

Chapter 41

Seismic Vulnerability of Ancient Colonnade: Two Story Colonnade of the Forum in Pompeii

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ABSTRACT

In this chapter, a numerical study to investigate the seismic vulnerability of the two storey colonnade of the Forum in Pompeii has been conducted. Software based on the Distinct Element Method (DEM) of analysis has been used. The colonnade was represented as an assemblage of distinct blocks connected together by zero thickness interfaces which could open and/or close depending on the magnitude and direction of stresses applied to them. Both static and non-linear static analyses have been undertaken. Also, a sensitivity study has been performed to investigate the effect of frictional resistance of the joints on the structural response of the colonnade. This was to simulate potential joint degradation effects and/or possible water lubrication at the joint.

INTRODUCTION

High-intensity earthquake events have caused the destruction and/or massive damage to several ancient monuments, such as classical columns and colonnades with great archaeological significance.

Examples of such damaged structures can be found in high seismicity areas including Greece and Italy (Croci 1998a; Croci 1998b; Macchi, G., 1998). Experience has demonstrated that, in general, classical monuments which are in their intact condition are not vulnerable to earthquake

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motions (Papantonopoulos 2002). However, if imperfections (e.g. inclined columns due to foundation failure; damaged drum corners; missing structural components; misplaced drums etc) are present in the structure, then collapse of the monument can occur.

The understanding of the seismic behaviour of ancient monuments contributes to the proper assessment of proposals for their structural rehabilitation and strengthening. Also, as ancient monuments have been exposed to a large number of strong seismic events throughout the many centuries of their life spans, those survived successfully passed a natural seismic test which has been extended over several centuries. Therefore, it is very useful to understand the mechanisms that have allowed the surviving monuments to avoid structural collapse and destruction during several strong earthquakes. Finally, the study of the earthquake response of classical monuments may reveal important information about past earthquakes which had struck the respective regions. For example, a detailed analysis could provide information on the characteristics of past earthquakes, and this information can be used to “re-engineer” the process and bring the monument to its previous condition (before the deformation).

In most cases, classical columns have been constructed by carefully fitted stone drums (usually marble or limestone) placed on top of each other, without connecting material between them. The seismic behaviour of these structures is characterized by high non-linearity and complication since both rocking and sliding phenomena between the individual drums can be occurring. In fact, the drums may rock either individually or in groups resulting in several different shapes of oscillations. As a result, the analytical investigation of their response is almost impossible. Since analytical investigations of such multi-drum columns under strong earthquake excitations is practically impossible for large numbers of blocks, while laboratory tests are very difficult and costly to perform (Omori

1900 & 1902), numerical methods can be used to simulate and assess their dynamic behaviour and seismic response.

There are several numerical methods available for the analysis of the seismic behaviour of historic masonry constructions (Beskos 1993). The most suitable method, among other factors, depends on the structure under analysis, the available input data, the computational cost, and the analyst experience (Lourenco 2002). It should also be expected that different methods of analysis will lead to different results. According to Lourenço (2001), a more complex analysis tool will not necessarily provide better results than a more simplified tool. Also, most refined theories require the knowledge of mechanical and geometrical parameters. However, it is in general not straightforward to idealize the geometry of historic masonry structures because there is no clear distinction between decorative and structural elements. In any case, there should be a balance between the knowledge level and the complexity of the analysis.

Analytical solutions on the dynamic behaviour of infinitely rigid bodies during horizontal excitations was studied by Housner (1963), who estimated the minimum horizontal acceleration of the support base that is required in order to overturn an infinitely rigid body. Later on, other researchers (Makris & Zhang 2001; Manos et al. 2001; Mitsopoulou & Paschalidis 2001; Pompei et al. 1998) used both experimental tests and advanced Finite Element Methods of analysis to investigate further the required conditions to overturn rigid bodies. Although the FEM can be used for the analysis of problems with some discontinuities (de Martino et al. 2006), it is not suitable for the analysis of discontinuous systems that are characterized by continuous changes of the contact conditions among the constituent bodies. On the contrary, Discrete Element Methods (DEM) have been specifically developed for systems with distinct bodies that can move freely

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