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Scotiabank Saddledome Roof Structure Monitoring Program

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ABSTRACT: Scotiabank Saddledome, an indoor arena in Calgary, Alberta, constructed in 1983 with a hyperbolic paraboloid (saddle shaped) roof, has concave cables running in the east west direction to support gravity loads and convex cables in the north-south direction to support lateral loads. The stranded cables, encased in concrete and anchored into a ring beam, are not visible to detect the signs of corrosion. Events held in the arena require suspension of entertainment loads from the roof structure which, when coupled with snow loads, pose a major safety concern.
The installation of an acoustic monitoring system in 1999 to detect breaks in cable strands did not perform as intended. In 2014 the roof membrane was damaged by a significant hailstorm exposing concrete to moisture infiltration. In 2022, a Building Condition Assessment of the roof recommended further investigation of the bonded cable system.
Learning from strand failures at the Arizona Veterans Memorial Coliseum resulting in costly remediation work, a Structural Health Monitoring (SHM) system with strategically mounted sensors and a laser-based deflection measuring device, was implemented in July 2023. The objective of this SHM program is to collect data on monitoring parameters for roof movements continually over a period of 3 years in order to identify trends and implement an active alarm system based on data collected in the first year.
This paper presents the field application of SHM for risk management of a complex roof structure.

KEY WORDS: Hyperbolic paraboloid roof; Monitoring program; Parameters; Loads; Cables; Risk management; Analysis

1 INTRODUCTION

The Scotiabank Saddledome is a multi-use indoor arena located in Calgary, Alberta, Canada. Partnered with the City of Calgary, Calgary Sports and Entertainment Corporation (CSEC) maintains and operates the facility. The Saddledome was constructed in 1983 with a complex hyperbolic paraboloid (saddle) shaped roof. The arena hosts numerous events throughout the year requiring the suspension of entertainment loads from the roof structure. Event loads in combination with heavy snow loads during winter months lead to deformation of the roof structure. The roof structure's safety performance is correlated with the condition of its constituting components. As the facility ages and deteriorates reliable methods are needed to assess the overall condition of the structure.

Figure 1. Scotiabank Saddledome[1]

A Structural Health Monitoring (SHM) system was installed on the underside of the roof structure in July 2023 to monitor deflection and movement at key locations. The system sends an email alert when deflection at any of the key locations exceeds its preset threshold. In addition, the system detects changes in vibration characteristics which could indicate strand failure. This allows the condition of the roof structure to be monitored continually to manage risk while minimizing exploratory destructive testing and interruptions to the daily operation of the facility.

2 SADDLEDOME ROOF STRUCTURE

The roof of the Saddledome is a complex structure consisting of sagging (concave) cables running in the east-west direction to support gravity loads on the roof and hogging (convex) cables running in the north-south direction to support lateral loads on the roof. The cables are anchored into a ring beam around the perimeter of the roof, which is supported on thirty-two bearings, four of which are fixed A-frames at the low ends of the saddle. The sagging cables are spaced at 6 m on center and consist of two cables with twelve stainless steel strands each. The sagging cables in the center of the roof supporting the scoreboard consist of fifteen strands. The hogging cables consist of nineteen strands and are also spaced at 6 m on center. Precast panels are supported by intersecting cables to form the roof surface, as shown in Figure 2. Lightweight concrete was poured between the precast panels to encase the strands in concrete and form the ribs of the roof as shown in Figure 3. In addition to the bonded sagging and hogging cables, six unbonded post-tensioned strands are located within the ribs. These cables were most critical during construction and

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contribute minimally to the roof's capacity. A catwalk system, scoreboard, and other rigging for event loading are suspended from the main cable system. Entertainment and concert events can impose up to 22,700 kg (50,000 lbs) of load on the roof.

Figure 2. Sagging and Hogging Cables[2]

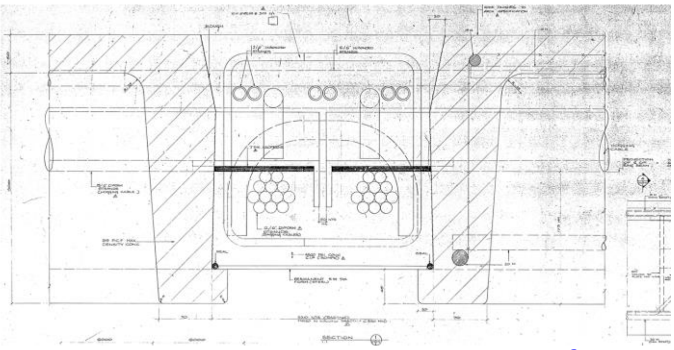

Figure 3. View of Embedded Cables in a Typical Rib[3]

The main risk to this type of roof structure is deterioration of the anchor connections at the ring beam or the loss of tension in the cables. Moisture infiltration at the anchor connection can result in corrosion of the anchor plate or cable strands. Loss of tension in the cables can occur if one or more strands were to break. The load would be redistributed to the remaining strands increasing and possibly exceeding their tensile stress. There are 4 main causes of strand failure:

- *Overloading of the structure*
  If the load imposed on the structure exceeds the design load the strands can become overstressed and fail.
- *Physical damage*
  During the life of a building new equipment may be installed requiring drilling or coring into the concrete. This can potentially cut or damage the strands.
- *Friction and wear*
  At the points where the cables cross, if a bearing pad is not present, the cables can rub against each other as the structure deflects under load or expands and contracts with changes in temperature. This cyclical rubbing can wear the strands down causing them to break.
- *Corrosion*
  The most common cause of strand failure is due to corrosion of the strand from moisture infiltration into the concrete or moisture build-up in void spaces.

