeable joints, as the synthetic resin has a high resistance to washout and a short setting time.

Concerning the work process, primary and secondary drillings – also known as split-spacing-method – in confined space from the inside of the inspection gallery and from the crest of the dam were performed. Similar to the observational method, it was reacted constantly to the encountered conditions as well as the actual grouting volumes to define whether secondary drillings or tertiary drillings are necessary. In the end, the entire work process concerning primary and secondary drillings (or so-called “split-spacing-method”) was changed from the tender design to the execution design.

The last operation was the sealing and the frictional connection of the so-called “dry crack”. This crack was an open horizontal joint near the entrance of the inspection gallery on the downstream surface of the dam and showed great deformations during the change of warm and cold seasons. This crack was equally sealed and frictionally connected with low pressure grouting using synthetic resin. The entire work was finally completed in autumn 2014.

The presentation will give an overview over the drilling works in confined spaces and explains the benefits of the applied drilling system. Furthermore, the sealing works of the concrete gravity dam with low pressure grouting using microfine cement and synthetic resin will be described.

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THE OPERATION AND MAINTENANCE EXPERIENCE OF INDONESIA'S 1ST UNDERGROUND DAM, CASE OF BRIBIN DAM IN KARST CAVE OF GUNUNGSEWU GEOPARK; INDONESIAN INSIGHTS ON THE GERMAN-INDONESIAN IWRM PROJECT (2010-2017)

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1. INTRODUCTION

Karst area all over the world always faces water scarcity. However, the water potential runs deep under the ground can be extracted using new technology and high-risk undertaking. The case study presented here is located in Gunungsewu Geopark [1], Java. The project is supported by the German–Indonesian "IWRM" project, which consist of scientific, governmental institutions, companies of both countries to develop and implement the management strategies [2,3] of the first underground dam in a natural Karst cavern in Indoensia. The barrage is of a multi-angular low-reinforced concrete with the dimension of 8.5 x 2.5 meter.

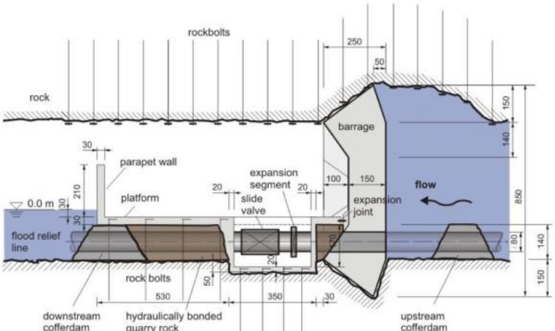

Fig. 1
Longitudinal Section of Bribin Dam [4]

Using this barrage, the pressure head is 15 meter in the upstream cavern and resulted in the volume of water yield of approximately 400,000 m3. The natural Bribin river discharge is up to 1000 l/s, but due to limitation of the Pump as Turbin (PaT) design and higher safety factors, the yield is only between 30 to 45 l/s [3]. The paper would focus on the operation and maintenance experience of the Indonesian operational team of Bribin, from 2010 up to 2017.

The methods used are qualitative research tools, such as interviews, site visits and document analysis of printed materials, reports and will be dealt through historical review. The document analysis is done using Atlas.ti software and coded based on the activities' types, which later on being arranged to clusters of O&M activities.

2. RESULTS

Lessons learned from this pilot project's O&M is divided into normal tasks (daily operation tasks, data monitoring, advancing reservoir level, etc.), flood operation (all modules stop and monitor water level to normal level), medium scale maintenance (spare parts changing, coupling fix, etc.) and big scale maintenance (additional grouting campaigns, lift change, etc.). These experiences enriched the Indonesian members to excel on this subject.

Fig. 2
Condition of Bribin in 2016

Keywords: concrete dam, dam operation, reservoir operation, and maintenance.

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HYDRAULIC MODEL FOR DESIGN OF DIVERSION-CUM-DEPLETION TUNNEL

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There are instances where part of river diversion tunnels have been used as depletion tunnel after construction of dam is completed. In India projects such as Yamuna, Doyang, Nagarjunsagar, Salal have successfully used the concept of multipurpose tunnel for diversion of river flow during construction of project and depletion of reservoir after construction of project is over. Hydraulic design associated with such tunnels has to function satisfactorily for high discharge at low head during construction and also high head low discharge during operation period of project. Present paper describes hydraulic problems associated with design of diversion cum depletion tunnel. Methodology adopted to arrive at solutions for design parameters in estimating frictional head loss, inlet transitions, energy dissipater at tunnel exit and smooth return of flow to river downstream of the structure. Design parameters are illustrated with a case model study of Diversion-cum—Depletion Tunnel, Doyang Hydro Electric Project, Nagaland, conducted at Central Water and Power Research Station (CWPRS).

Paper starts with describing various components of a tunnel. Frictional loss estimation in a tunnel flow by implicit and explicit equations given by various investigators is discussed in detail. Flow control structure such as emergency / service gate needs hoist for operation of gates. Estimation of hydraulic uplift / down pull is essential for trouble free operation of gates and finalizing the gate hoist capacity. Energy dissipater downstream of tunnel exit is important to mitigate erosion of river banks. Various alternatives for energy dissipaters studied in the model are described.

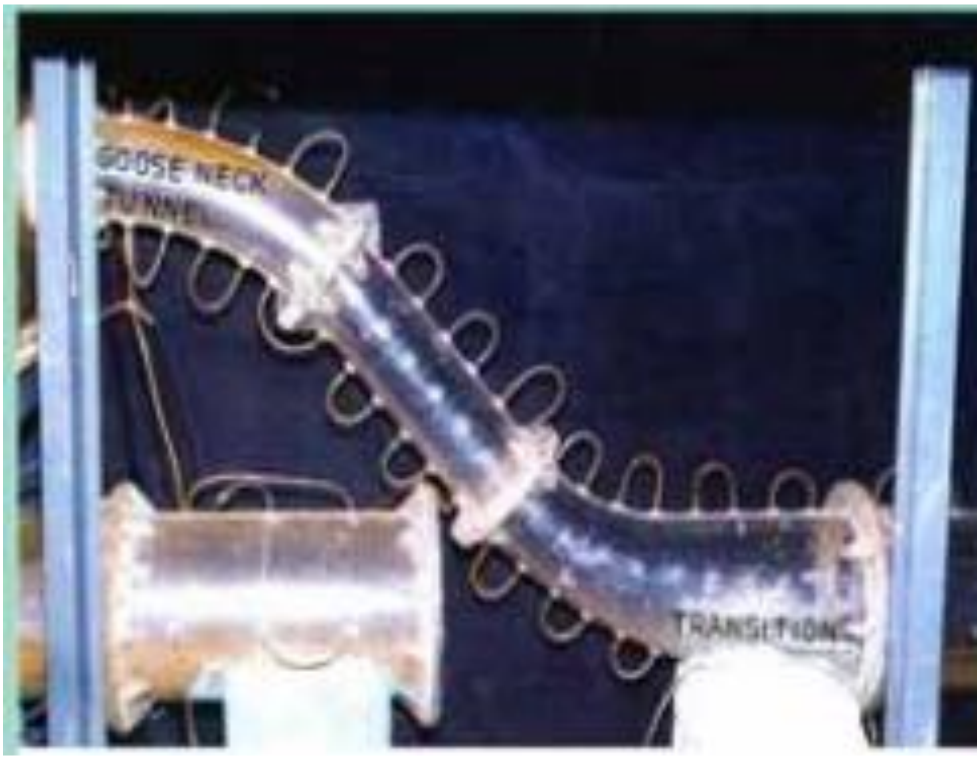

Fig. 1: Photograph-1 Model setup of Diversion cum depletion Tunnel

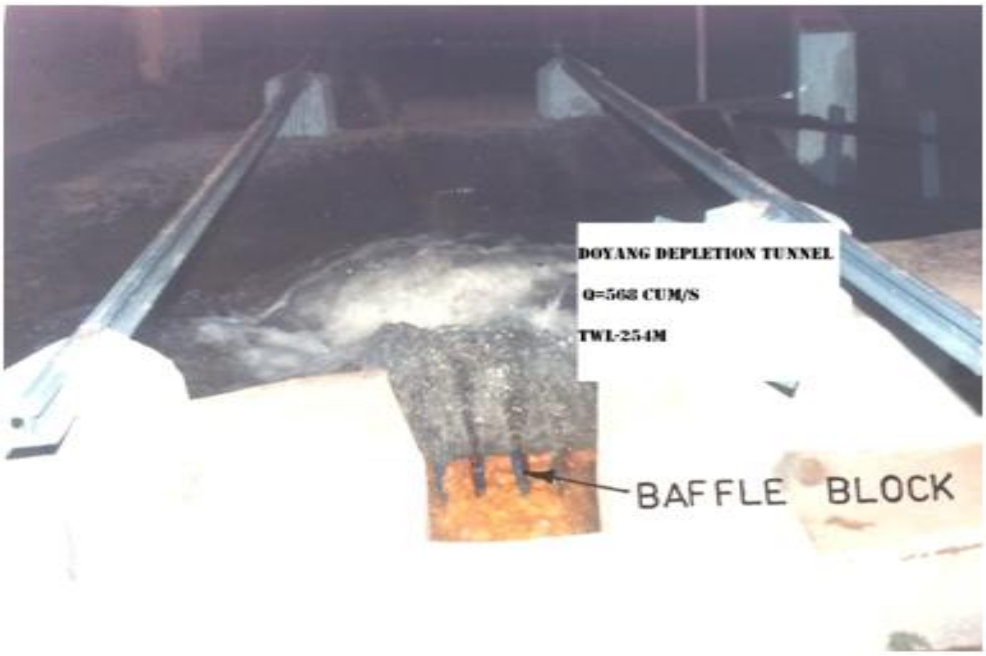

Fig. 2: Photo of model showing Energy Dissipator with Baffle Blocks at the exit of depletion tunnel

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RESEARCH ON CONTROL MEASURES OF LIMNOPERNA FORTUNEI IN PUMPED STORAGE POWER STATION WATER DELIVERY SYSTEM

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Liu XUESHAN

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ABSTRACT

Biofouling problems on water delivery system caused by Limnoperna Fortunei are a new challenge for both construction and operation periods of pumped storage power station. This paper is mainly discusses on the anti-fouling materials research of Limnoperna Fortunei prevention and coating technology which were studied in Guangzhou and Qingyuan pumped storage power station.

In Guangzhou Pumped Storage Power Station, the attachment experiment results show that SK-polyurea 1, silane impregnation, SK-epoxy YEC, fluorocarbon resin, modified silicate, modified acrylic resin and cementitious permeable crystals have a better adhesion resistance. Considering a poor durability of silane impregnation and fluorocarbon resin and a higher cost of polyurea and other factors, SK-epoxy YEC, modified acrylic resin and cementitious permeable crystals are recommended as the suitable protective materials for concrete in combination with the consideration of adhesion resistance, erosion resistance, environmental protection, construction feature, durability, economic benefit and other factors.

In Qingyuan Pumped Storage Power Station, it is decided to brush or coat the cementitious permeable crystals onto the concrete of inlet/outlets and brush the epoxy to the concrete of waterways after the comprehensive consideration of the material prices and construction process safety technology and other factors.

Our practice might as well serve as a reference for similar projects to come.

KEY WORDS

Pumped Storage Power Station, Water Quality, Concrete Protection Limnoperna Fortunei.

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BEHAVIOR ANALYSIS OF THE UNDERGRAOUND POWERHOUSE BASED ON PRECISE DISPLACEMENT MEASUREMENT

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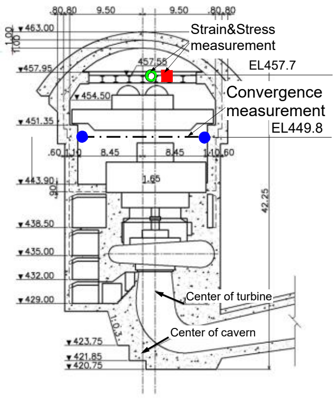
ABSTRACT

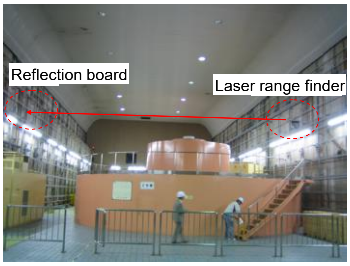
A few damaged pre-stressed anchors were identified in the 40-year aged underground powerhouse, while no other deterioration in the cavern was found. The underground powerhouse includes output of 220 MW and two generator units. The cavern located 100 m beneath the reservoir has the dimension of 23 m wide, 42.25 m high and 70.2 m long. The monitoring of the convergence has been conducted at two generator sections of the cavern to clarify its long-term performance using a newly developed laser range finder since then as shown in Fig. 1.

The monitored convergences have behaved stably reproducible and been clearly consistent with the yearly and/or the seasonal fluctuations of the reservoir water depth and the ambient temperature in the cavern. These characteristics are

shown in Fig. 2. These are less than the unusual convergence which is designated under the assumption of the entire loss of the support effect as the risk scenario. No concerns are found in the current situation of the cavern so far.

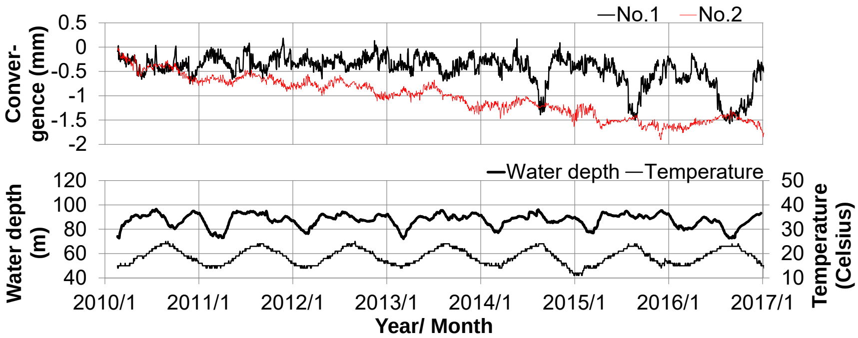


(a) Section of underground powerhouse

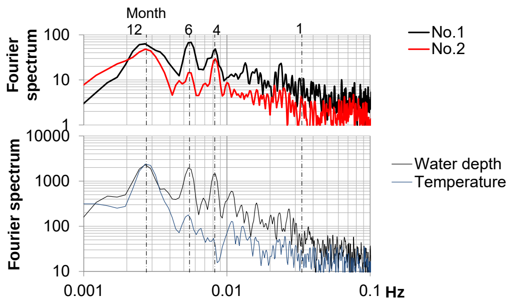


(b) Diffused laser range finder

Fig. 1
Underground powerhouse and monitoring arrangement



(a) Convergence and related records



(b) Frequency characteristics

Fig. 2
Convergence records of the cavern

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MODELING TURBULENCE PHENOMENA AND WAVE PROPAGATION IN AYANUNGA HEPP FOREBAY AND ADDUCTION SYSTEM, THROUGH IBER-2D AND ANSYS-3D

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Enel Green Power is constructing a RoR hydroelectric power plant in Peru (Monzón district), named Ayanunga. 20 MW installed capacity, 2 small dams of approximately 6m high, equipped with Tyrolean intakes and desanders, 2 free-flow adduction channels in site-cast concrete (total length more than 7km), until the forebay, a penstock made of GRP, and 2 Francis turbines. The plant will have a rated flow of 12.38 m3/s. The gross head is of 190.5 m and the average annual expected production is 141.64 GWh/y. It is currently under construction, first synchronization is foreseen for may-2018, and full production by the end of 2018.

This plant is equipped with a unique forebay, despite of two intakes and two adduction channels: this give advantage as cost savings and increased production.

However, this optimization choice generates unexpected problems: vortices in the forebay and problems in the good performance of its emergency spillway. These difficulties usually emerge in the operational phase, but the experience of the group allowed detecting and optimizing it in the design phase. The optimization done was based on computational analysis.

Two analyses have been performed using IBER-2D and ANSYS-3D, in order to:

1) Assess the occurrence of turbulence phenomena in the forebay near the penstock inlet, and evaluate measures to allow good functioning of the system and avoid inlet of air into the penstock, managing to optimize the basic design;

2) Study the propagation of the big wave (surface wave) caused by the turbine load rejection, and model its evolution in time and space from the forebay to its spillway, characterizing discharged water behavior during this case. Furthermore, big wave propagation throughout the plant's adduction system has been modeled, in order to assess the risk that the wave crest touches the upper limit of the adduction conduction.

Original flow velocity near inlet is almost 2 m/s, exceeding submergence safe conditions (1m/s as recommended by good practice). Furthermore, two big vortices are localized near the penstock inlet with noticeable recirculation motion. This is due to high flow speed of water, which enters forebay from adduction channels, and also due to its uncommon shape.

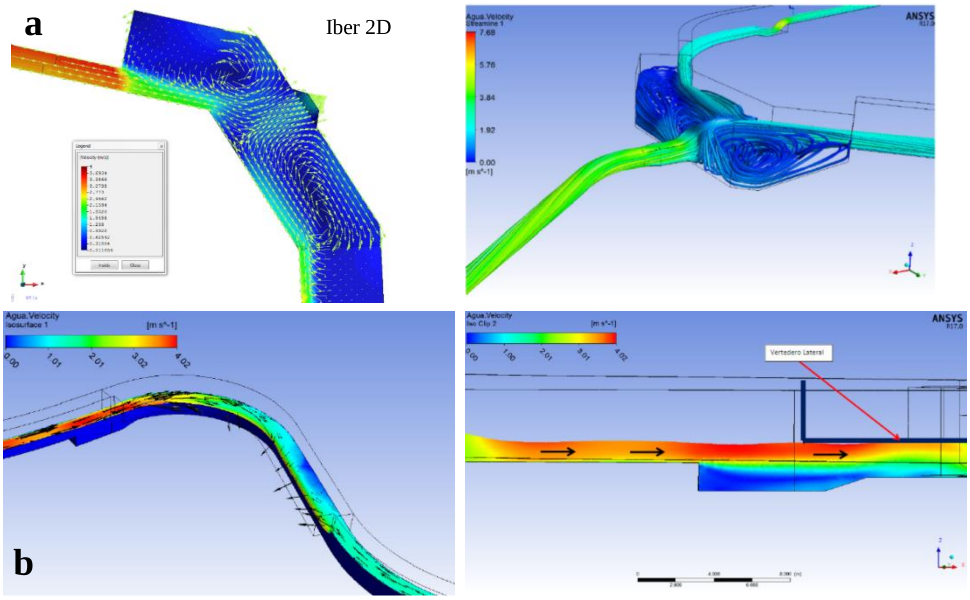

Fig. 1a-b

a) Original design of Ayanunga forebay, example of results modeled through Iber 2D and Ansys 3D. b) Surface wave propagation and spillway discharge efficiency during load rejection in Ansys 3D.

Consequently, original design was modified, by introducing internal walls in the forebay. As result, the vortices are localized upstream of the walls and far from penstock inlet.

The second analysis observed that wave propagation modeling reduces spillway efficiency. Results helps on proper re-location and optimal design of spillway to improve its discharge capacity.

In conclusion, a deep knowledge of hydraulics allows savings and efficiencies (forebay optimization): the use of 2D (Iber) and 3D (Ansys) simulations allows to solve complex problems like vortices formation and transients with tools that, until recently, for their cost, were reserved to much larger projects.

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COMPLEX HYDROGEOLOGICAL RESPONSES DEFY CONSERVATIVE DESIGN OF A PRESSURE TUNNEL – FAILURE OF THE BESAI HEADRACE TUNNEL*

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On first filling the headrace tunnel of the Besai Hydropower plant in Sumatra developed heavy leakage, which caused a landslide. Comprehensive investigations were carried out to find the causes of the failure and to develop appropriate remedial measures.

Volcanic breccia (TBr in Fig. 1), alternating with lava flows and tuffaceous layers form the bedrock. The tunnel runs inside a horizon of massive breccia with few intercalations of tuff (Tf in Fig. 1). 15 boreholes with 1,540m core drilling, in-situ and laboratory tests had provided the base for the design.

For most part of the tunnel route, the cover falls into the range, which according to experience would not have required a liner. Piezometers showed an external head of 46m and jacking pressures derived from Lugeon tests were still at least 40m higher. The designer adopted a reinforced concrete liner (0.5m thick,

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* *Les réponses hydrogéologiques complexes défient la conception conservatrice d'un tunnel sous pression – défaillance du tunnel de amenée de Besai*

1% steel in 2 layers). Conservatively selecting the rock mechanical parameters at the lower range of the test results and a reduced external head, cracks in the liner should not have opened to 0.25mm. Additionally, consolidation grouting was applied to pre-stress the liner and to contain seepage.

The investigation of the failure, including sonic survey, core drilling with permeability and dilatometer tests and local opening of the liner, found one major penetrating crack in the crown, which inside the rock had eroded to 2cm width. The crack connected with a layer of dispersive tuff, 9m above the crown, causing subsequent piping in the tuff. The seepage pressure triggered a landslide in the soil cover of the slope, opening the drainage from the tuff and eventually allowing 1.8m³/s to seep from the tunnel. A small clastic dike in the breccia appears to have concentrated the seepage, promoted erosion in the breccia and initiated diverse

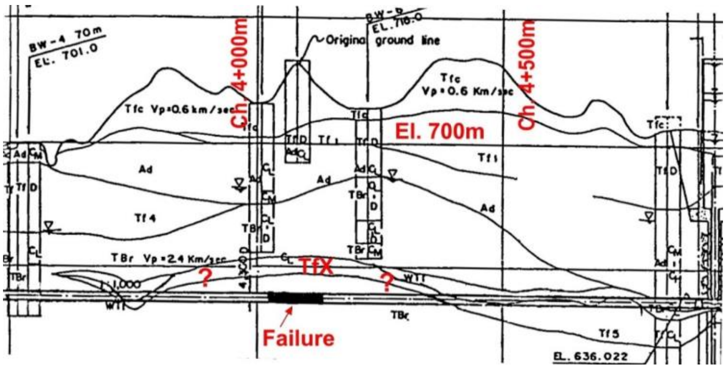

Fig. 1: Longitudinal geological section near the failure
Coupe géologique longitudinal près de la rupture

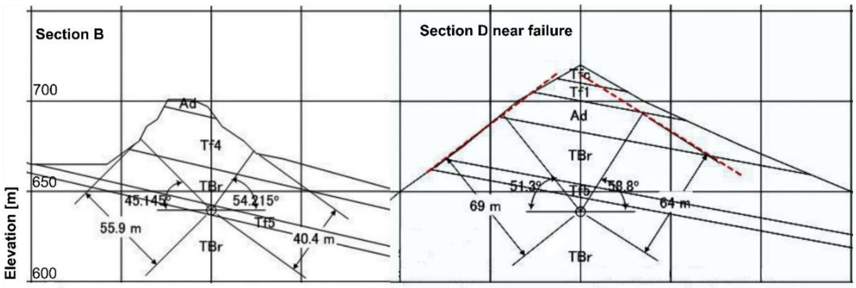

Fig. 2 :Cross sections at minimum cover and near failure
Coupes transversales de couverture minimale et près de la rupture

processes contributing to this development, which significantly affected the hydro-geological parameters and drastically changed the hydrogeological model that had served as basis for the design. Whereas the rock mass modulus in the perimeter of the tunnel essentially remained constant, the permeability in breccia and tuff had increased substantially. The ramifications of events revealed by the forensic investigations was not predictable and their mutual boosting defeated a conservative design philosophy.

