Numerical Analysis of Geosynthetic Strengthened Brick Masonry Panels

Hasim Ali Khan, Radhikesh Prasad Nanda, and Diptesh Das

Abstract Un-reinforced masonry (URM) structure is extremely vulnerable to seismic actions. Their susceptibility to collapse has provided the concussion to develop strengthening techniques to strengthen URM buildings. The numerical analysis of the in-plane behaviour of un-reinforced and geotextile strengthened brick masonry specimen, using a 3D macro nonlinear model, is presented in this paper. All specimens are subjected to diagonal compression tests. Two different patterns viz. parallel and diagonal are strengthened. Numerical analyses are carried out to verify the efficiency of the reinforcement with geosynthetic. From the investigation, it is noticed that geosynthetic strengthening enhanced the load-bearing capability, diagonal shear strength and stiffness remarkably. It is estimated that the diagonal shear strength enhanced from 36% to 39%. Hence, masonry strengthened with geosynthetic will perform better in the seismic prone area.

Keywords Strengthening · Geosynthetic · Geotextile · Masonry panels · Diagonal compression test

1 Introduction

URM buildings are weak to failure in an earthquake. Un-reinforced masonry (URM) is widely used in the world. Mortar is a weak part of masonry. Two types of collapse are commonly noticed during seismic prone areas. In-plane and out-of-plane collapses are noticed in URM structures [1]. The in-plane collapse mode is vitally significant in URM walls under seismic action. Past investigator shows that

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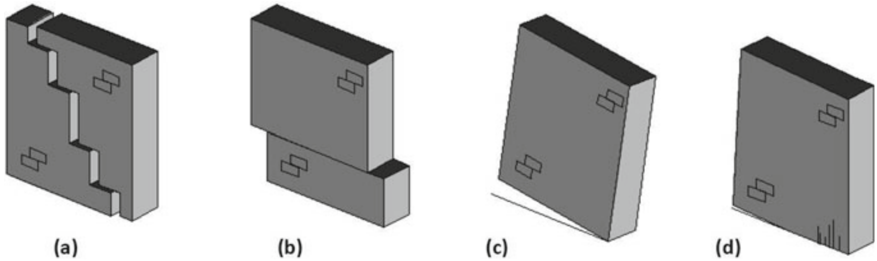

Fig. 1 In-plane failure techniques of un-reinforced brick walls **a** Shear failure, **b** Sliding failure, **c** Rocking failure, **d** Toe-crushing failure

throughout an earthquake, the principal collapse mode is shear [2–4]. The vital in-plane collapse strategies of URM walls exposed to seismic actions are presented in Fig. 1 [5, 6].

Application of geosynthetic products has been utilized widely in numerous civil engineering construction viz. retaining walls, embankments, soil backfill [7]. Geosynthetic enhances the execution of roads inside the base course [8, 9]. Geosynthetic, as a form of base isolation, has been investigated by Yegian and Kadakal [10]. There is an expansion to develop new applications to resolve different civil engineering problems [11,12]. In-plane strength is significantly enhanced by using Geosynthetic products [13].

This aim of this study to calculate the in-plane shear behaviour of un-strengthened and strengthened brick walls by application of geotextile with various patterns numerically using ANSYS [14]. To get a diagonal shear collapse mode of a masonry wall, a force can be applied along diagonal of masonry panel as per ASTM E519 [15].

2 Numerical Model

2.1 Introduction

Masonry is an anisotropic component found by the assemblage of bricks and mortar. Numerical models of un-strengthened and strengthened masonry have been formed by finite element analysis in ANSYS. Therefore, numerical models of masonry habitually display a reasonable level of complexity. Generally, three different methods are implemented for the modelling of masonry. The modelling approaches are complete micro-modelling, simplified micro-modelling and macro-modelling [16–18]. In this research, a macro nonlinear 3D model has been formed to determine the in-plane performance of un-strengthened and geotextile strengthened brick masonry specimen.

Table 1 Composition of the masonry constituents [13]

Properties	Brick	Mortar
Density, ρ (kg/m^3)	1750	2150
Elasticity modulus, E (MPa)	2020	4050
Poisson's ratio, ν	0.15	0.22
Ultimate tensile strength, f_t (MPa)	1.66	0.86
Ultimate compressive strength, f_c (MPa)	8.93	3.49

Table 2 Composition of nonwoven polypropylene geotextile [13]

Property	Unit	Value
Tensile strength	MPa	0.18
Young's modulus	MPa	15850
Poisson's Ratio	–	0.35
Thickness (at 2 kPa)	mm	1.5
Mass per unit area	g/m^2	262
Elongation	%	85

2.2 Parameters Utilized in Masonry

The parameters utilized in masonry are determined experimentally. The material utilized in the research is illustrated in Table 1. The parameters of the nonwoven geotextiles utilized in the present study are presented in Table 2.