3 CONDITION ASSESSMENT OF THE ROOF STRUCTURE

3.1 Experience from Similar Structure

The Arizona Veteran's Memorial Coliseum, located in Phoenix Arizona, has a similar hyperbolic paraboloid shaped roof structure consisting of a grid of post-tensioned cables tied into a compression ring supporting precast roof panels. In 2006 a dip in the roof was discovered and further investigation revealed eleven cables had failed, one due to corrosion from past roof leaks and the others due to overloading. Costly emergency repairs were undertaken to replace the failed end anchorages. From the engineering team involved with the repairs it was understood that various non-destructive testing options to assess the condition of the cables were inconclusive. However, the change in shape of the roof surface was a sign that a loss of tension in the cables may have occurred.

3.2 Saddledome Structural Assessment History

The Saddledome roof has experienced deterioration over the years. In 1999 an acoustic monitoring system was installed in the facility to record potential strand breaks. Since the system was installed, nine potential strand breaks were detected, four of which were in the sagging cables. In 2018 an unbonded post-tensioned strand failed and erupted through the concrete panel at the bottom of the rib where a void in the concrete had formed during construction. This event was not detected by the acoustic monitoring system. It was found that the wi-fi system in the building was interfering with the monitoring system and the event was not recorded.

In 2014 a significant hailstorm damaged the roof membrane exposing the system to moisture infiltration. Due to the strands being encased in concrete the condition of the strands could not be determined through visual assessment.

In 2020 a consultant was engaged to complete a condition assessment of the cable anchors and cable system. The cable anchors were assessed from the roof and found in good condition[4]. Ground Penetrating Radar (GPR) scanning was completed from the roof surface to assess the cables and locate other void spaces in the ribs that may be present however, due to the depth of the concrete and concentration of material in the ribs the results were inconclusive. Completing scanning from below was also challenging due to the access issues. Five locations were then selected to remove the concrete from the underside and expose the cables for visual assessment and penetration testing (two at the midspan of the sagging cables near the center of the building where moisture was likely to collect and three near the perimeter). The cables were found to be in good condition with no corrosion or tension deficiencies[5].

A Building Condition Assessment (BCA) of the Saddledome completed in 2022 recommended further investigation of the bonded cable system to better understand the condition of the roof structure[6]. Given the inconclusive results of non-destructive testing completed in the past and the challenges of accessing the underside of the roof structure, options for monitoring the roof structure were explored. A monitoring plan was established to measure the shape and movement of the roof on a continuous basis over the next 3 years. This allows the City of Calgary and CSEC to manage the safety risks associated

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with the roof structure and better understand how the roof structure behaves under varying loading conditions.

4 MONITORING PROGRAM AND FIELD IMPLEMENTATION

SHM Canada Consulting Limited (SHM Canada) was engaged by CSEC to design, install, and operate a comprehensive structural health monitoring system at Scotiabank Saddledome to provide data on the performance of the saddle-shaped roof on an ongoing basis. The automated structural health monitoring system was installed and commissioned in late July 2023. It is currently active and provides valuable information to help maintain structural integrity of the roof.

4.1 Instrumentation and Plan

The Scotiabank Saddledome roof monitoring system consists of a combination of wired and wireless sensors. The arena roof is divided into three main monitoring zones: Zone-1, Zone-2, and Zone-3. These monitoring zones are equipped with a total of twelve vibrating-wire strain gauges, twelve reflective target prisms, twelve triaxial tiltmeters, and nine triaxial accelerometers:

- *Vibrating-wire strain gauges*
  Installed on the roof soffit, these gauges measure strain-related changes in the post-tensioned concrete beam network. These strain gauges are equipped with integrated temperature sensors that detect changes in the internal temperature of the arena. They are connected via signal cables to a datalogging system with highspeed acquisition modules capable of capturing burst strain data based on the required trigger points. The strain gauges were calibrated and set at the mid-range to ensure a sufficient offset for measuring both compression and tensile strain. Six strain gauges are installed in the direction of the two central sagging concrete ribs, while the remaining strain gauges are installed in the direction of the two central hogging concrete ribs.
- *Surveying system with reflective prisms*
  The wireless system consists of a total station with a precision of 1 mm + 1 ppm and two types of reflective prisms. The target reflective prisms are installed in the roof soffit and the reference reflective prisms are installed along the peripheral wall. The total station measures the current baseline elevation and the roof elevation to provide precise roof deflection in the targeted regions. Six target reflective prisms track changes in roof elevation at the high-to-high direction along the two central sagging cables. The remaining six prisms record elevation changes at the low-to-low ends along the two central hogging cables. The approximate locations of the target reflective prisms are shown in Figure 4.
- *Triaxial tiltmeters*
  Installed on the roof soffit, the wireless triaxial tiltmeters measure angular changes in two directions: in-plane and out-of-plane. Similar to the target reflective prisms, the tiltmeters are placed along both the central sagging and hogging directions. They are positioned near the prisms to measure in-plane and out-of-plane angular movements caused by event-specific loading arrangements.
- *Triaxial accelerometers*