With the installation of 300m steel liner the seepage eventually reduced to 6 l/s.

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ESTIMATION OF EQUIVALENT PERMEABILITY OF ROCK MASS USING BACK ANALYSIS AND DFN MODEL- CASE STUDY IN IRAN

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LEBANON

The evaluation of the hydraulic conductivity (HC) of a rock mass must take into account the characteristics of the discontinuities. The issue is to define the dimensions of the representative element and deduce its hydraulic behavior from the geometrical and mechanical properties of the discontinuities. It is vital to have a precise estimation of the equivalent permeability for calculating seepage into underground openings such as tunnels and caverns. Many methods are used to obtain the hydraulic conductivity tensor from the geometrical characteristics of the discontinuities. One of these methods is the discrete fracture network (DFN), as a numerical method, that is used to obtain a representation of the rock mass, simulate the flow in the discontinuities and calculate the HC tensor. The predicted hydraulic conductivity by DFN method will be compared to the hydraulic conductivities that are obtained by back analysis of the recorded volumetric flow rate. Analytic methods used for the back analysis.

In this research, the noncommercial discrete fracture network code, 3DFAHAM*, will be used to generate 3D representations of the rock mass at Rudbar-Lorestan pumped storage power plant and predict the HC tensor of a representative element. The powerhouse cavern of the pumped storage plant is located at the right bank of the main dam (earth dam). The rock mass around the powerhouse cavern consist of the moderate to thick bedded limestone and dark gray dolomitic limestone. The main dam has been impounded and the powerhouse cavern should be excavated in a distance not longer than 350 m to main dam reservoir. After impounding and increasing the reservoir height (100 m), the water level in the boreholes of the powerhouse cavern raised 30 meter. Therefore, the hydrogeological modeling of the interaction between the cavern and reservoir is assigned a high priority to understand the problem of the water level raise into the cavern. To this end, the geometrical and mechanical characteristics of 1035 recorded discontinuities at Rudbar-Lorestan powerhouse cavern will serve as input data.

Two tunnels have been designed to convey water from the main dam reservoir to the powerhouse cavern and vice versa. More than half of the lengths of these tunnels have been lined keeping the remaining lengths unlined. The measured amount is 35 lit/s water into the 200 m of unlined part of the tail race tunnel.

The calculated HC by back analysis has a range between 9 to 26 Lugeon. On the other hands, the equivalent permeability extends over a wide between 5 to 157 Lugeon. Various studies revealed a low level of the water table, a smooth slope of its gradient, water bearing zones with weak and crushed rocks, local openings and various discontinuities and fractures, leak points and local springs. So, the hydraulic conductivity that is obtained by back analysis with the analytic method for a homogeneous aquifer should be considered cautiously. And the calculated value with the DFN code should be considered an upper limit or a maximal value for homogenous rock mass.

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3 Dimension of Fracture Characterization and Hydraulic Analysis using Mapping Methods

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OBERVERMUNTWERK II: NUMERICAL MODELLING AND DESIGN

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AUSTRIA

INTRODUCTION - PROJECT OVERVIEW

The Vorarlberger Illwerke AG, Vorarlberg´s state-owned energy supplier, is constructing the 360MW Obervermuntwerk II pumped storage power plant (PSPP). The project area is located in the rear Montafon in the municipality of Gaschurn, Austria. Upon completion, it will be the second biggest pumped storage power plant of the Vorarlberger Illwerke AG. The construction of the approx. 500 million € project began in May 2014 and is expected to start operating in 2018. Fig. 1a shows an overview of the entire project area. All water-filled tunnels are cement grouted with special attention to the interaction between steel lining and concrete, additionally rock grouting had to be done especially in the high-pressure tunnel and in the penstock.

SUMMARY OF INVESTIGATIONS

The length of the underground powerhouse cavern is 125m, the width is 25m and the average height is 33m (Fig. 1b). In the pre-designing phase 2D-FE analysis for the powerhouse cavern were performed and during the main excavation of the cavern, 3D finite element calculations using Plaxis 3D have been conducted. One objective of the paper is to summarize results from 3D finite element analyses performed in order to assess the performance of the two main caverns of the hydro power plant project. Additionally the headrace system of the power plant and its geotechnical design is presented. Finally, also some experience gained during the construction works is discussed.

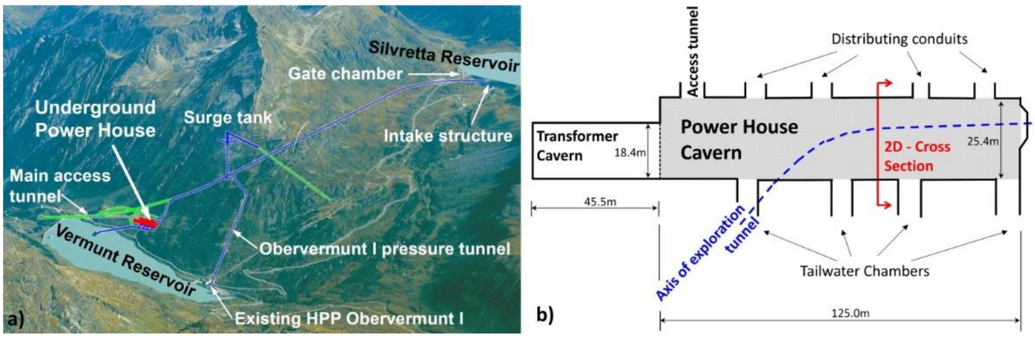

Fig. 1
a) General project overview; b) Plan view of power house cavern

CONLCUSIONS

Of main concern was the stress redistribution within the surrounding rock and the settlement behaviour of the cavern powerhouse during the different excavation phases. The computations predict 15 to 20mm of displacements at the crown of the powerhouse cavern and show that next to the side tunnels stress concentrations have to be expected.

The article provides also a brief overview of construction progress on the major project pumped storage works Obervermuntwerk II. Both the geotechnical design and the experience gained during the construction of selected sections is discussed. The complexity of the project with the technical requirements for the tunnel linings require some special measures, which are presented in detail.

KEYWORDS

Power plant, Finite element analysis, design

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CONSTRUCTION AND MONITORING OF POWERHOUSE CAVERNS THE CIRATA HYDRO POWER PLANT

Pangestu DWIPA AIRLANGGA

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INDONESIA

Powerhouse construction of PLTA Cirata (Hydropower Plant of Cirata) is located underground with 1.008 Mega Watt (MW) of installed capacity and the mean annual generation of electrical energy is 1.428 Giga Watt hour (GWh). To produce 1.428 GWh, eight turbines are operated with the capacity of each turbine is 126.000 KW and 187,5 RPM for rotative speed. The effective head through penstock is 112,5 meters and the water discharge is 135 m3 per second. The tunnel (an excavation area) below the rock mountain is one of the largest Power House Caverns constructions in the world by regarding to its wide. The construction which is located among the rocks will be affected by enormous pressure from the surrounding rocks; therefore the design of the tunnel is made as it aims to limit the impact of pressure from the rocks as small as possible.

The construction of Power House Caverns of PLTA Cirata has 320.000 m3 in volume with longitudinal dimension of 1300 m2, 49,5 m of the height and 35 m of the width of the tunnel. This construction was built by using Geo New Austrian Tunneling Method (NATM) in 1984. The cavern structure reinforcement used rocks around the tunnel as the prior buffer, then it was shotcrete-lined and it was reinforced by rock bolt and pre-stressed concrete. Since NATM was a method for rational construction by using surrounding rocks as the buffer, so it was very important to do monitoring towards the change of the rocks regularly and to keep the safety and the reliability of the underground construction; the monitoring and maintenance activity towards caverns wall were implemented.

The monitoring and maintenance system for the safety of Power House Caverns structure of PLTA Cirata, which had been operated for 30 years, are regularly implemented every month. The monitoring activity uses three instruments, i.e. Rock Displacement Extensometer, Crack Displacement Meter,

and Convergenmeter. The instruments of Power House Caverns of PLTA Cirata were installed when the cavern construction is being built.

The monitoring system towards Power House cavern of PLTA Cirata was being done regularly by PT PJB. Monitoring was done by using three instruments where each of the instruments had different monitoring function. On the cavern age which almost reached 30 years, the monitoring showed that the construction behavior was categorized as normal.

Key words: Construction, Monitoring, Power Plant, and Cirata

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LINING CONCEPT TO CONTROL HYDROFRACTURING OF THE POWER WATERWAY OF HPP QUITARACSA IN PERU

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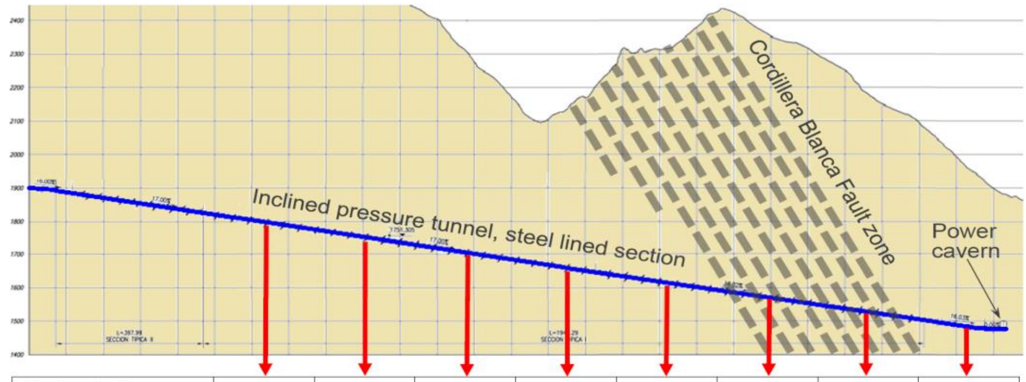
1. INTRODUCTION

Engie's 118 MW Quitaracsa hydropower project is located in the Cordillera Blanca mountain range in Ancash/Peru, on the Quitaracsa River, a main tributary of Río Santa, which is one of Peru's mayor rivers flowing into the Pacific Ocean. HPP Quitaracsa's gross head is 874 m and its design flow 15 m^3/s. The plant comprises an hourly regulation reservoir of 270 000 m^3 and a 5.5 km long inclined pressure tunnel, with 16% constant slope, connecting the reservoir and intake works with the underground powerhouse.

The entire underground structures of the project are located in granodiorite of the Cordillera Blanca Batholith, and the original design provided for only 160 m of steel lining, followed by 200 m of concrete lining, to protect the powerhouse cavern against seepage inflow. However, the Cordillera Blanca Fault Zone, tectonically active, runs in the immediate vicinity of the power cavern.

2. HYDRO-FRACTURING TESTING AND DESIGN ADJUSTMENTS

In combination with low horizontal and vertical overburden, the presence of this fault affects the stress pattern, and several hydro-fracturing tests, performed during tunnel excavation, determined significantly reduced horizontal stresses, with k_0-values between 0.2 and 0.3, which is uncommonly low for a young mountain range. Coping with the insufficient in-situ rock stresses (Fig. 1), the steel liner had to be extended for 2000 m upstream of the power cavern.



Hydrostatic pressure [MPa]	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5
Minimum shut-in pressure [MPa]	5.0	2.6	2.4	8.4	6.1	4.5	5.7	2.1
Safety factor	1.00	0.47	0.40	1.29	0.87	0.60	0.71	0.25

Fig. 1

Comparison of hydrostatic water pressure with the minimum shut-in pressures within the 2000 m of the inclined pressure tunnel close to the power cavern

Comparaison de la pression hydrostatique avec les pressions de shut-in minimales le long des 2000 m du tronçon aval de la galerie en charge.

3. CONCLUSION

The literature lists ample precedence of unlined pressure tunnels with satisfactory performance and offers empiric and semi-empiric methods and criteria for their design, but the experience with the Quitaracsa pressure tunnel serves as an example of exception from the rules and demonstrates the need for reliable and representative information on rock mechanical and hydrogeological conditions, particularly for projects with medium or high pressure tunnels.

KEYWORDS

Failure, Fault, Geology, Geotechnical Investigation, Hydraulic Fracturing, Penstock, Safety Factor

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IN-SITU TESTING AND MONITORING OF TUNNELS AND CAVERNS AT A PUMPED-STORAGE POWER PLANT IN THE SWISS ALPS

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SWITZERLAND

EXTENDED ABSTRACT

The pumped storage power plant Limmern in the Swiss Alps was an important hydropower project during the last years. To pump water from the lake Limmern in the about 600 m higher lake Mutt and to increase the power production up to 1,420 MW, a new underground machinery centre and a new gravity dam for the lake Mutt were constructed. The design required comprehensive investigations of rock parameters. Hydraulic tests were performed to obtain information on the hydraulic conductivities and the static formation pressures in the partly schistose and karstic Quinter limestone. The E- and D-moduli of the rock were determined with dilatometer tests. Finally, hydraulic fracturing tests were conducted to estimate the minimum primary stresses in the rock. These investigations considerably helped to improve the models of the underground and to adjust the design of the three caverns.

During the construction of the central machinery cavern, a complete data set of the convergence behaviour was obtained from the anchor forces and the extensometers, which were installed in cross-sections close to the advancing excavation.

A further task was the long-term monitoring of the lake Mutt dam. 166 sensors were installed, including pressure sensors for flotation measurements and lake level monitoring, sensors for temperature and seepage measurements

and pendulums. All sensors were connected with a redundant bus system to a data acquisition system installed in the dam guard cabin. The database is transferred to the dam operator's main analysis system.

The combination of in-situ measurements and monitoring of critical geotechnical parameters for the design and during the construction of the pumped-storage power plant has significantly contributed to optimize the construction process by reducing uncertainties regarding the subsurface properties and their associated risks. The final geotechnical monitoring of the lake Mutt dam is still ongoing and represents an essential part of the safety assessment of the dam.

La centrale de pompage-turbinage de Limmern dans les Alpes suisses a été un important projet hydroélectrique au cours des dernières années. Pour pomper l'eau du lac de Limmern vers le lac de Mutt situé 600m en amont, une nouvelle caverne souterraine pour la salle des machines et un nouveau barrage-poids au niveau du lac Mutt ont été construits dans l'objectif d'augmenter la capacité de production de la centrale à 1,420 MW.

Des études approfondies des paramètres du massif rocheux ont été nécessaires pour la conception du projet. Des tests hydrauliques ont été effectués afin d'obtenir des informations sur les conductivités hydrauliques et les pressions hydrostatiques dans la formation calcaire de Quinten partiellement schisteuse et karstique. Les modules d'élasticité des roches ont été déterminés à l'aide de tests au dilatomètre. Enfin, des essais de fracturation hydraulique ont été menés pour estimer les contraintes primaires minimales dans le massif rocheux. Ces études ont considérablement aidé à améliorer les modèles du sous-sol et à adapter la conception des trois cavernes de la centrale.

Durant la construction de la caverne pour la salle des machines, une multitude de données sur les caractéristiques de convergence du massif rocheux ont été récoltées par le biais des mesures des cellules de chargement sur les ancrages, ainsi que des extensomètres installés au niveau des sections transversales proche du front d'excavation.

Une autre tâche a consisté en la surveillance à long terme du barrage du lac de Mutt. 166 capteurs ont été installés, comprenant des capteurs de pression pour les mesures de flottabilité et la surveillance du niveau du lac, des capteurs de température, des capteurs pour les mesures d'infiltration et des niveaux à pendule. Tous les capteurs ont été connectés de façon redondante à un système BUS contrôlé par une centrale d'acquisition des données installée dans la station de surveillance du barrage. Les données sont ensuite envoyées vers le système général de l'opérateur du barrage.

Le couplage des mesures in-situ avec la surveillance du comportement hydro-mécanique du terrain avant et pendant la construction de la centrale de pompage a contribué significativement à optimiser le processus de construction de la centrale en réduisant les incertitudes sur les propriétés du sous-sol et les risques associés. La surveillance géotechnique du barrage du lac de Mutt est toujours en cours et représente une composante importante dans l'évaluation de la sécurité du barrage.

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SIPHON INTAKE AS SHPP INTAKE & WATER WAY, A SOLUTION DESIGN FOR SECURING THE LEFT BANK OF WLINGI DAM IN BLITAR, INDONESIA

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INDONESIA

Wlingi Dam in Blitar, East Java Province, Republic of Indonesia is a multipurpose dam which one of the purposes is to supply Lodoyo Irrigation Area in Blitar and Tulungagung District of 12,687 Ha, through Lodagung Irrigation Canal. According to the importance of this food security infrastructure, the guarantee of discharge dependability becomes an absolute necessity. The outflow for irrigation is 8.89 m^3/s to 13.78 m^3/s that is available throughout the year. There is also a gross head of 12.50 m between the water level on Wlingi Reservoir and after canal escape. Thus, the availability of head and discharge make the potential of additional small hydroelectric power plant (SHPP) in Lodagung Irrigation Canal sounds very promising.

Jasa Tirta I Public Corporation, a State-Owned Corporation on Water Resources Management in the Republic of Indonesia has been constructing SHPP

Lodagung 2x850 kVA since August 2016 and it will be completed on December 2017. This project is expected can meet the lack of electricity supply that has been relied only on two local hydropower plants, HEPP Wlingi and HEPP Lodoyo with total installed capacity of 75.38 MVA. These supplies have not increased since 1983, whereas in 2010 the peak load exceeded 75 MVA and in 2017 is projected to be at 92 MVA.

The Wlingi Dam itself encountered geological problems during impounding in 1977. At that time, there was an excessive leak in the formation of lime soil, in form of seepage in left abutment of the dam. The seepage appeared also in the raising of well water level in the village around downstream of the dam and reached parallel to the yard. The investigation was conducted on 12 February – 14 March 1978 using radio isotope tracer with “multi well technique” method. Radioisotope Cr^{51} and Br^{82} injected into a borehole and then observed on the other holes. The investigation concluded that seepage raised on the left bank of the dam, mainly through the upper part of the limestone rock and centered near the irrigation outlet. Then the problem was dealt with the three curtain grout lines on the left bank area, and until now is an effective treatment.

Crossing curtain grout lines that intersect with the irrigation canal, so far become the most economical path for intake pipes and penstock. However excessive digging will surely disturb curtain and have bad impact on overall dam safety. Therefore, the design of the intake and water way are planned to be placed on top of crest dam. Siphon intake that made from steel pipe was chosen as a best solution for the design, even though need precise hydraulic calculation to ensure that it will work properly. The challenge is that it will be also the first application for hydropower intake and water way in Indonesia.

Siphon intake was designed by steel material SS 400 with specification technical data: 2 units each diameter 1.5 m, thickness 10 mm, length 60 m. The specification technical data of penstock i.e.: Inner Diameter 2.5 m, thickness section-I 10 mm with length section-I 315 m, thickness section-II 12 mm with length section-II 30 m, total length 345 m. After the installation and construction works has completed in January 2018 since construction works started in August 2016 (18 months), the system performed well. The turbines and generators worked with the pressure in penstock similar with turbines in range 0.83 – 1.03 bar with output capacity of each turbine 407 – 643 kW.

Keywords: SEEPAGE, SIPHON, POWER PLANT

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MODIFYING METHOD FOR VORTEX FLOW IN TRIFURCATION IN HYDROPOWER PLANT

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1. INTRODUCTION

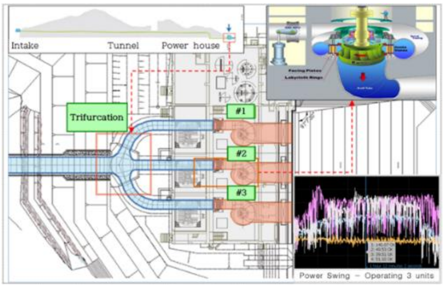
The Patrind hydropower project developed by SHPL (being a special purpose company established for the project) and owned by K-water (being the main sponsor for the project) is a trans-river diversion type hydropower project on the Jhelum River, approximately 200km northeastward of Islamabad and at the west bank to the township of Muzaffarabad in the Azad Jammu & Kashmir, Pakistan.

2. OCCURRENCE OF POWER SWING

According to the project overall layout conditions, the power plant has a trifurcation to enable the proper supply of the water into each branched penstock leading to 3 units and turbine from the upper side of the main penstock.

In order to minimize the head loss of water flows through trifurcation, the trifurcation was installed as a shell type is expected to have relatively smoother water flows than other types. Nonetheless, during the final commissioning test, the occurrence of severe power swing as shown in Fig. 1 that is not acceptable by global standards (IEC 60308) was identified in the full load condition (3 units in simultaneous operation) and the test failed to pass.

The reason for power swing is estimated due to the vortices created in the water passing the un-linear water ways such as the expansion and reduction point having sudden change of cross section area around and in the trifurcation despite adopting the shell type trifurcation generally known as having relatively smooth water flows.



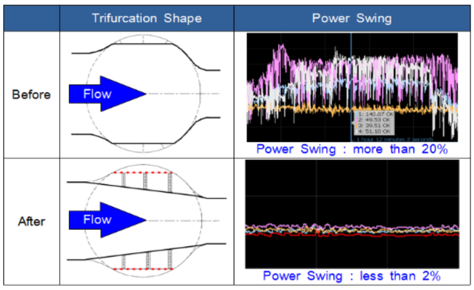


Fig. 1
Power Plant Layout and Power Swing

Fig. 2
Power Swing after Modifying Trifurcation

It is not possible to replace readily the trifurcation with modified trifurcation because the trifurcation is embedded in the deep underground and covered with thick steel-concrete.

