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25-year Field Monitoring of the Tsing Ma Suspension Bridge in Hong Kong

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ABSTRACT: The Tsing Ma Suspension Bridge in Hong Kong has been the world's first batch of bridges equipped with a long-term health monitoring system since 1997. For the first time, this study reports the first-hand field monitoring data of the bridge from 1997 to 2022. The 25-year data provide an invaluable and rare opportunity to examine the long-term characteristics of loads, bridge responses, and their relationships, thereby enabling the assessment of the bridge's load evolution and structural condition over time. The current status and recent update of the health monitoring system are also reported. This study is the first to report the one-quarter-century status of a structural health monitoring system and the behavior of a long-span suspension bridge. This research provides a benchmark for many other bridge monitoring systems worldwide.

KEY WORDS: Structural health monitoring, Long-span bridges, Long-term behavior, Load evolution.

1 INTRODUCTION

Large-span bridges are vital economic lifelines, and their failure can have catastrophic human and socio-economic impacts. Proactive maintenance is essential to ensure the serviceability and safety of long-span bridges that are subjected to complex loads (e.g., typhoons, earthquakes) and harsh environments (e.g., corrosion) during operation. Structural Health Monitoring (SHM) is essential for monitoring the health of bridges, assessing their safety, guiding their maintenance and providing early warnings. Although SHM systems are now being adopted in major bridges (e.g., Akashi Kaikyo Bridge, Runyang Bridge, etc.) and newly designed bridges around the world, there is a lack of long-term operational history data for SHM systems. This creates a research gap in analyzing long-term data, actual structural degradation, and service life assessment [1-11].

The Tsing Ma Bridge (TMB), operational since 1997 with a pioneering SHM system, offers a unique 26-year dataset (1997-2022). This study analyzes the long-term data, SHM system status of TMB and the health monitoring system, and investigating long-term trends in environmental loads and structural performance.

2 THE TSING MA BRIDGE

The Tsing Ma Bridge is a highway and railroad dual-purpose large-span suspension bridge with a main span of 1,377 m, a total bridge length of 2,160 m and a tower height of 206 m, which was opened to traffic in 1997. An elevation of the bridge is given in Figure 1.

3 MONITORING DATA

3.1 Temperature

The annual maximum bridge temperatures are given in Figure 2. A linear regression analysis shows that the maximum deck effective and ambient temperatures increase at rates of 0.51 ℃/decade and 0.72 ℃/decade, respectively. The bridge temperature in 2022 is 44.9 ℃, close to bridge deign limit of 46 ℃.

3.2 Deflections

The bridge displacement is subject to the temperature and the traffic effects. The mid-span deflection without traffic load is shown in Figure 3, using data between 2:00 to 4:00 am to exclude the traffic effect.

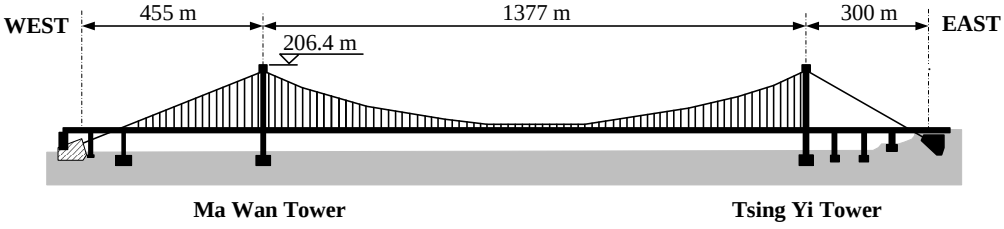

Figure 1 The elevation of the Tsing Ma Bridge

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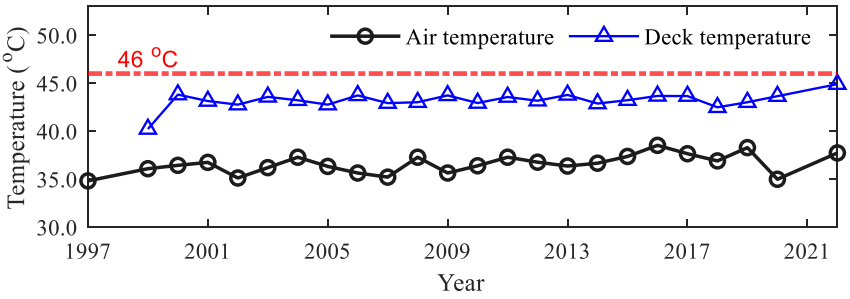

