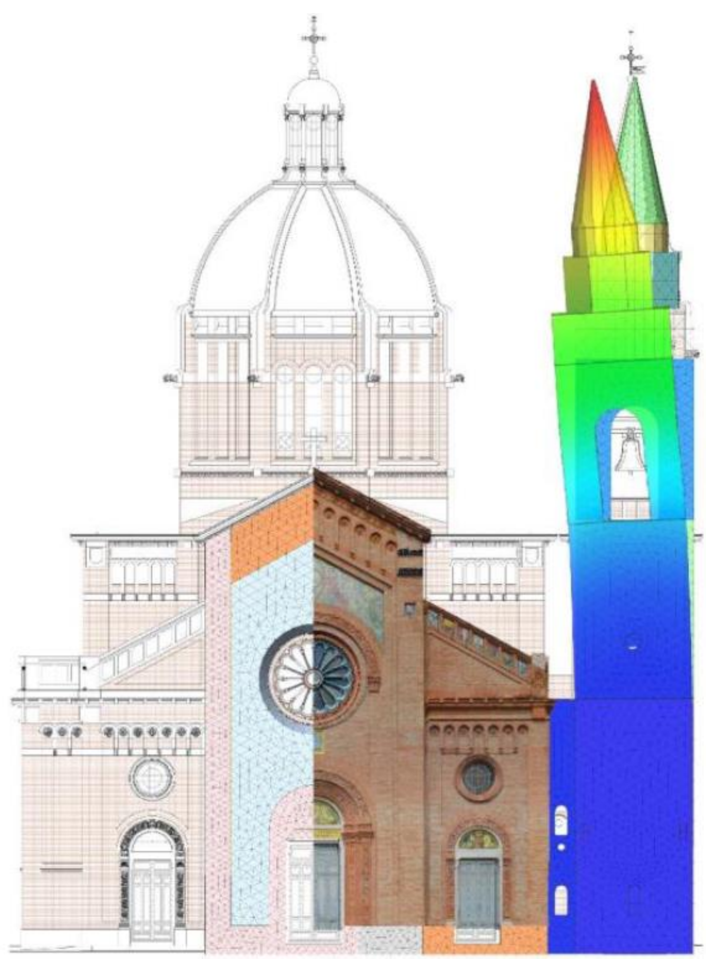
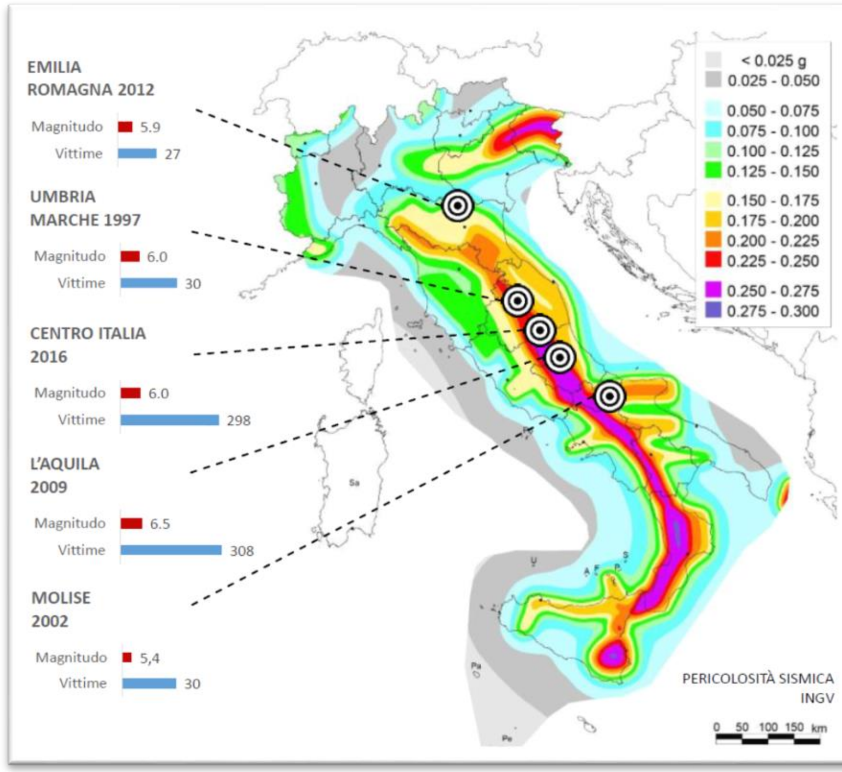
Dynamic Analysis on Historical Building.