Before remedial works, the design was finalized after verifying the power swing and status of water flows estimated by the numerical analysis for each operative condition for all units of turbine in modified inner shape trifurcation.

The results of numerical analysis shows that the best solution is to minimize the un-linear points around the trifurcation. For more stable water flow distribution, it was planned to install enlarged deflection plates linearly connecting and covering the inner space of trifurcation between the main penstock and the branched penstocks.

After remedial works, the size of the power oscillation is significantly smaller and meet the IEC standard as shown in Fig. 2 below.

The Patrind hydropower project achieved substantial completion on 11 November 2017 and has been in operation since without any issue with the trifurcation.

3. CONCLUSION

Except for the case of very slow velocity of water flow, sudden expansion and reduction points through the water way should be minimized, especially in the trifurcation.

Where there is some uncertainties about water flow conditions, the hydraulic model test should be conducted to get an optimized design and mitigate the risks from uncertain hydraulic conditions.

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HOLLOW CONE VALVE (HCV) IR. H. DJUANDA DAM AND MURI INDONESIA RECORD

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INDONESIA

1. INTRODUCTION

Construction of Ir. H. Djuanda Dam or better known as Jatiluhur dam which was implemented from 1957 until 1967. Basically Jatiluhur / Juanda Dam construction project is designed to irrigate tens of thousands hectares farmland and fisheries, electricity for Java - Bali lighting, main supplier of water for industry, raw water supply for capital city and tourism. Currently Jatiluhur Dam/Juanda age have reach 50 years, pollution and sedimentation become a worrying problem.

Mechanical equipment existing condition in Jatiluhur Dam at this time has decreased function, hollowcone valve only optimal at the opening position of 20%.

2. EXISTING CONDITIONS

Hollowcone equipment is under the morning glory tower which is a tower structure made from concrete that has an outside diameter of 90 m and height 110 m. This tower function as main valve (spillway threshold elevation ±107.00 m) and hollow cone valve is located on el. 49.00 m. Morning Glory has 14 windows without a door (ungated spillway) with an overall length of 151.1 m. Abundant capacity is 3,000 m^3 / s at water surface elevation of 111.6 m. Based on results from a major (large) inspection in 2014, hollow cone valve left there is a leak due to stoplog is not able to close perfectly. As well as the unbalanced of openings up to 100% so two hollowcones with large size (3850 mm) each and rubber seal on two stoplogs will be replaced and repaired.

3. CONCLUSION

New HCV removal process from pontoon and drop to baseline morning glory, the sequence is almost same as old HCV lifting process but reversed sequence. It starts from new HCV lifting from outside of morning glory and lowered down using balanced cantilever.

Hollowcone valve (HCV) mechanical replacement at Jatiluhur / Juanda Dam requires special skills to be initiated during HCV manufacture at the plant up to the installation in the field (Jatiluhur Dam / Juanda). Hollowcone valve Jatiluhur / Juanda Dam is the largest HCV in Indonesia even in the World, so MURI Indonesia record museum awarded the certificate with the largest valve category (diameter 3850 mm).

KEY WORDS

HCV, Manufacturing, MURI Record

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THE GROUTABILITY INVESTIGATION OF PUMICE PACKED BEHIND TUNNEL LINING SYSTEM

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IRAN

1. INTRODUCTION

In traditional tunneling methods, over-excavation due to geological conditions and collapse of weak rock area is almost inevitable. Any gaps between tunnel ceiling and reinforcement system can cause unpredictable deformations of the surrounding rock. Therefore, such gaps should be filled with stiff and solid materials.

2. GENERAL LAYOUT AND CONCLUSION

In this paper, the results of the groutability of pumice pieces packed in onion and flour sacks and placed in the gaps behind the lining of the tunnel are investigated. The most important questions in this research are: 1-is it possible to filling the porosity between sacks and inside pumice pieces? 2. when is the appropriate time for contact grouting, Before or after concrete lining? And 3. Is it necessary to revise the contact grout holes' arrangement?

To find the answer of the first question, a simulation phase has been done on the workshop. Answering the second question by selecting of two situations in tunnel. One situation was shotcrete face finished and the other was finished face of lining. The last question was find out after implementation of grouting and according to the check-holes result. The results indicate that:

- Both types of sacks (onion and flour sacks) used to placing pumice pieces in the empty space behind the lining have acceptable groutability.
- The results of contact grouting taken after the initial supporting is not satisfactory, therefore the implementation of contact grouting was postponed after the installation of the final lining.
- The grouted cement in secondary grout holes still shows a peak absorbed cement locally, therefore the third grout holes grouted between initial and secondary holes. Check-holes drilled after grouting of third series shows that the voids inside the pumice sacks and the gaps between sacks completely filled with cement grout.

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STATUS AND FUTURE PROSPECTS OF RENEWABLE ENERGY IN SUB-SAHARAN AFRICA

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1. ABSTRACT

Access to reliable and clean energy is a major problem for many sub-Saharan countries. The Region is faced with long-lasting electricity crisis resulting in most the economy sectors crippling. It is estimated that Close to 600 million people in sub-Saharan Africa about two-thirds of the population live without electricity access. Majority of the country's electricity grid is mainly powered by large hydropower and depleting hydrocarbon resources. Renewable energies represent a foundation to steer the energy system in the direction of sustainability and supply security in sub-Saharan Africa. electricity Generation, biofuels from renewable energy sources has become a high priority in the energy policy strategies in most countries in the Region at their national level as well as the global scale. Most of the countries are blessed with abundant Renewable Energy resources that have not been fully exploited; these renewable resources have the potentials to change the status quo of power generation and consumption in the countries. this paper seeks to bring out the current status and future prospects of Renewable Energy in Sub-Saharan Africa along with recognizing the key challenges confronting full scale development of Renewable Energy in the Region. Future prospects have been discussed through the analysis of energy policy

scenarios conducted by the International Energy Agency (IEA)'s ''World Energy Outlook''-series. And proposed possible solutions for the involvement of renewable energies to help speed up power supply in sub-Saharan Africa as well as Africa as whole. It is our hope that this paper will inspire more research on the Renewable Energy is addressing use energy crisis in sub-Saharan Africa as well as the entire African continent.

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"THEORY OF EVERYBIM" – WORKFLOW OPTIMIZATION HYDROPOWER NORWAY

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NORWAY

1. INTRODUCTION

Traditionally, construction and hydropower projects have been undertaken based on multiple 2D drawings. Drawings have been used since ancient times when they were cut into stone. Our experience with drawings is that a lot of time is spent on unnecessary perfection of the appearance of the drawings, such as line thickness, textures, company standards, etc. - much of this is not relevant for building the desired construction. Today's technology is developing rapidly, and it is up to us to utilize the enormous digital potential we all have access to.

The whole industry, both internally and externally, at home and abroad said that it was too early to challenge the well-known methods of drawing production. A group of young Engineers at Norconsult did not agree. They wanted to see how far they could push the boundaries. Someone had to take the first step to see if it was possible to complete a project without drawings at all. Someone had to see if it was possible to complete a project using only a single digital model - available to all involved parties at any time, consisting of all the necessary information. A fully integrated “Building Information Model (BIM)”.

The chosen project was the complex 125MW Run Of the River hydro power plant "Vamma 12". All parties involved in the project were equally motivated to make this work. The contract was established with respect for all involved expertise and focus on who would be responsible for what at all times. Knowing that there would be some initial disappointment, the project team started developing an innovative workflow that would become a milestone in our industry. The methods used offered several benefits for both client and contractor including: cost reduction, ease of cost quantification and scheduling, reduction of errors, clash control, optimization, construction of complex geometry, planning and coordination. The biggest challenge was not to make the technology work, but to establish necessary attitudes and teamwork in the project. You can make a good plan, but you cannot plan everything.

Today the "Vamma12" project is close to being finished and shows the way for a new generation of fully integrated BIM projects. Workflows are continued and optimized day by day.

This presentation will give you details of how we have worked as a team to realize what we believe to be world's first project of this kind.

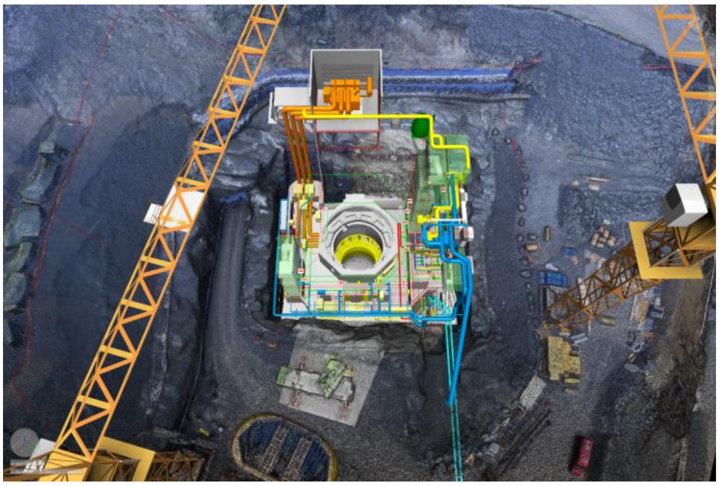

Fig. 1 The Digital Coordination Model – Vamma 12

Fig. 2 Construction work in progress – Vamma 12

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HIGH PERFORMANCE PRESSURE TUNNEL EXCAVATION AND LINING

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AUSTRIA

1. ABSTRACT

Pressure tunnels of either, the headrace- and/or the tailrace system of high head (gross head >500m) hydroelectric power plant (Fig.1) commonly are those parts of the plant that are bearing the maximum costs and the maximal potential of cost saving as well. For that reasons the optimization of the technologies applied has performed steadily within the last 20 years.

The performance has rather developed within the following topics:

- Optimized layout selection allowing a maximal benefit from the geological and hydrogeological surroundings.
- TBM- excavation predominantly based upon hard rock double shield technology.
- Precast segmental linings optimized towards the fundamental requirements of pressure tunnels.
- Grouting technologies in order to involve the rock mass into the lining concept as much as possible.
- Construction concepts that allow the performance of construction with a high percentage of semiskilled local workers supported by a small, specific skilled key staff.

The contribution proposed is going to deal with the topics lined out above in detail.

Since economically sealing and grouting will require a sufficient overburden of the pressure tunnel, the optimized layout selection is putting its focus to those

tasks. A special benefit can be gained, as long as the ground water table is located above the internal pressure of the tunnel.

The internal diameter of pressure tunnels most frequently is ranging from 4 to 7 meters with a tendency toward bigger diameters. This range of diameters is a range, where TBM- tunnelling can be applied most economically, compared with other excavation methods.

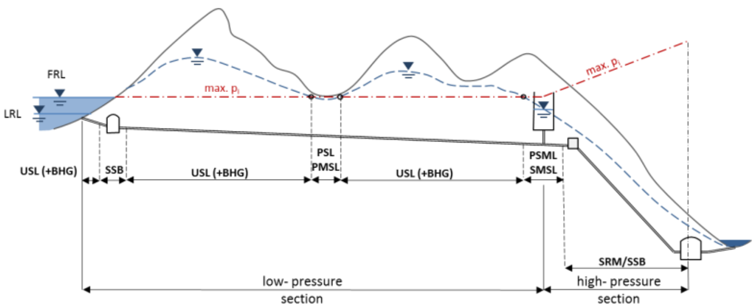

Fig 1: Longitudinal section of a typical Alpine high head power plant, Legend see Tab.1

Tab. 1: Legend for different lining systems

NOL	no lining(invert only)
USL	unsealed concrete lining
USL+BHG	unsealed concrete lining + borehole grouting
PSL	pre stressed lining
PMSL	plastic membrane sealed lining
SMSL	steel membrane sealed lining
SRM	rock mass supported steel liner
SSB	self bearing steel liner

Tunnel support according NATM and in situ concrete lining of course can be the best choice on a Gripper TBM for special projects with a short length and / or small diameters. However, most probably it requires especially skilled workers and is bearing a high risk regarding construction time and costs. The qualification in skills and the risks regarding construction time and costs can rather be reduced by applying the technology of mono shell precast tunnel linings. Such precast segmental linings are linked to high performance excavation predominantly with double shield hard rock TBM’s. For that reason, both technologies were developed to a special state with a special focus upon pressure tunnels within the recent years.

In order to involve the surrounding rock mass into the pressure tunnel concept, grouting is a special task. The most frequent grouting types will be lined out with their key tasks.

For worldwide application of economically high performance pressure tunneling and lining, it is a postulate, that construction can be performed with a high percentage of semiskilled local workers supported by a small specific skilled key staff. This postulate is fulfilled with the technologies lined out.

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GEOMEMBRANES IN HIGH-PRESSURE TUNNELS AND SHAFTS

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1. INTRODUCTION

Hydraulic tunnels and shafts are usually lined, to provide stability and watertightness, to avoid excessive water infiltration undermining the stability of the slopes and of the structure, and to minimise head losses. Traditional lining systems have been steel, and reinforced or un-reinforced concrete, whose construction is expensive and time consuming, can be complicated in locations with difficult access, and may require expensive maintenance. As the concrete deteriorates water infiltrates into the soil through fissures and/or failing joints and increased permeability, and increased roughness results in reduced hydraulic efficiency. Similarly, steel liners may be stressed above their yielding point. Deterioration of the lining and loss of watertightness can have serious consequences: continuous water seepage into the surrounding soil may affect the stability of natural slopes, eventually triggering landslides and ultimately causing partial or total collapse of the structure. Rehabilitation must restore watertightness and bring the pressure tunnel/shaft back to its design conditions. Local repairs are not efficient in the long term. Overall repair with a new liner must be designed to optimise hydraulic efficiency, lifetime, outage time for installation, costs.

2. METHODS, RESULTS AND CONCLUSIONS

Geomembrane lining systems are a permanent repair solution, and in new construction a solution increasing the project's safety. The geocomposite liner (a watertight flexible geomembrane heat-bonded to an anti-puncture geotextile) is placed on the existing liner/regularisation ring; where needed, support/anti-puncture layers are placed on the existing subgrade. The geocomposite is anchored by longitudinal fastening lines and by watertight perimeter seals at beginning and end of the lined section. A drainage system behind the geocomposite allows relieving backpressure when the tunnel/shaft is dewatered. The elongation capability of the geocomposite allow resisting existing and future cracks maintaining watertightness. High pressures (several MPa) and water velocities (up to 6 m) are sustained. Low hydraulic roughness enhances efficiency. No routine maintenance, long durability. The geocomposite liner protects the concrete from deterioration. Installation can be completed in short times. Geomembrane are an efficient reliable alternative to traditional lining systems, with many successful precedents. They increase the safety of the structure.

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Keywords: Leakage, rehabilitation, shaft, tunnel, waterproofing.

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INCREASING POWER OUTPUT AND FLEXIBILITY OF EXISTING HIGH HEAD POWER PLANTS WITH THE HELP OF WATERHAMMER SIMULATIONS

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AUSTRIA

1. INTRODUCTION

In a changing energy market with decreasing energy prices, energy suppliers try to ensure their yield with their existing hydro power plants. One possibility to raise the annual energy earnings is not only to increase the power output but also the availability and flexibility of an existing power plant. Most of the older power plants – in particular storage power plants – are not designed for such operating modes – especially not for rapidly changing and fluctuating load.

As many plants operated today were constructed decades ago, the original plant design was based on operating conditions which are completely different to the ones actually required. To prove the ability for higher flexibility in power generation, detailed investigations of the power water way, especially surge tank limitations, are necessary. Since the main constructive infrastructure cannot be changed or just in a limited way, only limited additional power generation is possible. The higher the demand for an increasing power output, the higher are the limitations in operational flexibility. An overflow of the surge tank must be prevented in any possible operational or exceptional scenario of the power plant. On the other hand a ventilation of the headrace by means of an ineligible empty surge tank must not occur during operation.

Flexible operation induces a highly transient fluid flow in the headrace and especially the surge tanks of high head hydro power plants. In the planning phase of activities to increase the power output and/or the flexibility, a reliable prediction of the transient plant behaviour and especially the surge tank performance in unsteady load cases - such as periodic machine starts and stops or switching load cases - is necessary.

Modern techniques in numerical simulation methods provide the only feasible possibility to accurately calculate the occurring mass oscillations and pressure pulsations as well as for the optimization of the transient behaviour. Commercial software-packages for water hammer simulations usually do not provide numerical models for a realistic calculation of complex components like surge tanks, hydraulic turbines or emergency closing valves in a high head hydro power plant. But especially these components need to be modelled correctly in order to get a significant and reliable solution. A validation of the numerical models by means of onsite measurements at the existing hydro power plant yields additional confidence for a safe operation after the power increase.

The present paper shows the successful application of custom designed numerical models for surge tanks and hydraulic turbines in the course of waterhammer analysis. An executed example of a power plant with increased power output and flexibility is demonstrated.

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IMPROVEMENT OF INTAKE STRUCTURES WITH NUMERICAL SIMULATION

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AUSTRIA

1. INTRODUCTION

The design of inlet and outlet areas of hydro power plants significantly influences the overall cost of a plant not only in the design and construction phases but also during operation. Due to an incorrectly shaped inlet geometry, vortices and flow separation occurred at several river power plants. These phenomena can cause flow problems and losses at the turbines and must not be neglected, especially for low head turbines with relatively high specific speed turbines. Sources of such inhomogeneous inlet flow distribution could be a wrong design of dividing piers, gravel steps and other points of discontinuity in the flow guiding walls and river bed. In this paper, samples of waterway designs and their optimisations are presented aiming to avoid wrong inflow and outflow designs together with cost-optimised design.

2. POWER PLANT EXAMPLES

The first example is an Austrian river power plant where a gap between the powers of the two identical horizontal axis Kaplan bulb turbines was assessed. It is assumed that the difference is caused by flow problems at the inlet area. The hydro power plant consists of two units with a maximum discharge of Q = 100 m³/s per turbine, whereas the units were brought into operation in 2012. Multiphase calculations were carried out to verify the air-sucking turbulences and swirls. Based on the results of these simulations, different kinds of structural measures were developed. The various types of measures range from simple accessory elements to large-scale structural interventions at the inlet area of the power plant. The effects on the inflow of all these different structural adjustments were further investigated by applying computational fluid dynamics.

The second example is located on the Swiss-Austrian border and refers to the GKI power plant on the river Inn. The weir system is a multiple function system including the weir flap, the diversion channel to the main power plant, which is located 23 km downstream, and the connection of a residual water turbine as well as a fish pass. The main turbines for Austria's largest diversion power plant are two vertical Francis turbines with a net head of H=160.7 m and a design flow rate of Q=75 m³/s for the power plant. The Kaplan S-turbine with its maximum flowrate of Q=20m³/s increases the feeding to Q=95m³/s for this installation. As the fine screen in the front has a clear diameter of only 20 mm, a special focus must be given to a correct inflow situation at the screener as well as at the residual water turbine.

The last example describes the intake situation of the MKF hydro power plant at the river Mur. The design flow rate for this residual water turbine is Q=40 m³/s. The model of the river bed starts 350m upstream and includes the diversion channel to the main power plant. A significant cost reduction could be realised by changing the rotational direction of the turbine, and with an optimised design of a diversion pier directly in the turbine intake a smooth and homologous flow situation could be realised.

3. CONCLUSIONS

Based on three case studies that have been worked on in recent years at the Institute of Hydraulic Turbomachinery at the Graz University of Technology, it can be shown that the numerical flow simulation is very well suited for the detailed analysis of the inflow of power plants as well as for the development of geometric improvements. Especially in the area low head power plants, where axial turbines are often used (such as Kaplan tube or S-turbines), such studies should be carried out already in the planning phase in order to avert potential problems in advance.

KEYWORDS

DESIGN, FREE SURFACE FLOW, INTAKE, TRASH RACK

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THE IMPACTS OF THE DIFFERENCES BETWEEN CHINESE AND FOREIGN TECHNICAL STANDARDS ON DEVELOPING INTERNATIONAL HYDROPOWER PROJECTS

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CHINA

1. INTRODUCTION

Chinese contractors play a more and more important role in the hydropower industry worldwide due to the experience and technological strength accumulated from delivering many significant hydropower projects such as the Three Gorges Dam. However, the Chinese contractors encounter ongoing difficulties in achieving the objectives of developing international hydropower projects, which arise from unfamiliarity with the differences between Chinese and foreign technical standards. Although many researchers have pointed out the importance of understanding the differences of technical standards (Orr et al., 2008; Javernick-Will et al., 2009; Kwon and Kareem, 2013; Lee et al., 2016; Lei et al. 2017), there is still a lack of solid and practical investigation to reveal the impacts of the differences in technical standards on developing international hydropower projects. Therefore, this research collected the data from international hydropower projects, which are scattered in Asia, Africa, Oceania and Latin America. With support of the case studies, this research reveals the impacts of the technical standards' differences

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on hydropower project development processes, including bidding, design, procurement, construction, occupational health and safety management, and environment protection. It is suggested that Chinese contractors should more clearly understand the differences between Chinese technical standards and foreign technical standards in project delivery for providing more cost-effective and environment-friendly hydropower projects worldwide.

2. RESEARCH METHODOLOGY

Data was collected through questionnaire survey. The questionnaire aims to investigate Chinese contractors' perceptions on how technical standards affect the delivery of an international project according to their practical experience in a specific project. Questionnaires were sent to 17 Chinese construction companies, which all have rich experience in international hydropower projects through fieldtrips as well as e-mail. Ranking analysis and Pearson correlation analysis were applied in this research.

3. CONCLUSIONS

This study reveals the impact of the differences between Chinese and foreign standards on developing international hydropower projects with the findings as follows:

- USA, ISO, Chinese and European technical standards have significance influence on international hydropower projects conducted by Chinese contractors.
- The difference of Philosophy of the standard ranks first among 8 aspects of differences between Chinese and foreign standards;
- Standard management problems are most frequently occurred in implementation of an international hydropower project.
- Engineering-Procurement-Construction integrated management problems happen constantly, which reminds Chinese contractors to concentrate on interface management between design, procurement and construction.
- Design problems usually occur, showing that there is an urgent need to improve the design capability of Chinese contractors using foreign standards
- Construction cost increasing has a significant impact during project implementation.
- Technical standard differences related problems have a significant impact on project performance, especially on project cost and time performances. It is necessary for Chinese contractors to figure out the differences between Chinese and foreign standards in order to perform better and provide more cost-effective and environment-friendly hydropower projects worldwide.