Mounted on the roof soffit, the wireless triaxial accelerometers measure the acceleration in three orthogonal directions. The accelerations are recorded based on the ambient and induced acceleration of the arena roof under regular and event-specific vibrations, impacts, and other dynamic forces. The accelerometers are capable of measuring trigger data depending on their preset threshold limits. Out of the nine accelerometers, five are placed near other monitoring sensors, and the remaining four accelerometers are positioned near the non-axis boundary. Figure 5 demonstrates the axis orientation of triaxial monitoring sensors.

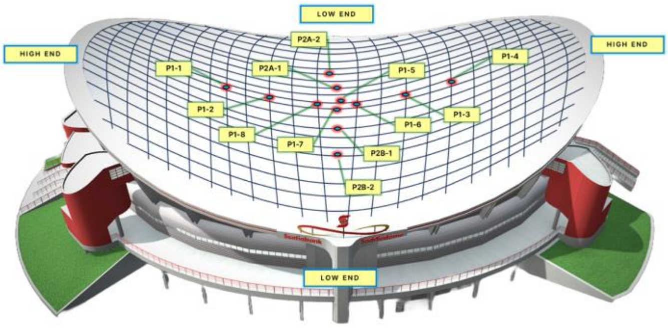

Figure 4. Approximate Positioning of the Survey Prisms

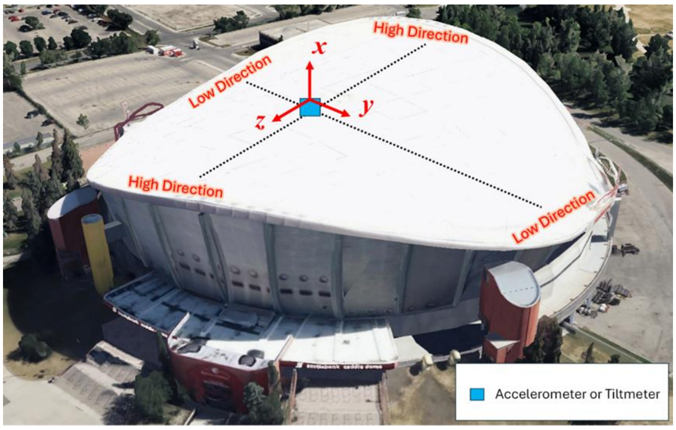

Figure 5. Orientation of the Triaxial Sensors

The monitoring sensors - strain gauges, reflective prisms, and triaxial sensors (including tiltmeters and accelerometers) - are installed in clusters positioned at the midpoint of cross ribs to maintain symmetry along the axes of the arena roof. The specific configuration of each cluster varies, allowing for tailored monitoring that addresses different structural requirements across the roof. This setup systemically provides comparative monitoring data based on the roof profile, helping identify any unbalanced loading effects and anomalies developing in the roof's structural system.

4.2 Implementation

Implementing an effective monitoring program can be a complex task, especially when faced with challenges inherent in the arena and its environment. Several factors can influence the design, implementation, and ongoing management of the monitoring program. A few notable challenges faced by SHM

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Canada team during the implementation and management of this monitoring system include access for installing the monitoring sensors due to unique roof geometry, the height of the roof, existing electrical and electronic fixtures, and tight project timelines.

One of the pressing challenges during the installation of monitoring equipment was the complex roof configuration and other hard to access areas. The limited access points, the concave and convex nature of the roof geometry, combined with existing fixtures on the arena roof, created significant complications in positioning, installing, calibrating, and maintaining proper line-of-sight (for reflective prisms) of the sensors. In addition to the roof geometry, sensor installation on the roof soffit of a significant height presented a time-consuming process and required a team of specialized rope access professionals.

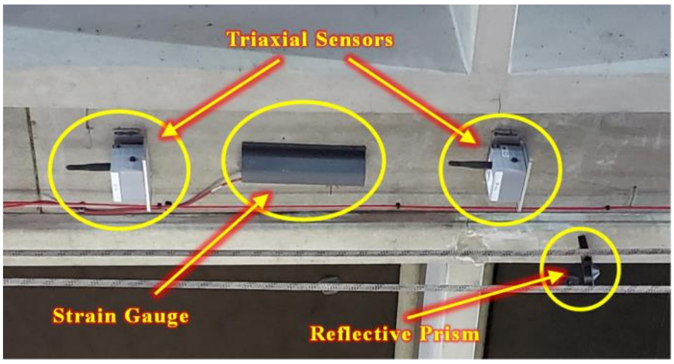

Figure 6. Typical Sensor Cluster

The Scotiabank Saddledome is considered the third busiest indoor arena in North America, hosting multiple professional sports teams as well as a variety of concerts and events throughout the year. As a result, the timeline for implementing the monitoring system posed a significant challenge due to the need to avoid disruptions to the packed event calendar. The limited timeline and opportunities to install the monitoring systems, perform pre-commissioning tests, and commissioning a fully functioning monitoring system without interfering with the arena's operations were essential requirements.

