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Ambient vibration testing and dynamic identification of a historical building. Basilica of the Fourteen Holy Helpers (Germany).

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Abstract

The preservation of the architectural heritage is a fundamental aspect in the cultural development of modern cities. This heritage has to be preserved and different technical analysis are usually necessary to ensure its proper preservation. Due to this fact, before performing these analyses, non-destructive techniques are usually an indispensable tool to provide information about the current structural behavior of the building. The use of ambient vibration tests is widespread as a technique to identify dynamic properties of historical constructions from a global point of view, but not to identify these dynamic properties of specific elements with a local character. In this paper, these techniques are used to characterize dynamically concrete parts of a historical building. These dynamic structural parameters identified by using the operational modal analysis method allows the adjustment of numerical models in order to obtain a more accurate estimation of the actual behavior of the structure. In this way, updated FE models can be used to assess the structural behavior of the historical building.In the present paper, the use of ambient vibration tests on the masonry roof of the Basilica of the Fourteen Holy Helpers is presented. This is a church located near the town of Bad Staffelstein near Bamberg, in Bavaria, southern Germany. The late Baroque-Rococo basilica, designed by Balthasar Neumann, was constructed between 1743 and 1772. It is dedicated to the Fourteen Holy Helpers, a group of saints venerated together in the Catholic Church, especially in Germany at the time of the Black Death.

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Keywords: Historic construction; Masonry structures; Ambient Vibration Tests; Operational Modal Analysis

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1. Introduction

The historical construction, purpose of this study, is the Basilica of the Fourteen Holy Helpers [1]; a Baroque-Rococo church located in Bavaria, southern Germany (Figure 1). It was designed by Balthasar Neumann [2, 3], and constructed between 1743 and 1772. This chapel is a very singular construction, mainly due to the configuration of its vaults, with a complex spatial geometry, which includes warped intersections between them, and due to the high level of technology required from a construction point of view. In this sense, it is one of the few examples that can be found in Europe with this level of complexity [1].

Fig. 1. Basilica of the Fourteen Holy Helpers.

One of the main difficulties that need to be addressed in structural analysis of historical buildings is the level of uncertainty associated with many factors affecting the behaviour of the structure. Aspects like the mechanical properties of the structural materials, the building construction process, the connections between structural parts or the cracking condition of the building may cause important changes between the results obtained from a numerical analysis and those experimentally observed [4]. In this sense, non-destructive techniques appear as useful tools to provide information about the structural behaviour of the building [5, 6]. In particular, dynamic properties provided by ambient vibration techniques have proved to be quite well-suited to validate and update numerical models [7].

Operational Modal Analysis (OMA) has consolidated as one of the most adequate methods to estimate the modal parameters of a structure, due to the facts that: (i) it is a non-destructive and non-invasive technique and (ii) it can be performed under service conditions. For these reasons, OMA is currently recognised as a quite convenient technique to dynamically characterise historical buildings, since the use of the stronger external excitation (impact hammers or shakers) required to perform the traditional Experimental Modal Analysis (EMA) is not needed. The interested reader is referred to reference [8] for a more involved discussion on the practical and technical differences between OMA and EMA when applied for testing of masonry vaults. Subsequently, modal properties provided by the application of OMA allows the adjustment of numerical models in order to obtain an accurate estimation of the actual behaviour of the structure. In this sense, updated FE models can be used to carry out a structural analysis under existing conditions or further predict the effects of different structural situations that the structure could undergo. In the last decades, many cases of application of ambient vibration tests to update numerical models can be found in historical buildings [9, 10, 11, 12]. However, the applications of OMA to assess structural behaviour of specific complex parts of a building, such as domes or vaults, are much more limited [13, 14]. The main purpose of this study is to characterize dynamically the vaults of the chapel in order to gain further knowledge over such complex structure and, in later studies, update a finite element model with the objective of estimating and analysing its current safety level. A brief description of the chapel, the methodology followed to dynamically characterise the building and the results obtained will be presented in this document. The paper is organised as follows: Section 2 summarizes the main characteristics of the chapel. Section 3 presents the dynamic characterisation of the vaults of the chapel by using the Operational Modal Analysis method. It further describes the initial finite element model developed to estimate the modal parameters of the system. Finally, Section 4 draws the main conclusions of this study.