FBG Based Structural Health Monitoring for the Conservation of the Ponari Nymphaeum

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Ponari Nymphaeum, located in the archaeological area of ancient *Casinum* at the foot of Montecassino (Italy), is one of the best-preserved examples of a Roman *coenatio aestiva*, a summer dining and leisure space dating to the 1st century BC. Although previous investigations indicated that the monument has reached a relatively stable equilibrium, it remains affected by geotechnical risks associated with slope instability, debris accumulation, and inadequate drainage. These conditions generate lateral earth pressures that contribute to the development of extensive cracking within the masonry. To assess the long-term structural response of the monument, ENEA implemented a permanent Structural Health Monitoring (SHM) system based on Fiber Bragg Grating (FBG) optical sensors [1]. This study presents the results of the latest monitoring campaign conducted between December 2025 and February 2026.

A key advantage of FBG technology is the ability to multiplex several sensors along a single optical fiber, enabling simultaneous observation of multiple critical locations while minimizing cabling and reducing the impact on the archaeological site.

Variations in Bragg wavelength were compared with meteorological data from the nearby Cassino weather station. Despite differences between the two locations, sensor responses showed a clear correlation with daily temperature fluctuations.

To distinguish thermal effects from structural behavior, differential analyses between temperature and strain were performed on the sensor signals. The differential result displayed significant amplitude and temporal variability, indicating the presence of a mechanical component. This result suggests that the monitored cracks exhibit different kinematic responses, reflecting localized variations in stress distribution and masonry behavior.

This recent experimental campaign confirmed the high sensitivity of FBG sensors for detecting small deformations in historic masonry. Overall, the results demonstrate the effectiveness of fiber-optic monitoring systems for the long-term assessment of archaeological structures. Although the limited number of fully operational sensors prevented complete thermo-mechanical compensation, the acquired data successfully captured both environmental influences and structural responses. The observed differential behavior between adjacent cracks indicates that localized deformation mechanisms are still active within the monument, highlighting the importance of continuous monitoring.

Future work will include the installation of a new generation of FBG sensors with dedicated thermal compensation and an on-site meteorological station synchronized with the optical acquisition system. These improvements will provide a more accurate interpretation of environmental and structural interactions, supporting preventive conservation strategies and enhancing the understanding of slope-related instability affecting the Ponari Nymphaeum.

[1] M.A. Caponero et al. “Structural health monitoring of the Ninfeo Ponari by combined use of fibre optic sensors, photogrammetry and laser scanning”. 2019 IMEKO TC-4 International Conference on Metrology for Archaeology and Cultural Heritage. Florence, Italy, December 4-6, 2019