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Strengthening the structural behavior of adobe walls through the use of plaster reinforcement mesh

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ABSTRACT

This study presents an experimental investigation on the use of additives and plaster mesh in adobe wall panels. Three different groups of adobe soil mixture are considered for forming adobe blocks in wall panels with and without mesh placement along horizontal mortar joints. The groups consist of plain adobe blocks, blocks with 1% straw and 10% fly ash. Wall panels are loaded under diagonal compressive axial load in order to evaluate their ultimate load capacities, deformability, and energy absorption characteristics. According to the results obtained from tests, the combined use of plaster mesh with additives enhances the structural behavior significantly.

1. Introduction

The need for housing poses significant strains on the society in terms of costs, especially in developing countries. The rising costs of Portland cement and steel also leads to significant challenges in the housing needs. In this regards, earth is considered as the cheapest material readily available for construction in rural areas of Asia, South America to Africa. This simplest form of construction material also finds applications in developed countries due to its environmental friendly nature. Furthermore, in several countries, preservation of historic structures is a rising awareness, where some of these structures are made from adobe.

The main reasons for the popularity of adobe can be summarized as follows [1]: (a) local material is available everywhere; (b) a high level of skill and technology is not required for the production of adobe bricks and constructions; (c) repair and maintenance of adobe structures do not require specialized labor; and (d) inherent properties of earth make it an efficient heat and sound insulating material [2,3]. Despite these numerous merits, adobe houses are prone to damage under seismic excitations and they are susceptible to water.

The lateral resistance of an adobe structure is obtained from the in-plane shearing behavior of the adobe walls. In addition to this structural behavior, the out-of-plane bending of adobe walls become a critical issue, as well [4,5]. In regions of high-seismicity, the lack of in-plane and out-of-plane stiffness and strength of the walls pose significant risks for the occupants. Even under moderate ground shakings, ductility and strength of adobe walls are in question. Since adobe is not a strong and ductile material, keeping an adobe structure stable after a severe ground motion may not be possible. Thus, providing enough strength and energy dissipation in the adobe walls become a critical issue under moderate to severe ground shakings. Increased energy absorption will especially provide more time for the occupants to escape from an adobe structure.

Several studies are conducted in terms of improving the physical and mechanical properties of adobe and some new methods are developed to stabilize the adobe soil [1,6–8]. The use of horizontal and vertical reinforcement in the construction of adobe walls was presented by Blondet et al. [5], where timber, steel bars and locally available materials such as bamboo were considered as reinforcement material. Despite these efforts, the research on the structural behavior of adobe buildings is still inadequate. Considering the fact that more than half of the damages in earthquakes occur in unreinforced masonry and adobe buildings [9], it becomes clear that more emphasis should be given to the studies related to the behavior of structural members of adobe buildings, i.e. the walls, under various loading conditions besides the studies carried out for the improvement of mechanical properties and the resistance of adobe against weathering effects.

This paper deals with improving the structural properties of adobe structural members such that it could provide an alternative

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construction material to those communities using adobe in seismic regions. Since adobe has low compressive strength and energy absorption capacity, it is necessary to improve the properties of plain adobe soil by using some stabilizers. Straw, sand, lime, cement and sodium silicates are some of the well-known stabilizers. Turanli [6] considered 10 different adobe soil mixtures in order to enhance the physical properties of adobe blocks. In that study, the use of fly ash in general enhanced the physical properties better than lime, where the best result was achieved with the use of 10% fly ash. Furthermore, Turanli also found out that the use of 1% straw by weight also provided a similar improvement to adobe blocks when compared with other mixtures. For this purpose, three different soil mixtures were prepared in the current study: plain soil, soil with 1% straw and soil with 10% fly ash. The experimental investigations were performed on square wall panels with and without the use of plaster reinforcement mesh made of fiberglass along the horizontal mortar joints (a.k.a. bed joints) between adobe blocks. The mortar material between the blocks is the plain soil used for adobe production. The wall panels were loaded under diagonal compressive axial load in order to evaluate their ultimate load carrying capacity, deformability and energy absorption characteristics.

2. Experimental study

2.1. Materials

The materials used in this study for the production of adobe consisted of soil, straw, and supplementary cementing materials.

