

## Seismic-V: Vernacular seismic culture in Portugal

M. Correia, G. Carlos & S. Rocha

*Escola Superior Gallaecia, Portugal*

P.B. Lourenço & G. Vasconcelos

*Universidade do Minho, Portugal*

H. Varum

*Universidade de Aveiro, Portugal*

**ABSTRACT:** For a long time, reactive seismic retrofitting was focused on monumental heritage and very little on vernacular architecture. In the last years, there has been a growing interest on seismic resistant design and solutions and several research units emerged to produce important research in the scientific field. However, for some time, international focus to address earthquake-damaged buildings was on intrusive techniques and technological materials to retrofit monuments. This paper aims to explore how the research project SEISMIC-V intends to fill the gap regarding this critical research problem. The research will contribute to the awareness and protection of the local seismic culture. The project outcomes will provide data for the strengthening of seismic-resistant architectural components in in-use vernacular heritage.

### 1 INTRODUCTION

The present paper addresses the layout of the research project 'SEISMIC-V: Vernacular Seismic Culture in Portugal: PTDC/ATP-AQI/3934/2012', recently approved and funded by the FCT (Fundação para a Ciência e a Tecnologia), the Portuguese National Agency for R&D.

The development of the SEISMIC-V project will be coordinated by CI-ESG, a unit structured to address Scientific Research at Escola Superior Gallaecia. Created in 2005, CI-ESG has developed scientific research, consultancy, and particularly research projects integrated in National, Iberian, European and Iberian-American R&D programs, within its expertise fields. The increase of the school's scientific production, the integration of new researchers, thus widening the scale and the expertise of its scientific areas, and the regular articulation of the research areas had as result the restructuring of CI-ESG scientific fields into four research areas: Architecture and Heritage; Ecology and Environment; Urban Design and Territory; Art and Design. This project is integrated in Architecture and Heritage research fields, within Vernacular Heritage Research (CI-ESG 2012).

Rather than the conventional descriptive survey related to the vernacular architecture problem, the research is intended to extract operative contributions to the actual building state. Intervention on built

heritage, without disregard the original construction systems, is a relevant endeavour of the project's outcomes, special framed by the increasing awareness, regarding conservation intervention approach.

Although Portugal has been identified as a moderate-hazard country with respect to earthquakes, the fact is that the country is susceptible to earthquake occurrence and damage in the future, and more information is required regarding vulnerability. Given this information, the broad question of the research interest became: What did the local populations do to repair and retrofit the buildings where they were living? The question concerns the identification of which architectural elements and techniques did the local population use to repair and retrofit their houses. The research will address the query related to the identification of seismic resistant architecture elements that can be identified in the in-use vernacular heritage. It will also respond to the question whether 'Local Seismic Culture' (LSC) can or cannot be consistently identified in Portugal.

The project findings will become a helpful instrument to identify seismic features used in the past to retrofit buildings; and traditional techniques and architectural elements applied related to safety standards. It is expected that part of the Local Seismic Culture, either of preventive or reactive origin, will be influenced by the intensity and / or by the frequency of earthquakes.

The Project SEISMIC-V aims at providing a useful tool to understand and to apply traditional techniques reinforcing the actual building state, according to the current safety parameters.

## 2 THE RESEARCH PARTNERSHIP

ESG as the project leader of the project has an international expertise in vernacular architecture, with regular scientific activities and research projects addressing this research field. The partnership with the University of Aveiro and the University of Minho, through their Departments of Civil Engineering contributed to the advance of knowledge regarding experimental characterisation and numeric modelling in this field of study. The research project received support by the Ministry of Culture, to ensure the institutional impact regarding the dissemination of results among local populations. SEISMIC-V has the support of ICOMOS-CIAV, ICOMOS-ISCEAH, Chair UNESCO-Earthen Architecture and the European University Centre for Cultural Heritage.

