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Earthen masonry infill walls: Use of wooden boards as sliding joints for seismic resistance

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HIGHLIGHTS

- Infill construction technique for seismic resistance.
- Application of the earthen masonry as construction material.
- Test results on adobe infill with vertical sliding joints.
- Post-earthquake damage mitigation compared to traditional infills.
- Out-of-plane stability.

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ABSTRACT

The paper describes the results of quasi-static tests performed on a real-scale adobe masonry infill wall partitioned into sub-panels by means of the introduction of vertical wooden planks, acting as sliding joints. The specimen was tested both in-plane and out-of-plane, exhibiting good performance in terms of both stability against out-of-plane actions and in-plane deformation capacity and damage control. The results emphasize the applicability of adobe masonry as material for infill walls in seismic prone regions, coupling the good structural response with the inherent positive performance in terms of indoor ambient comfort and production sustainability demonstrated in literature.

1. Introduction

In nearly all hot-arid and temperate climates, earth has been for centuries the most prevalent natural building material and, even nowadays, a third of the world population is housed in earthen structures, mainly in developing countries. Also in the most industrialized countries earth is being rediscovered as a performance building material thanks to its properties in terms of sustainability, cost-effectiveness and indoor climate control [1,26,27]. Because of its poor mechanical properties, earthen materials do not ensure sufficient bearing properties to be adopted alone as structural materials in modern seismic resistant buildings [13]. Therefore, their current main applications consist in partition and infill walls, plasters, pavements, etc.

Previous studies [29,30] investigated experimentally and numerically the in-plane performance of an adobe infill wall, compared to a fired clay masonry one, showing the better performance of the former in terms of post-earthquake damage limitation and mitigation of the well-established detrimental infill-frame interaction [5,6,8,9,12,17,36], thanks to the inherent high deformability of earthen material. In the same research work, the authors observed a further improvement of the infill performance when partitioning the masonry with horizontal sliding joints, which made the infill even more deformable. To the author knowledge, no experimental test was performed on the out-of-plane resistance of adobe masonry infills, which is penalized by the inherent low mechanical properties of the material. Regarding the in-plane response of the infill, several authors in the last years proposed and tested different technical solutions to increase the in-plane deformability of masonry infills in order to limit the frame-infill interaction and, thus, to control the structural damage and/or collapse during an earthquake. Some of them proposed the adoption of deformable

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material at the infill-frame interface [19], others adopted different technological solutions to partition the wall with horizontal deformable [40] or sliding joints [22–24,33]. A different configuration of the sliding joints was also proposed by [2,31,38], introducing vertical joints partitioning the infill. In particular, in [31] it was showed that, for a hollow clay masonry infill, the vertical partitioning of the wall allowed a further reduction of the infill-frame interaction, compared to the horizontal configuration of the joints, thanks to a different resisting mechanism activated in the infill deformation. With regard to out-of-plane response of the infills, the vertical configuration of the sliding joints demonstrated to be particularly efficient in retaining the wall against the out-of-plane overturning, when the vertical joints are connected to the frame beams.

As an extension of the work presented in [29–31], this paper presents the results of an experimental campaign about the adoption of adobe masonry in the construction of infill walls with sliding joints. A real scale adobe infill with vertical sliding joints was tested to assess the effectiveness of the technique when applied to earthen masonry. The specimen was tested in- and out-of-plane, under quasi-static actions and the results are compared to the response obtained in previous experimental campaigns, varying the sliding joints configuration and/or the infill masonry material. The application is meant to obtain a stable response of the infill under seismic actions with a negligible interaction with the frame and negligible post-earthquake damage.

2. Earth as a construction material: characterization tests

Earthen material is adopted in the constructions under various techniques: rammed earth, cob, adobe, wattle and daub, poured earth [25]. In the here presented work, adobe technique was studied and adopted for the tested infill. It consists in a masonry made of earthen bricks with mud mortar joints. The bricks are produced with moist earth compressed inside a mold and then sun-dried, instead of fired (differently from clay bricks). Straw or other vegetable fibers are often added in the mix to limit shrinkage cracking [34].