Successfully addressing each of these obstacles required careful navigation and an understanding of each challenge to plan and prepare tailored solutions, ensuring the monitoring system provides accurate, reliable data without interfering with arena operations.

5 DATA ACQUISITION AND ANALYSIS

The Scotiabank Saddledome monitoring system collects four different types of SHM data: strain, deflection, tilt, and acceleration at varying acquisition rates. Therefore, data acquisition, communication, and management procedures depend on the capabilities and requirements of the different monitoring sensors. The unprocessed data from various sensors collected by data-logging systems is then transferred and stored in SHM Canada's server for reliability checks and further analysis.

Figure 7 illustrates a typical flow diagram for the Saddledome monitoring program protocol related to data collection, storage, and analysis. This diagram visually illustrates the steps, sequences, and decisions within the monitoring process. Data collected from strain gauges, target reflective prisms, and tiltmeters are processed both individually and collectively to identify data trends, establish relationships, and perform statistical analysis.

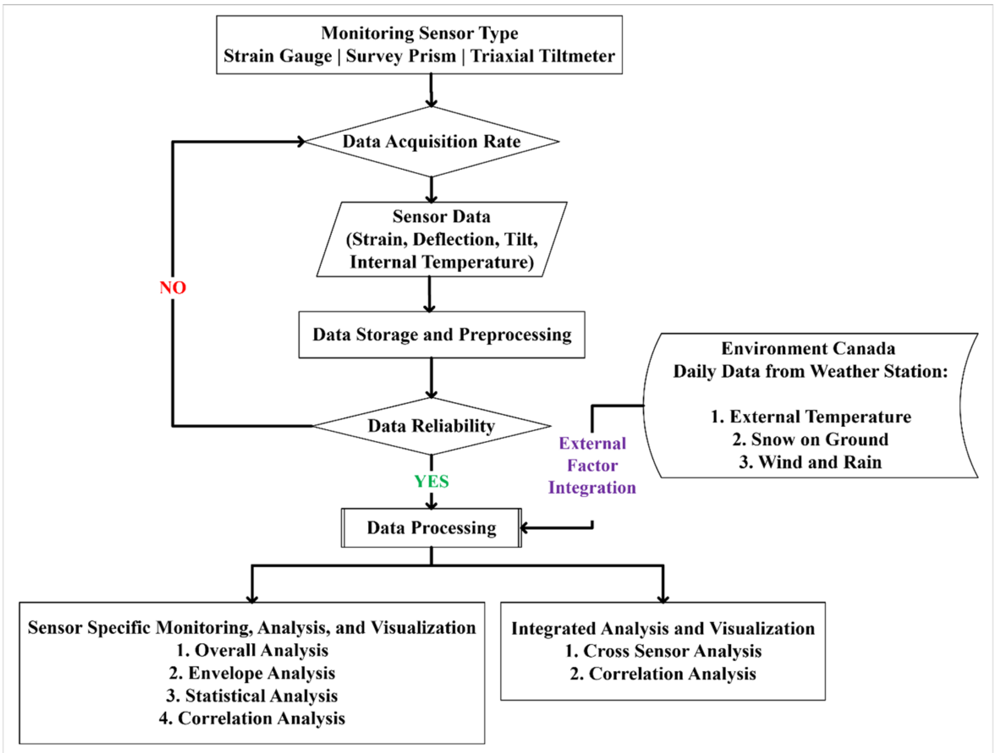

Figure 7. Data Acquisition and Analysis Process

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The acceleration data is processed separately for peak-to-peak acceleration changes and spectral density analysis to understand the frequency response of the arena roof under ambient and excited conditions. The acceleration analysis helps to determine the overall performance and detect any significant changes in the dynamic behaviour of the arena roof.

Furthermore, the city of Calgary is known for its highly variable weather, often experiencing dramatic shifts in a single day. Located on the eastern slopes of the Canadian Rocky Mountains in Alberta, the city's proximity to the mountain system causes weather patterns to change quickly. During winter months, temperature can drop suddenly, while in the summer, warm spells can occur unexpectedly. Calgary "chinook" winds from the mountains, can raise temperatures by 20˚C or more in a matter of hours, leading to a wide range of conditions throughout the year. Calgary's snowfall can be unpredictable, with snowstorms occurring any time during the winter months even as late as April. The city often experiences light and dry snow that accumulates rapidly but doesn't always accumulate for long. However, heavy snowfall can also occur, particularly in the winter and early spring.

