SEISMIC SAFETY ASSESSMENT OF ADOBE VAULTED ARCHITECTURE IN IRAN

Neda HAJI SADEGHI
ISISE, University of Minho, Department of Civil Engineering, Guimarães, Portugal
neda.hsadeghi@gmail.com

Daniel V. OLIVEIRA
ISISE, University of Minho, Department of Civil Engineering, Guimarães, Portugal
danvco@civil.uminho.pt

Mariana CORREIA
ESG/Escola Superior Gallaecia, Vila Nova de Cerveira, Portugal
marianacorreia@esg.pt

Hamed AZIZI
ISISE, University of Minho, Department of Civil Engineering, Guimarães, Portugal
hamed.azizi@civil.uminho.pt

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For millennia, earth has been used by humans as a construction material in different forms. It is estimated that around 25% of the world's population lives in earthen buildings (Jaquin, 2013) and among the several earth architecture techniques, the most common find worldwide is adobe (Correia and Fernandes, 2006).

Post-earthquake observations have shown that the poor seismic performance of adobe buildings, due to its very low tensile strength, low compressive strength and brittle behavior, has led to a significant loss of lives and high costs for strong or even moderate earthquakes. This aspect becomes even more important due to the fact that the majority of adobe architecture is located in regions with moderate and high seismic hazard.

From the structural point of view, the roof is one of the constitutive elements that plays a significant role in an adobe building subject to an earthquake. Most of the adobe constructions have pitched or flat roofs, but in some hot and dried region, due to lack of wood, adobe vernacular architecture has been built with adobe curved roofs (i.e. vault and domes). Adobe vault constructions have originated and developed in Middle East, one of the high seismic prone regions of the world, and date back to more than 3000 years ago (Minke, 2006). Adobe vaulted buildings, as predominant vernacular architecture in Middle East, are vulnerable to earthquake and their vaults collapse have caused fatalities due to their heavy weight and material brittleness. Consequently, it is obvious that improving seismic safety of the adobe vaulted architecture is essential.

Since strengthening of weak adobe structures before earthquake may reduce the fatalities, loss of cultural heritage and decrease the high costs of repairing damaged buildings after earthquake, a scientific and versatile safety assessment method is necessary. Seismic safety of adobe vaulted architecture should be evaluated to distinguish the necessity and also the degree of intervention. For this reason, the main objective of this paper is to perform a numerical parametric study considering the main influential parameters on the seismic behaviour of adobe vaulted roofs aiming at assessing their seismic safety. For this purpose, it is needed to identify and select some case studies located in seismic-prone regions.

This study is focused on the houses of the city of Yazd, Iran, due to the reasons given herein. Iran, as one of the largest countries in the Middle-East, is located on the Alpine-Himalayan belt, one of the most seismically active areas of the world, where a long series of catastrophic earthquakes with an important number of casualties and economic losses has taken place. On the other hand, the city of Yazd has a vast number of historic vernacular adobe houses with adobe vaults, where most of them still remain in good condition, see Figure 1.

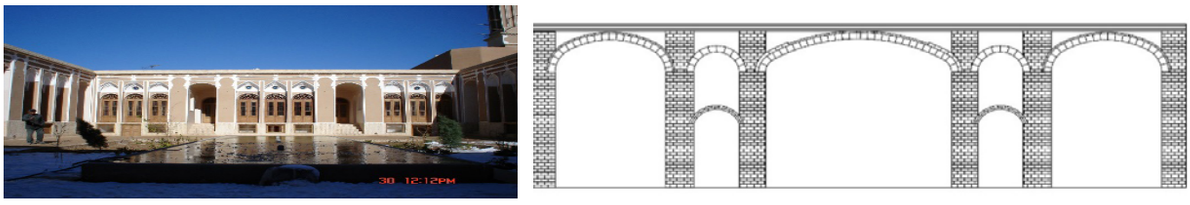

Figure 1. Elevation view and 2D modelling of an adobe house in Yazd, Iran

The structural and seismic behaviour of these adobe vaulted structures have been assessed using the Block2D software as a numerical tool based on the limit analysis theory (Orduña, 2003). In order to obtain a deep insight into the most important parameters controlling the seismic response, a parametric analysis has been performed on them, see Figure 2. The most important parameters to be analyzed are:

- Vault shape: pointed vault, semicircular vault, segmental vault and catenary vault.
- Vault construction methods (according to the way that brick can be laid).
- Geometry proportion: vault span (s), rise (r) and thickness (t); fill depth at the crown of vault (d) and buttress width (w).
- Physical properties of the fill, existence of spandrels or backfill above the adobe vaults.

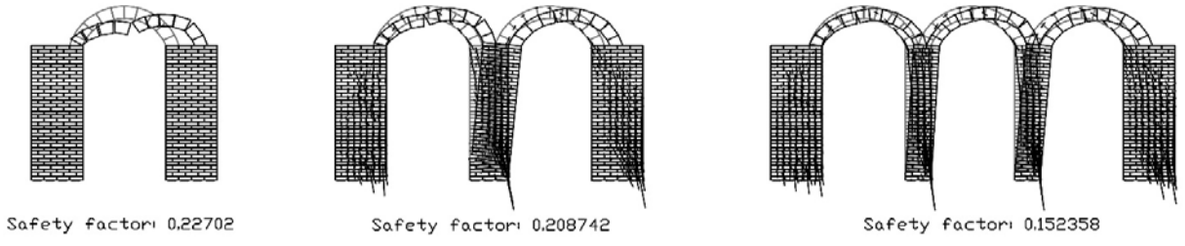

Figure 2. Block 2D models and obtained safety factor of adobe vaults

Based on the detailed results from parametric studies, analytical equations that allow estimating seismic safety factors of the vast number of adobe vaulted construction based on their influential parameters have been developed. These equations can be used as a simple tool, applicable for safety assessment of a large number of adobe buildings as the primary step within a conservation process.

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