## 3 LITERATURE REVIEW

There were memorable and deadly earthquakes in Portuguese recent history—for instance, in 1755, 1909, 1969, 1980 (LNEC 1986). The fact is that earthquakes are susceptible to occur and to affect populations and their assets through damage of the in-use vernacular architecture. The research of vernacular seismic culture in Portugal is therefore relevant, so as to save lives through risk prevention mitigation. This was one of the principal recommendations published by TERRA 2012 Advisory Committee, during the international conference organized by PUCP, ICOMOS-ISCEAH and UNESCO, in April 2012, in Peru, which gathered 550 participants. It is a fact that preventive or reactive seismic retrofitting was, for a long time, focused on monumental heritage and very little in vernacular architecture. In the last years, there has been a growing interest on seismic resistant design and solutions, especially addressing housing and monuments (Vasconcelos & Lourenço 2009a) (Neves et al. 2012). Several scientific groups emerged to produce important research in this field area (Varum et al. 2011) (Vasconcelos & Lourenço 2009b). However, for some time, international focus to address earthquake-damaged buildings was on intrusive techniques and technological materials to retrofit monuments. This was perceived during the discussions held by experts during the closing of the Getty Seismic Adobe Project, held at the Getty Conservation Institute, in 2006. Julio Vargas from

Pontificia Universidad Católica del Perú (PUCP) acknowledged as well, the international tendency of applying a technical approach originated from modern engineering. This trend was also detected on the work developed by ICOMOS-ISCARSAH, International Scientific Committee on the Analyses and Restoration of Structures of Architectural Heritage.

Therefore, it is missing an international focus on the strengthening of vernacular in-use architecture. However, research in retrofitting solutions for earthen housing had been consistently and systematically addressed by PUCP for the last 30 years, as Peru is a highly seismic country (Vargas Neumann et al. 1983) (Vargas Neumann et al. 2007). The trend on research, in spite of continuing concentrated on new and modern techniques and materials, also started to address sustainable and natural materials with reinforcing solutions for earthen housing. This was possible through less intrusive techniques, like for instance, the use of some natural additives (sand and straw) (Vargas Neumann et al. 1986), or the application of the earthen grouting techniques; a strengthening technique for earthen structures applied recently in seismic countries. SismoAdobe2005 conference, organised by PUCP, brought international focus on the research, regarding less intrusive seismic retrofitting solutions with compatible materials for adobe housing. Notwithstanding this fact, there was little focus on solutions emerging from the vernacular architecture heritage, as just a few papers addressed this subject (Correia 2005).

A focus by the scientific and academic community on the identification of seismic features applied historically on vernacular and monumental architecture was still missing. This gap in knowledge was identified by Ferruccio Ferrigni at Centro Universitario Europeo per I Beni Culturali (CUEBC), located in Ravello, Italy. Ferrigni (1990a, b) recognised with his team, the existence of a 'Local Seismic Culture', consisting in the application of architectural elements with technical knowledge and comprehensible behaviour, following an efficient ensemble to reduce the impact of earthquakes. A systematic emphasis was then given to the study of historical architectural prevention and post-earthquake reaction, but for several years it focused on the emergency reaction and less on the scientific international recognition of LSC research.

A funded project addressing this thematic was the European Taversism Project. Due to Portuguese earthquake history, the country was selected as a case study. An expert on Portuguese vernacular architecture was appointed to address the research. As a result, a preliminary Report was produced (Correia & Merten 2001). However, a sound

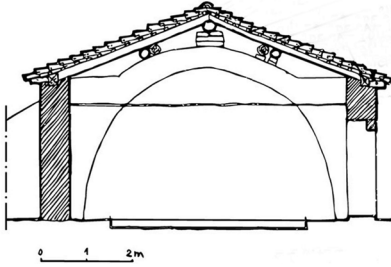
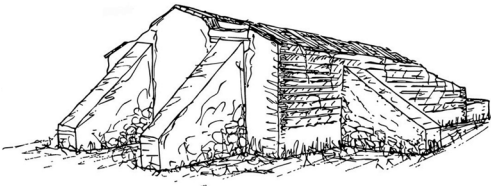


Figure 1. Structural reinforcement solutions of vernacular architecture in *Alentejo*, Portugal. (Credits: Correia, 2007).

research on the identification of seismic resistant features in Portuguese vernacular architecture, and the methodological tracing of a Portuguese Local Seismic Culture still needs to be addressed. The literature review on seismic resistant Portuguese architecture reveals that most of the studies have been focused either on the seismic resistant Pombalino construction (Lopes dos Santos, 1994), on the architectural heritage, or on urban housing (LNEC, 1982), but very little related to local seismic culture (Correia & Merten, 2001).