Santuario del Santissimo Crocifisso
di Treia (MC).



ABSTRACT

The high seismicity of the Italian territory has led over the years to the occurrence of numerous seismic events of varying intensity. This has caused numerous losses, as can easily be seen in the infographics in picture 1.
However, it is useful to observe how; the intensity of the seismic event is not closely related to the number of victims associated with the event.
This is because the variables that regulate this parameter are multiple. Such as, for example, the stratigraphic, topological nature of the terrain and the quality of the building that is impacted by the event.
It is precisely this last variable on which we should act with greater insistence with works of monitoring and structural analysis. Also, for the nature of the Italian historical heritage, rich in valuable artifacts.
The procedure for dynamically characterizing the Sanctuary of the Holy Crucifix of Treina, in collaboration with the **Polytechnic University of Marche**, hit by the earthquake in central Italy in 2016, will be illustrated below.



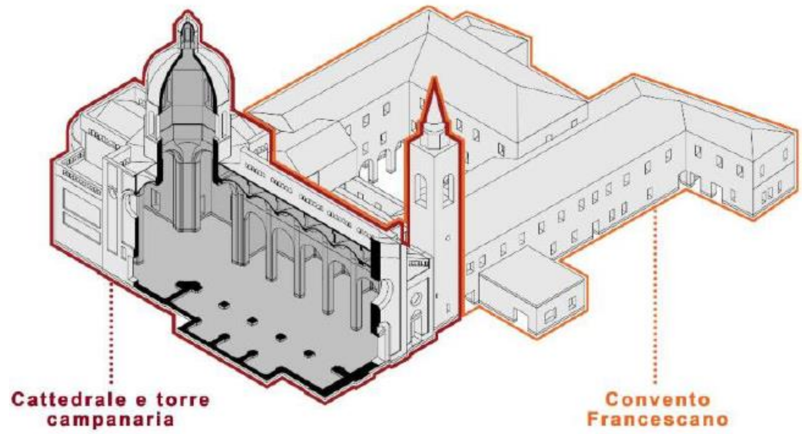
Picture 1 Seismic Hazard INGV

OVERVIEW - OMA

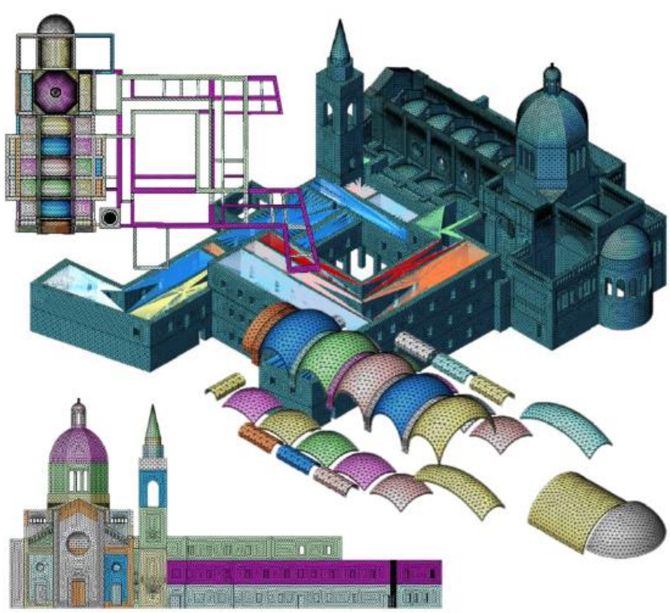
Operational modal analysis (OMA) is a complementary technique to traditional modal analysis methods and is based on measuring the response of the test structure.
The technique allows the monitoring of structures, such as civil structures, which are difficult or inconvenient to excite by controlled external forcing, due to their boundary conditions, or their large size. The quality of the data has improved, also because they represent the real conditions of use of the dynamic system. Measurements are also made with real boundary conditions guaranteed. The civil structures can therefore be tested in situ, without compromising their intended use (e.g. traffic for bridges), avoiding interference or interruptions in their daily use. Finally, for all the reasons given, the cost of the OMA analysis is significantly lower than the EMA analysis.
However, there are some problems related to this type of analysis, such as the fact that it is necessary to use very sensitive equipment in order to appreciate the response, given the small amount of stress, and the need to pay particular attention to data processing, as you have only the output data.
In general, the force that excites the structure is a white noise or an unknown force plus a white noise. In any case, the input is unknown from the analytical point of view and must be treated exclusively in probabilistic terms. Therefore, hypotheses of statistical distribution of the forces are formulated, and the theory of dynamic identification derives from this.

