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In-plane strength of masonry panel strengthened with geosynthetic

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HIGHLIGHTS

- Masonry panels strengthened with Geotextile investigated.
- Experimental findings show un-strengthened panel showed brittle behaviour.
- Strengthening increased deformation capacities.
- Also increases the load carrying capacity, in-plane strength and stiffness.

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ABSTRACT

The in-plane strength of solid clay brick masonry panels strengthened with non-woven geotextile was studied numerically and experimentally. The panels were strengthened on one side with different geometric pattern viz. parallel, diagonal and cross. These panels were subjected to diagonal compression. Finite element modelling with the micro non-linear model is used in the analysis to simulate the in-plane behaviour of masonry panels with and without strengthening. From the study, it was observed that geosynthetic strengthening increased the load carrying capacity, shear strength, in-plane strength and stiffness remarkably with better performance in case of the cross pattern. Experimental results also showed a less brittle behaviour when compared to the un-strengthened panel. Hence, geosynthetic can be ideally used for strengthening of the brick panel to protect the brick buildings in seismic active areas.

1. Introduction

Masonry is one of the oldest and most widely used construction materials because of its low cost, availability, thermal insulation, need of less skilled labour, less engineering intervention etc. But, these buildings are vulnerable to seismic loads because of their relatively high mass and lack of ductility and energy absorbing capacity. The majority of un-strengthened masonry (URM) buildings have been constructed with little or no seismic requirement. This has resulted in a large stock of buildings, which possess an inability to dissipate energy through inelastic deformation in an earthquake event. The history of past earthquakes has shown that masonry buildings have performed the worst, suffered the maximum damage and also accounted for the maximum losses of life, more than any other type of structural element. Therefore, it is needed to improve their seismic performance by strengthening. Again, many of these masonry structures are historical buildings that should be preserved as cultural heritage.

URM walls have two possible failure mechanisms under seismic loading: in-plane and out-of-plane. The in-plane shear failure mode is the most important in-plane damage mode in URM walls under earthquake loading. Past researchers show that during an earthquake, the predominant failure mode is a shear failure [1]. Due to shear failure mode, masonry walls tend to develop a diagonal crack in the following patterns, viz. along the bed and head joints for strong masonry units and weak mortar, across the masonry units for weak units and strong mortar. The principal in-plane failure mechanisms (Fig. 1) of URM walls, subjected to earthquake actions, are as follows [2–4]:

a. *Shear failure:* It is a typical mode of failure of a masonry wall subjected to seismic loads, and it can take place where the principal tensile stresses, developed in the wall under a combination of vertical and horizontal loads, exceeds the tensile strength of masonry.
b. *Sliding failure:* In the situation of low vertical load and poor-quality mortar, seismic loads frequently cause shearing of the wall, causing sliding of the upper part of the wall at one of the horizontal mortar joints.

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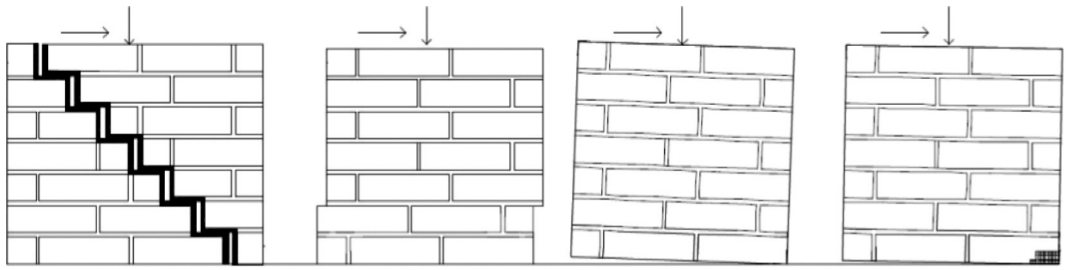

Fig. 1. In-plane failure mechanisms of un-strengthened brick walls.

c. *Rocking failure and toe-crushing failure:* In the case of high moment/shear ratio or improved shear resistance, the wall may be set into rocking motion or toe crushing depending on the level of the applied normal force.

