Real-Time Structural Monitoring of Bibi-Khanum in Samarkand (Uzbekistan) Combined with Subsequent Laser Scans

Shakhzod Takhirov[*], Ilyes Aripov[†], and Takhirjan Pulatov[†]

[1)]Structures Laboratory, Civil and Environmental Engineering Department, University of California, Berkeley; 337 Davis Hall, UC Berkeley, Berkeley 94720; email: takhirov@berkeley.edu

[†] Turin Polytechnic University in Tashkent, 100095, Tashkent, Uzbekistan, email; email: iljasar@mail.ru

[†] Polytechnic University in Tashkent, 100095, Tashkent, Uzbekistan, email; t.pulatov@polito.uz

Abstract

The Bibi-Khanym Mosque was originally built in 1399-1405 and in the 15th century it was one of the largest and most magnificent mosques in the Islamic world. In the recent years, the monument underwent several complex reconstructions. Among many other major restoration activities, the inner arch of the portal collapsed in an earthquake in 1897 was restored. Since the monument has been restored to one of the best shapes in its history, the continuous structural health monitoring (SHM) has become essential to ensure its preservation for the mankind. The SHM became the main objective of the ongoing extensive project, some results of which are presented herein. The structural health monitoring consisted of three majors components. First, a real-time monitoring of the monument by accelerometers, which were permanently installed throughout the monument. They were used to monitor effects of large and small earthquakes and ambient vibrations on the resonant frequencies of all major structures of the monument. By utilizing system identification approach, a possibility of structural anomaly's development may be detected from the change in its resonance frequency. Second, subsequent laser scanning was deployed to monitor anomalies of the monument's geometry in 3D. The monument's geometry was captured as a collection of points, which is called a "point cloud". The laser scanning was conducted several times a year to capture global movements of the monument due to change of elevation of the underground water table in rainy and dry seasons. Third, a finite-element (FE) model based on the as-found geometry of the point clouds was generated. It was calibrated based on the collected data to ensure acceptable correlations with the results of the measurements. The FE model was generated for future restoration efforts to evaluate the performance and efficiency (if any) of the proposed restoration measures. Based on the results of numerical simulations and health monitoring results, preventive measures were developed. In addition, the recommendations on further preservation of the historic monument were developed.

Keywords: *Structural Health Monitoring, Seismic Assessment, Laser Scanning, Accelerometers, Real-time monitoring, Samarkand, Great Silk Road.*