ANALYTICAL MODEL

In order to create a good analytical model, it is necessary to make a first study on the knowledge of the structure under examination.
Evaluate geometric factors, resistance of materials and the events to which over the years has been subjected.
A first preliminary investigation was then modeled the whole structure with shell elements in a fem program by give the same elastic module to the different components.



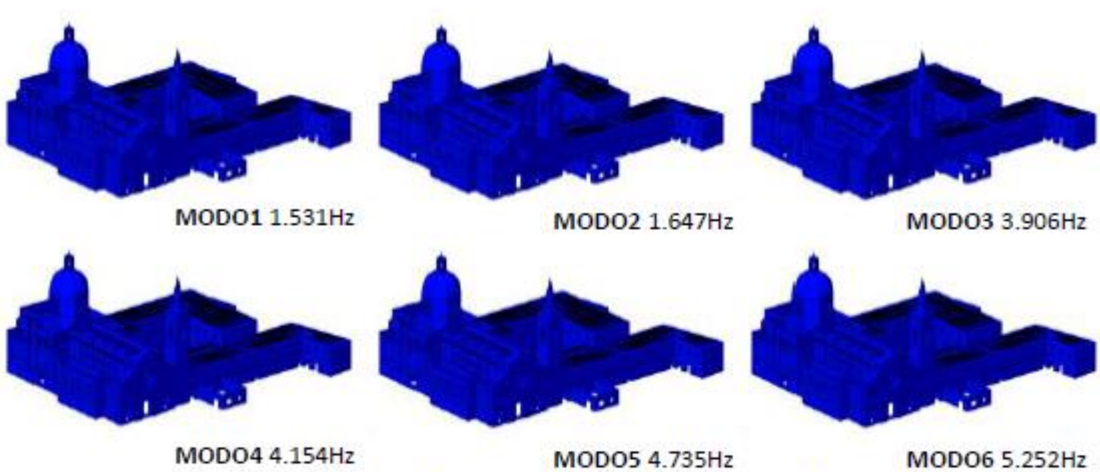
Picture 2 Element of Building



Picture 3 FEM Model

As can be seen from picture 3, each structural element has been attributed a different type of material.
So that we can then act on the elastic modulus in the phase of Model Updating. To match the response of the analytical model with the experimental model.
A first modal analysis has been carried out making reference to the resolution of the fundamental equation of the dynamics of the second order defined damping null:

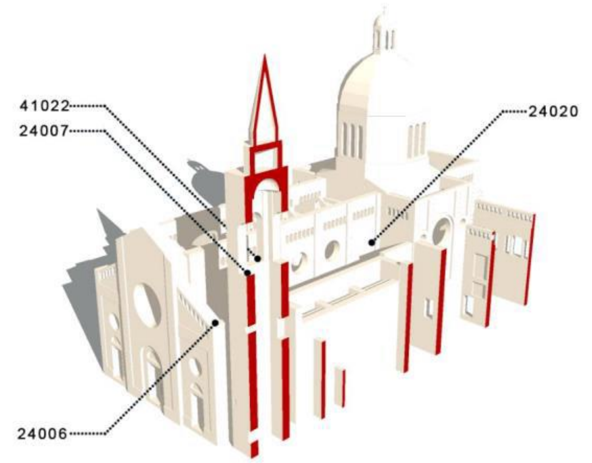
$$[M]\{\ddot{X}(t)\} + [K]\,]\{X(t)\} = \{f(t)\}$$