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TWO YEAR OF PERFORMANCE OF A PENSTOCK ANCHORED BY PU-FOAM

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ABSTRACT

The drop in Norwegian electricity prices in recent years has reduced the potential income for new small hydro projects, and therefor measures to reduce the costs must be introduced. Today the most commonly used backfill for penstocks for small hydro are gravel and rockfill, which is time consuming and costly due to transportation. Penstock BV with Guy Harris developed a method with polyurethane foam as a replacement for gravel and rockfill which may lead to lower investment costs and reduced construction time. NTNU made the required initial laboratory tests in 2015 and Statkraft AS initiated a research project to verify the method in 2016. The full-scale project is located in Finnmark County, Norway, and the construction work was done the summer of 2016. By the summer 2018 this penstock have experienced two years of operation. Monitoring of elastic and non-elastic displacement of the bends proves the behavior during start/stops and other dynamic load situations.

The project involves the construction of Lille Måsevann Pump with a buried penstock connecting Lille Måsevann to Store Måsevann – the intake reservoir for Adamselv hydropower plant. Lille Måsevann Pump is the first of its kind where sections of the penstock, including two bends, are enveloped in polyurethane foam (PU foam). Previously only scale tests have been carried out. Out of the total length (1130 m) approximately 300 m were anchored by in foam.

PU foam is a two-component material composed of polyol and isocyanate. In contact the materials will go through a chemical reaction and form polyurethanes. During the reaction the foam expands up to 30 times and is 70 % cured after 10 minutes. Through adhesion the pipe and the foam is glued together to work as one unit. Investigations of both tensile and compressive strength has been performed through tests at NTNU and a

method for calculating necessary foam cross section to obtain required bend stability is developed. Different methods for applying the PU foam to the pipe were tested as the construction work at Lille Måsevann Pump progressed. The foam was applied with three different methods: open formwork, a fully enclosed capsule and spraying the PU foam directly on the pipe.

The experiences made from both construction and two years of operation at Lille Måsevann Pump has acquired new knowledge to the subject. The behavior of the penstock is without any kind of unexpected observations and the penstock performance is as for other penstocks constructed in traditional ways.

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DESIGN OF AERATOR FOR ORIFICE SPILLWAY

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INDIA

INTRODUCTION

Recent trends in run of the river projects involves high intensity discharge and high heads. Such situation leads to pressures on the surface of spillway to drop below atmospheric leading to cavitation damages. To mitigate cavitations damage, measures such as control of geometry, smoothness of the spillway surface, use of cavitation resistant materials are adopted. There are limitations for adopting preventive measures. Provision of aerator only alternative to mitigate cavitations damage. There are various methods to measure air concentration in a spillway overflow flow. Most reliable being intrusive phase detection probes, like optical probe and resistivity probes. Present study employs use of resistivity probes along with PC based Data Acquisition System (DAS) to measure air concentration in a spillway over flow downstream of aerators. Two locations were selected to measure the air concentration. Two alternatives with offset of 1.5m and 2.5m namely without ramp and with ramp upstream of aerator were studied in the model. Comparison of various alternatives are presented in a table using non-dimensional parameters jet length λ, air entrainment coefficient β, cavity pressure. Model study indicated that provision of ramp increases the air entrainment. Air concentration along the bed is more for small gate openings and decreases drastically in the vicinity of 2-3% for decreasing Froude number. Flow depth is fully aerated for small gate openings. β decreases with increase in gate openings. Addition of ramp improved pressures in aerator, jet length increases with addition of ramp. Study also proved that functioning of an aerator on the orifice spillway is different from the flat slope chute spillway. Spillway surfaces of high dams are susceptible to cavitation damage due to high velocities, surface roughness and geometrical deformities.

Fig. 1 Model set up for testing of or spillway profile and air demand in an orifice spillway

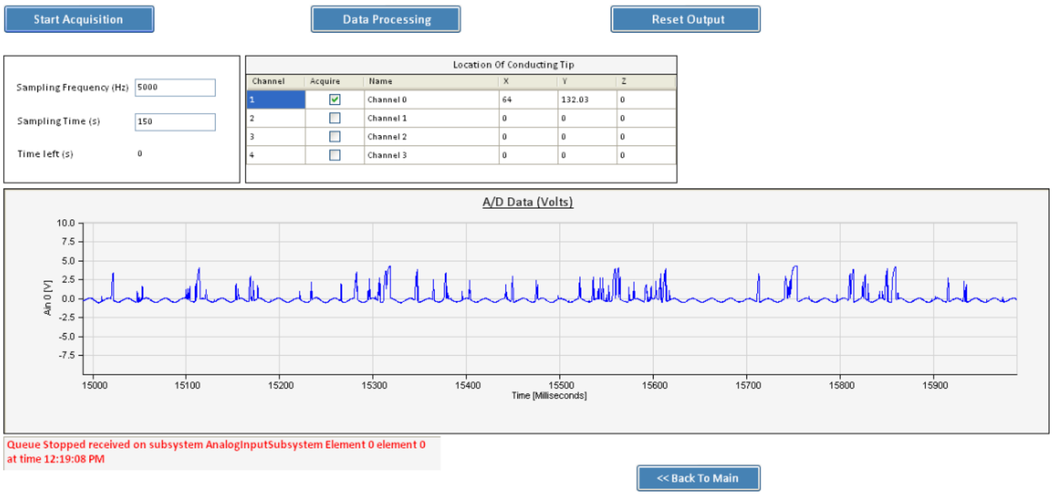

Fig. 2 Typical air concentration measurement output.

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STRAIN MEASUREMENTS AND AXIAL FORCE PREDICTIONS AT THE END OF A STEEL LINED PRESSURE TUNNEL

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AUSTRIA

1. INTRODUCTION

A new steel lined pressure shaft was constructed for the existing Kaunertal high head hydro-power plant in the years 2012 to 2015. The project included the construction of a 1430 m long 4.3 m diameter inclined pressure shaft, a 325 m long penstock tunnel section, a new surge tank consisting of two chambers connected by a 150 m deep vertical surge shaft [1].

Before starting operation, initial filling tests were carried out in particular to investigate the stress and strain distribution of the steel penstock. Each test consisted of two loading and unloading cycles of the new facilities. The first fill-test was carried out before the interface between steel lining and backfill concrete was grouted. The second fill-test started after interface grouting was completed. This rather lengthy testing procedure should primarily facilitate the grouting. The rock mass / steel lining response to loading and unloading of the shaft and eventual benefits gained from interface grouting were recorded with optical strain gauges spot-welded to the steel lining.

The axial force in the pipe due to internal pressure acting on the end cover of the pipe is necessarily transferred via friction into the rock mass embedding the penstock. Based on strain measurements at several pipe sections the distribution of the axial forces was studied in detail.

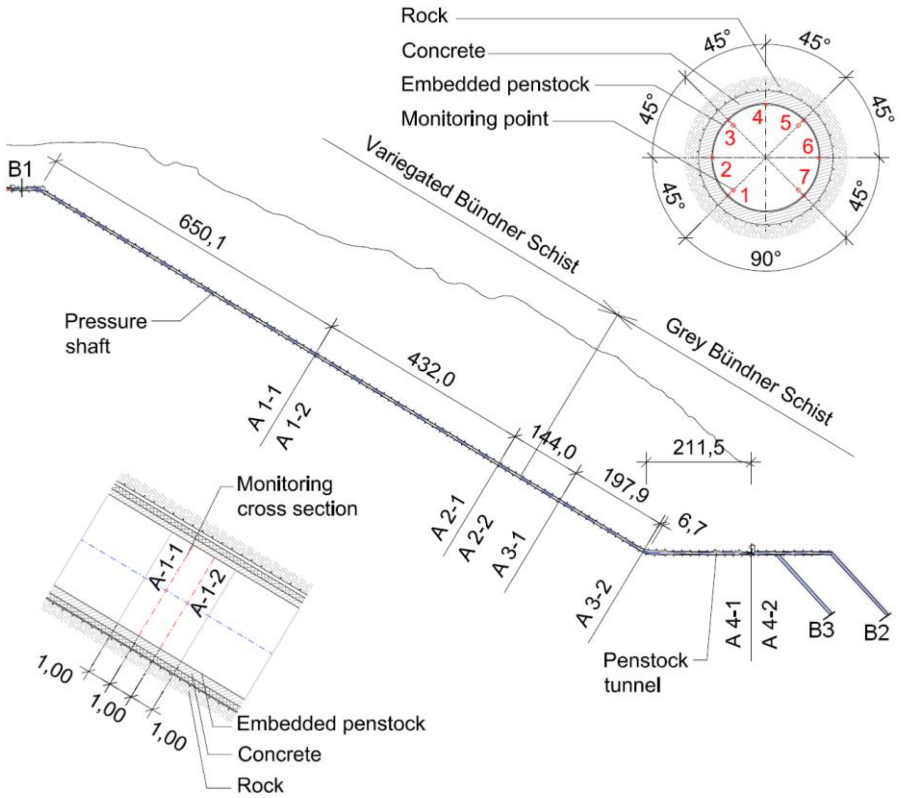

Fig. 1
Monitoring cross sections “A” and locations “B”

2. SUMMARY

- Strain measurements can be realized with optical strain sensors at high accuracy, bridging distant locations and sustaining high water pressure.
- At the second loading and unloading cycle of the first fill test (still before interface grouting took place), a “thermal gap” between steel pipe and backfill concrete, which could be detected, provided space for free deformation of the steel lining.
- A considerable improvement of stress redistribution from the steel pipe into the rock mass was noticed in Fill-Test 2 after the interface grouting took place.
- After interface grouting took place circumferential strains responded purely elastically and returned to the starting point of the pressure-strain diagram
- After only 3 m to 4 m (1.5 diameters) of the embedded pipe length a substantial portion of the full cover pressure acting as an axial force in the steel pipe was transferred to the rock mass even without any shear rings.

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END OF STEEL LINED PRESSURE TUNNELS - LOAD TRANSFER OF LONGITUDINAL PIPE FORCES

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AUSTRIA

1. INTRODUCTION

Within a recently finished research-project the load transfer of axial loads in penstocks only due to friction between the filled steel pipe and the surrounding concrete and rock, without thrust rings, has been studied.

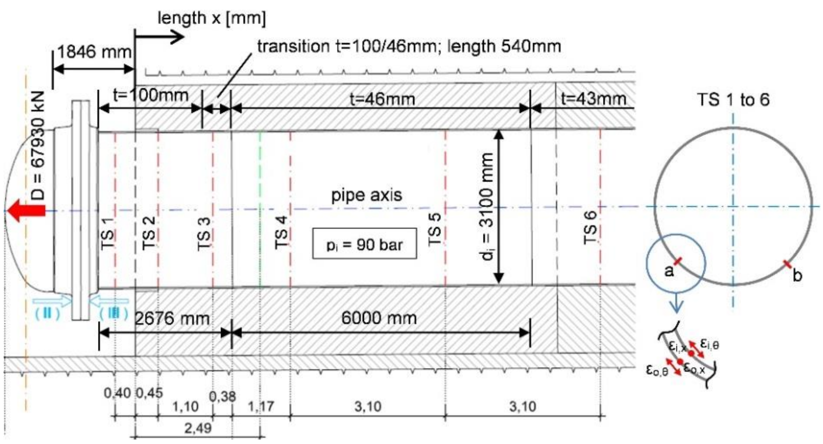

Fig. 1
Penstock at Kaunertal in the erection phase. Transfer of longitudinal force due to internal pressure without thrust ring and measuring points in the individual test sections (TS1 to TS6)

Axial loads arise due to water pressure on caps or valves and temperature differences between steel pipe and surrounding concrete. Thrust rings are traditionally used to transfer the axial loads in the steel pipe into the surrounding concrete and further into the rock.

This paper deals with a summary of the measurements on a part of a penstock to evaluate appropriate coefficients of friction μ between steel pipe and the backfill concrete (see Fig. 1). Within this part of the penstock no thrust rings were erected and a high axial force D acts at the steel pipe due to internal pressure on the cap. Parametric studies are presented to show the principal behavior of load transfer along the pipe, with and without thrust rings.

Based on that, a simplified analytic model has been developed for practical design including regions without friction. In addition, the effects of the important boundary conditions – longitudinally free or fixed – of the steel pipe within the rock are presented.

2. SUMMARY

Within this research project, based on measurements on a penstock during erection and a comprehensive numerical study the following results are worth mentioning:

- High local longitudinal forces acting on the steel pipe in penstocks, due to closed valves for example, may also be transferred to the surrounding concrete and rock due to friction only – without thrust rings.
- This requires internal pressure in the steel pipe. Then the length for transferring the longitudinal forces l_{fr} is very short ($l_{fr} < 2 \cdot d_i$, for $\mu = 0.25$ and $V_F > 2500$ N/mm²).
- Only a part of the longitudinal force n_D is transferred locally over the length l_{fr}. This proportion n_{fr} / n_D increases with higher radial stiffness of the rock.
- Additional thrust rings, when they are not directly situated at the beginning of the rock and concrete surrounding, get only small amounts of the longitudinal forces.
- If the transfer of longitudinal forces within the friction length l_{fr} is possible (guaranteed coefficient of friction μ) also the longitudinal displacements u_x of the steel pipe on the free end will be small.
- If the steel pipe has also a free end inside the mountain also the remaining part of the longitudinal force $n_{AP} = n_D - n_{fr}$ will be transferred over a very short length l_{fr}. For the estimation of this length the same behavior is given as at the free end of the steel pipe. It is highly recommended to set up an anchorage point inside the mountain due to safety reasons. If this is not possible, the friction length should be long enough, because the whole longitudinal force is transferred by friction.
- A simple analytical model was developed to calculate the transferred load n_{fr}, the friction length l_{fr} and the displacements u_x at the free end of the steel pipe.

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THRUST RINGS FOR TRANSFERRING LONGITUDINAL PIPE FORCES – DEVELOPMENT OF A DESIGN MODEL

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AUSTRIA

1. INTRODUCTION

Thrust rings with rectangular cross-sections are mainly used in penstocks to transfer the longitudinal pipe forces via the exterior concrete to the surrounding bad rock mass (Fig. 1). The new design model – presented here – is limited to usual applications with continuous full penetration welds at the thrust rings.

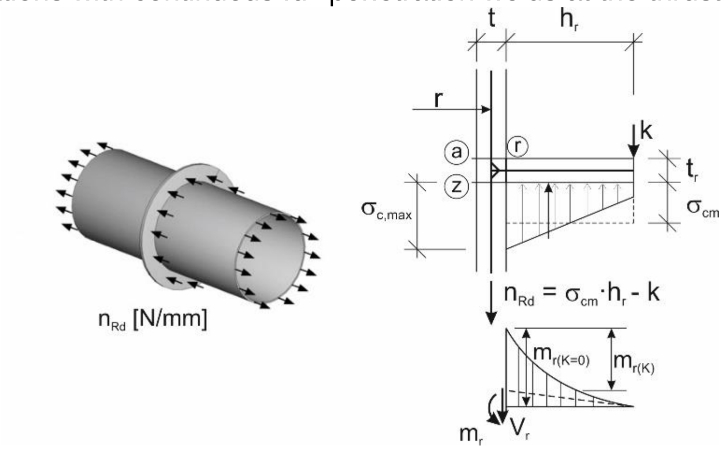

Fig. 1
Overview of pipe and thrust ring and simplified cantilever model used in practice

Thrust rings can be seen as a composite component, which may transfer very high pipe forces – up to 50.MN, because of increasing diameters and pressures in recently erected penstocks.

Longitudinal forces in penstocks can have various reasons. For example, they may act due to the internal pressure on a closed valve, to Poisson-effects or temperature changes. Surprisingly, in relevant design codes for penstocks no detailed information is given for the design of thrust rings. In practice, simplified models are used, considering the thrust ring as a cantilever (Fig. 1). The maximum force n_{Rd} and also the maximum moment m_r at the thrust ring are depending on the distribution of the concrete pressure σ_c and the maximum concrete stress $\sigma_{c,max}$ at the thrust ring. In the past, different assumptions with no physical background based on test results were used. In some cases an additional prying force k at the non-loaded side of the thrust ring which reduces the maximum moment m_r, was assumed. Based on the internal forces m_r and V_r, transferred from the thrust ring to the pipe, the stresses in the relevant sections (r, a and z in Fig.1) of the thrust ring and the pipe can be calculated based on shell theory.

For usual large penstock diameters (d = 3-5 m) the cantilever model for the thrust ring is quite accurate, because the effect of the circular ring plate is negligible. This result is based on 3D-FEM-analyses by the authors for cases with practical dimensions. That means, if the pressure distribution σ_c and the acting contact force k are known for the simple model in Fig. 1 the design of the thrust ring and the pipe may be based on the well-known codes for steel design. Therefore, a research project was executed by the authors, which includes also laboratory tests to calibrate FEM-models for the prediction of these pressure distributions σ_c at the thrust ring, was executed by the authors.

At the beginning of the full paper the load carrying behavior of thrust rings will be shown based on a practical example with a pipe of an inner diameter d_i = 3800 mm, a thickness t = 74 mm and a thrust ring h_r/t_r = 370/62 mm. In the second part a new design model for thrust rings is presented. In this brief paper only the basic model, considering the elastic behavior of thrust rings is shown in detail.

2. SUMMARY

Based on tests and numerical results of a FFG- research project operated by the authors a comprehensive design model for thrust rings has been developed. It includes the elastic load carrying capacity of the thrust ring and the verification of the stresses in the steel pipe and the ring. Further, it´s also possible to calculate the stiffness of the thrust ring. The interaction behavior of serval thrust rings was investigated also, leading to a very simple design rule. As a result a significantly higher load carrying capacity $N_{R,el}$ of the thrust ring can be achieved, in contrast to the current design concepts (Fig. 1). Also higher load carrying capacities than $N_{R,el}$ can be utilized in case of an additional radial elastic support of the rock mass, but they are not described in this brief paper.

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A CASE STUDY OF A HIGH STRENGTH STEEL DESIGN: APPLICATION OF DIFFERENT SAFETY CONCEPTS AND THE RESULTING IMPACTS ON A BIFURCATION

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AUSTRIA

The application of high strength steels for modern, highly pressurized penstocks allows for reduced wall thicknesses. Hence, this should result in lighter components and easier fabrication, transport and handling conditions. This paper presents a case study of a complex geometric steel liner component – a bifurcation for access to a vertical tunnel – made of steel grade S620QL.

Besides geometrically optimizing the design of a bifurcation with respect to the reduction of hydraulic losses, the choice of an appropriate safety concept influences the layout strongly. Usually, the owner or the owner's engineer specifies a safety concept, which is stipulated by a standard or a guideline. As for steel penstock design, several international standards and guidelines with their own integral safety concepts are available throughout the world. The most common European standard for steel penstocks is still C.E.C.T. [1]. English speaking countries prefer for example ASCE manual no. 79 "Steel Penstocks" [2].

The problem now is that the safety concept of C.E.C.T. is historically based on nominal design stress, which means that stresses or minimum required plate thicknesses are calculated by analytical formulae. This approach does not match with the application of finite element analysis, which is the state-of-the-art approach for complex structures (and often required by owner's engineers) and where dimensioning by means of formulae is not possible any more.

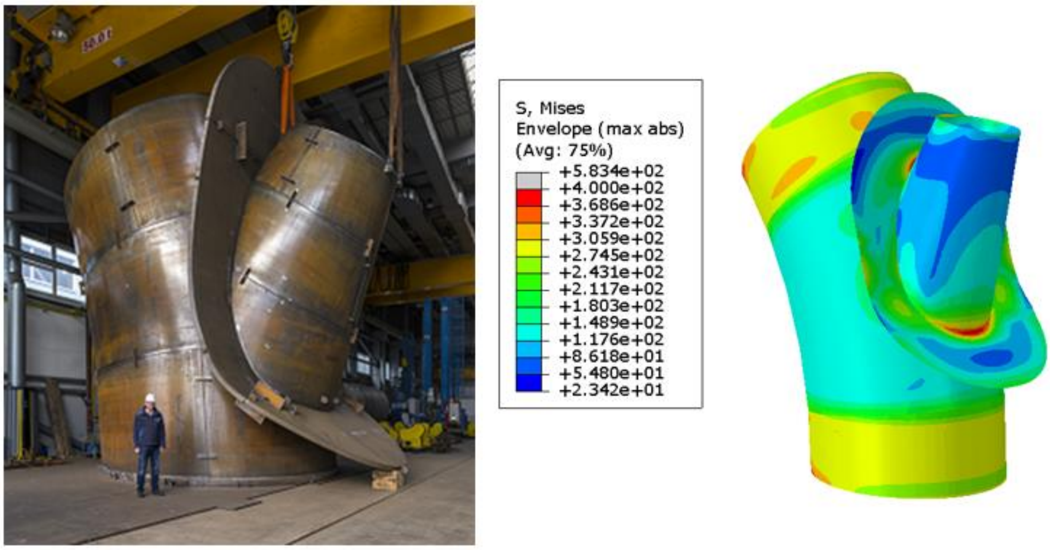

Fig. 1
Left: Shop assembly of a bifurcation; right: Stress plot of numerical simulation model

Moreover, finite element analysis usually shows regions with locally increased stresses due to structural discontinuities. Compared with allowable stresses derived by nominal stress concepts this would unnecessarily lead to increased plate thicknesses and thus a higher dead weight of the component.

ASCE manual no. 79 clearly denotes allowable stress intensities for finite element models, which can be increased depending on the respective stress category. It distinguishes between different primary and secondary stresses (e.g. allowable local primary membrane stress for a reinforcing girder of a bifurcation is 1.5-times of the allowable stress intensity). Peak stress assessment, which becomes relevant for fatigue analysis, is also dealt within this guideline. The case study of a bifurcation presented in this paper opposes the traditional C.E.C.T. safety concept to the ASCE safety concept and points out the problems transferred to successive processes, e.g. fabrication and welding procedure, assembling and erection problems, which originate from an inadequate safety concept application and makes the economic benefits from high strength steel irrelevant.

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DESIGN OF STEEL LININGS OF PRESSURE SHAFTS MADE OF HS-STEEL ULTIMATE LIMIT STATE AND CYCLIC LOAD CONDITIONS

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At the 3. International Conference “HSS for Hydropower Plants” in 2013 [1] the state of developments of that time was reported, - this paper is to present the progress achieved since then in Austria. Two topics are dealt with in the following.

