Finite Element Models for assessing the structural behaviour of complex historical buildings

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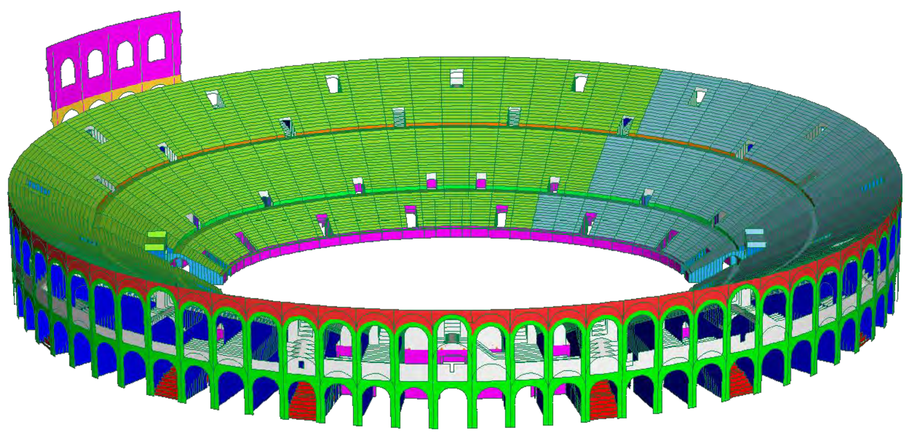
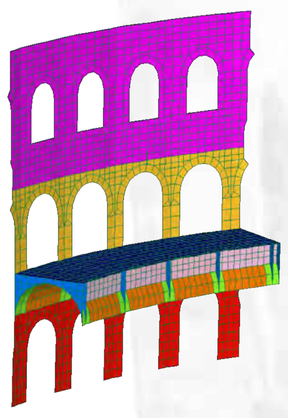
Introduction

The simultaneous **need to preserve historic heritage** and to appreciate its seismic vulnerability requires the **development of techniques and methods** used to properly **establish the structural behaviour of historical monuments**.

In this context, the **Roman Amphitheater of Verona**, dating back to the first century AD and wherever known as Arena, **is an important case study** in support of a conservation project of the building itself promoted by the mutual agreement between Municipality of Verona, Archaeological Superintendence of Veneto and Fondazione Arena.





Method

The main purpose of the present work is the **creation of a Finite Element Model** of the Roman Amphitheater of Verona, able to reproduce the static and dynamic behaviour of a monument **characterized by marked morphological and constructive complexity**.

The study is based on the **combined use of numerical modeling and experimental data** resulting from non-destructive diagnostic tests, carried out on the masonry structures of the building, which allow to detect the real mechanical behaviour without loss of their functionality and efficiency.

Steps of the work

The work has required the completion of the following basic steps:

- creation of a Finite Element Model complete in terms of structural geometry, loads, constraints and material properties;
- recovery of data from experimental studies previously carried out in significant positions of the monument;
- calibration of the model on the basis of the results of tests in situ.

Assumptions

The starting hypothesis on which is based the development of the entire modeling is the use of **materials with a linear elastic constitutive law**.

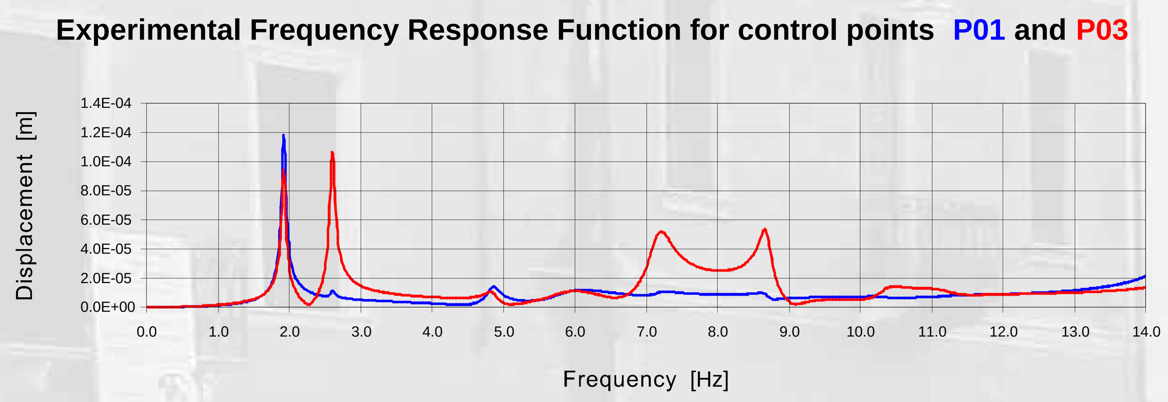
This assumption is generally recommended especially for qualitative analysis designed to asses the structural behaviour of a complex building.

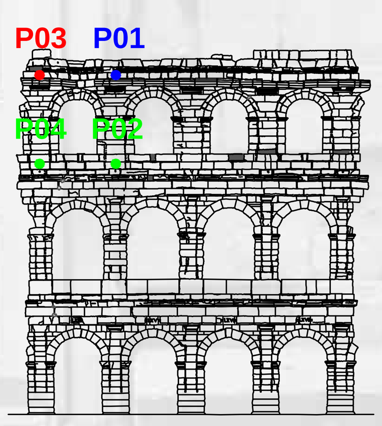
Simulation and experimental validation

The Finite Element Model of the whole building was refined and calibrated on the basis of data from **experimental investigations carried out on the so-called "Ala"**, what is left of external ring after destructive past earthquakes.