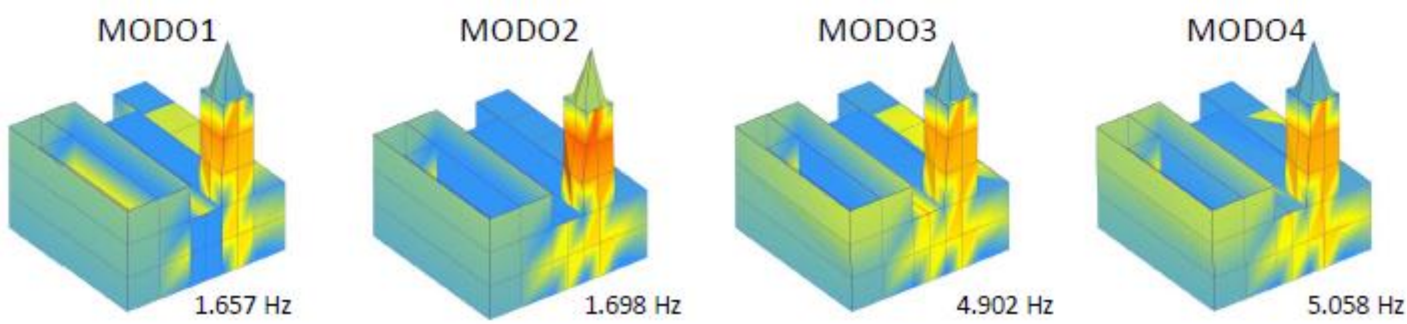
Picture 4 Fist 6 Analytical Modes

EXPERIMENTAL MODEL

To identify the modal parameters of the experimental model, several measurement campaigns were carried out with the GEA System vibration monitoring system.
By varying the positions of the sensors from time to time, taking care to leave at least one sensor in the same position during the various measurement campaigns. In this way, the various measurements can be reconnected.
Once the raw data had been obtained, the experimental methods were identified with the various stabilization techniques. (SSI FDD)



