Geosynthetic as Sustainable Materials for Earthquake resistant of Masonry Structures

Hasim Ali Khan, Biplab Behera, Radhikes Prasad Nanda
Department of Civil Engineering, National Institute Technology, Durgapur, West Bengal, India

E-mail: hiihasim@gmail.com

Abstract. When exposed to simultaneous in-plane and out-of-plane behaviour generated by earthquakes or high wind pressure, unreinforced masonry (URM) walls are vulnerable to failure. The paper presents the performance of brick masonry panels using non-woven geotextile in-plane shear and out-of-plane bending experimentally tested. The panels were reinforced with a diagonal geometric pattern on both sides. From the laboratory assessment, it was determined that geosynthetic enhancement significantly improved the capacity of load carrying, displacement capacity, bending moment, stiffness, diagonal shear, in-plane shear, and flexural strength with higher performance for both cases in the case of the cross pattern. In contrast to the un-strengthened panel, experimental findings have demonstrated a less fragile behaviour. Geosynthetics can therefore be preferably suited for strengthening the brick masonry panel in order to defend brick constructions in seismic populated places.

1. Introduction

Masonry is the major form of building structures for habitation in developing countries. It has innumerable advantages, including thermal insulation, sound resistivity, the option of addition and alteration after construction, less formwork, easy and low-cost repair, use of local and eco-friendly materials, need of less-skilled labor, and less interference in engineering over other present-day reinforced concrete and steel construction. Masonry buildings are constructed via a combination of non-engineered bricks and mortar [1-4]. Bricks have good compressive strength, perform well under gravity loading, and act vertically on the structures. However, such unreinforced brittle structures are not strong enough for resisting lateral thrust generated due to earthquake ground motion; hence they cause major hindrance in seismically active regions. The history of post-earthquakes has resulted in maximum damages to structures and has also accounted for the maximum loss of lives and properties. Moreover, field surveys of past earthquake affected areas have illustrated that low-strength failure dwellings are mainly responsible for the loss of lives and properties. Figure 1 presents the critical in-plane collapse strategies of URM walls exposed to seismic behaviour by Eigawady et al [1]; Kalali and Kabir [2, 3]. In various civil engineering building ventures, the application of geosynthetic materials has been commonly used. Walls of retention, embankments, soil backfill [7].

Most of the experimental and numerical work concentrate on obtaining capacity of strengthened masonry wallettes under either in-plane or out of plane loading. Since during seismic action, a wall is subjected to loading in all the direction and undergoes simultaneous in plane and out of plane loading,
the accuracy depends upon the simultaneous effect [4-9]. Present investigation focuses the performance of masonry wallettes strengthened by geosynthetic material viz. geotextile with different patterns subject to in-plane shear and out-of-plane bending loading activities, separately.

Figure 1. In-plane shear (wall A) and out-of-plane bending (wall B)

2. Experimental Programme

2.1. Introduction
To assess the in-plane shear and out-of-plane bending for masonry wallettes, a series of tests was aimed at wallettes. Twenty-four masonry wallettes, 600 mm in length, 600 mm in width, and 125 mm in depth, were cast for the experiments in this report. Masonry bricks, manufactures by a local supplier in Durgapur, were used in this experimental project. A cement mortar with a mixed proportion of 1:5 (cement: sand) was adopted, and a proper quantity of water was used to guarantee the mortar's good working ability. The water-cement ratio was maintained at 0.45. Six mortar cubes were prepared and cured for 28 days. The compressive strength of the mortar was evaluated by dividing the cross-sectional area with the maximum load. The descriptions of masonry wallettes before and after geosynthetic reinforcement are shown in Figure 2.

| Component of the brick-masonry | Brick | Mortar |
|--------------------------------|-------|--------|
| Density                        | 1750  | 2150   |
| Elasticity modulus             | 2020  | 4050   |
| Poisson’s ratio                | 0.15  | 0.22   |
| Ultimate tensile strength      | 1.66  | 0.86   |
| Ultimate compressive strength  | 8.93  | 3.49   |

Table 2. Composition of nonwoven polypropylene geotextile

| 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/m²    | 262    |
| Elongation                | %       | 85     |
2.2. Parameters taken in brick-masonry
In Table 1 and Table 2, the physicochemical characteristics of the brick, mortar and non-woven geotextiles used throughout the presenting research are summarized. Nine single-leaf masonry Wallette, having dimensions of 600 mm × 600 mm × 125 mm, were constructed in a casting yard at normal temperature. Each brick masonry wallette was cast with seven layers of bricks via English bond. The schematic of a masonry bond pattern is illustrated in Figure 2. Out of thesis nine wallettes, three wallettes were kept un-strengthened, named as UR (un-reinforced), three wallettes were kept as diagonal and cross pattern.