The first topic deals with the composite behaviour of HSS-liners with the rock mass by the design concept [2] which aims at the ultimate load resistance of steel liners considering the post-failure capacity of the cracked rock. Thereby the effects of crack-water pressure as well as the ductility demands on the steel liner for bridging the cracks in the rock soffit play an important role. The latter may pose a challenge for HSS-liners due to their reduced ultimate strain, particularly in the welds. Specific safety elements were defined for the rock by a safety factor of 2,0 on the rock modulus V_R* and by a factor of 1,75 on the yield stress f_y of the steel.

Fig.1 presents the basic outcome of a design example under internal pressure for a liner of S690 and the rock modulus V_R* =6GPa. At the ultimate load level (ULS) the design pressure of 10MPa is reached in the plastic range of the steel and is just covered by the crack bridging limit. At the service load level (SLS) the liner is in the elastic range which is important since cyclic loading –as discussed later- presupposes the elastic behaviour of the steel. The result of the liner-design by the new concept is firstly, that the traditional rock participation is no longer limited by the elastic resistance of the uncracked rock and secondly, that the traditionally used ULS-check based on the fictitiously free liner with the allowable limit stress of 0,9xfy is overcome, which both result in saving of steel by about 33%.

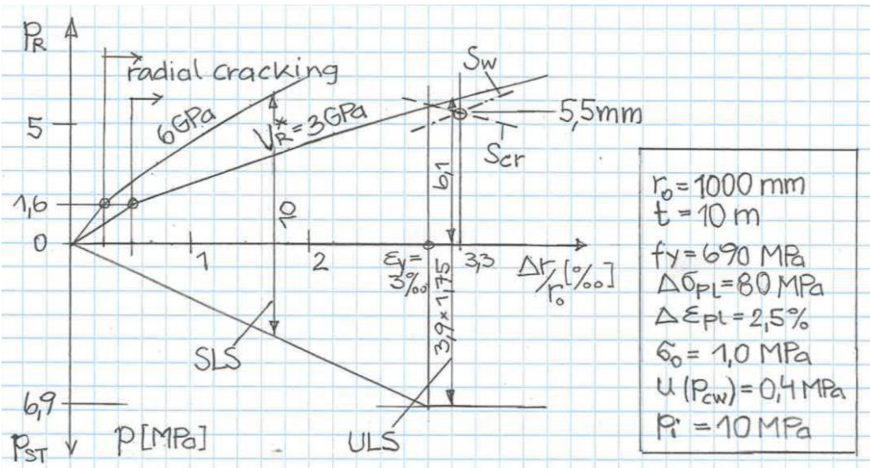

Fig.1: Design example of HSS-lining based on collaboration with cracked rock

The second topic deals with the effects of cyclic loading on the steel liner. There are two kinds of cycles; - those with high frequency leading to failure by fatigue and those with low frequency, which may cause cyclic plasticity. The first ones are summarized by load spectra resulting from pumping and turbine-operation, the second ones are pressure oscillations due to emptying the penstock. These effects may lead to limiting design conditions for the liner and cause great demands on the detailing and fabrication of welds and constructional parts like nipples, openings, thrust-rings etc. Load conditions of liners in HSS 690 recently under construction show that stress raisers like injection openings, nipples etc. determine the utilisation of the steel compared to the static one.

The design limits for fatigue may be taken from appropriate standards, however for certain constructional details of linings specific solutions are still missing. The design rules for cyclic plasticity alike would need further investigation because the given standards do not cover the behaviour of HSS-grades and multiaxial stress states adequately. The given examples underline the necessity of further research to solve the needs of practical design.

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ADVANCED DESIGN OF HIGH STRENGTH STEEL-LINED PRESSURE SHAFTS ACCOUNTING FOR FATIGUE CRACK GROWTH

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The recent development of high strength weldable steels has enlarged the range of design alternatives for the optimization of high-head steel-lined pressure tunnels and shafts in the hydropower industry. Storage hydropower and pumped-storage plants are subject to more severe operation conditions than before, resulting in frequent transients. Whilst the use of high strength steel allows the design of thinner steel liners, welded high strength steel do not provide higher fatigue resistance than lower steel grades, and may be subject to the risk of cold cracking (Fig. 1). Fatigue behavior may become the leading limit state criterion.

The research project presented hereafter aimed at: (i) improving the comprehension of the mechanical behavior of steel-lined pressure tunnels and shafts (influence of anisotropic rock behavior and geometrical imperfections on stresses and linear elastic fracture mechanics parameters, studied by means of the finite element method, vide Fig. 1); and (ii) developing a framework for

probabilistic fatigue crack growth and fracture assessment of cracks in the weld material of longitudinal butt welded joints (Paris-Erdogan law for fatigue crack growth in the scope of Monte Carlo simulation, vide Fig. 2).

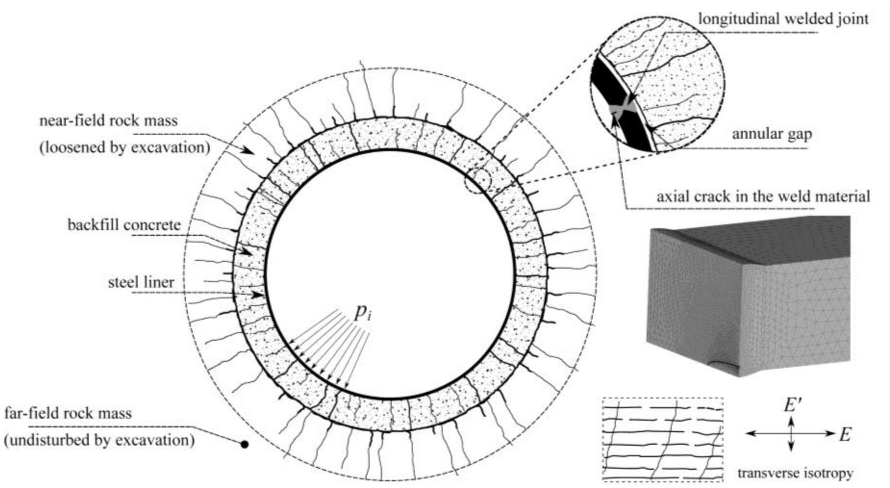

Fig. 1
Conceptual model of steel-lined pressure shafts and finite element models
Modèle conceptuel des puits blindés en charge et modèles éléments finis

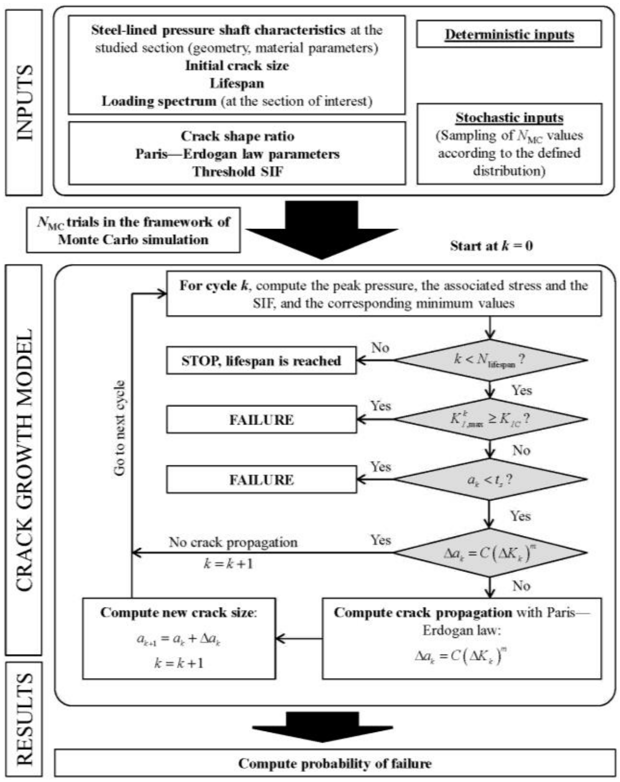

Fig. 2
Flowchart of the proposed Monte Carlo simulation procedure
Fluxogramme de la procédure de Monte Carlo proposée

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EFFECT OF RTE TREATMENT ON TOUGHNESS OF HSS WELD METAL

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During pressure test of a manifold of a brand new huge hydro power penstock fabricated from advanced high strength steel a catastrophic fracture appeared by breaking the circumferential weld of the closure head before reaching the design pressure. By analysis of the reasons of this event severe embrittlement of weld metal has been detected by observing intergranular fracture surface and toughness testing of the weld metal. Further investigations revealed that the embrittlement was caused by unqualified post weld heat treatment (PWHT) during fabrication, characterized by extremely low cooling rate of 15°C/h from holding temperature at 570°C. Temper embrittlement has been found as root cause for the embrittlement. For assuring safe service conditions all PWHT treated welds has completely been removed and re-welded. This was possible because of full access to the manifold welds in the tunnel. Further investigations revealed that many welds present in the inclined shaft has also been PWHT treated by application of the slow cooling rate. In these welds also severe embrittlement has been observed. The welded shells present in the inclined shaft has already been fixed in the mountain by concrete. That fore re-welding could not be applied because of water intake after removal of the existing welds. Therefore, consequently the fabrication of a new penstock in a newly drilled tunnel had to be considered, taking into account costs and schedule consequences.

Various possibilities has been studied to solve that severe problem. Reversible temper embrittlement treatment (RTE), a short time heat treatment at a peak temperature around 600°C, was found as method to recover the toughness of the embrittled welds. Intensive investigations has been performed to realize this idea in the project. Electrical mat heating was selected and carefully qualified to be applied in the shaft.

The procedure of application of electrical mat heating on brittle welds in the penstock is discussed in this contribution. By qualified controlled application of electrical mat heating in the shaft, rehabilitation of the brittleness in the existing welds could successfully be achieved. The penstock after finishing this procedure has successfully been commissioned and could start service operation. (1)

The results of the industrial application of RTE treatment performed are doubtless very successful and reproducible. Basic scientific investigations to explain the surprising positive effect of RTE treatment on the recovery of the toughness of temper embrittled weld deposit have been performed. By application of Atom Probe investigations, the effect of embrittlement observed as well the surprising effect of de-embrittlement by RTE application could be explained. (2) (3)

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INFLUENCE OF PIPE FABRICATION QUALITY ON LIFETIME OF PENSTOCKS OF PUMPING STORAGE POWER PLANTS

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AUSTRIA

ABSTRACT

With the increasing demand for energy and dynamic distribution of electric power the requirements on power plants are rising. This means for pumped storage hydro power stations an increasing amount of load cycles per year. One of the essential parts of a pumped hydro power station are the penstocks which are used to transport water back to the reservoir and as fall pipe down to the turbines. As welded pipes with longitudinal and circumferential welding seams the welding seams demand attention as a disturbance of the idealized geometry and microstructure of the steel. This paper shows the influence of fabrication on the stress situation and resultant lifetime of welded penstock pipes made of high strength steels.

High strength steels promise higher fatigue strengths and gently inclined gradients compared to the standard steel SN-curves. On the other hand high strength steels are more sensitive on notches, cracks and residual stresses. In conjunction with usually and exceptionally loadcases it is recommended to perform a fatigue calculation.

A very detailed investigation of the geometry of an exposed penstock with a succeeded stress and lifetime calculation was made in the course of an analysis of a typically realized hydro power plant. The geometry, especially of the longitudinal welds, was measured by laser measurement along a length of more than 1000m. This measurements provided the data input for detailed CAD and FE models of the longitudinal welding seam and the adjoined surface of the penstock. The detailed stress distribution at the welding seam is the result of the geometry measurements and the disposed measurements of water pressure at some locations along the penstock. To perform a lifetime calculation with suitable SN-curves it was necessary to test and evaluate welding samples which correlate with the penstock material. The result were three SN-curves for three different kinds of welding seam conditions. Combining all the data results in a lifetime calculation which shows the effect of fabrication quality on the lifetime of welding seams at a penstock.

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ATOM PROBE INVESTIGATIONS ON TEMPER EMBRITTLEMENT AND REVERSIBLE TEMPER EMBRITTLEMENT IN S 690 STEEL WELD METAL, TO EXPLAIN SUCCESSFUL REHABILITATION OF BRITTLE PENSTOCK WELDS

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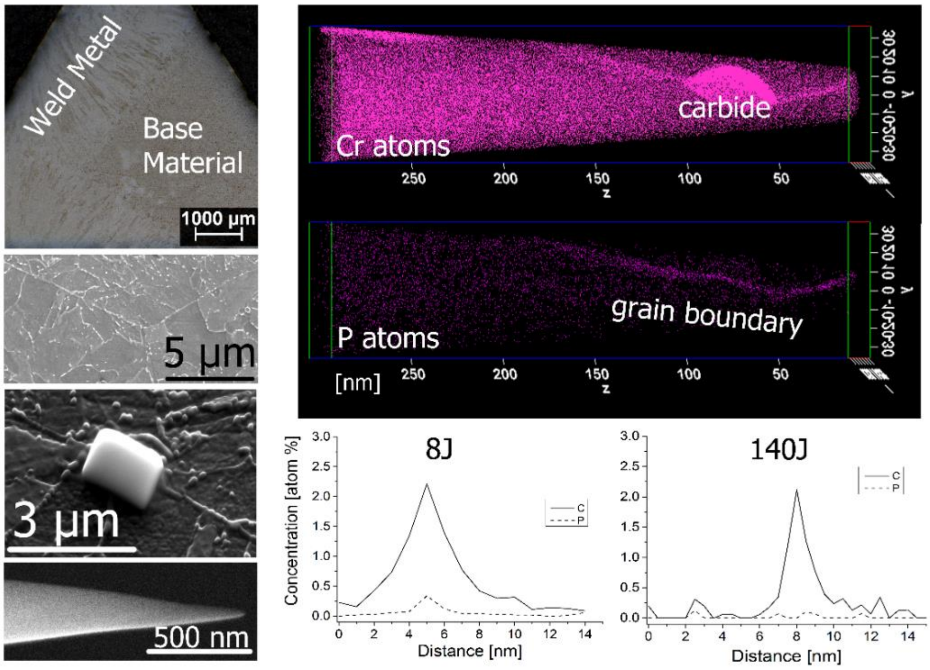
During the hydrostatic pressure test of a penstock, in a brand new large pumped-storage hydropower plant, a spectacular brittle fracture of a closure head occurred. The embrittlement was located in the manifold weld seams as well as in the post weld heat treated welds of the completed penstock.

The reason for the failure was temper embrittlement (TE), produced by a low cooling rate during the post weld heat treatment, having a strong influence on the toughness of the weld material. Our investigations were focused on one side in the clarification of the failure cause and on the other side to clarify why by application of a short time heat treatment (starting at 10 seconds at 600° C) the toughness of the embritteled weld material significantly recovered - effect of reversible temper embrittlement (RTE).

In order to understand the mechanism of RTE, high resolution analytics as Atom Probe Tomography (APT) were applied. The investigations reveal

phosphorus segregation in the high angle grain boundaries of the temper embrittlement material, see Fig. 1. When RTE treatment for few seconds was applied, phosphorus segregation in the grain boundaries disappears keeping the concentration of the other alloying elements unchanged.

The mechanism of this behavior could be explained by referring the Mc Lean based grain boundary equilibrium segregation of phosphorous. Grain boundary impurities, as can be phosphorus, can produce embrittlement in steels which can be explained by electronic models based on quantum mechanical cluster calculations. The impurity is electronegative with respect to the metal and draw charge from the metal onto themselves. As result, less charge is available to



participate in the metal–metal bonds and they are weakened. By the application of a RTE treatment around 600°C, diffusion of the impurities elements occurs faster because segregation starts at lower temperatures (around 550°C). During RTE treatment, the diffusion is much faster, producing the fast recovery of toughness.

The brittleness occurred in the post weld heat treated penstock welding`s could be recovered by site by application of qualified local electrical mat heating.

Fig. 1 shows the specimen preparation of a high angle grain boundary tip for atom probe tomography analysis. The results reveal segregation of phosphor at the high angle grain boundaries in the temper embritteled specimens (8J). The RTE specimens (140J) show phosphor free grains.

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SEISMOTECTONIC FEATURES AT RUDBAR LORESTAN DAM IN IRAN AND RESERVOIR SLOPE STABILITY DURING FIRST IMPOUNDMENT

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EXTENDED ABSTRACT

The 156 m high Rudbar Lorestan earth core rockfill dam, located in a narrow canyon in the seismically very active Zagros Mountain Range in Iran, had to be designed against multiple seismic hazards including ground shaking, movements along discontinuities in the footprint of the dam caused by nearby strong earthquakes, and rockfalls. Furthermore, in view of the proximity of a large fault, reservoir-triggered seismicity may occur during impounding and the first years of operation of the reservoir. The main concerns in the dam design were the discontinuities formed by joints, bedding planes, fissures and faults although there exist no active faults in the dam foundation, which could produce large earthquakes. The special design features of the dam, to cope with movements along multi-directional discontinuities in the footprint of the dam and the deformations in the dam body due to ground shaking are discussed. Construction of the dam body was completed in 2016 and first reservoir impounding was done in early 2017.The possible hazards from the failure of steep slopes in the

reservoir are presented. The different types of slope failures and wave erosion of the slopes, observed during the first impounding of the reservoir, are described. The volume of the largest activated slope is about 1.0-1.5 Mm^3. Further mass movements may be triggered in the future by earthquakes or heavy rainfalls.

Fig. 1
Rudbar Lorestan earth core rockfill dam, located in narrow gorge with multiple seismic hazards: ground shaking, movements along discontinuities in dam footprint and mass movements (rockfalls and landslides)
(Photo by M. Wieland)

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EVOLUTION OF STABILITY OF THE VERNAGO RESERVOIR SLOPES UNDER WATER LEVEL VARIATION, DURING SIXTY YEARS OF OPERATIONS

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1. THE DISPLACEMENTS OF THE RIGHT SLOPE OF THE VERNAGO BASIN

The right slope bounding the hydroelectric basin of Vernago, in northern Italy, showed slow and small movements associated with the drawdown-filling cycles of the reservoir, mainly concentrated in the glacial deposit within which the estimated sliding surface develops [1]. These movements, first observed and recorded during the early '70s, suggested new, specific geophysical and geotechnical investigations as well as the careful monitoring of the slope.

Inclinometer measurements showed that the slope displacements exhibit both reversible and non-reversible components (Fig. 1a), the later generally increasing during the slow reservoir drawdown. To reduce the strain rate of the slope and increase its safety factor, a stabilising berm at the bottom of the slope was built (Fig. 1b).

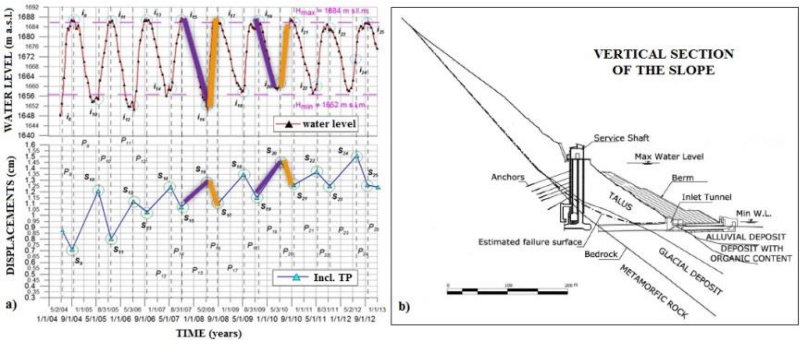

Fig. 1. a) Measured displacements; b) Vertical cross-section of the slope

Piezometer readings revealed differences between the water level in reservoir and the piezometric head (p.h.) within the upper portion of the slope subjected to movements, during operation; therefore, a transient seepage flow regime occurs.

2. ANALYSES AND MAIN RESULTS

The relationships between the changes of slope safety of the Vernago basin, the cumulated displacements and the variation in the reservoir water level during the drawdown phase are investigated through coupled transient seepage flow and stability analyses (FEA, LEM) [2] [3] [4]. The time evolution of the measured values of the piezometric heads has been numerically simulated; the hydromechanical response of the slope always depends on the adopted variation in reservoir water level (Fig. 2a) which in turn induces a transient seepage flow regime, affected by different characteristics according to filling and drawdown phases. Analyses showed that the displacements only occur under specific drawdown conditions, confirming the in situ measurements. Several regression analyses of measured slope displacements (Fig. 2b) finally allowed to identify the correlation between displacements and variables related to filling - drawdown cycles (e.g. maximum and minimum water levels, rate of change in water level, persistence of maximum water level). The results can be also used to forecast different displacements evolutions following new operation procedures.

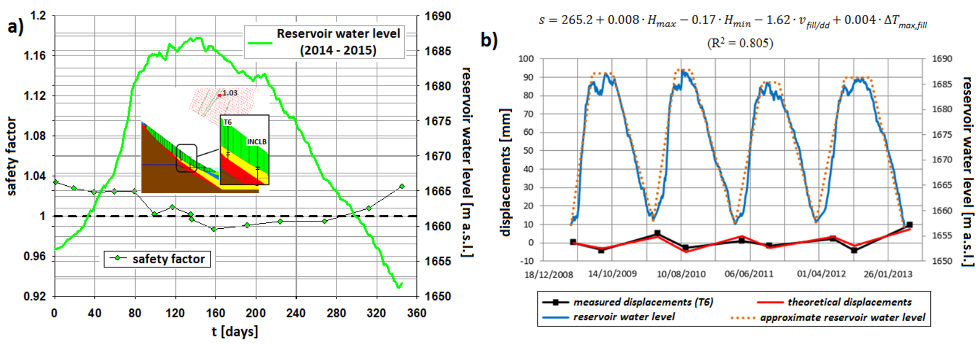

Fig. 2. a) Coupled transient seepage flow and stability analyses; b) Regression analyses

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RESEARCH ON STABILITY OF RESERVOIR ACCUMULATIVE BODY SLOPE AND THE IMPACT OF WATER STORAGE

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The landslide of reservoir slopes during the course of water storage and reservoir operation may cause heavy casualties and loss of property. A large-scale

high-speed landslide may cause high wave surge which may even endangers the safety of a waterpower project. Therefore, the stability of those slopes is an important subject in the design of a hydropower station.

As shown in Fig.1, there is a large-scale high steep reservoir slope that is now in critical steady state which is only 5 km away from the 315m high rockfill dam of the hydropower station in the south-west china. It may lose stability during the process of reservoir filling or operation, and the landslide wave surge is dangerous to the safety of the rockfill dam.