#### 4 SEISMIC-V METHODOLOGY

The project will be structured under five progressive stages related to the principal tasks:

1. Definition of the areas of study, according to the seismic hazard, supported by the survey missions and preliminary analysis. The task will result in an Atlas of Local Seismic Culture in Portugal;
2. Experimental characterisation (*in situ*), to study the materials and their application through benchmarking in paradigmatic cases;
3. Numerical modelling and parametric studies, which will be developed through testing, and whose conclusions will be presented in Laboratory Seminars.
4. Identification and description of the most efficient seismic resistant strengthening solutions, as well as the most frequent faults. A manual of practical construction “warning of erroneous

solutions” will be produced doomed to communities and local agents.

5. Finally, the Project will systematise the information collected and produced, featuring the analysed solutions. According to their feasibility study, a publication, accurately verified by the scientific advisers, will be prepared, so as to become a reference on the research area.

##### 4.1 The project research methodology

The research methods to address are:

1. To identify data source based on factual entries, such as the selection of the earthquake sample related with:
  - a) The date of the earthquake [a pre-selection would be (LNEC, 1986): 1755, 1855, 1856, 1858, 1903, 1909, 1914, 1926, 1969, 1980-in Azores and 1998-in Azores];
  - b) The location impact [a pre-selection would be five different regions mentioned in Task 1 description];
  - c) The assessment of damage [through Mercalli scale referenced in registered data].
2. To collect data from reliable sources archives, as the national geographic institute, the military database, Forte de Sacavém from the archives of ex-DGEMN (to identify regions to visit). The National Library and LNEC library should be visited, as well. It will also be important to collect data from local Municipalities, Libraries and the Order of the Architects archives and library (to define local characteristics of damaged structures), as experience of frequent quakes might not be reported by national agencies.
3. To address literature review of historical and local data, with the following criteria:
  - a) A time limit framework, no longer than 1755’s earthquake, as vernacular architecture would have a span time related to its renovation and maintenance;
  - b) To analyse earthquake intensity through history, with damage equal or higher than VI, on the Mercalli scale. This would be the scale’s degree at which populations would start to feel the earthquake quivers and would react to prevent damage;
  - c) To consider Local Seismic Culture literature;
4. To define regions to study and co-relate them to data collection and literature review:
  - a) To define a sample for data collection;
  - b) To contemplate other possible regions in Spain, based on active faults near the Portuguese borders, as they would have consequences in the Portuguese territory;

- c) To visit pre-selected regions, even if not exposed to high intensity earthquakes;
  - d) To analyse local conditions and to identify dynamics of change within the community and the environment.
5. To address on-site data collection, a number of tools were employed, namely:
    - a) To establish assessment forms for sample data collection, with local buildings observation, evaluation, and also integrating quantitative data collection;
    - b) Interviews to architects and engineers from municipalities targeted as potential data sources. Formal interviews will be conducted using a survey form of previously determined questions, allowing for both multiple-choice and open-ended answers;
    - c) To develop a community survey, incorporating informal interviews to be conducted following a predetermined set of questions that will enlighten the qualitative analyses;
    - d) To develop specific drawing surveying, when seismic features are identified, to produce observation drawings of seismic resistant features. Later it will provide visual information to produce booklets for dissemination among local communities.
  6. To analyse qualitative and qualitative data, considering:
    - a) The study of seismic resistant architectural features used;
    - b) The co-relation and triangulation of the analysed findings to the revision of literature and the analysed archives data.
  7. To create an atlas of local seismic culture in Portugal, as a visual tool for knowledge dissemination. Analysis will be supported by geographic information system (GIS) software. Architectural Data will be compiled into GIS attribute tables. This application of GIS will allow to visualise geographically the origin of the data, but also to analyse the descriptive statistics of the all information.
  8. To collect selected case studies data, to address quantitative comparative analyses of material, structural solutions, building configurations, dimensions, and non-destructive tests performed *in situ*.
  9. Data will be collected from the previous task, to analyse the structures behaviour under earthquakes and to produce computer models. Comparative analyses of buildings performance under earthquakes will be addressed as well.
  10. To correlate and to triangulate the analysed findings through: Data collection; assessment forms; buildings observation; drawing survey; interviews; literature review, experimental characterisation, etc.

