

# JRC contribution to the protection of the European architectural heritage

## 1. Aim

JRC activities are aimed to contribute to the development of new methodologies, techniques and guidelines for diagnostics, retrofitting and repair of the structures of the European architectural heritage.

## 2. Objectives

The Joint Research Centre (JRC) is engaged in research in the field of cultural heritage protection through its own institutional programme (financed by the Framework Research Programme of the European Commission). These activities are complemented by competitive actions performed in close collaboration with international networks (shared costs actions) or regional Authorities (technical support to Regions of southern Europe).

The main objective is to contribute to the definition of intervention methodologies and design guidelines for the structural diagnostics and retrofitting/repair techniques for structures of the Cultural Heritage.

To reach the objective, an effort is done to extend the recent advances in optical technologies and earthquake engineering to the structures of the Cultural Heritage. This attempt to make compliance between the engineering and the architectural approach for the retrofitting/repair techniques is a first step to set-up a unified theory for the restoration of Cultural Heritage structures.

The purpose of the activity is the development of innovative techniques for the structural diagnostics and for the improvement of the overall stability, in particular seismic protection, applicable to the rehabilitation of cultural heritage.

∞∞ The technologies used by JRC for the structural diagnostics are related to photogrammetry and laser-vibrometry.

∞∞ The research and validation tests for strengthening and retrofitting the structures of cultural heritage is performed at the European Laboratory for Structural Assessment (ELSA) that is a unique facility in Europe for dimensions and characteristics.

## 3. Typology of intervention

The most relevant activities are related to:

- Application of Photogrammetry for the tridimensional digital description of the geometry.
- Dynamic characterisation of structures by laser-vibrometry.
- Characterisation of new materials (Composite, Shape Memory Alloys and others) for static and seismic loads and experimental validation of devices.
- Non-linear numerical analyses of masonry buildings
- Pseudo-Dynamic (PsD) seismic testing of large-scale models of structures.
- Development of guidelines for the retrofitting of masonry and Cultural Heritage structures.

## 4. Interventions

### 4.1. Palazzo Geraci in Palermo (<http://tintin.jrc.it/htdocs/>)

Activity executed in close collaboration with the Sicilian Universities and related to the front wall of "Palazzo Geraci" and to "Fontana Pretoria" in Palermo. Photogrammetry and Laser Vibrometry have been used for the geometric and mechanic characterisation of the monuments. The effectiveness of retrofitting techniques for "Palazzo Geraci" have been analysed through numerical analyses and seismic tests on a large-scale model tested at the ELSA laboratory.