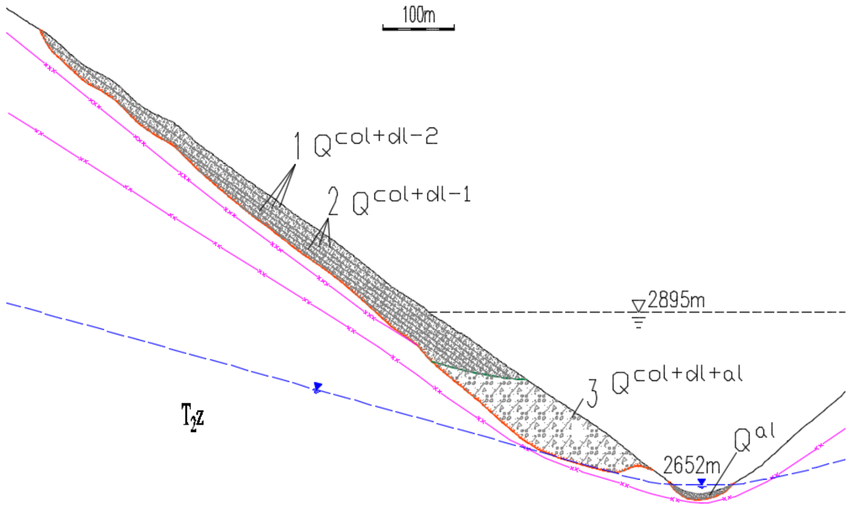

Fig.1

The typical geological section of the reservoir slope

1 Colluvial gravel with a certain amount of fine grain soil; 2 Gravel sandwich

3 Gravel soil with a small amount of gravel

The accumulative body of the slope is composed of a gravel with fine soil layer with multi-layer s gravel sandwiches and a gravel soil. The parameters of shear strength of these gravel or soils decreases while its saturated. Both sliding mode of circle arc or combined curve which go through a sandwich are possible. In this paper, both the sliding mode and factors of safety along a circle arc and the combined rigid body slip surfaces in different water level conditions are analyzed by the strength reduction method and the improved limit equilibrium method based on finite element stress calculation. The influence of reservoir water level rise on sliding mode and safety factor is discussed.

KEY WORDS

reservoir slope, stability; safety factor; slip surface; seepage

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DAM UPGRADES USING MECHANICALLY STABILIZED EARTH

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1. INTRODUCTION

The first Mechanically Stabilized Earth (MSE) walls for dam applications were constructed using Reinforced Earth® in 1973, soon after development of the MSE technology by Henri Vidal in the late 1960s. Since these first structures, MSE walls have been used around the world to meet the challenges represented by a variety of waterway structures that include dams and dam upgrades. With time, the technology has evolved primarily in the type of reinforcements used to meet the site conditions imposed by geotechnical and hydraulic conditions. When galvanized steel reinforcements were used, as done with the first MSE walls, the physio-chemical parameters of soils created somewhat more restrictive considerations than those for ordinary dry land structures. Over time, geosynthetic materials were an additional reinforcement type evaluated to meet the submerged conditions represented by hydraulic-based MSE structures. This paper will provide an overview of MSE wall technology in dam structures. It will then go on to address specific considerations needed on dam upgrades for stability and increased water storage retention that has been the more recent application focus. The paper will be supplemented by case studies representing steel and geosynthetic reinforcement applications for dam upgrades.

2. MSE WALL DAMS AND UPGRADES

MSE structures are typically composed of precast concrete facing panels joined by reinforcing strips or grids (either steel or geosynthetic) within a soil or gravel select fill matrix. The frictional bond between the back¬fill and the reinforcements is permanent and predictable and there is a reliable mechanical connection between reinforcements and facing panels. As a retaining structure, MSE represents a unique, composite construction material having great strength and stability, a limited footprint and the ability to distribute loads uniformly, even on poor foundation soils.

The use of MSE walls in the construction of earth dams allows the reduction or elimination of the structure's upstream and downstream slopes. Resulting in considerable project savings. MSE walls make it possible to build a dam spillway with sill at the very crest of the structure, eliminating costly gates and other flood control structures that would otherwise be required in addition to the dam. These advantages may also be realized in other types of vertical walls. However, MSE walls have the additional unique benefits of structural flexibility, speed of construction and integration of embankment and spillway work.

The stability of a dam and spillway under MSE applications essentially depends on computing the slope stability of the upstream embankment against failure and computing the internal downstream stability of the MSE volume. The normal operations and flood condition considerations must be incorporated into the design evaluations. In cases of upgrades, the modifications made need to follow new storage or flood level volumes dictated for the dam and spillway. More detailed design considerations for upgrades will be addressed in the full paper.

3. CASE STUDIES

Two case studies will also be addressed in the full paper to represent dam upgrades using reinforcement applications of steel and geosynthetic strips. The steel strip reinforcement application for dam and spillway upgrades to capacity was used in the 54 meter high Chaffey Dam located 43 km southeast of Tamworth, NSW, Australia. The geosynthetic strip reinforcement application will address a dam upgrade also to increase capacity for the resulting 69 m high Los Vaqueros Dam located in northern California, USA.

Conclusions to the paper will summarize technical and economic benefits to use of MSE walls in dam upgrades. References will also be addressed at the conclusion of the paper as well.

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STUDY OF RESERVOIR RIM SLOPE STABILITY DUE TO OPERATION OF SUSU DAM

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MALAYSIA

1. INTRODUCTION

Susu Dam is part of the Ulu Jelai Hydroelectric Project undertaken by the national power company (TNB) which could generate 372MW. Its main dam, with a height of 88m, is located in Cameron Highlands, about 200km north of Kuala Lumpur. This reservoir is one of the dams in Malaysia with major fluctuation during its operation. Leryar Village, which is a settlement for about 400 aborigines, is located on the bank and a rim slope failure could be catastrophic to the community. As such, this study investigates the landslide hazards due to the fluctuation of Susu reservoir and rainfall infiltration, by conducting soil investigation, hazard mapping and advanced laboratory tests.

2. METHODS

Rainfall data for the past 30 years were analyzed so that the intensity and duration of a rainfall event with a return period of 1:10 years could be estimated. Field assessments and GIS analyses were conducted so that hazard maps could be produced using methods proposed by Anbalagan (1992). Advanced lab tests, i.e. permeability, CU, CD and SWRC, were carried out to obtain the hydraulic and mechanical properties of the top soil layer, in the saturated and unsaturated states. The hydraulic conductivity relationship and the shear strength contribution with increase in suction were then deduced using methods proposed by Van Genuthen (1980), Freudland & Morgenstern (1977) and Ho & Freudland (1982).

3. RESULTS

Results of Factor of Safety (FOS) from slope stability analyses using this method differs greatly from the methods normally used by practitioners. Conventional methods would conclude that the slopes are sufficiently stable with FOS values of at least 1.47, while this method, which involved rigorous testing and numerical modeling, resulted in FOS as low as 0.37. It is also noted that hazard maps produced using a qualitative and probabilistic approach agrees well with the FOS of the specific slopes, which is quantitative and deterministic.

4. CONCLUSION

This study exhibits the need to conduct extensive soil tests and apply the latest theories in soil mechanics to obtain reliable FOS for shallow failures involving transient flow conditions, such as rapid drawdown and rainfall infiltration. It also suggests that qualitative hazard assessment could be used as a precursor to advanced soil tests and numerical modeling, which are costly.

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Keywords: Landslide, Stability, Safety Factor, Finite Elements Method, Soil Mechanics, Soil Investigation, Shear Stress, Susu Dam.

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MONITORING OF THE SLOPE STABILITY OF RESERVOIRS: AN UPDATE ON THE OBSERVATIONAL METHOD. THE CASE OF A DAM IN PORTUGAL

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PORTUGAL

1. INTRODUCTION

The observational method applied to monitoring slope stability in dams and reservoirs aims to provide substantial information for a proper risk management, during the construction and operation of these critical infrastructures.

This paper proposes to describe, explore and discuss the advantages and limitations of the data obtained by geological in situ inspections, classical geotechnical monitoring techniques (such as inclinometers, piezometers, etc.) and geodetic surveying techniques applied in large areas, together with the use of remote sensing techniques, like InSAR. This combination allows the information to be maximized in terms of areal coverage, accuracy and data integration.

In the case study presented, this analysis proved to be a great help to decision making in the context of a hydropower reservoir in Portugal owned by EDP, with a capacity of 106 hm3 and an area of 421 ha, created by a dam 110 meters high and 275 meters long at the crest, which has associated a powerhouse with a generation capacity of 263 MW.

2. MONITORING PROGRAMME FOR SURVEYING SLOPE STABILITY

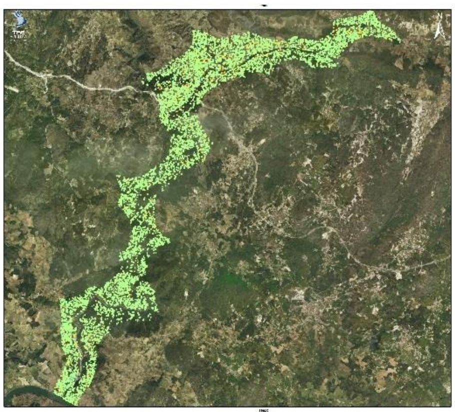
The program for monitoring the slope stability of the reservoir included, locally, the installation and reading of several inclinometers and also the observation of several particular slopes whose safety can be compromised for geotechnical reasons and/or for their specific characteristics.

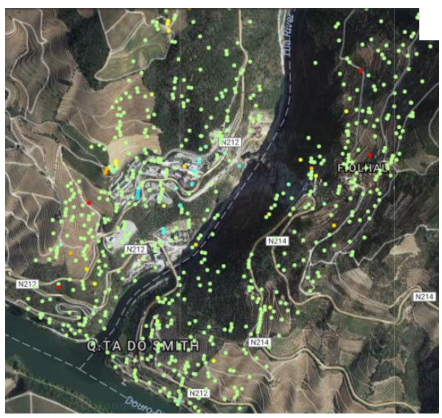
Dam monitoring includes the installation of topographical prisms over the dam body and also several topographic references that help the stability of the system in terms of precision and accuracy. Those reference prisms are also installed in the slopes, so in areas of potential movement. The use of other systems that can help to monitor these references and correct the final real displacement is also of interest.

InSAR remote sensing monitoring was analyzed in order to verify if this technique could be applied to:

- obtain displacement information over the remote slopes where there is no option to install in-situ devices,
- check if the reference prisms are in moving areas,
- obtain a general overview of the stability of the slopes and also helps to optimize the installation and readings of other geotechnical instruments.

Figure 1
Results obtained for slope monitoring with InSAR technology. Displacement map with general overview on the area (left) and results showing motion on the slopes close to the dam body (right).





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COUNTERWEIGHT AS JATIGEDE DAM LANDSLIDE STABILITY COUNTERMEASURE

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INDONESIA

1. INTRODUCTION

Jatigede Dam is the second largest storage dam in Indonesia that reaches almost 1 billion m^3. Completed in 2016, this dam is located in Cimanuk River, Jatigede Subdistrict, Sumedang District of West Java Province, Jatigede Dam is a center core rockfill dam with 114 m height and 1,715 m length. The main purposes of Jatigede Dam are to fulfill 90,000 ha irrigation area, 3,500 l/s of Cirebon and Indramayu water supply, 2 x 55 MW of hydropower, and flood control of 14,000 Ha area around Cimanuk River.

The dam site area generally has an intensive and complex tectonic geological structure. The existence of this complex structure causes the dam site area be vulnerable of landslide. Downstream of the left and right slope of the dam and the upper left bank of main cofferdam are the landslide locations. Geological structure and high rainfall intensity are the main factors that cause the landslide.

During the early initial excavation, some landslides had occurred on both left and right banks, wrecking the facility buildings and access roads thus halted the construction progress. This issue is fixed by anchor method consists of bored piles as well as drainage and slopes improvement until the completion of all the construction.

2. PROPOSED COUNTERMEASURES

With regard to the analysison type, some countermeasures are proposed based on cause and mechanism of the landslide:

1. Construction of proper surface and subsurface drainage system.
2. Improvement on bored piles lines or soil nailing down to depth perpendicular to the deep sliding plane, around the bank’s toe. Specifications of bored piles/soil nailing should be based upon detailed engineering calculation.
3. Construction of counterweight at the toe of left bank, which could also serve as footing for the right bank after the landslide configuration is fully discovered.
4. Intensive monitoring on the mentioned proposed measures, with addition of inclinometers, piezometers, observation wells as well as mirror reflector for robotic monitoring system, especially in the landslide zones.

CONCLUSION

A recent visual inspection and instruments reading show a diminishing sliding magnitude and tends to be constant in line with rainfall intensity. Therefore, it is strongly advised for the initial imponding to be carried out gradually with a temporary halt at elevation +221 m in order to have a better understanding on the correlation between water level and land sliding.

The proposed sequential countermeasures, namely bored piles, counterweight construction and drainage system, could be implemented in parallel with or after the initial imponding.

Keywords: Counterweight, Jatigede Dam, Landslide

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EVALUATION OF SEISMIC PERFORMANCE OF EARTH DAMS DUE TO THE LEVEL OF ITS RESERVOIR USING FINITE ELEMENT METHOD

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ABSTRACT

One of the challenges in engineering world is investigation on seismic behavior of earthdams during an earthquake. The complexity of this issue is lack of adequate information about the impact of the earthquake on earthdams behavior. Many scientists presented an important research in this area. Dam stability during the earthquake is one of considerable factors which can be estimated by various parameters. In this paper, as a reliable parameter, safety factor is estimated using finite element method in PLAXIS 2D software.

In this paper, reservoir water level is considered as a noticeable parameter which affects on stability of earthdam and safety factor during an earthquake. For this purpose, two different water levels, %30 and %70 of earthdam height, is assumed for reservoir. Also, in order to consider effects of earthquake, a magnitude MW 6.8 earthquake is applied to model. Angle of internal friction of earthdam materials is 30 to 35 Degree and the side slopes are 1:2.7. Additionally, as isotropy has no enormous impact on results, isotropic materials are assumed for earthdam. Analysis results indicate reservoir water level increasing from %30 to %70 of earthdam height has direct impact on safety factor reduction up to %8.

KEYWORDS

Earthdam, reservoir level, finite element method, seismic performance, safety factor

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THREE LARGE RESERVOIRS OPERATION IN THE CASCADE SYSTEM CITARUM RIVER - INDONESIA

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The three reservoirs are all situated on the Citarum, West Java. The Ir. H. Djuanda reservoir, which already exists since 1967 is the most downstream one. The next upstream reservoir is Cirata which is expected to become operational by 1987. The Saguling reservoir is the most upstream one and will start its operation in the most upstream one and will start its operation in the course of 1985.

Reservoirs can be operated by means of rule curves. These curves relate storage and time, several curves can be applied at the same time. Depending on the position of the release for the next periods are taken. The linier or dynamic programming method is a famous and classic method to optimize a reservoir system, and it was therefore chosen for application here. With this method it is possible to decide under uncertainly with in the most optimal “path” of reservoir level.

For the integrated hydro-power optimization from the three reservoirs cannot be special for the power production, caused by the multipurpose dam in downstream which fulfill water requirements and the system as a whole has to be operated such that flood control is maximal. Ad hoc adjustments are made during emergency situations on daily or even shorter basis. The rule curves produced had

been optimized with respect to power production in the system. At the same time monthly target storage was derived with respect to flood protection and water supply for all purposes. Optimization method cannot always be applied considering the complexity of constraints that must be adopted.

The methodology to develop normal system operations in a multipurpose reservoir and include development of optimal end-of-month storage which maximize the expected value of selected primary objective function for the system, subject to satisfying other system objectives based on the specification of target performance levels.

Reservoirs can be operated by means of rule curves. These curves relate storage and time, several curves can be applied at the same time. Depending on the position of the release for the next periods are taken. The linear programming method is a famous and classic method to optimize a reservoir system, and it was therefore chosen for application here.

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ANALYSIS THE EFFECT OF SOIL PERMEABILITY OF THE UPSTREAM SHELL ON THE DAM STABILITY UNDER RAPID DRAWDOWN (BRADON DAM)

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INTRODUCTION

The stability of the dams' upstream shell is changed under the rapid drawdown conditions, where the pore water pressure has different values according to the soil permeability. Transient groundwater flow calculations and stability analysis were analyzed with Geo-Studio Program. The aim of this study is to determine the effect of the rapid drawdown of the Bradon dam reservoir on the upstream shell stability for two different discharges scenarios and different types of available soils in situ.

The dam to be considered is 62.5 m high and the width is 366 m at the base and 12 m at the top. The dam consists of a central clay core, tow filter zones and rock fill shoulders. The normal water level behind the dam is 193.8 m high.

Various scenarios for rapid discharge cases were studied to determine the safety factor of water drop from 193.8 m to 167 m in linear form for two discharge cases. The first case is through the irrigation outlet 25 m3/s and the second is through a tunnel transforming 500 m3/s.

The obtained results show that the stability of the upper slope change under considered boundary conditions according to the soil type. Some soil has good stability factor while other soil collapsed after a specified time. So, we can conclude that the soil type of the upper dam slope is important and we could choose the appropriate type which does not cause danger during the rapid drawdown. Also, the effect of the ratio between the permeability of the upper slope and the permeability of the clay core (ks/kc) was calculated, the results show for the studied soils in the first case of discharge that the ratio (ks/kc)=165 is interval value between stable and unstable soils. While for the second case of discharge the ratio is (ks/kc) =7898.

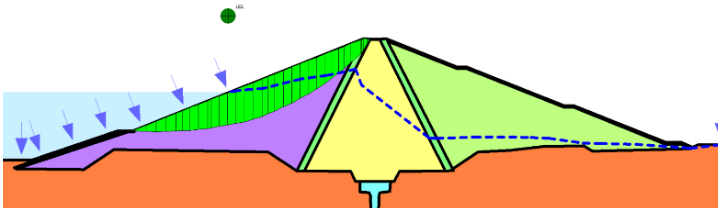

Fig. 1: Safety factor of upper slope in case of the discharge through the tunnel (gravel)

Table 1: Minimum safety factor in the case of the first discharge program through the irrigation outlet

Soil type	Safety factor	the ratio ks/kc	The range
gravel-pebble (Bradon dam state)	2.25	16949.15	>10000
gravel	1.729	14644.07	
Sand	1.595	7898.305	>1000
Uniform Fine Sand #1	1.359	3148.475	
Embankment (silty clay)	1.279	169.4915	>100
Uniform Fine Sand #2	1.198	165.4237	
Silt #2	0.981	146.4407	
Silt Loam	0.968	102.5424	
Sandy Loam	1.169	85.76271	>10
Silty Sand	0.984	73.22034	
Sandy Silty Clay	1.166	20.50847	
Silty Clay	0.936	4.40678	<10
Very Fine Sand	1.046	2.881356	
Clay (Core soil)	2.01	1	1

KEYWORDS

Rock fill dam, safety factor, stability, transient seepage, Bradon dam.

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EARTH DAMS SAFETY UNDER SEISMIC MOTION USING LIMIT EQUILIBRIUM METHOD AND PHYSICAL MODELING

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ABSTRACT

The aim of the present research is the evaluating of Limit Equilibrium method to assess factor of safety under the nseismic load for earth dam using physical small-scale modeling. For this purpose, numerical analysis to evaluate slope stability under the vertical peak ground acceleration (PGA) was carried out using Geostudio program. In parallel, small-scale physical modeling (1/100) was tested using vibrator table device in order to observe slope stability of the dam by seismic motion effect. As result, the weak performance was obtained for assessing factor of safety under the seismic load using Limit equilibrium method (LEM). Based on Physical modeling, damage with respect to longitudinal cracks was dramatically observed at upstream and crest during the seismic motion while the simulated models were safe with same acceleration. Consequently, the good agreement was found between modeling tests and lesson learned from literature. Finally, due to predict dam safety along seismic motion using LEM, design acceleration of the dam site should be increasingly applied using (PGA+ 0.2g) for simulation.

KEYWORDS

Factor of safety, Vibrator table, Acceleration, Physical modeling, Limit Equilibrium

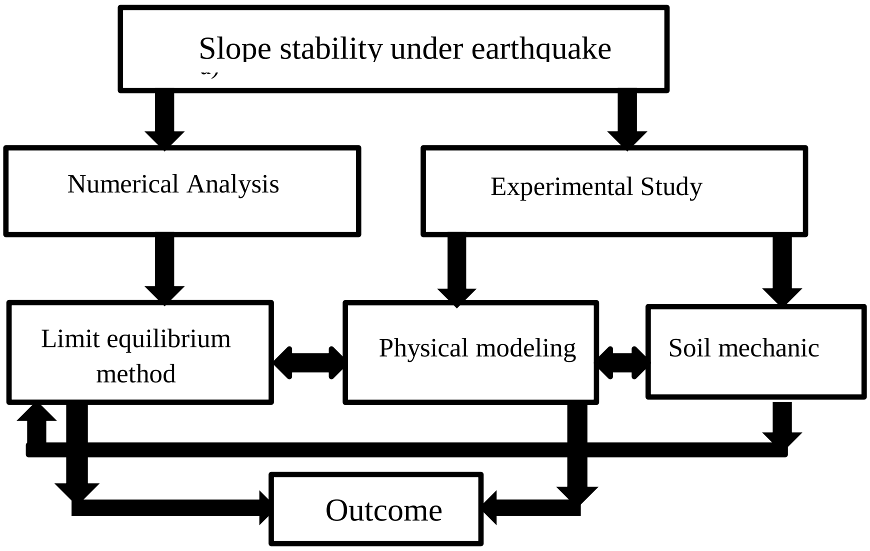
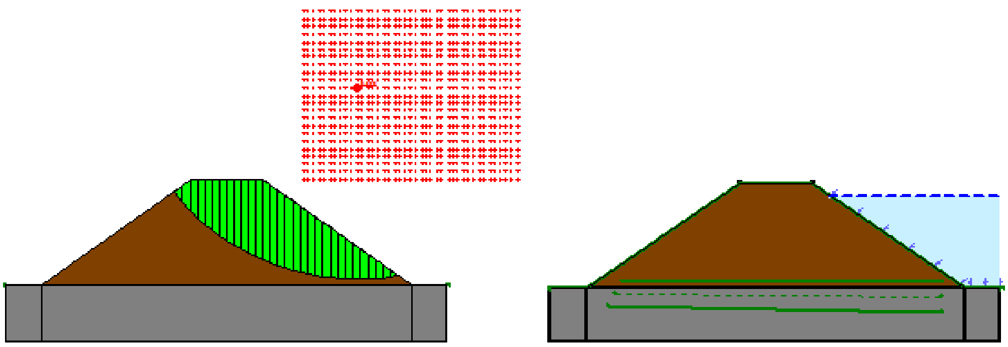


Fig. 2: Flowchart

Fig. 12: First small scale mode on vibrator table



a) b)

Fig. 24: Factor of safety in dynamic condition, a) Safety map b) model with tank

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FLOOD WAVE ANALYSIS OF EMBANKMENT DAM FAILURE BY USING 2D MODELS

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ABSTRACT

The present paper deals with the topic of flood wave analysis due to embankment dam failure. The key part of this thesis is the flood routing of two case studies by using two-dimensional flow models. The first case describes the failure of a permanently impounded large dam in an alpine area due to an initial breach. In the second case study, a smaller flood retention basin in the lowlands is analyzed according to an overtopping failure. The two investigated cases are widely different in terms of dam height, reservoir volume and downhill gradient.