## 5 MAIN EXPECTED OUTCOMES

The main outcomes of the research project will be the development of recommendations for strengthening of in-use vernacular housing seismic features. This information will be disseminated by specific communication tools programmed to reach all the identified mediators on the area, such as:

- An atlas on vernacular architecture and LSC: exposing a graphic circumscription of the identified Local Seismic Culture, in areas where vernacular architecture is significant. It will implicate the geographic analysis of its configuration and limits, facing the landscape and the main built infrastructures, considering the distribution of seismic resistant representative solutions in the national territory.
- A scientific publication for a better dissemination of results among the scientific community: in the final stage of the project, a reviewed (by two of the Project International Consultants) edition of the Project Synthesis and the systematization of results and achievements will be published. It will be organized by region and the VSC Atlas will be integrated.
- A technical publication, in the format of a graphic manual, for a better dissemination of the results among the local community and municipalities. Focusing on LSC worldwide, the project will propose retrofitting solutions and the implementation variables of Portugal, comparing them to similar regions and systems. A booklet pointing out the usual LSC errors will be presented, as an operational tool for the communities.
- Training for local agents regarding LSC, through technical seminars, which will become an important milestone for the preparation of Municipal technical counsellors located in seismic regions. This will consist of practical seminars, where the laboratorial activities elaborated within the project are exposed to external agents, mostly technicians, through a controlled repetition of the most interesting results related to the numerical modelling and parametric study phase.

## 6 SYNTESIS AND CONCLUSIONS

The main research questions to be addressed throughout the project will be: what did local populations, following an earthquake, to repair and retrofit the buildings where they were living? How did local populations prevent buildings from falling under an earthquake incidence? Are these seismic features in vernacular architecture still playing an active role to improve its behaviour in case of earthquake occurrence?

This research will address a critical gap in knowledge, regarding vernacular architecture earthquake readiness. The fact is that Local Seismic Culture (LSC) research in vernacular architecture has had little attention by the Architecture and Engineering scientific communities. This research is based on the statement that vernacular architecture is an outstanding inheritance, from which remarkable solutions can be obtained and improved.

The long-term goal of SEISMIC-V is to contribute to the awareness of LSC, but also to suggest recommendations to improve the existing solutions and to avoid common errors. Thereby, it would be necessary to collect data concerning the efforts that were taken by the population in the past, and to contribute to the restoration and repair of the buildings that sustained damage from the earthquakes.

Regarding the assessment general aims, the project relates:

1. To identify local seismic culture and architectural seismic resistant features throughout the Portuguese regions exposed to frequent quakes, even of low/moderate intensity, and earthquakes of high intensity, though less recurrent.
2. To identify materials and techniques to repair and to retrofit damaged in-use vernacular buildings, related to local population reactive efforts to earthquake incidence.
3. To identify actions addressed by the local community on their attempt to prevent from earthquake damage.

The plan description is structured under 5 phases:

Phase 1 will identify the Portuguese regions with seismic resistant vernacular architecture, as well as the existence of a local seismic culture, through quantitative and qualitative data collection and analyses, literature review, drawing surveying, and data mapping, thus creating an Atlas.

In phase 2, the question to address will be, if vernacular architecture seismic resistant features are still in good use. To answer this problem, experimental characterisation needs to be addressed through the analysis of representative case studies. Results will emerge from comparative analyses of material, structural solutions, building configurations, dimensions, as well as non-destructive tests.

Phase 3 will explore vernacular architecture performance in an earthquake situation. Numerical modelling with parametric studies, originated from quantitative analysis, will be created to compare the buildings performance under earthquakes.

Phase 4 will provide a response on how to reduce the vulnerability of the in-use vernacular architecture in an earthquake situation. The identification of common mistakes and the suggestion of retrofitting

solutions will address the research problem. An analysis of results emerging from task 2 and 3 will be correlated to the findings, resulting from task 1.

Phase 5 will present the conclusions emerging from buildings performance under earthquakes, as well as solutions regarding seismic resistant features. Recommendations for local communities' vernacular housing will be suggested.

It is important to state that the Ministry of Culture supports the project due to the importance of the research problem, contributing for LSC awareness, at regional and national levels.

The research problem needs to be methodologically addressed and comprehensibly implemented. Furthermore, the overall outcomes of this project will provide data to reinforce architectural seismic improvement features, which in an earthquake event can save lives.

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