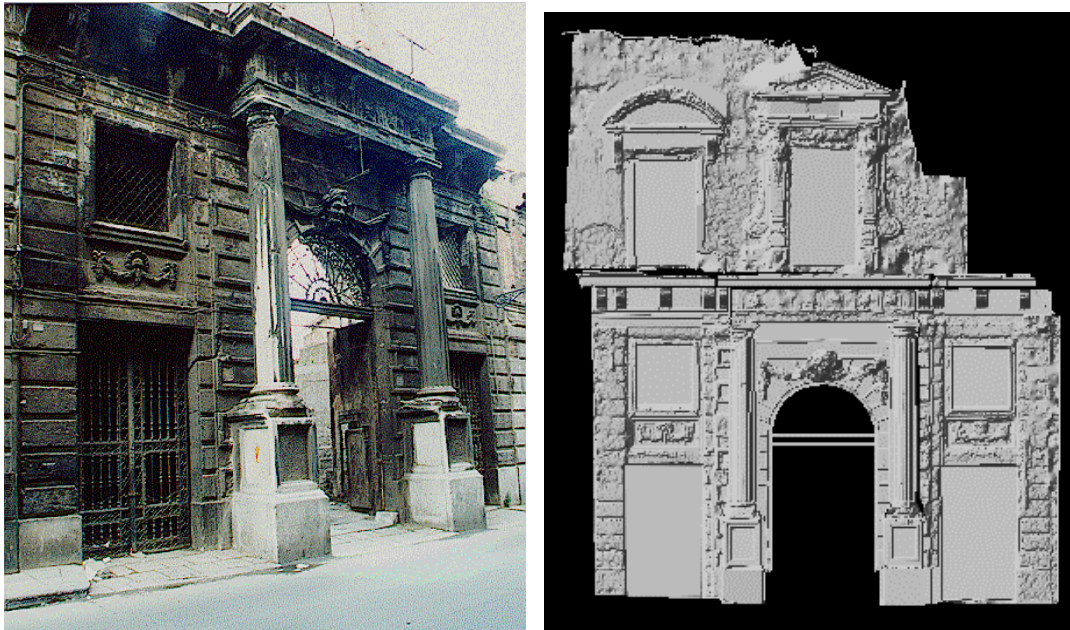


Figure 1: Palazzo Geraci in Palermo and photogrammetric reconstruction

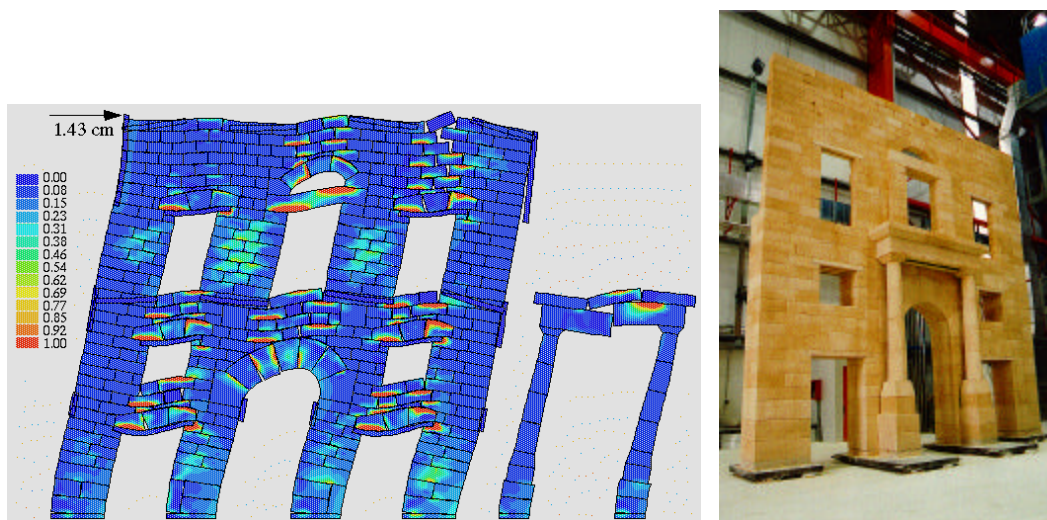


Figure 2: Numerical analyses and large -scale Model at ELSA

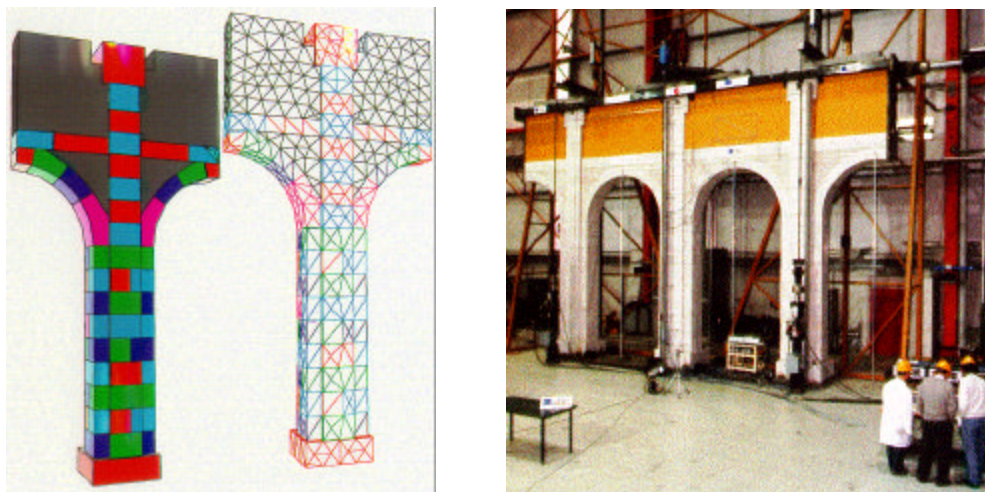
#### 4.2. Sao Vicente de Fora Monastery in Lisbon

The activities, run in close collaboration with the national research centre of Portugal and other partners, focused on the behaviour of the cloister of Sao Vicente de Fora Monastery in case of earthquake.