2.3 Model Description

To determine the in-plane performance of masonry panel under the diagonal compression test, a 3D macro model is analysed. The masonry is assumed as a homogenous considered. The mechanical parameters of the whole structure being homogeneous elements. The dimensions of the masonry panel are 600 mm × 600 mm × 125 mm. Figure 2 illustrates the detail description of the setup and boundary limitations. The compressive loads are applied simultaneously along one diagonal. Therefore, one diagonal gets contracted, and other gets extended.

In this model, masonry specimen is modelled with a higher-order 3D, 10 nodes of SOLID187 tetrahedron elements Fig. 3a.

Geotextile is utilized with SHELL 63 element due to its bending and membrane capacities in the ANSYS, and the detail description is depicted in Fig. 3b. The interface between masonry and geotextile is modelled with CONTA174 element Fig. 3c. The Drucker–Prager formulation is considered for the masonry specimen [13]. Nonlinear behaviour is investigated.

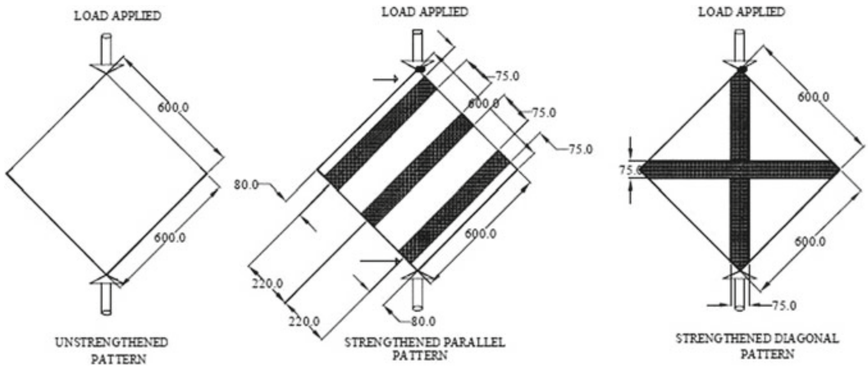

Fig. 2 Masonry specimen loaded diagonally

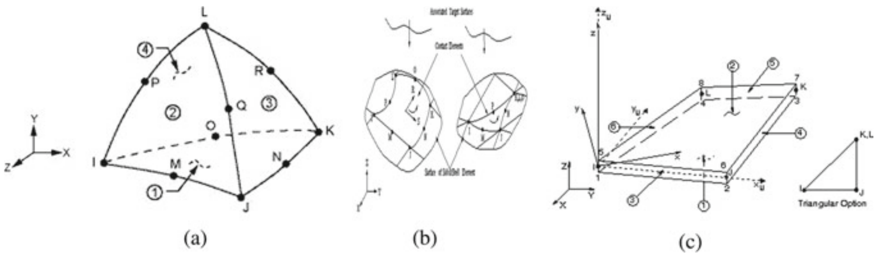

Fig. 3 Elements taken of model **a** SOLID 187 **b** CONTA174 **c** SHELL63

Figure 4a–c depicts finite element mesh utilized for the masonry panel before and after strengthening correspondingly. Nonlinear static analyses are adopted by using the Newton–Raphson iteration method.

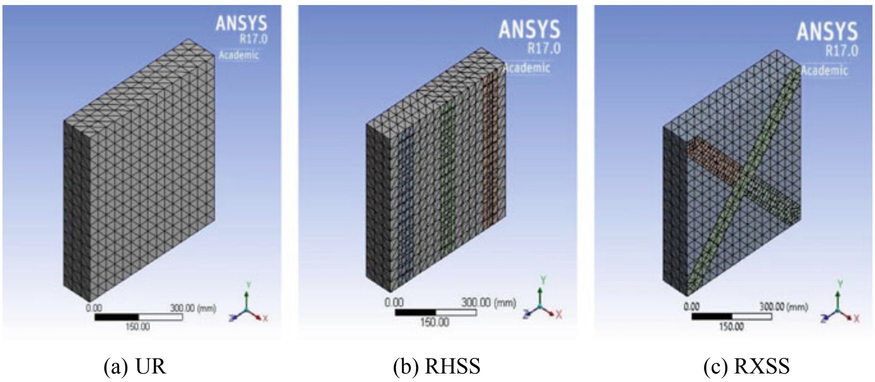

Fig. 4 Mesh details of **a** UR, **b** RHSS, **c** RXSS

3 Results and Discussion

The strengthening of masonry specimen was evaluated. Figure 5 depicts the distribution of shear stress. Shear capability is enhanced from UR to RHSS and RHSS to RXSS correspondingly.

The load-deformation graphs evaluated along the compressed diagonal is investigated. The load-deformation capacities increase with strengthening giving maximum in case of the diagonal pattern. Figure 6 depicts the graphs of comparative load-deformation performances for masonry specimen. The comparison indicates almost equal before and after strengthening in collapse load and the stiffness correspondingly.

