Chapter 13
Ancient Materials and Singular Constructions:
Numerical, Experimental, and Heritage Strategies to Preserve Masonry Structures in Seismic Areas

Paloma Pineda
University of Seville, Spain

ABSTRACT

Analysis and evaluation of seismic reliability of masonry cultural heritage buildings by means of numerical models is a difficult task, owing to uncertainties that mainly affect structural behaviour and mechanical material properties. The former includes lack of information on model definition -geometry, constraints, materials, constructive details...-, and the latter is focused on non-linear masonry behaviour and low tensile strength. Furthermore, if a comprehensive study of structural behaviour is going to be performed, accuracy and suitability of the analytical or numerical method selected are essential issues. For those reasons, multidisciplinary analyses combining numerical, experimental and heritage tools may be very useful to face the challenge of effective preservation. This chapter focuses on the role of the building materials as controllers of collapse phenomena under seismic loading. The first section is devoted to some heritage strategies that may be learnt from the wisdom of ancient builders. The second section focuses on numerical strategies, reviewing different constitutive models via FEM under seismic loading and analysing the role of the control parameters. That section provides a brief reflexion on different analytical strategies. Finally, as a way of conclusion, Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis of historic building materials and associated techniques within a dynamic framework, by means of multidisciplinary tools is provided.

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1. HERITAGE STRATEGIES: THE WISDOM OF ANCIENT ARCHITECTS USING MATERIALS UNDER DYNAMIC LOADING

According to Kirikov (1992), an earthquake-resistive building must be protected against two main features: (i) unequal settlements of the foundation that overstress the structure and (ii) the resonant phenomena. The present day builders take into account the aforementioned features and recognize the vital task of ductility, reinforcements and new composite materials, as main issues under dynamic loading. But unfortunately, it is common to forget the importance of "simple" material properties as effective way of improving the structural response under major or minor earthquakes. However, the most highly qualified ancient builders knew the crucial role of the building materials and their associated properties, as seismic-resistive elements, joining structural techniques together with other multipurpose measures. For instance, the relationship between hydraulic properties and seismic resistance and the use of non-rigid, light or reinforced materials as collapse controllers were well known by ancient builders.

Sumerian builders systematized the erection of earthquake resistive walls by combining two external rigid layers (burnt bricks) with a soft core (adobe bricks bonded by clay mortar and bitumen). High elasticity and ductility was provided due to that material combination. Some earthquake-resistance improvements were also reached by the Aegean culture in Crete (e.g. by means of reinforcing masonry with wooden beams). Roman builders also combined rigid and elastic materials, for instance embedding rings of clay vessels into the cast concrete (Adam, 1994), in order to increase ductility and decrease the weight. They also built facing walls of brick with internal core of concrete and stones, improving the structural response under seismic loading (Fig.1). In Byzantium, courses of chiselled stone were combined with bricks resulting in seismic-resistant belts. In addition, high plasticity lead plates were placed between the units providing seismic isolation.

Figure 1. Three layered walls which improve the seismic behaviour, (a) Sumerian wall; (b) Roman wall

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