At the beginning of every case study, a computational model is set up on the base of a digital terrain model of the downstream area. By using different breach models, it is possible to generate a range of hydrographs, describing the outflow of the reservoir. The analysis is carried out by using HEC-RAS 2D in order to predict the flood areas as well as the maximum flood levels in the effected villages. Furthermore, a special focus is set on modelling geometric boundaries caused by structures like culverts, bridges or tunnels (see Fig. 1a). The validations of the numerical models are conducted through previous investigations with other software packages.

The gained results, such as water depths and flow velocities (see Fig. 1b and 1c) are analyzed for critical parts of the studied downstream area. Furthermore, a comparison of the characteristic flooded areas for every failure hydrograph is conducted, in order to investigate the influence of the peak value on the gained results.

Finally, warning times for the different flood waves will be determined, which build the basis for emergency action plans as well as a following loss of life estimation of the two case studies.

Fig. 1
a) LIDAR data with grid, b) contour plot of water depth with flow vectors, c) contour plot of flow velocity

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RISK MANAGEMENT FOR THE LAGO BIANCO RESERVOIR IN CASE THE CAMBRENA GLACIER RUPTURES*

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ABSTRACT

The Lago Bianco reservoir is situated in southeastern Switzerland at an altitude of 2235 m and is used for electricity production. The reservoir with a storage volume of 19×10^6 m^3 is formed by two dams, the 13 m high gravity Arlas dam in the north and the 26 m high gravity-arch Scala dam in the south. The dams were originally built in 1911, extended in 1941 and renovated in 2001.

During the in-depth safety review, which according to Swiss legislation is carried out every fifth year, it was discovered in 2014 that the retreating Cambrena glacier had introduced a new risk to the reservoir: The melting southern glacier tongue is slowly moving backwards into a steep rock step and therefore losing its support at the front end and on both sides. According to the glacier specialists there is a danger for a maximum rupture of 1.5×10^6 m^3 of ice. They estimate that the glacier front will be above the steep rock step in about 10 years, at that point the possible volume of an ice rupture will decrease down to zero.

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* *Gestion du risque au réservoir de Lago Bianco en cas de rupture du glacier de Cambrena*

Numerical simulations carried out immediately after the discovery of the new risk showed that a substantial part of the rupturing ice could reach the Lago Bianco reservoir with high speed and initiate an impulse flood wave of up to 4.5 m height directed towards the Arlas dam. For reservoir levels close to the maximum operating level the impulse flood wave could overtop the dam crest and possibly initiate a dam break.

A glacier rupture announces itself by an increasing speed of the regular ice flow. A continuous measuring of the ice flow speed allows for a warning and gives time—at least a week—for additional safety measures. Therefore, a photographic camera was installed on rock above the melting tongue of the Cambrena glacier. Using the camera pictures the glacier specialists evaluate the ice flow speed on a daily basis and give immediate warnings, if predefined threshold values are exceeded.

The owner of the Lago Bianco reservoir established an emergency preparedness plan specifically for the case of a rupture of the Cambrena glacier. If the threshold values for the ice flow speed are reached, the reservoir level will be lowered as far down as is necessary to prevent an overtopping of the Arlas dam. For the maximum rupture of 1.5×10^6 m^3 of ice the safe reservoir level is 2.5 m below the normal operating level. If the ice flow speed increases faster than predicted before the safe reservoir level is reached, the emergency service of the Swiss civil protection will alarm the population in the danger zone and close down both highway and railway passing by the Lago Bianco reservoir.

Fig. 1
Arlas dam of the Lago Bianco reservoir with the Cambrena glacier, whose southern (left) tongue is threatening with a rupture (Photo J. Maier)
Barrage d’Arlas au réservoir de Lago Bianco avec le glacier de Cambrena, dont la langue sud (gauche) menace de se rompre (Photo J. Maier)

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SERVER DESIGN STANDARDS OF RESERVOIR FAILURE ALERT SYSTEM

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1. INTRODUCTION

The increased number of residents due to the development of downstream areas is directly related to massive casualties and property damages. Therefore, along with the existing safety evaluation, a failure alert system that detects and controls early signs of failure and damage in real time, considering various risk factors and uncertainties, is desperately needed.

2. SERVER DESIGN STANDARD ESTABLISHMENT METHODS

This alert system is aimed to be developed as a web system to respond actively to various sensors, business logic and changes of user's work, and to improve system utilization by reducing logic changes and client maintenance with minimal interface change.

3. CASE STUDY AND ANALYSIS

Tab. 1 Purpose of H/W structure

Item	Purpose
Data Logger	To collect data from installed sensors in site
Collection Server	To collect data from Data Logger and send to DB Server
DB Server	To save observed data in the format of raw, statistic, backup, and processed
WAS Server	To access sensor data and to drive alert program
WEB Server	To save/service HTM and, image file

Tab. 1 shows the H/W and configuration purposes to be achieved in the failure alert system based on similar case studies such as "Ubiquitous Sensor Network (USN) Reservoir Failure Forecasting and Warning System", an information pilot project of Korea Rural Community Corporation, the "Disaster Prevention Monitoring System", the "USN Steep Slope Failure Forecasting and Warning System" of the Ministry of Public Safety and Security, and the "Waterfront Structure Integrated Safety Management System" of Korea Water Resources Corporation (K-water).

4. SERVER DESIGN STANDARD SUGGESTIONS

Table 2 Selected S/W for alert system

Item	S/W	Reason
Development language	JAVA	- WEB program standard - e-Government standard framework
Operating system	Linux	- Open source so low application cost - To work in low H/W spec
Communication F/W	Apache spark	- Open source so no application cost - IoT real time data collection and analysis
DB	Cubrid	- Open source so no application cost - DB of eGovernment standard
WAS Server	JBOSS	- Open source so low application cost - WAS S/W of e-Government standard
WEB Server	Apache	- Open source so low application cost - WEB S/W of e-Government standard

The H/W configuration of the introduced WEB, WAS, and DB server use the introduced H/W that supports the open O/S Linux as the standard, and the basic O/S is based on the Open S/W Linux. Table 3 shows selected S/W for server design standards.

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SLOPE MONITORING BY DISTRIBUTED FIBER-OPTIC SENSING: PROJECT EXAMPLES, RESULTS AND LIMITATIONS

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1. INTRODUCTION AND METHODOLOGY

Reservoir slopes, dams and hydropower infrastructure, such as water pipelines or transportation ways, often lay within areas of potential soil movements. These areas, affected by unstable slopes and differential settlements, mostly have a large aerial extension, which makes it particularly difficult to identify the critical zones. Distributed fiber-optic sensors that are capable of providing monitoring data for thousands of individual sections along a sensing cable of up to several kilometers of length can reveal possible threats over a large area. The authors have wide experience with soil- and rock-embedded distributed fiber-optic sensing solutions for landslide and infrastructure monitoring and share their particular experience in this paper. Besides detailed project examples and monitoring data, the challenges and limitations of the fiber-optic methods are discussed.

2. PROJECT EXAMPLES

- Pipeline monitoring in creeping landslides;
- Dam stability monitoring by borehole-embedded sensors;
- Landslide site investigation by horizontal and vertical sensors;
- Possible substitution of inclinometers by fiber-optic sensors.

For example, Figure 1a shows the instrumentation of a hydropower pipeline crossing creeping slopes and Figure 1b shows the strain data measured along this pipeline. It can be clearly seen that at a specific location, a strong compression is measured. This compression indicates a shear zone which may endanger the pipeline integrity.

a)

b)

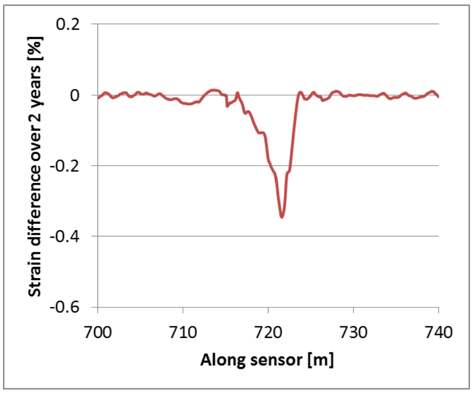

Fig. 1
(a) Pipeline monitoring by soil-embedded fiber-optic sensor; (b) field data.

3. CONCLUSIONS

From the projects shown, the following main conclusions can be drawn:

1) Well-funded monitoring results were obtained and compared to alternative data. Due to the high sensitivity and the ideal positioning of the sensors, movements are often much quicker detected compared to other methods. This adds time for decision making and reaction.
2) The equipping of soil (horizontal and vertical) with only one longitudinal sensor is a simple and efficient method. The installation is straightforward and cost-efficient, even for large size projects.
3) For boreholes, one must be aware that this is not a one to one substitution of an inclinometer. Nevertheless, depending on the project, it may as well provide more than sufficient information about the ground behavior. And in contrary to the inclinometer this information can be obtained by a moderate installation and readout effort.
4) For most cases, qualitative assessment should be the main priority since it is rather difficult to obtain quantitative results.

KEYWORDS

Automated Monitoring, Extensometer, Landslide

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INSAR & PHOTOMONITORINGTM FOR DAMS AND RESERVOIR SLOPES HEALTH & SAFETY MONITORING

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EXTENDED ABSTRACT

Remote Sensing techniques have proven to be a powerful tool for different purposes in dams and reservoir slopes monitoring applications. The evolution of traditional technologies (e.g., GNSS, Laser Scanner) and the development of emerging technologies (e.g., Satellite & Terrestrial radar technologies and PhotoMonitoring™) are currently offering a wide spectrum of applications, providing effective monitoring solutions at different stages of the life cycle of a dam (i.e., design, construction, operation and maintenance), such as: dam reservoir site selection, reservoir catchment management, detection and control of reservoir geohazard-prone areas, structural health monitoring of dams, risk management and risk-informed decision-making.

As regards the radar-based technologies, Satellite and Terrestrial SAR (Synthetic Aperture Radar) interferometry, represent some of the most advanced and effective techniques for monitoring deformations of both ground and man-made structures.

The capability of monitoring large areas with high accuracy of Satellite SAR Interferometry, as well as the ability to perform historical analyses (thanks to archive satellite SAR images available from 1992), make it a suitable monitoring solution for the characterization of reservoir slopes and the detection of potentially unstable slopes at reservoir scale, allowing to undertake the appropriate risk management strategies.

Terrestrial SAR interferometry, on the other hand, thanks to its high sampling frequency of data collection (in the order of few minutes or even seconds) and its high accuracy of displacement measurement (up to decimal millimetre order), has proven to be effective for local-scale real-time slopes and structures monitoring, currently considered a proper technology for Early Warning purposes.

In addition to radar-based technologies, cutting-edge solutions like the PhotoMonitoring™ are now available for dams and reservoir slopes monitoring. The concept PhotoMonitoring™ refers to different image processing techniques can be used for geotechnical and structural monitoring purposes. Among these techniques are included Digital Image Correlation (DIC), Change Detection and 3D Photogrammetry.

An overview of some of the most challenging projects carried out by NHAZCA using both Satellite and Terrestrial SAR Interferometry and PhotoMonitoring™ techniques, for landslide risk management, Early Warning, dam safety and surveillance purposes will be presented.

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SLOPE STABILITY ANALYSIS IN GAMBIRI DIVERSION DAM USING NUMERICAL MODELS

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IRAN

1. INTRODUCTION

The Gambiri diversion dam site is located in Kunar province, eastern Afghanistan, near Asadabad city. The site location in the global coordinates system is defined with X =680248 and Y =3842647. The Gambiri diversion dam is an earth dam with a clay core and elevation from river bed is 10.5 meters.

2. ANALYSIS METHOD

In order to achieve the objectives of this study, Slope/W software [1] is used. In the slope stability of upstream and downstream slopes of an earth-fill dam, stability analysis is generally performed in the following states:

- During or at the end of construction
- Operation state (steady seepage) and full reservoir (maximum water level)
- Each of above states in earthquake conditions
- Reservoir rapid drawdown

3. STABILITY ANALYSIS OF EARTH DYKE BODY SLOPES

3.1 ENGINEERING CHARACTERISTICS OF EARTH DYKE FOUNDATION AND BODY MATERIALS

In this analysis, dyke foundation is assumed to consist of two major layers:

- Upper alluvial layer consisting of sand and gravel with average density and a thickness of about 10 m
- Lower dense layer of sandy gravel with thickness about 60 m

In the pseudo-static analysis using MDE seismic level and prior comments acceleration 0.18 g is selected.

CONCLUSION

In the present study Slope/W software is used under different conditions to evaluate slope stability. Based on the results from all slope stability analyses performed on critical section of Gambiri earth dyke in different loading conditions (static and pseudo-static analysis), it is observed that dyke body with upstream slope of 1:3 (vertical: horizontal) and downstream slope of 1: 2.5 (vertical: horizontal) is always stable.

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KEY WORDS

Analysis, earthfill dam, finite elements method, slope stability

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A METHODOLOGY FOR THE MAPPING OF TERRAIN MORPHOLOGY OF DAM BASINS BY MEANS OF SPACEBORNE SAR IMAGES

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PORTUGAL

EXTENDED ABSTRACT

The dam basin and the area around it could affected by important geological phenomena such as slope instability, erosion and sedimentation. Recently, a new methodology for the mapping of intertidal for the mapping of intertidal zone in estuarine, based on the use of Synthetic Aperture Radar (SAR) images [1]. This result makes the use of SAR images an interesting alternative for the mapping of small changes of terrain morphology due to erosion and sedimentation. The intensity variations in a SAR image are related to the surface roughness and dielectric proprieties as well as to the polarimetric proprieties and the local incidence angle of SAR acquisition. Geometrical distortions such as foreshortening, layover and shadowing strongly affect the amplitude of SAR images in mountainous regions and even in areas with a moderate topography. A water basin appears as a dark patch on a SAR image as a result of the surface

specular reflection. The exposed terrain surface behaves as a diffuse reflector due the terrain roughness. This property of SAR image intensity allows to identify the waterline and distinguish between the dam lake and the terrain surface around it. The waterline of dam basin changes in time according to the water level. As a consequence, if the time series of water levels is known, the temporal evolution of the waterline can be observed and the land/water separation used to generate the DEM of the dam basin. The precision of terrain morphology estimation depends on the precision of water level measurements. The proposed algorithm is based on the assumption that soil moisture and roughness have different temporal scales. The idea of this work is to use the temporal changes of water level in the dam basin to map the terrain morphology of the whole area covered by water during the maximum extension of the lake. This would allow to identify areas in the dam basin where soil accumulated due to sedimentation or affected by soil depletion due to erosion and so to estimate the seasonal variation of useful water volume of the dam. Furthermore, this would also help to map the lake shoreline variations due to erosion as a function of the water level. The result depends on the spatial resolution of SAR images and the wavelength of the SAR sensor. The spatial resolution provides the precision of the waterline identification and so the spatial resolution of the DEM. The wavelength directly affects the scattering properties of terrain and water surfaces and so the capability to distinguish between water and land which at the basis of the proposed methodology. Furthermore, the application of the methodology depends also on the exposure of the dam basin with respect to the line-of-sight of current spaceborne SAR sensors which are always moving along a polar orbit. It could happen that portions of the lake cannot be observable on SAR images, especially in mountain areas, due to shadow effects. In this work we used X-band CosmoSkyMed to map the terrain morphology of the earth-filled dams of the Consorzio di Bonifica di Capitanata, located in the Apulia region, southern Italy.

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MODELLING EARTH-FILLED DAMS: MERGING GBSAR AND TRADITIONAL MEASUREMENTS

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EXTENDED ABSTRACT

The mechanical parameters of earth dams is one of the key issues of geotechnical problems. Parameter back-analysis using internal or external monitoring data has been proven to be an efficient way to solve this problem. In fact, based on the identified parameters, the stability and security analysis can be investigated using the finite element method (FEM). However, traditional internal or external monitoring methods have limitations in efficiency, long-term monitoring and spatial coverage. The internal monitoring methods include e.g. tension wire alignment, hydraulic overflow settlement gauges, extensometers. However, these internal monitoring methods do not meet the safety monitoring requirements of large dams in terms of efficiency and long-term observations because of their low coverage and durability, and labour-intensive monitoring needs. Traditionally, external monitoring methods include levelling or Global Position System (GPS) measurements, but they are rarely used in back-analysis because of their low coverage. Therefore, the external monitoring results from the InSAR observation can be used as a integration for traditional monitoring methods to analyse the parameters of the dam. In this work we present the results which have been obtained within the AIM-DAMS project for the monitoring of earth-filled dams. The project has been funded by the Apulia Innovation Agency. Both Ground-Based and Spaceborne SAR systems have been used. Ground-based radar interferometry has provided deformation measurements of earth-filled dams of the Consorzio di Bonifica di Capitanata, located in the Apulia region, southern Italy. Earth dams have similar scattering properties as landslides for which the Ground-Based Synthetic Aperture Radar (GBSAR) technique has been so far extensively applied to study terrain displacements [1]. In this work, SAR and Real Aperture Radar (RAR) configurations are used for the measurement of earth dam surface deformations. A methodology is described for the acquisition of SAR data and the rendering of results. The geometrical correction factor needed to transform the Line-Of-Sight (LOS) deformation measurements of GBSAR into an estimate of the horizontal deformation vector of the dam surface is derived. For this study, a ku-band ground-based radar equipped with horn antennas having different radiation patterns have been used. Spaceborne radar interferometry provided maps of vertical deformation of the dam crown. X-band CosmoSkyMed SAR images have been processed using the Persistent Scatterer technique.

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CRITICAL REVIEW OF DAM BREACH PARAMETERS

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ABSTRACT

The rate of dam construction has been rapidly increasing in the last two centuries especially embankment dams. This may be attributed to the increase of water scarcity all over the world. Embankment dams represent the major portion of dams in the world. It represents about 80% of dams in the United States. One of the major risks that are associated with dam construction is dam failure. Dam failure is a catastrophic event where both peak flow and volume significantly affect downstream property and could result in loss of life. The amount of the affected property and loss of life depend on the inundated area and the degree of inundation, which are in turn a function of the reservoir size and other breach parameters. Because of the high risk associated with dam failure, especially for large dams, international standards recommend performing a dam break analysis during the design stage, in which the designer should study the effect of dam failure on the downstream region. So, it is very important to accurately represent the

breach process and its final opening dimensions to mitigate flood hazards due to dam failure. Several studies were conducted to predict dam breach parameters. This paper presents a critical review of the available studies.

A comparison between the available equations for prediction of dam breach parameters is conducted to select the best equations for each breach parameter using the breach parameters of about 1400 dam failure events. The comparison between the existing equations is based on the coefficient of determination (R^2) and Root Mean Squared Error (RMSE). So, the equation which has the minimum RMSE and the maximum R^2 will be described as the best equation for this parameter. Also, the available equations is sorted from the best to the worst based on the same two evaluation factors.

Applying the comparison criteria, **Fehler! Verweisquelle konnte nicht gefunden werden.** (see fullpaper) presents the sorting of the existing prediction equations from the best to the worst equation based on R^2 and RMSE.

Based on the comparison and its results (presented in **Fehler! Verweisquelle konnte nicht gefunden werden.**- see fullpaper), it is found that Soliman 2015 equations for H_f and B_{avg} prediction are the best equations followed by Elsayed 2018 equations for the same two parameters. Regarding T_f, Elsyaed 2018 is classified as the best equation based on R^2 while Von Thun & Gillette, 1990 is classified as the best equation based on RMSE and both are followed by Soliman 2015 equation.

Additionally, it is very clear from the above table that the prediction equations for T_f are uncertain as all of them have very low values for coefficient of determination (R^2). So, additional investigation and analysis should be conducted in future to find a better equation for formation time prediction.

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SLOPES STABILITY IN THE CATCHMENT AREAS AND EFFECT OF LARGE-SCALE ROCKSLIDE DAMMING ON HYDRAULIC PROJECTS SAFETY BY EXAMPLE OF CATCHMENT AREAS OF VAKHSH AND SIANG RIVERS

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RUSSIA

1. INTRODUCTION

Outburst floods often affect mountainous rivers, being caused by breach of the moraine and glacier lakes mainly. The most dangerous are floods caused by the breach of large rockslide dams that could create large short-term or long-term dammed lakes exceeding reasonable excessive storage of the downstream artificial reservoir and, thus, endanger hydraulic schemes. Adverse effects of river-damming rockslide must be considered if such blockage exists in the catchment area but also if it can be anticipated there during the dam's lifetime.

2. HISTORICAL AND PREHISTORIC OUTBURST FLOODS CAUSED BY ROCKSLIDE DAMS' BREACH

Historical events and geomorphic interpretation of prehistoric case studies show that breach of large rockslide-dammed lake could produce flood with peak discharge exceeding those caused by hydro-meteorological processes.

It can be exemplified by the breach of seismically induced rockslide dam in the Dadu River in Sichuan, China in 1786; by the 1841 and in 1885 outburst floods in Indus River valley; by the 1914 breach of the prehistoric rockslide dam in the Rio Barrankos valley (Argentina); by the 1985 outburst flood with 100 m high surge wave just downstream from the Bairaman landslide dam in Papua New Guinea; by the 2000 breach of the rockslide dam in the Yigong River valley – tributary of the Siang (Brahmaputra) River in Tibet, China, which peak discharge in India, more than 400 km downstream, was about 44,200 m^3/s.