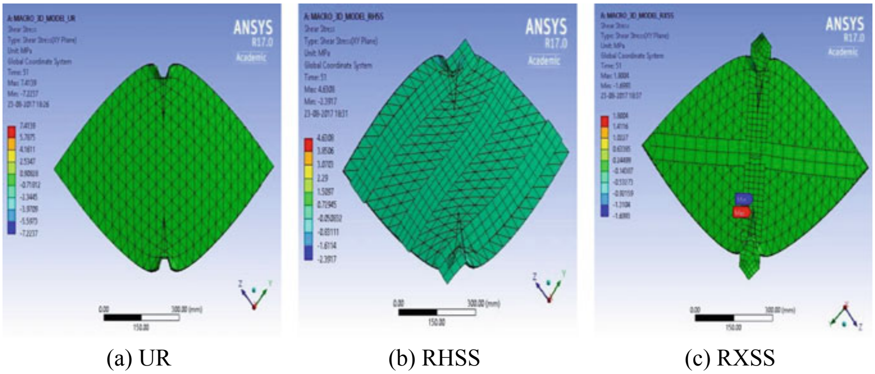

Fig. 5 Shear stress distribution for **a** UR, **b** RHSS, **c** RXSS at collapse

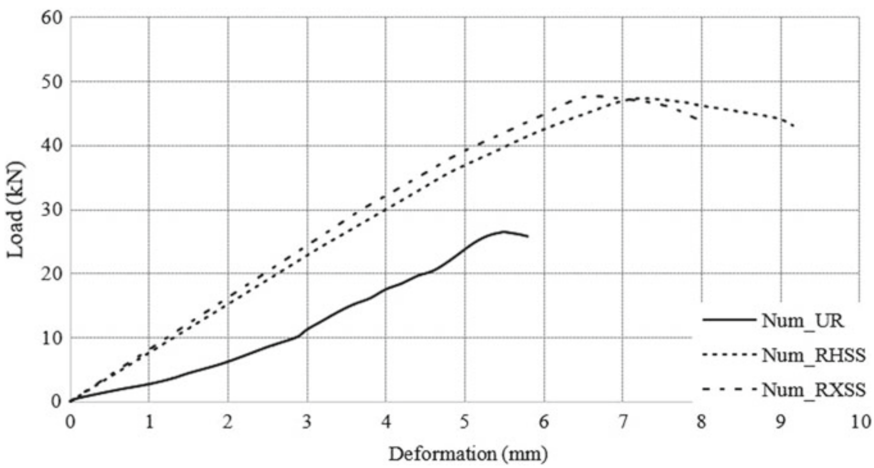

Fig. 6 Diagonal compression of masonry specimen

Table 3 Evaluated diagonal strength

Strengthening pattern	Diagonal shear strength (MPa)	Increase in Diagonal shear strength over UR (%)
UR	0.23	–
RHSS	0.3128	36
RXSS	0.3197	39

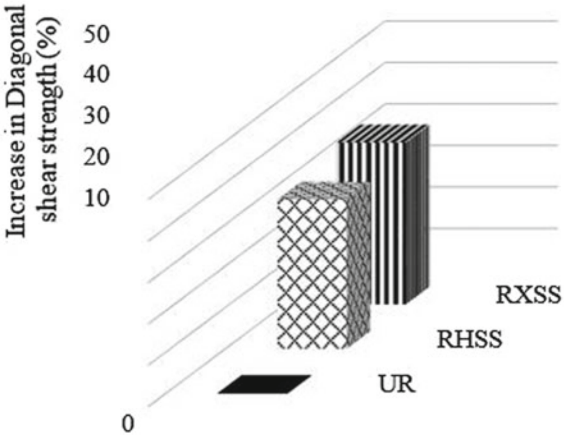

Fig. 7 Comparison of the Diagonal shear strength of one-side strengthened specimen

As per ASTM E 519, the distribution of shear stress for masonry specimen is evaluated and shown in Table 3 and Fig. 7.

The Diagonal shear strength enhanced from 36 to 39%. Furthermore, it was also illustrated that the panel with diagonal strengthening gives better performance.

Figure 7 illustrates the comparisons of the diagonal shear strength of the one-side strengthened specimen. RXSS indicates the highest stiffness and deformation capability.

4 Conclusions

The numerical observation was investigated under diagonal compression tests to develop the diagonal shear strength of masonry specimen. Based on the analysis, the following findings are pointed out:

- The strengthened specimen enhanced the failure load and deformation from UR to RHSS and RHSS to RXSS correspondingly.
- The diagonal shear strength enhanced from 0.3128 to 0.3197 MPa.
- Furthermore, diagonal strengthening has more stiffness than others.

- Brittle failure noticed for un-strengthened panel while strengthening enhanced its deformation capability.
- It is also pointed out that load-carrying capability, deformation capability, diagonal shear strength and stiffness are significantly increased from parallel to diagonal, respectively.

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