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Structural analysis of Azurara church, Portugal

Amruta Uplekar*, Ellen Key*, Estefanía Chaves*, Omar Pino*, Ozlem Balik*, Graça Vasconcelos[††]and Javier Ortega[††]

* University of Minho
Campus of Azurém, 4800-058, Guimarães, Portugal
e-mail: amrutauplekar@gmail.com; ellenkey@ucla.edu; e.chavesmoreno@gmail.com;
opino31@gmail.com; ozlembalik@gmail.com

[††] ISISE, University of Minho
Campus of Azurém, 4800-058, Guimarães, Portugal
Email: - Web page: https://isise.net

ABSTRACT

Azurara church is a Catholic church and was classified as a national monument in 1910. Presently it is property of the Portuguese state. The construction of the church dates back to 1502 and was concluded in 1552. The building has not only the influence of the *Manuelino* architectural style (Portuguese late Gothic style), but also Baroque and Mannerism styles. It is a stone masonry building with a timber roof. The church is rectangular in shape and is composed of three naves separated by semicircular arches supported by stone columns (5 spans). The chancel is covered by a ribbed vault. The façade has a bell tower at the left side. The church underwent interventions in the past, namely in the second half of the 20th century and in the 80s and 90s. The later interventions were focused mainly at the level of the timber floor due to problems related to severe and permanent moisture in the ground, and they included the cleaning of moss, lichen and algae in the lateral walls and columns of the nave.

The church presents mainly non-structural problems due to different sources of moisture, which led to: biological colonization with the development of algae, mosses and lichens at the surface of the stone materials; granular disaggregation of granite in the lateral portal frame, the tower and the rose window of the main façade; and wood decay of the altarpieces due to severe termite attack. However, there are a few structural cracks on the stone masonry walls and particularly in the bell tower.

The main objective of the present paper is to explain these structural cracks with the aid of advanced structural analysis. It details the numerical analysis performed using the finite element method to model the structural behavior of the church under different load conditions. Significant problems in this type of analysis include the definition of the material properties, boundary conditions, level of connection between structural walls, and modelling of non-structural elements. In order to overcome these difficulties, non-destructive tests can be useful for both, to estimate the material properties as well as to identify the dynamic properties of the building using Operational Modal Analysis (OMA). Through OMA, it is also possible to update and calibrate the numerical model by modifying the material properties and boundary conditions until fitting the numerical natural frequencies and mode shapes with the experimental ones. The numerical analysis was based on a macromodel approach, considering the masonry as a homogeneous and isotropic material and adopting adequate constitutive laws to describe the nonlinear behavior of masonry. A nonlinear static analysis (pushover) considering both vertical and horizontal loading was carried out in order to obtain the maximum load factor for the structure. Finally, although earthquakes are rare in this region, the structure was also analysed for low intensity ground motions.