Saddledome data analysis, therefore, integrates daily external weather data details (e.g., external temperature, snow on ground, rain, and wind) from the Environment Canada weather station near the Scotiabank Saddledome, along with different loading scenarios for major concerts and events hosted in the arena. This analysis protocol helps explore and incorporate all available internal and external factors that could influence the structural behavior of the arena roof.

The threshold limits are set based on the structure's age and history, combined with engineering judgment, allowing for a 10% increase or decrease over Year-1 recorded data. A notification system was implemented based on the established threshold limits to generate email alerts in the case of exceedance.

6 KEY MONITORING RESULTS AND DISCUSSION

This paper provides an overview of key monitoring results generated during the monitoring period from August 1, 2023, to January 31, 2025.

During this period, the Scotiabank Saddledome hosted a total of 51 major concerts and other events. This does not include minor events and other sporting events (such as hockey, lacrosse, skating etc.) The major events and concerts are indicated as vertical lines in Figure 8, 9, 10, 11, and 12. It is a well-established fact according to the National Building Code of Canada (NBCC) that the snow on ground data does not precisely represent actual snow accumulation on the arena roof. Actual snow accumulation on the arena roof and the nature of the accumulated snow plays a significant role in the roof's structural behavior. Due to limited information, the snow on ground data collected from the nearest weather station is integrated to provide context related to potential effects of heavy snow accumulation and snow drift. Any snowfall event is represented and incorporated by light-blue layers added in Figure 8, 9, 10, and 11.

The monitoring results presented as part of this study are referenced from their individual baseline readings and do not account for preexisting conditions (strain, deflection, tilt) present on the arena roof. The sensor-specific data is primarily analyzed to understand the localized effects of changes related to the internal conditions inside the arena. In contrast, a comparative study of different types of sensors provides insights into the arena roof's structural performance based on both internal and external variations.

6.1 Strain

The strain gauges installed on the sagging concrete ribs primarily experience tensile forces, while those on the hogging concrete ribs experience compressive forces. Figure 8 presents differential strains in the most active strain gauges in both the sagging and hogging directions.

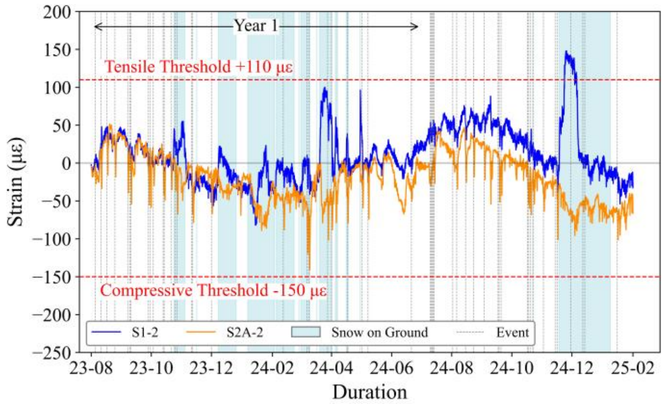

Figure 8. Strain Data from Different Zones

Analysis of the strain data revealed that the arena roof experiences event-specific changes in the strain levels both right before and after the events. These localized peak strain variations are primarily caused by the addition of event-specific mechanical and electrical fixture loads and their subsequent unloading from the arena roof. The strain levels are further increased due to snow accumulation and reduction in external temperatures. During these events, the internal temperature in the arena varied between 10°C and 22°C. The results also indicate that, during each scheduled event, the strain variations exhibited a similar pattern as the variation in the internal temperature inside the arena. The maximum tensile and compressive strain recorded by the strain gauge network is 148 με and 140.5 με, respectively against the threshold values of 110 με and 150 με. During this period, the absolute change in strain registered by a strain gauge was 230 με.

6.2 Deflection

The deflection levels recorded by target reflective prisms are compared with prisms symmetrically positioned about the orthogonal axis of the dome to detect any unbalanced deflection conditions. The comparative differential deflection results showed some localized behavioral patterns. A steep increase in downward deflection is observed during the day of each scheduled event in the arena. When accompanied by snowfall events higher levels of deflection are recorded. Figure 9 provides an overview of comparative differential deflection results from three different zones.

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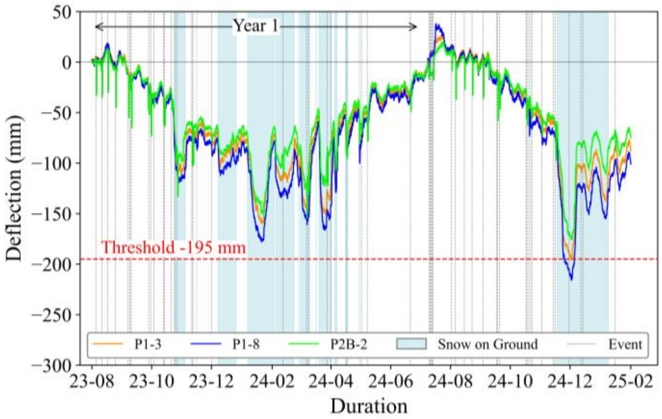