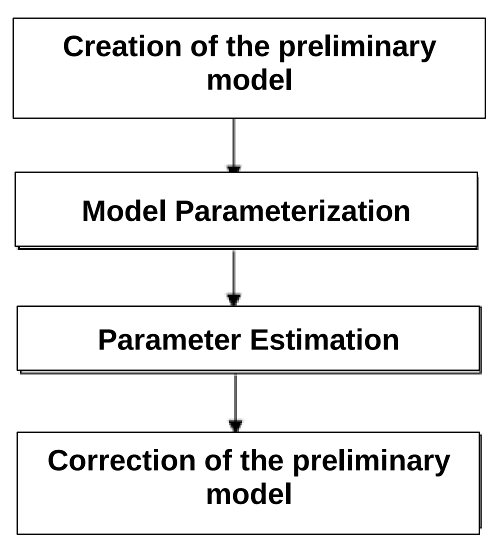
Picture 5 Example Setup Sensor Position



Picture 6 Fist 4 Experimental Modes

MODEL UPDATING

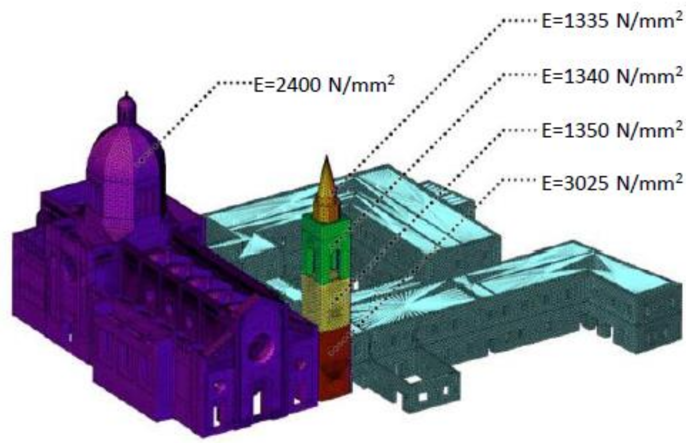
Model Updating is a procedure through which you can improve the behavior of a preliminary model by correcting errors related to assumptions made in its formulation.
For the achievement of this purpose, the role played by the experimental modal analysis is fundamental, which allows the identification of the structure starting from the processing of the accelerometric signal recorded during the execution of dynamic tests.
The next step is the choice of the parameters to be calibrated for each macro-element; this phase is very delicate because it greatly influences the quality of the results obtained. Moreover, the number of parameters to be calibrated must be limited in order to avoid bad conditioning. In general, in parameterization, variables are attributed to individual elements or groups of the same characteristics and are varied within a certain range.



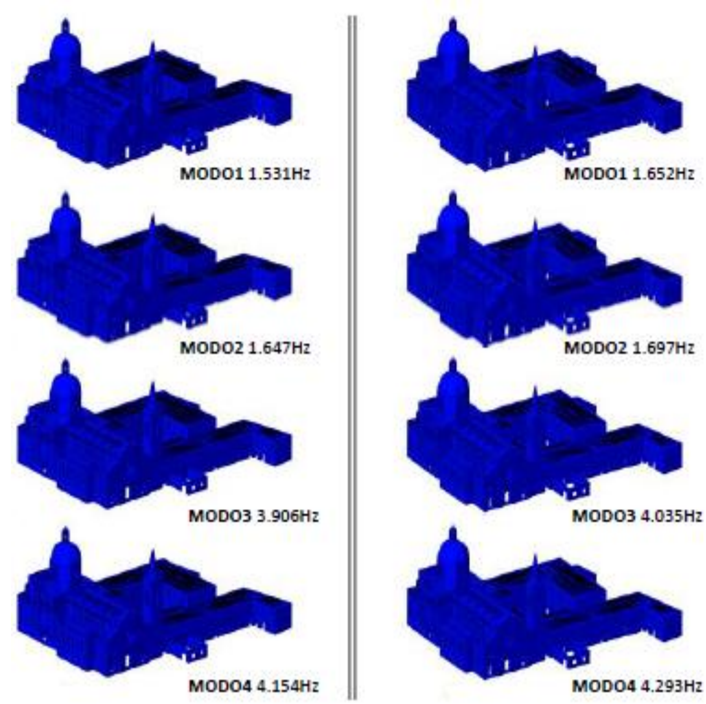
Picture 7 Flow Chart Model Updating

Another important moment in Model Updating is the comparison between the experimental data and the numerical data obtained by the FEM. The delicacy of this step is due to the fact that, being the degrees of freedom of the structure is more over respect to model and also having assumed zero damping, the comparison between these data is very complex. In fact, the comparison between theoretical and experimental vibration modes takes place in the light of the MAC coefficient variable between 0 and 1.

Finally, the last step is the calibration of the starting model by estimating the correct mechanical parameters. This can be done either in a single step (in the case of direct methods) or in an iterative way (indirect methods) and depends on the optimization technique chosen among those possible.



Picture 8 FEM Model Calibrated



Picture 9 Comparison of uncalibrated (left) and calibrated (right) models

CONCLUSIONS

The dynamic knowledge of historical buildings is very difficult, especially with regard to the parameters of materials that, over time, can undergo significant changes.

The FEM models alone are not able to respond fully to this need.

Having, by their nature, intrinsic limits such as the inconsiderate damping. (or by forcing diagonalization)

The definition of a permanent dynamic monitoring system has the double advantage: evaluating how the modal parameters of the structure evolve and carrying out permanent monitoring at the same time.

COLLABORATIONS

Work result of a close collaboration between the Polytechnic University of Marche, Department of Civil Engineering, Construction and Architecture, Structures section and Novastest S.r.l.

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