CASE STUDY

OPERATIONAL MODAL ANALYSIS OF THE LUXOR OBELISK

PLACE DE LA CONCORDE, PARIS

SITE PROFILE

The Luxor Obelisk, Paris, is more than 3,000 years old, is an emblematic monument of Parisian heritage. Built in the centre of the Place de la Concorde, it is located in a particularly dense environment and exposed to multiple stresses: vibrations due to road traffic, public demonstrations, works, and seasonal thermal variations.

As part of a contract awarded by the Regional Directorate of Cultural Affairs (DRAC) of Île-de-France, under the aegis of the Ministry of Culture, a structural and vibration monitoring system has been installed on the Luxor Obelisk (figure 1).

The presence of visible cracks on the structure and its age justifies increased observation. The device includes static sensors (inclinometers, extensometers, temperature probes) for monitoring slow movements, and permanent vibration monitoring via dynamic sensors. An operational modal analysis is carried out each year on the basis of natural loads, to detect any change in the dynamic behaviour of the structure.

Figure 1: The Luxor Obelisk, Paris

THE SITUATION

This project, planned for a period of four years, aims to continuously monitor the condition of the historic monument, through the observation of slow movements, existing cracks and the dynamic behaviour of the structure. The objective is to anticipate any abnormal developments, particularly in connection with climatic conditions, surrounding urban activities or public events.

Each year, it includes conducting an experimental modal analysis influenced by environmental factors to determine the structure's natural frequencies, modal shapes, and damping characteristics. This method helps establish a baseline of modal data, enabling long-term tracking of any variations that may indicate structural changes.

Figure 2: SYSCOM ROCK Acceleration

Supervised structure: Luxor Obelisk, Paris
Application: Operational Modal Analysis (OMA)
Technology: SYSCOM ROCK Acceleration (figure 2) Standalone Device with Self-Orienting, Self-Leveling, and Time Synchronization
Measurement points: 2 GNSS-synchronized ROCK Acceleration devices with internal triaxial sensor
Objective: Continuous monitoring of the structural condition of the monument
Monitoring time: 1-3 months
Engineering company: ITMSOL (Conducts the study) AVNIR Energy (Distributor)

TECHNICAL SOLUTIONS

PRINCIPLE OF OPERATIONAL MODAL ANALYSIS

Operational modal analysis (OMA) is a method used to characterise the dynamic behaviour of a structure based on natural environmental stresses, particularly ambient vibrations. This technique enables the identification of a structure's natural frequencies, modal deformations and damping without the need for artificial excitation. This technique is particularly well-suited to the long-term monitoring of monumental structures, where non-intrusive and reversible interventions are essential.

INTEREST OF THE OPERATIONAL MODAL ANALYSIS

In the urban context, natural stresses (traffic, wind, thermal variations, etc.) are sufficient to excite the vibratory modes of structures, making possible a continuous and minimally invasive analysis of their dynamic state. This monitoring makes it possible to detect subtle structural changes, often imperceptible to the naked eye, but revealing an alteration in the integrity of the structure.

The modal analysis applied to a heritage monument such as the Luxor Obelisk is part of a preventive approach, providing a baseline from which to identify any abnormal changes in the structural response over time. It is part of a global approach to structural health monitoring (SHM), combining static and dynamic measurements.

AVANTAGE OF ROCK ACCELERATION FOR OPERATIONAL MODAL ANALYSIS

The modal analysis of the obelisk was performed with SYSCOM ROCK Acceleration sensors.

These sensors (Figure 3) incorporate a triaxial accelerometer, 4G connectivity, a GNSS module, a built-in SIM card, and a rechargeable battery, all in a compact and rugged package. The ROCK Acceleration HD version is particularly suitable for massive structures: its extremely low intrinsic noise level (0.2 µg RMS/√Hz) makes it possible to detect extremely low vibration amplitudes.

High-precision time synchronization (< 10 µs) between sensors enables synchronised multichannel recordings, essential for reliable modal analysis.

Figure 3: ROCK Acceleration on the Obelisk

Figure 4: Luxor Obelisk with the installation of the SHM SYSCOM ROCK Acceleration device

RESULTS

On-site deployment (figure 4) was efficient and straightforward, thanks to the compactness and autonomy of the sensors. Automatic time synchronisation between sensors ensured the quality of the data acquisitions.

Campaign management was streamlined using the SYSCOM Cloud Software (SCS) platform, which enabled remote sensor configuration, real-time recordings monitored (figure 5), and seamless data retrieval - eliminating the need for on-site intervention.