Figure 9. Deflection Data from Different Zones

The prisms located within the central region of the roof experienced higher deflection levels compared to the rest of the prisms. This phenomenon can be directly attributed to the consistent and balanced loading from the Jumbotron digital display system. The peripheral prisms in the hogging direction encountered a sudden increase in deflection levels during each major event. These specific changes in deflection levels are the result of the additional suspended loading. The maximum upward and downward differential deflections recorded by the survey prism network were 39 mm and 216 mm, respectively against the threshold values of 50 mm and 195 mm. The central prism recorded a maximum change of 254 mm in overall roof deflection during this period. The upward movement of the arena roof occurred during the removal of the old Jumbotron and the installation of the new Jumbotron of similar weight. A few hours after lowering the Jumbotron to the arena floor, the central region of the arena roof lifted upwards by 39 mm. With the installation of the new jumbotron, the deflection levels at the central zone returned to their previous deflection levels.

6.3 Tilt

The tilt levels are compared with respect to the in-plane and out-of-plane axes of the sensors at their symmetrical positions to infer any unbalanced rotation and its magnitude. The peripheral tiltmeters in both sagging and hogging directions recorded the maximum in-plane rotations. Steep changes in both the in-plane and out-of-plane tilt directions were observed mainly during the scheduled events. The maximum in-plane rotation for both high-to-high (sagging) and low-to-low (hogging) directional tiltmeters were 0.36 and 0.19 degrees, respectively. The absolute rotational range recorded by both high-to-high and low-to-low directional tiltmeters are 0.40 and 0.28 degrees, respectively. Similar to strain and deflection, the tilt is also influenced by event and environmental loading.

Apart from the in-plane rotation, the Zone-2 tiltmeters experienced noticeable out-of-plane rotation during scheduled events, with the maximum rotation recorded at about 0.1 degrees. These out-of-plane rotations have primarily occurred due to the additional suspended loading and unloading during scheduled events. Figure 10 demonstrates the in-plane rotation in both the sagging and hogging directional tiltmeters. All the central tiltmeters showed a similar level of rotation on both planes when compared to the peripheral tiltmeters due to the consistent presence of Jumbotron loading. Similar to the deflection behavior, during the replacement of the Jumbotron, the tiltmeters recorded a reverse angular shift but regained their normal levels after installation of the new Jumbotron.

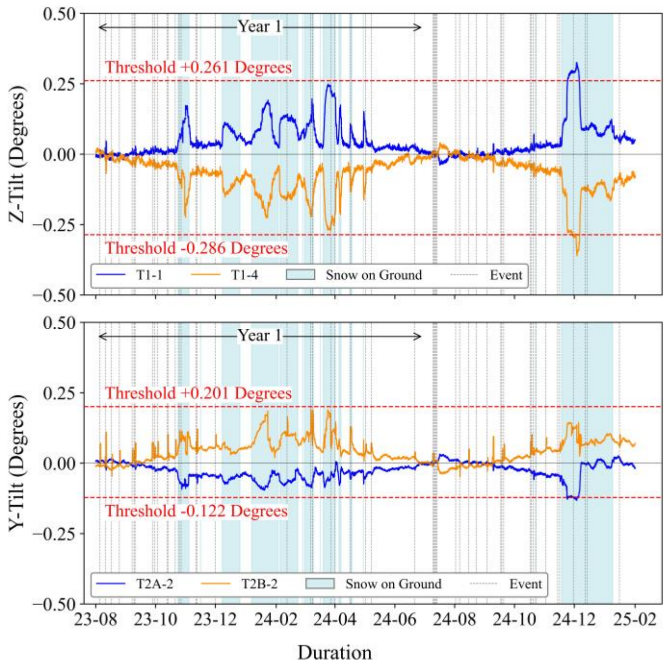

Figure 10. Tilt Data from Different Zones

6.4 Acceleration

The acceleration responses collected by triaxial accelerometers depending on two different acquisition modes: ambient and triggered, provided an understanding of the natural and induced frequency responses of the arena roof under different vibration levels and dynamic forces. The acceleration responses from different zonal accelerometers were analyzed using the Fast Fourier Transformation (FFT) and spectral density analysis. The peak frequencies were extracted and divided into four separate frequency bins based on their acquisition modes. Figure 11 presents the extracted ambient and induced frequency response from a Zone-2 accelerometer in the z-direction. Overall acceleration analysis showed that the natural frequency range of the arena roof is between 0 to 20 Hz. During an excited scenario, the frequency range of the arena roof lies primarily between 30 to 40 Hz.