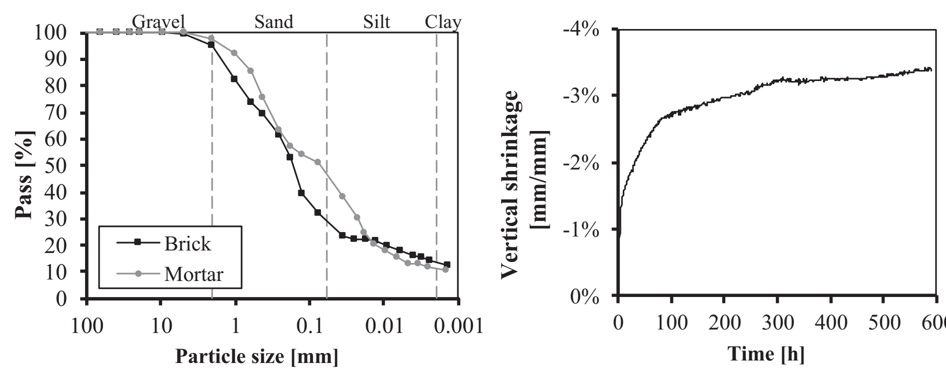
Table 1
Summary of the main advantages and disadvantages of earthen masonry as building material.

Suitable for	Drawbacks
Ambient humidity balance	Not a standardized material
High thermal inertia	Shrinkage at drying
Acoustic isolation	Poor water resistance
Reusability	Low mechanical properties
Low production cost	Need for protection from ground humidity
Energy savings and no carbon emissions	Suitable for in-situ construction only
Compatibility with organic materials (timber, straw, etc.)	Labor intensive
Good fire resistance	

Many authors focused in the last years on the benefits of earthen materials applied in buildings constructions in terms of: improvement of the indoor environmental quality [3,16,35,41] reduced costs [42] and sustainability [1,28]. Table 1 summarizes the main advantages and drawbacks of the adoption of earth as a construction material, according to the referenced literature. From the mechanical point of view, different authors performed studies focused on the earthen materials mechanical characterization [15,18,20,37]. As reported in [20], typical values for compressive strength of historical earthen materials are in a range from 0.5 up to 5.0 MPa, with a modulus of elasticity ranging between 400 and 2000 MPa.

In the here presented research work, several material characterization tests were performed on the adopted adobe material, to define its physical and mechanical properties. The adopted material was selected among those available on the market. Fig. 1a shows the granulometric distribution for the selected adobe material, obtained through sieving and sedimentation tests.

Drying shrinkage tests were also performed on a 60 × 30 × 80 cm (width × thickness × height) adobe wallet. Fig. 1b reports the vertical shrinkage of the wallet in the 25 days after construction, showing a significant deformation of the specimen, with a final average vertical shrinkage larger than 3%. The most part of the shrinkage (about 1.5% strain) occurred in the first hours after the construction, due to the first water leakage and evaporation. However, the drying process proceeded along the time, doubling the strain after 25 days. As explained in the following sections, the relevant shrinkage of adobe material influences the design construction choices when the infill is built with the sliding joints technique. The material characterization was performed through tests on bricks, on 40 × 40 × 160 mm mortar specimens, on masonry wallets and triplets. The commercial bricks tested had a nominal size of 120 × 240 × 70 mm and the obtained results are reported in Table 2, showing an average compressive strength of 2.28 MPa. For mortar, Table 3 summarizes the results of flexural and compressive strength, obtained adopting the procedure defined for common lime- or cement-based mortar materials in [39]. For specimens characterized by different water contents, within the range recommended by the supplier (20 ÷ 30% in weight), the obtained results showed a limited strength variation, leading to a flexural strength in the range 0.81–1.02 MPa and a compressive strength between 2.28 MPa and 2.34 MPa.



(a) granulometric curves *(b) shrinkage test*

Fig. 1. Granulometric distribution and shrinkage of the adopted adobe material.