In 1996 were realized some tests to determine its structural behaviour in relation to dynamic stresses: the acquisition of the signals was made with four accelerometers placed in pre-selected points of the structure.

The Frequency Response Function obtained represents the deformability of each point of the structure to vary the excitation frequency.



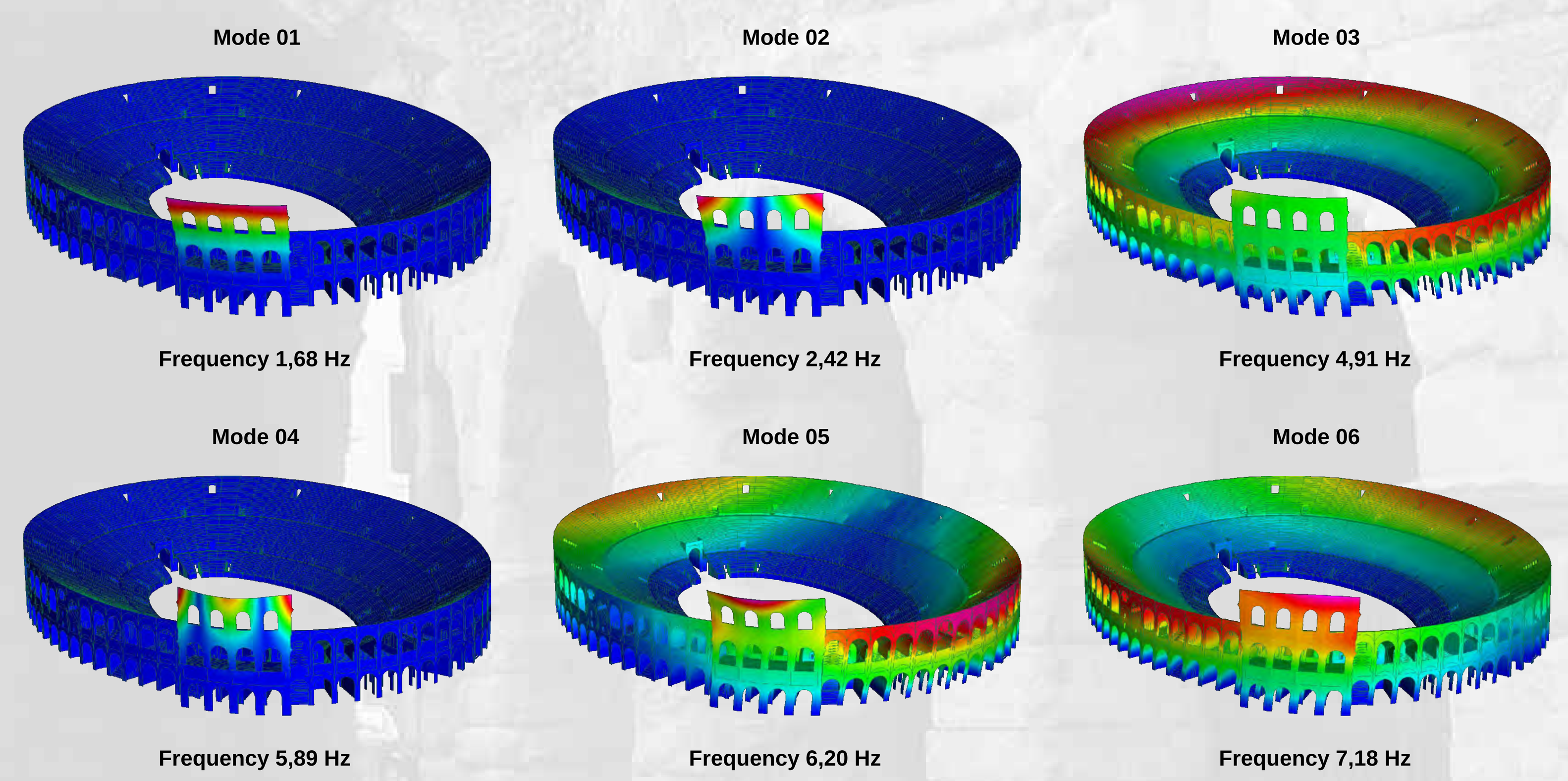


The term **validation** indicates the process by which it is shown that the results provided by the analysis conducted on a Finite Element Model are accurate enough to allow to describe correctly the structural behaviour.

From the graphical comparison, in terms of modal shapes, between six of the first eight vibration modes, it was obtained a **significant correspondence between simulation and experimental results** which has allowed to judge the correctness of the dynamic behaviour of the Finite Element Model.

The values of frequencies arising from modeling differ from the real ones for negligible amounts, therefore, it can be stated that the Finite Element Model is sufficiently precise.

Modal shapes resulting from dynamic simulation applied to the Finite Element Model



Findings

The modeling has been conducted assuming a linear elastic behaviour of all materials.

This approximation has proved to be very useful to develop a model sufficiently accurate, avoiding the complications introduced by the use of non-linear diagrams.

The validity of **elastic modeling** is demonstrated by the fact that the starting model, without corrections for adaptation to experimental values, has directly provided results **very close to reality**.

Future developments

The study could be further developed taking into consideration the real constitutive laws of materials and the localized phenomena of deterioration which may affect the structural behaviour of the building.

Following these developments will be possible to compare the effectiveness of different modeling approaches applied to historical buildings of this entity.

Optimized methods allow to support interventions on complex historical buildings.

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