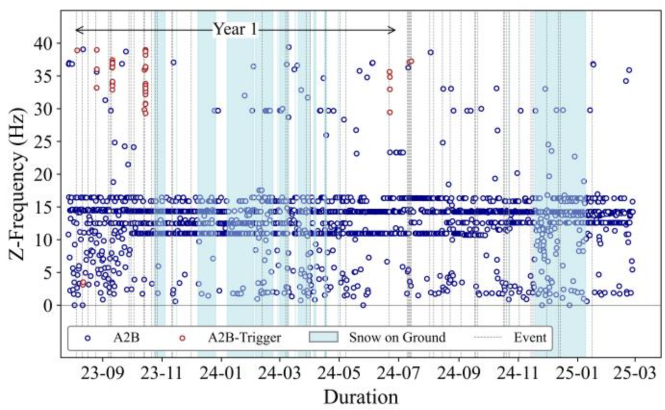

Figure 11. Typical Frequency Response of Arena Roof

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6.5 Data Envelope and Discussion

The data acquired from various monitoring parameters, as well as other internal and external factors, are integrated into the analysis program to provide a comprehensive and global understanding of the Scotiabank Saddledome's roof behaviour under both environmental and operational conditions.

The first year of the roof monitoring program at Scotiabank Saddledome helped SHM Canada understand the response of the arena roof, create a monitoring data envelope, and establish threshold limits for individual sensor groups based on their locations. These threshold limits are set to study the performance of this unique roof structure in the coming years. Figure 12 presents an overall monitoring data envelope based on the most active sensors in the system, with respect to external weather conditions.

The global analysis shows that the arena roof experiences significant thermal-induced stresses and deformations, irrespective of their source being of internal or external origin. The changes in the concrete ribs' strain, the overall deflection profile, and the tilt variation at different locations in the arena are primarily driven by the external weather conditions (such as external temperature and snowfall) as seen in figure 9 and figure 10. However, the steep changes in the monitoring data are attributed to the internal conditions (such as event-related loadings and internal temperature of the arena).

In the later months of the year, primarily during the colder months, the monitoring sensors recorded significant variations in their monitoring ranges. The relationship between monitoring data (e.g., strain, deflection, and tilt), and outside temperature greatly influences changes in the roof components due to its unique shape and internal load positioning.

The sagging concrete ribs in the arena roof are primary load-carrying members, and the tensile strain data recorded by those sensors installed on the sagging ribs showed elevated levels of strain. This period coincided with the increase in deflection and tilt levels observed by the central prisms and peripheral tiltmeters, respectively. In contrast strain gauges and tilt meters installed on the hogging ribs showed lower levels of strain and tilt respectively.

This behaviour can be attributed to movement in the arena roof caused by the temporary stretching of the sagging concrete ribs, the downward displacement of the central roof area, and the compressing of the hogging concrete ribs. In late 2024, accumulated heavy snowfall and additional event loading caused several deflection sensors to exceed their assigned thresholds, including a downward movement of up to 216 mm observed between November 25 and December 5. Upon clearing the accumulated snow, the roof rebounded to within acceptable threshold limits, indicating its elastic response to the loading conditions. The monitoring data indicate that changes related to external weather conditions are time-dependent rather than sudden. Additionally, the data analysis revealed a noticeable time lag between external weather changes and the corresponding monitoring data, likely due to the low thermal conductivity of the insulated concrete structure.