Similar prehistoric phenomena can be exemplified by the outburst flood with peak discharge of 400 000 – 500 000 m^3/s, which traces were found in the Sarydjaz-Aksu River valley in Xingiang (China).

3. POTENTIAL BLOCKAGES IN THE CATCHMENT AREAS OF VAKHSH AND SIANG (BRAHMAPUTRA) RIVERS

The necessity to consider hazards caused by similar outburst floods for dams design in mountainous regions is exemplified by potentially unstable high slopes identified in the catchment areas of the Vakhsh and the Siang (Bakhmaputra) Rivers which failure could create dams up to several hundred meters high. In Tajikistan the most hazardous site was found in the Rugnou River valley about 140 km upstream from the Rogun dam and ca. 100 km from the tail part of the future reservoir. In this case large Rogun reservoir could accommodate such a potential flood without dam overtopping. Much larger amount of water could be stored in the anticipated rockslide-dammed lake in China, in the Yigong River valley – left tributary of the Siang River, about 100 km upstream from the 2000 blockage. Considering that several dam projects are planned downstream in the Siang River valley in India, slope stability at this site should be studied and special measures should be performed, if necessary, to prevent most adverse effects of large-scale river-damming slope failure.

KEYWORDS

Rockslide dam, Outburst flood, Reservoir, Remote sensing, Rogun dam, Siang HPP.

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INFLUENCES OF WATER LEVEL CHANGES ON THE BEHAVIOUR OF A SLOW MOVING LANDSLIDE

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AUSTRIA

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1. INTRODUCTION

This contribution investigates the influence of water level changes in a storage basin of a pumped-storage power plant on the movements of a landslide. Based on numerical back-calculations, the reasons for the measured excess pore water pressures at the slope toe are discussed. The quantitative influence of the storage operation on the slope movements is estimated from the results of a fully coupled flow-deformation analysis (finite element analysis).

2. LANDSLIDE AND STORAGE BASIN

The dimensions of the landslide are approximately 220 x 270 m (see Fig.1). The average movement rate is 4-5 cm/year. The material of the landslide is mainly sheared and weathered rock. The subsoil at the slope toe and beneath the storage basin are lacustrine fine sediments (silt and fine sand). The installed measurement devices (inclinometers, pore water pressure gauges and extensometers) are also shown in Fig.1. Geodetic measurement points are distributed over the entire slope.

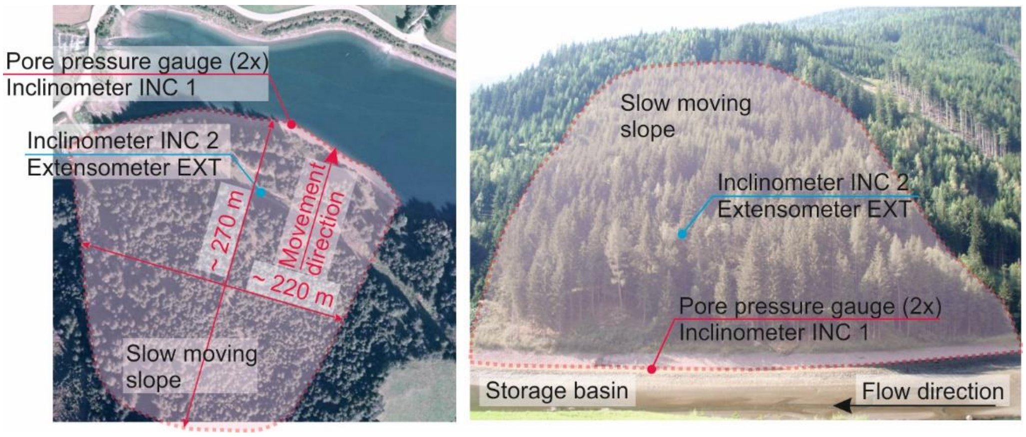

Fig. 1 Plan view and side view of water storage basin and slow moving slope

3. MEASUREMENT RESULTS AND BACK-CALCULATIONS

According to Fig.2-left the water level changes in the basin lead to excess pore water pressures, which cause a destabilization of the landslide. Considering various influencing factors for the back-calculation of the slope displacements (Fig.2-right), showed that the water level changes are the main reason for the slope movements (difference between yellow and green line). Based on these insights an efficient design of remediation measures is possible.

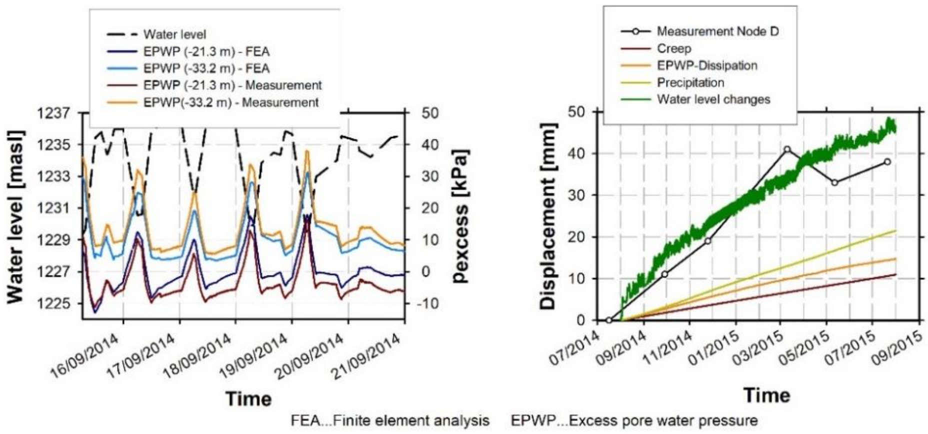

Fig. 2 Comparison of calculated and measured excess pore water pressures (left) and displacements (right)

Keywords: Deformation, Pore pressure, Reservoir slope, Slope stability

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ESTIMATION OF LANDSLIDE INDUCED IMPULSE WAVE IN A CHANNEL TYPE RESERVOIR

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CHINA

1. INTRODUCTION

The landslide induced impulse wave (LIIW) in reservoirs might result in tragic disasters. After the Huangtian LIIW event in 2009 at the Xiaowan Reservoir, the LIIW becomes a major concern to some of hydropower projects on the Lancang River, southwest of China. As most reservoirs in these projects located in narrow valleys, the estimation of LIIW damage in those channel-type reservoirs is very important.

Existing theories for LIIW are often generalized from wave flume and wave basin experiments, which assume that the wave generation direction is (partly) the same as the wave propagation direction. However, the LIIW in channel-type reservoirs is far more complex due to its distinguishing energy transport and dissipation mechanisms. The nearfield dissipation in the channel-type reservoir is very strong while the far field dissipation is limited because the wave propagation direction is generally the same as the channel stream direction. In this study, a novel numerical model, which characterizes both above two stages, is developed for LIIW in channel-type reservoirs and applied in engineering practices.

2. METHODS

The numerical model is constituted of two parts, the nearfield model and the far field model. In the nearfield model, the water is modelled with the Naiver-Stokes equation while the landslide is modelled with elasto-plastic model. The model is solved with the Smoothed Particle Hydrodynamics (SPH) method. And the far field model solves the 2D shallow water equation with adaptive mesh technique to simulate the wave propagation. These two models are connected unidirectionally using wave height matching technique.

The model is validated against several laboratory experiments and the results are promising. Both the deformation of the landslide and the initial wave could be reproduced reasonably and only a few artificial parameter is necessary.

3. RESULTS & CONCLUSION

The model is applied in the engineering design of a huge hydropower project on the upstream of the Lancang River. A slope, which locates at about ten kilometers upstream from the dam, is considered to be unstable during the attack of the extreme event. With prescribed slide surface from FEA simulation, the large deformation of the slide during both the slope failure and the impact process is well characterized.

The results show that while the initial wave generated in the impact process is huge, the wave propagated to the downstream is limited. This simulation shows the ability of the proposed model and also the unique characteristic of LIIW in channel-type reservoirs.

ACKNOWLEDGEMENT

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FAILURE OF EMBANKMENT DAMS DUE TO OVERTOPPING-EXPERIMENTAL STUDY AND HYDROGRAPH PREDICTION

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AUSTRIA

1. INTRODUCTION

Despite the most careful surveillance and construction measures, the risk of failure of an embankment dam cannot be completely eliminated. For the creation of more accurate hazard maps or evacuation plans, the outflow hydrograph is the decisive parameter. Currently used empirical equations and numerical models for hydrograph estimation display a wide range of possible results. Therefore, the database related to case studies of historical failure events is very diverse and the estimation of sediment transport using "classic" equations from river engineering (for example Meyer- Peter and Müller or Smart and Jaeggi) must be questioned.

2. METHODS

In order to contribute to the understanding of the significance of several parameters on breach processing and hydrograph, two physical model test series with more than 40 three-dimensional tests were conducted at the hydraulic laboratory of Vienna University of Technology [1], [2]. For the three-dimensional in place recording of the breach formation, an infrared based optical device called "Diketracker", developed by Vienna University of Technology, was installed.

3. RESULTS AND CONCLUSION

First series investigated the influence of the reservoir size and shape [1], followed by an experimental study on the influence of the shell material grain size (Fig. 1), an upstream impervious blanket, the depth of the initial breach as well as scalability and model effects due to sidewall and drainage [2]. The experiments show significant results on the investigated parameters. Whereas most significant influence on the hydrograph is due to the variation of the reservoir size, followed by the reservoir shape. Shell material grain size distribution and the upstream impervious blanket have clear effects on the breaching process, but the influence is not dominant. Tests results indicate that sediment transport in extreme hydraulic conditions, which occur at embankment dam breaching, cannot be comprehended by using equations from river engineering. The outflow hydrographs show significant characteristics despite the variation of parameters and boundary conditions. A model family displayed scalability according to Froude similarity law.

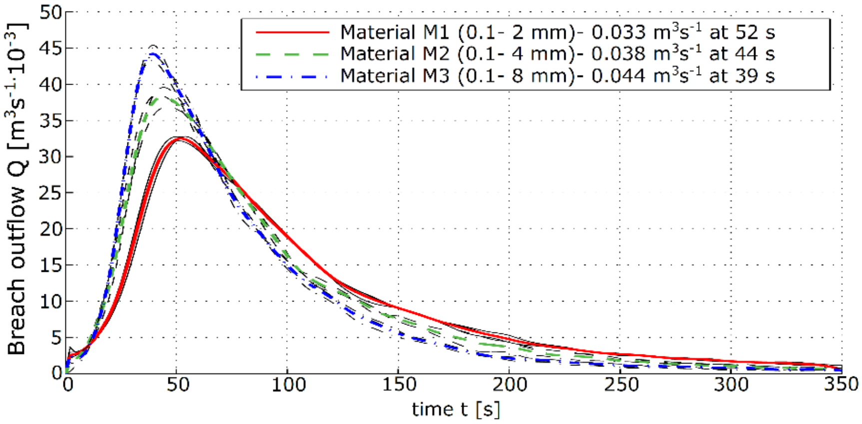

Fig. 1 Breach hydrographs using different shell Materials

Based on the results of the two experimental studies a simple method for hydrograph prediction using dimensionless dam and reservoir geometries is presented. The calculated results can be compared with data from historical failure events.

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A RESERVOIR SYSTEM SIMULATION METHOD TO LESSEN WATER SUPPLY DEFICIT AT DOWNSTREAM CONTROL POINTS USING A HEURISTIC METHOD *

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A discrete hedging rule that having through several hedging phases can be effective method for water supply operation of a reservoir against drought periods [1]. The discrete hedging rule for single reservoir operation can be derived by a historical time series of reservoir inflow. The rule, however, does not always ensure a stable supply of water against different future time series of drought inflow to the dam. If the water supply shortage from a dam may be supplemented by the other dams, overall water supply will be more stable. The first purpose of the study is to derive the hedging rule curves of reservoirs based on the current storage that does not need uncertain inflow prediction. The second purpose of the study is to decide some parameters on additional water supply from upstream dams to lessen water supply shortage at downstream control points.

Hedging rule curves for five multipurpose dams were determined independently by applying a mixed integer programming module in the Nakong River basin, the Republic of Korea. The derived hedging rule curves were used in the independent reservoir operations. The parameter values of additional water supply for reservoir system operation were decided for the five multipurpose dams by applying a dynamically dimensioned search method [2]. The two kinds of parameters are as follows: additional water supply proportion of the downstream

* *PROCÉDÉ DE SIMULATION DE SYSTÈME DE RÉSERVOIR PERMETTANT D'ÉVITER UN DÉFICIT D'ALIMENTATION EN EAU AUX POINTS DE CONTRÔLE EN AVAL EN UTILISANT UNE MÉTHODE HEURISTIQUE*

water supply shortage; minimum reserve volume above the trigger volume of the first hedging phase.

Table 1 shows comparison results of the water supply deficit at the control points between the independent and reservoir system operations. While the maximum water supply deficit at the control point 1 increased slightly, the total water supply deficit at the control point 2 reduced greatly.

Table 1. Comparison of the water supply deficit at the control points between the independent and reservoir system operations

Operational performance statistics	**Independent operation**			**Reservoir system operation**		
	Control point			**Control point**		
	1	**2**	**3**	**1**	**2**	**3**
Total water supply deficit (10^6 m^3/10 days)	2073	737	2	1974	67	0.2
Maximum water supply deficit (10^6 m^3/10 days)	28	12	0.7	31	11	0.3
The number of rationing	210	149	31	239	150	31
Reliability	0.47	0.62	0.92	0.40	0.62	0.92

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LANDSLIDE DAMS - LONG KNOWN, BUT JET OVERLOOKED RARE PHENOMENON: POSSIBILITY TO PREVENT DAMAGE

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SLOVENIA

1. INTRODUCTION

Nowadays lack of space is an important factor connected to economic development and the extent of damage (magnitude) from natural disasters. According to United Nation reports, 90% of all natural disaster is somehow connected or better triggered by weather and climate changes. Floods account almost 47% of all weather related disasters. The intensity of events and disaster extent increases and the extent of damage is almost directly commensurate with intensity of settlement and land use.

Apparat from flooding, heavy rain is closely connected to another major type of natural disaster – Landslides. When the mases slide down to the bottom of the valley and block the river course – we speak of the landslide dams. Landslide dams are an old phenomenon – many glacial and other lakes are a still an existing proof. The event is quite rare. However, due climate changes and due to rapid urbanization presents a significant threat. This type of dam may not be a long lasting structure - they may last for a few hours or for thousands of years. Furthermore, it is difficult to assess the condition and predict the breaching mechanisms, since usually there is no time to make complex analysis. Flush flood or debris flow caused by brake of this type of dams is even more dangerous, than the breaching of regular dams, because the breach happens quickly and the flow is strong and destructive.

In the paper we will present several such past events in Europe and worldwide and touch the question what we could learn from historical event.

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GEOLOGY AND GEOTECHNICAL CONDITION FROM GEOLOGICAL MAPPING, CORE DRILLING, AND SEISMIC METHOD AT MASANG II HYDROPOWER PROJECT, WEST SUMATERA, INDONESIA

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ABSTRACT

Masang II project is one of the hydropower projects to develop in Agam District, West Sumatra Province. To realize this project, a weir will be built on the river Sianok. Located this project on the Sianok River which empties into the Masang River on the border of Agam and Pasaman districts. Seeing the area supported by the topographic condition of the region, the Sianok River has considerable potential to develop into a hydropower energy source (hydropower).

This study was conducted to determine the geological and geotechnical conditions of Masang II project area. The foregoing study did not mention that this area belongs to the melange zone, but results from investigations conducted directly in the field and after being studied and investigated that the area of project area of Masang II Hydropower is a melange zone and it is something new. We use geological mapping, core drilling, and seismic method to identification geology and geotechnical condition in this project.

Masang II Hydropower Project seen from all of aspect like regional geology, stratigraphy, and topography, this area is included into Sumatera Fault Zone and bukit barisan which until now still declared active. In some areas found a lot of variation rocks from sedimentary rock, igneous rock, and metamorphic rock, with rock conditions that are destroyed or weathered due to the presence of structures in the area.

This is explained and reinforced by the presence of geological mapping, core drilling, and of geophysical data (seismic refraction). From geological mapping found the existence of various rocks like mica schist, diorite, phyllite, serpentinite, metalimestone, limestone and breccia which generally have deformation. From core drilling results, core sampels destroyed and weathered due to the structure and supported by seismic survey which is interpreted as melange deposit with many block in matrix and high deformation.

This geological condition also affects stability in hydropower development. The geological condition of the porject area is very unstable. Based on the results of the investigation on the area is an interesting geological condition so that detailed handling is required in geotechnical studies. In geotechnical classification all of rock classified into poor rock and fair rock conditions should be considered in conducting hydropower development in the area. With this condition, bearing capacity at this area ranging from 6.8 ton/m^2 - 68.1 ton/m^2 indicate bearing capacity in the melange zone is highly variable and heterogeneous. Hydrogeological conditions of the melange zone also varies from hard rocks with high permeability to rocks with low permeability.

Geological and geotechnical conditions are interconnected and needs to be considered to support the construction of Masang II Hydropower. Taking into these aspects, it can be well anticipated for all the possibilities that occur during the construction of the hydropower plan.

Key Word**:** Metamorphic, Melange, Bearing Capacity, Heterogeneous

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NUMERICAL MODELLING OF ROCK-FALL ON THE CONCRETE ARCH-GRAVITY DAM OF PLACE MOULIN

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EXTENDED ABSTRACT

Several mountain slopes of the Alpine valleys, where many Italian large dams are located, are characterized by hazardous instability phenomena that might give rise to rock-fall that could impact on the above infrastructures. In order to plan adequate mitigation and protection works for the safety of the dams, the first step is the assessing of the consequences that potential events of rock-fall could cause on the structures.

This paper presents the numerical modeling of a massive boulder falling from the left bank of the reservoir and impacting on Place Moulin arch-gravity dam. The most hazardous instability phenomena provided by recent geological surveys were considered to characterize the trajectory of the boulder whose volume has been assumed equal to 7,1 m^3 with a kinetic energy of 29.972 kJ.

Considering the large size of the dam with respect to both the impact zone and the boulder dimension, a three dimensional Finite Element model of only half dam was generated together with an extended part of the foundation. For sake of

simplicity, the numerical simulations have taken into account only a single boulder having a spherical shape. In order to reduce the computational time of each simulation, the mesh was progressively refined towards the impact zone.

Two contact surfaces were included to model the interaction between the boulder and the dam: the former completely covers the outer surface of the boulder, the latter partially covers the crest and the upstream face of the left part of the dam.

The numerical simulations have taken into account three different impact points on the dam: two on the crest and one on the upstream face.

The non-linear constitutive Concrete Damage Plasticity Model was used to simulate the concrete behavior while the Brittle Cracking Model was assumed to describe the failure mechanism of the boulder.

Preliminarily, sensitivity analyses were carried out to assess how the compression and tension damage varies on the dam body changing the brittle behavior of the boulder in terms of deformation at the formation of cracks and at failure. The results in terms of the tension damage parameter value have shown that the damage of the concrete is little influenced by the level of shattering of the boulder.

In all the three impact analyses, the compression damage on the concrete dam is limited to the impact area, and it is quite negligible when the boulder hits almost tangentially the upstream face of the dam. The tension damage is significant when the boulder hits the dam crest but it is negligible when it impacts the upstream face of the dam.

The results of this study will support the dam owner to select the most adequate mitigation works to guarantee the safety of the structure.

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EXPERIMENTAL STUDY ON OVERTOPPING BREACHING PROCESS OF EARTH DAM AND PEAK DISCHARGE

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1. INTRODUCTION

The pattern of dam break is important for the study of the dam failure, which decides how long the whole dam failure lasts, the level of the peak discharge and the damage to the downstream areas. Combining the indoor earth dam overtopping erosion experiment, the study tries to preliminarily explore the erosion process of earth dam, and makes further efforts to disclose the relationship between the breaching process and the peak discharge.

2. METHODS

The experimental flume is 25 meters long and 1.2 meters high with a 6-meter-wide reservoir on upstream. The profile of the flume on downstream is 2 meters wide. The reservoir on upstream is simulated with a certain volume of capacity which has a maximum capacity of 80m^3. The geometric profile of the experimental dam body is 100cm high, 1:1.5 slope of upstream, 1:3 slope of downstream, 20cm top width, 470cm bottom width.

3. RESULTS

Depending on the way of the overtopping flow, the density of fill and gradation composition of the dam's constructional material, overtopping erosion process can be classified into 3 types such as layer-by-layer erosion, entire overtopping erosion and headcut erosion.

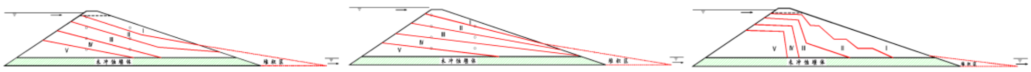

Fig. 1 3 types overtopping erosion process

Tab.1 Hydraulic parameter peak value of different breaching process

Breaching process	upstream water level Z_{max} (cm)	Breaching discharge Q_{max} (L/s)	Water level maximum fall in 30s ΔZ (cm)	Main dam breaching t (s)
layer-by-layer erosion	97.7	459	17.3	90
entire overtopping erosion	102.1	526	19.9	90
headcut erosion	97.7	654	24.8	60

4. CONCLUSION

There is a very close relationship between the peak discharge and the breaching process. The quicker of dam-break happens, the bigger the peak discharge is. In the same situation, the peak discharge of headcut erosion increases 40% to the one of layer-by-layer erosion.

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SETTLEMENT OF SOFT ROCKFILL MATERIALS IN MEDIUM-SCALE OEDOMETER

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1. EXTENDED ABSTRACT

Rockfill materials are used in construction projects such as dam construction, road construction and so on. Due to the increasing use of these materials, experiments and studies have also been carried out on this material and usually, these studies have been carried out on strong rockfill materials. Today, the use of soft and weak rockfill materials has expanded because the economic and environmental issues. and still no comprehensive studies have been conducted on soft rockfill materials and need more information on the behavior of these materials in different conditions. With considering that the dimensions of the usable rockfill material may be much larger than the dimensions of the laboratory equipment. Therefore, it is always a matter of scaling and matching the results of the laboratory and the field from the important items of rockfill materials. In this research, the behavior of weak rockfill materials has been investigated in different conditions. Based on the study, the following conclusions that in the wet condition, the axial strain and displacement are more than dry condition and in the initial steps of loading, the axial strain and displacement are greater than the end steps.

KEY WORDS

Particle Breakage, Weak Rockfill Material

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