![Figure 2. Masonry specimen (a) Diagonal Compression test (b) Four-point bending test](image)

2.3. Test setup
All wallettes were tested at the Hydraulic servo Dynamic Actuator Laboratory of NIT Durgapur. A servo-controlled actuator with a load-carrying capability of 100 kN was utilized for static and dynamic loading operations. In compliance with ASTM E-519 and ASTM E518, two steel loading shoes and steel rods were produced for diagonal compression and four-point bending tests of brick-masonry, respectively.

3. Results and Discussion
The deformed image of the panels is presented in Figure 4. For both in-plane and out-of-plane, deformation is expanded from UR to GRXSS.

![Figure 3. (a) Diagonal compression of masonry specimen (b) Four-point bending test](image)
The graphs of load-deformation assessed along the compressed diagonal are described. After strengthening with the highest in the case of diagonal pattern, the capabilities of load deformation increase. Shear stress and flexural strength for masonry specimens are measured in accordance with ASTM E 518 and ASTM E 519 and are shown in Table 3.

| Strengthening arrangement | Diagonal shear strength | Increase in Diagonal shear strength over UR (%) | Flexural Strength | Increase in Flexural strength over UR (%) |
|---------------------------|-------------------------|-----------------------------------------------|-------------------|------------------------------------------|
| UR                        | 0.23                    | -                                             | 0.99              | -                                        |
| RWSS                      | 0.3128                  | 36                                            | 1.76              | 73.73                                    |
| RWSS                      | 0.3197                  | 39                                            | 1.87              | 88.89                                    |

Diagonal shear strength and bending strength increased from 36% to 39% and from 73.73% to 88.89%. In addition, the panel with diagonal reinforcement was also seen to have more power.

4. Conclusions
The diagonal and flexural strength of brick masonry wallets, with diagonal reinforcement patterns, utilising geosynthetic, were experimentally tested under diagonal compression and four-point bending tests. The remarks below are illustrated based on the current report:

- For both in-plane and out-of-plane, the strengthened specimen enhanced the failure load and deformation from un-strengthened to diagonal reinforced.
- Diagonal shear strength and flexural strength are improved from 36% to 39% and from 73.73% to 88.89%. Diagonal reinforcement, in addition, has more rigidity.
- Brittle failure demonstrated an increased deformation potential for the un-strengthened panel when strengthening it.

It is also noted that the capacity of load bearing, the capacity of deformation and diagonal shear strength are substantially improved from un-reinforced to diagonal.
References

[1] ElGawady M A, Lestuzzi P and Badoux M 2007 Static cyclic response of masonry walls retrofitted with fiber-reinforced polymers Journal of composites for Construction 11 50-61

[2] Kalali A and Kabir M 2012 Cyclic behavior of perforated masonry walls strengthened with glass fiber reinforced polymers Scientia Iranica 19 151-65

[3] Kalali A and Kabir M Z 2012 Experimental response of double-wythe masonry panels strengthened with glass fiber reinforced polymers subjected to diagonal compression tests Engineering Structures 39 24-37

[4] Nanda R P, Agarwal P and Shrikhande M 2012 Base isolation by geosynthetic for brick masonry buildings Journal of Vibration Control 18 903-10

[5] Palmeira E M, Tatsuoka F, Bathurst R J, Stevenson P E and Zornberg J G 2008 Advances in geosynthetics materials and applications for soil reinforcement and environmental protection works Electronic Journal of Geotechnical Engineering 13 1-38

[6] Khan H, Roy P and Nanda R 2016 Retrofitting of Brick Masonry Panels with Glass Fibre Reinforced Polymers IOSR Journal of Mechanical Civil Engineering , 11-8

[7] Zucchini A and Lourenço P B 2004 A coupled homogenisation–damage model for masonry cracking Computers Structures 82 917-29

[8] ASTM 2010 Standard test method for diagonal tension (shear) in masonry assemblages

[9] Khan H A and Nanda R P 2020 Out-of-plane bending of masonry wallette strengthened with geosynthetic Construction Building Materials 231 117198