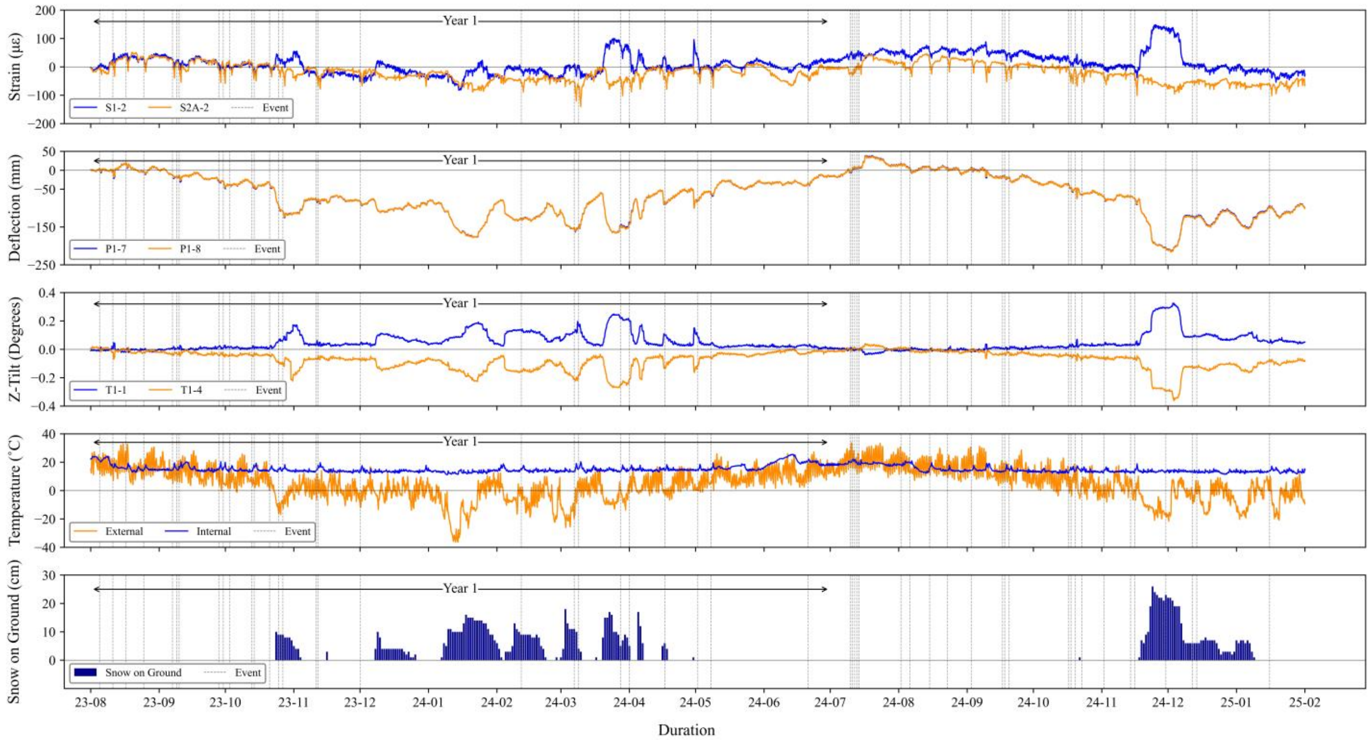

Figure 12. Monitoring Data Envelope for Strain, Deflection, Tilt, Temperature, Snow on the Ground

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Figure 13 presents a Pearson correlation table between external temperature and deflection data from various reflective target prisms. Correlation analyses of other monitoring parameters not presented in this paper (strain and tilt) also show a high degree of correlation with external temperature.

The weather starts getting colder in October and remains cold until April of the following year. During the same period, starting in December, the City of Calgary experiences snowfall, which continues until the end of April. During Year 1 of the monitoring period, from August 2023 to July 2024, Calgary's lowest recorded temperature was -37˚C, and the highest was 34˚C. So far, during the current period of 2024-25, the temperature has ranged between -28˚C and 31˚C. However, the snow on the ground data for the current period shows that the city recorded higher levels of snow on the ground for consecutive days compared to the previous year. Due to the height of the arena roof, combined with heavy winds and adverse weather conditions, the snow removal process from the arena roof can be challenging. This becomes an important factor to consider, particularly when it coincides with an ongoing scheduled event or a concert.

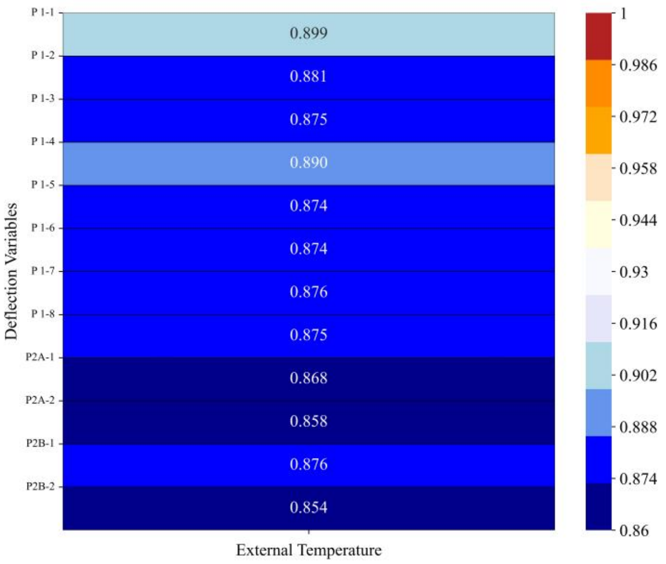

Figure 13. Relationship between Deflection and External Temperature

7 CONCLUSION

As asset owner, the City of Calgary is responsible for managing risk and ensuring safety of their assets. As the Scotiabank Saddledome ages the City of Calgary has taken proactive steps to assess the condition of the structure and mitigate potential risks. The monitoring program has provided CSEC and the City of Calgary valuable insight into the behavior of the roof structure under different loading conditions. It has ensured that necessary steps are taken to mitigate the risk of overloading the roof structure when environmental and entertainment loads are imposed on the roof. It has minimized the need to complete destructive exploratory assessments of the roof structure that are cost-prohibitive, disruptive to facility operations, and do not provide a thorough review of the system. In addition, the monitoring system has provided a method for identifying potential strand failures and thus reducing the risk of safety incidents. Structural Health Monitoring programs such as this uphold the City of Calgary's commitment to engineering excellence, ensuring the highest standard of care in maintaining and operating its infrastructure.

Accounting for the effects of climate change, which is causing aggressive shifts in weather patterns, as well as the age of the arena and other contributing factors, the current monitoring program of Scotiabank Saddledome provides valuable insight into ensuring safety, functionality, and structural integrity, while also aiding in prolonging the lifespan of this iconic arena through proactive measures. Not only is it an important venue, but it also represents the pride, spirit, and cultural heritage of the City of Calgary.

ACKNOWLEDGMENTS

Dennis Wipf with Gervasio and Associates provided valuable insights into the challenges and risks faced by the Arizona Veteran's Memorial Coliseum and methods for assessing and repairing a similar roof structure.

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