**Figure 3: The cloister of Sao Vicente de Fora Monastery in Lisbon**

3D numerical models able to represent the structural components including joints have been developed. These models will be calibrated and used, together with linear models, to assess seismic vulnerability and to help in the design of retrofitting systems for monumental structures in earthquake prone regions.



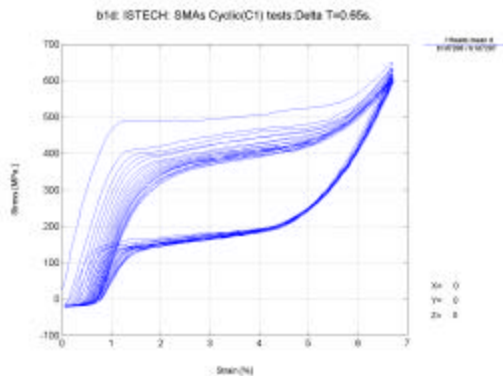
**Figure 4: Numerical analyses and full-scale Model at ELSA**

The testing campaign will be completed with tests on the retrofitted structure. The utilisation of *iron tie bars* at the floor and at the arch-base levels and their practical application will be investigated.

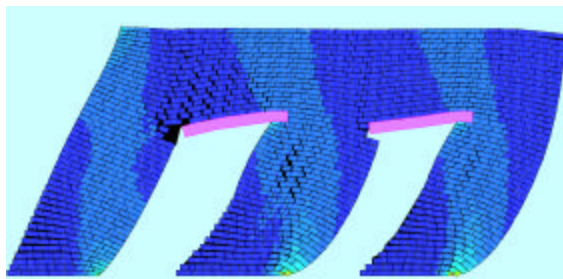
### 4.3. Innovative retrofitting techniques

The activity refers to the project ISTECH (Innovative Stability Techniques for the European Cultural Heritage) that investigated the possibility to use Shape Memory Alloys (SMAs) for the realisation of intrinsically energy dissipation devices for the retrofitting of cultural heritage structures. The work was carried out by an international Consortium (FIP-It, ENEA-It, JRC-EC, UROME-It, IST-Pt, AUTH-Gr) and was partially funded under the 4<sup>th</sup>-FP by the General Directorate XII through the Environment and Climate Programme.

The protection system based on SMAs devices couples strengthening due to compression on the masonry wall with energy dissipation that can occur for strong earthquakes. The strengthening with constant force will be use for the seismic upgrading of the structure, while the energy dissipation will provide improvement of stability to avoid the loss of the structure.



**Figure 5: Experimental result of characterisation tests on SMAs**



**Figure 6: Numerical model of the full scale masonry wall tested at ELSA**



**Figure 7: Full scale model of masonry wall and SMAs cross-bracing at ELSA**

JRC was involved mainly in the characterisation tests of SMAs samples for engineering applications foreseen in the project and in testing of large-scale models of masonry walls comparing cases without and with the application of the protection system.

The design and the preparation of the tests were supported with numerical analyses. The analyses had also relevant interest for the interpretation of the results and for the validation of the numerical models. A demonstrative application, foreseen in the project, was made to retrofit the bell tower of Trignano (RE) in Italy damaged by a recent earthquake.

The good results obtained from the project allowed other applications. SMAs devices were applied for the seismic protection of the tympanum of the St. Francis Basilica in Assisi repaired against the damages induced by the strong Umbria-Marche earthquake.

The SMAs devices constitute a semi-rigid anchorage system that becomes active only during relevant seismic events by dissipating energy and protecting the structure. The dissipation mechanism in fact is induced by relative displacements between roof and tympanum, which are generated by strong earthquakes.

JRC provided the experimental Database on SMAs characteristics used by the University of Rome “La Sapienza” for the design of the protection system based on SMAs devices provided and installed by FIP -Industriale of Padova.



**Figure 8: Tympanum of the St. Francis Basilica in Assisi**



**Figure 9: Detail of the damages in the wall of the Basilica**



**Figure 10: Application of SMAs devices for the seismic protection of the Tympanum**

## **5. Contact at ELSA**

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