



Nonlinear Finite Element Analysis of Historical Masonry Building of Imam Khomeini (Sultani) Mosque in Semnan

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Abstract

Historical buildings are an integral part of the built heritage to be preserved, and their safety is a primary requirement in seismic areas. Collapse of ancient masonry buildings due to seismic actions occur mostly due to failure of the perimeter walls. This paper addresses the issue of seismic analysis and vulnerability of historical masonry building of Imam Khomeini (Sultani) Mosque in Semnan. Imam Khomeini Mosque with four entrances was built at the beginning of the 19th century, under Fath Ali Shah Qajar, it is a charming example of the fragile grace so characteristic of Qajar style. The mosque consists of a spacious court, several prayer halls, a tile-decorated porch and lecture hall, four ivans, a marble manbar (pulpit), and numerous inscriptions in beautiful calligraphic styles. The finite element method was adopted for analyses, introducing nonlinear behavior of the materials. A quasi-static approach (the seismic coefficient method) for the evaluation of the seismic loads has been used (as indeed is common in many analyses of the seismic behavior of masonry structures). The comparison of demand vs. capacity confirms the susceptibility of this type of building to extensive damage and possibly to collapse, as frequently observed. The paper advocates that significant information can be obtained from advanced numerical analysis, namely with respect to the understanding of existing damage and to the minimum and adequate design of strengthening. A clear understanding of the structural behavior and reliable strengthening, based on sophisticated tools of structural analysis, can therefore reduce the extent of the remedial measures in the restoration of ancient structures.

Keywords: Nonlinear analysis; Seismic vulnerability; Historical masonry building; Imam Khomeini Mosque; Semnan.

1. INTRODUCTION

Semnan can be divided into sixteen sectors from the old days of Avesta. During the Medes and Achaemenid periods, it accounted for being one of the largest provinces of the empire. During the Islamic era, Semnan was part of the historical region of *Gomess* or *Komesh*, and The Silk Road paved its way from the midst of this region. The Cultural Historical Heritage Organization of Iran lists 470 sites of historical and cultural heritage such as palaces, forts, castles, caravansarais, ab anbars, and badgirs, in Semnan. In addition to these, there are various religious and sacred places as well. The local culture and the traditions are so incredibly diverse that Semnan can be called the Province of Varieties. For tourists, the locals' special way of practicing national and religious ceremonies, wedding parties, memorial functions for holy celebrities or the death of their beloveds would be very attractive.

A large portion of the Iranian cultural heritage is provided by Mosque masonry building. These historical buildings have demonstrated during the past to be particularly susceptible to damage, and prone to partial or total collapse, under earthquake loads, sometimes due to non-respectful restoration [1]. As a matter of fact, repairs and retrofitting techniques should always respect the original existence; any intervention not respectful of it could also create incompatibility with the original structural behavior. Masonry buildings are generally able to carry the vertical loads in a very safe and stable way, while they are rather sensitive, from a structural point of view, to horizontal loads. The high seismic vulnerability of this type of building is due both to the particular configuration and to the mechanical properties of the masonry. If in principle, the prediction of the structural response of