For strengthening of the existing URM buildings in order to increase their collapse time under seismic loading, various techniques are available such as the application of shotcrete, steel reinforcement, stitching and grout/epoxy injection, bamboo reinforcement as external reinforcement, post-tensioning, confinement, centre core, mesh reinforcement, etc. [4,5]. Many researchers have used FRP strengthening to increase the in-plane strength and strain capacity of masonry walls. FRP strengthened in-plane loaded URM walls have shown largely increased shear strength [6]. The compressive strength of the GFRP wrapped masonry panels was found to be more than that of the unwrapped panels. The in-plane strength considerably increased [7,8].

The geosynthetic materials have been used extensively in many Civil Engineering application viz. seismic stability of earth slopes, retaining walls, embankments and in the stability of landfills. Geosynthetic material wrapped around layers of soil backfill can act as a vertical wall [9]. Geosynthetic improves the performance of roads when they are placed between the subgrade and base course, or within the base course [10,11]. The improved performance consists of increases in the volume of traffic that can be carried by a given thickness of base course, decrease of the base course thickness required to carry a given volume of traffic or combinations of both increased traffic and thickness reduction of base course. The application of geosynthetic as base isolation form has been studied by Yegian and Kadakal [12] and Nanda et al. [13,14]. Still, there is an increase in the tendency to develop new products and applications on a routine basis to solve different civil engineering problems [15].

The present study was conducted on masonry wall with and without strengthening. The main objective of this paper is to assess the in-plane shear performance of masonry panels with and without strengthening using non-woven geotextile of geosynthetic with different patterns and to compare the results to investigate any improvement of the same. A numerical model is developed to obtain a diagonal shear failure mode of a masonry panels. It was then validated with experimental work, where twelve brick panels were tested for the diagonal compression (shear) test as recommended by ASTM E519 to simulate the in-plane shear failure mode [16].

2. Numerical approach

2.1. Introduction

Masonry is an anisotropic composite material made with masonry units and mortar. Numerical models of masonry walls with and without strengthening have been created using finite element software ANSYS [17]. Generally, three different approaches are adopted to model masonry depending upon the level of accuracy, the simplicity desired, the size of the model and type of the analysis. The modelling strategies are as follows [18]:

- *Detailed micro-modelling.* Masonry Units and mortar are modelled separately. They are represented by continuum elements, whereas the interface between brick and mortar is represented by discontinuous elements. Each constituent of the masonry material and their characteristics are considered in this model, thus it reflects the realistic behaviour of masonry but at the cost of great computational effort. However, this model can be adopted for simulating laboratory results satisfactorily.
- *Simplified micro-modelling.* In this approach, masonry units are represented by continuum elements whereas mortar joints and unit-mortar interface are modelled with discontinuous line interface elements. The units are expanded in order to keep the geometry of the whole structure unchanged. Thus, with the simplification of the model, the computational cost gets reduced.
- *Macro-modelling.* Without distinguishing the units and mortars, the units, mortar and the unit-mortar interface are smeared out in a homogeneous continuum. Mechanical properties of homogeneous elements represent the whole structure. The model is unable to show micro-mechanisms occurring in the masonry, but it is very effective from the computational point of view as it requires a very less computational time.

In this study, a micro non-linear 3D model has been developed to simulate the laboratory test results. The commercial multipurpose finite element software ANSYS has been used for developing the model.

2.2. Mechanical properties of the constituents

The mechanical properties of the constituents of masonry are determined experimentally. In the case of diagonal compression, a combined state of shear and compression occurs in the mortar joints and hence, the parameters of masonry in compression and shear is required. Material properties used in the model are presented in Table 1. Fig. 2 shows the tensile strength test for geotextile as per ASTM D4595–17 [19]. The tensile strength of geotextile was obtained by using wide-width strip specimen of 102 mm × 204 mm. A relatively wide specimen was gripped across its entire width in the clamps of a constant rate of extension (CRE) type tensile testing machine. The longitudinal force was applied to the specimen until the specimen ruptures. Tensile strength, elongation of the test specimen can be calculated from machine scales, dials, recording charts, or an interfaced computer. Table 2 shows