Figure 2 Annual maximum deck effective temperature of the Tsing Ma Bridge in 1997–2022

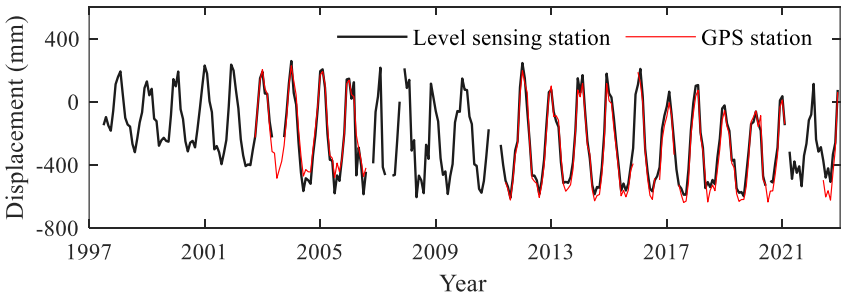

Figure 3 Monthly mean mid-span deflection of Tsing Ma Bridge in 1997–2022

CONCLUSIONS

The operational condition of the Tsing Ma Bridge and its Structural Strength Monitoring (SHM) system has attracted much attention. In this paper, field monitoring data from the past 26 years are analyzed to study the long-term loading and response of the bridge. In addition, this paper discusses the current status and latest updates of the SHM system. The following conclusions are drawn from this study.

(1) Observed trends in bridge deck effective temperatures show significant increases over recent decades. Specifically, the maximum effective temperature has risen at a rate of 0.51 °C per decade, while the mean effective temperature increased at 0.16 °C per decade. Critically, the recorded maximum values are now approaching the original design thresholds for the deck.

(2) The monthly bridge midspan deflection show an increasing trend, the trend can be caused by the cracking and creep of materials.

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REFERENCES

[1] Zhou Y, Xia Y, Chen B, Fujino Y. “Analytical solution to temperature-induced deformation of suspension bridges”, Mechanical Systems and Signal Processing, 2020, 139, 106568.

[2] Xu YL, Xia Y. Structural Health Monitoring of Long-Span Suspension Bridges, CRC Press, 2012.

[3] Li LF, Chen B, Zhou LR, Xia Q, Zhou Y, Zhou XQ and Xia Y. “Thermal Behaviors of Bridges – A Literature Review, Advances in Structural Engineering, 2023, 26 (6), 985-1010.

[4] Zhang L, Lu T, Wang F and Xia Y, “Over 25-year Monitoring of the Tsing Ma Suspension Bridge in Hong Kong”, Journal of Civil Structural Health Monitoring, 2025, 15 (1), 263-283.

[5] Xia Q, Zhang J, Tian Y, Zhang Y. Experimental Study of Thermal Effects on a Long-Span Suspension Bridge. J Bridge Eng. 2017;22(7):04017034. https://doi.org/10.1061/(ASCE)BE.1943-5592.0001083.

[6] Xia Y, Chen B, Zhou X, Xu Y. Field monitoring and numerical analysis of Tsing Ma Suspension Bridge temperature behavior. Struct Control Hlth. 2013;20(4):560-575. https://doi.org/10.1002/stc.515.

[7] Xia Y, Chen B, Weng S, Ni Y, Xu Y. Temperature effect on vibration properties of civil structures: a literature review and case studies. J Civ Struct Health Monit. 2012;2(1):29-46. https://doi.org/10.1007/s13349-011-0015-7.

[8] Shan Y, Li L, Xia Q, Gao W, Jing Q, Xia Y (2023) Temperature behavior of cable-stayed bridges. Part I—global 3D temperature distribution by integrating heat-transfer analysis and field monitoring data. Adv Struct Eng 26(9): 1579-1599

[9] Xia Q, Wu W, Li F, Zhou X, Xu Y, Xia Y (2022) Temperature behaviors of an arch bridge through integration of field monitoring and unified numerical simulation. Adv Struct Eng 25(16): 3492-3509

[10] Wang X, Wu W, Du Y, Cao J, Chen Q, Xia Y (2023) Wireless IoT Monitoring System in Hong Kong–Zhuhai–Macao Bridge and Edge Computing for Anomaly Detection. Ieee Internet Things 11(3): 4763-4774

[11] Zhou Y, Xia Y, Sun Z, Fujino Y (2022) Analytical formulation of the temperature-induced deformation of multispan suspension bridges. Struct Control Hlth 29(6): e2937.