Table 1
Properties of the soil.

Properties of adobe soil at standard consistency	
Natural water content (%)	34
Dry unit weight (kN/m^3)	16
Compressive strength of 7 × 7 × 7 cm cubes (MPa)	4.0
Tensile strength (kPa)	39.2
Shrinkage (2.5 × 4.0 × 20 cm bars) (%)	7.1
Softening in water (min)	59.0
Geotechnical properties	
Specific gravity	2.68
Organic matter (%)	2.1
Liquid limit (%)	47.1
Plastic limit (%)	16.3
Plasticity index (%)	30.8
Shrinkage limit (%)	13.3
Clay content (%)	49.0

2.1.1. Selection of soil for adobe

The sample of soil contained 35% sand, 25% silt and 40% clay. The properties of adobe soil is given in Table 1. The grain size distribution of plain soil used in adobe production is given in Fig. 1.

2.1.2. Straw

Wheat stalk is used as fiber material in adobe production.

2.1.3. Supplementary cementing materials

A low-calcium fly ash was utilized in the study as supplementary cementing materials. Chemical composition and physical properties of fly ash is given in Table 2.

2.2. Proportions of adobe mixtures

In this study, three different soil mixtures were prepared: (I) plain soil; (II) soil plus 1% straw; and (III) soil plus 10% fly ash. The materials were first thoroughly mixed in dry state. The mass of water mixed with the dry adobe soil mass was adjusted in order to obtain a workable adobe mud for each soil mixture; thus a uniform distribution of ingredients was available with proper mixing.

2.3. Preparation of adobe blocks and wall panels

The size of adobe blocks was selected as 11.5 × 10.5 × 21.5 cm. The adobe mud was placed in molds, where the internal surfaces of the molds were first oiled. Compaction of the adobe mud in the mold was achieved by hand, similar to the regular practice in the field; thus a uniform compaction of all adobe blocks may not have

Table 2
Chemical composition and physical properties of fly ash.

Definition	Fly ash
Chemical compositions (%)	
SiO_2	58.44
$A1_2O_3$	18.79
Fe_2O_3	10.60
CaO	3.34
MgO	4.52
SO_3	1.75
Loss on ignition	0.77
Insoluble residue (%)	86.72
Physical properties	
Specific gravity	2.10
Fineness	
45-μm sieve residue (%)	27.3
Specific surface, Blaine (m^2/kg)	289
Strength activity index (%)[a]	
7-days	89
28-days	82

[a] Strength activity index with Portland cement in accordance with ASTM C311.

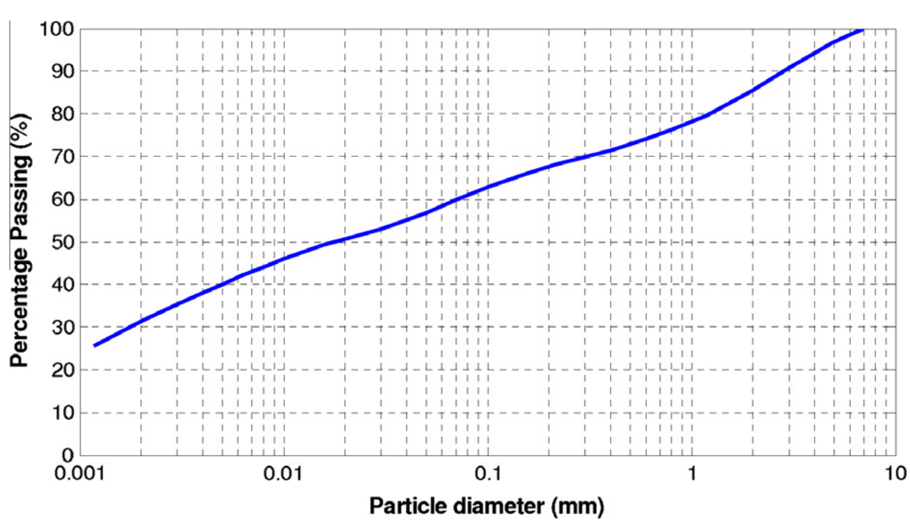

Fig. 1. Grain size distribution of the soil used in adobe production.