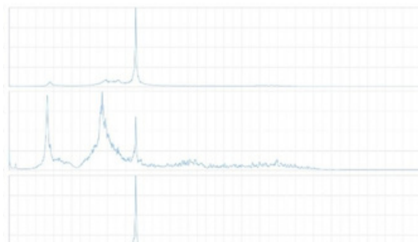

Figure 5: Frequency domain analysis of an event

Multiple acquisition modes were programmed: (figure 6)

- Acquisition of one-off events at threshold exceedances to capture possible shocks
- Dynamic ambient vibration acquisition of 7 minutes 30 seconds every 12 hours for the OMA

Continuous acquisition of a "background" mode with recording of the maximum acceleration value of each of the three axes per sampled period of 30 seconds (two acceleration values per minute saved).

The use of SYSCOM ROCK Acceleration sensors proved to be highly effective in this urban heritage context, meeting all technical requirements of the project with precision and reliability.

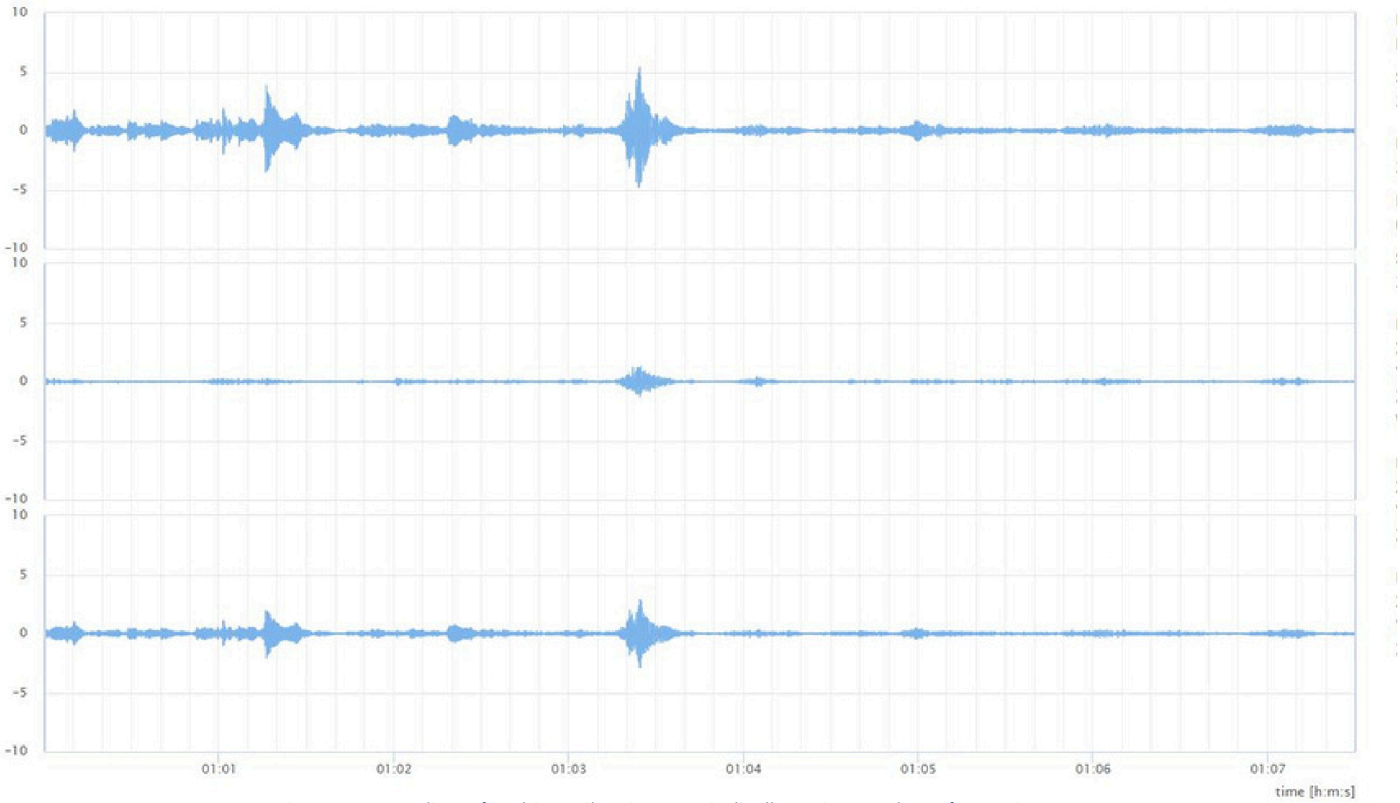

Figure 6: Recording of ambient vibrations, periodically, 2 times a day, of 7.5 minutes

CONCLUSION

The Luxor Obelisk Dynamic Monitoring Project illustrates the effectiveness of operational modal analysis for the non-intrusive structural monitoring of a historic monument. SYSCOM ROCK Acceleration sensors have proven to be fully adapted to the requirements of the urban and heritage given their low noise, compactness and precise timing. Their rapid deployment and built-in connectivity have greatly facilitated the implementation and long-term data management enabling efficient and reliable monitoring.

ACKNOWLEDGEMENTS

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