International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878, Volume-8 Issue-3, September 2019

Effect of Polypropylene (PP) Geo-Fabric Reinforcement in Brick Masonry under Axial Loads

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Abstract*: The brick masonry is used in a wide range as an infill material in reinforced concrete (RC) frames. In general masonry infill (MI) are treated as non-structural elements and ignored in many structural designs, But the contribution of infill under lateral loads shows the better performance and contribution to strength and stiffness of RC frames. The stiffness of masonry controls the failure of MI and plays a significant role under lateral loads. Masonry is a brittle material and exhibits poor performance under shear and flexure. The Geo-fabrics are used as tensile property enhancing materials in many infrastructural works. The prime focus of this work has been focused to make brick masonry to more stiff by compositing the polypropylene geo-fabric at parallel to mortar bed joint and perpendicular to mortar bed joints with the help of cementitious matrix. In this work, 18 numbers of 0.7m×0.7m×0.23m brick masonry wallets (6 wallets conventional + 6 wallets reinforced by PP Geo-fabric parallel to bed joint + 6 wallets reinforced on the face of the wallet with cementitious matrix) are subjected to load bearing test and Diagonal Compression. The experimental results under both the test were compared with normal conventional specimens. The results showed that better performance with PP geo-fabric reinforced specimen compared with conventional masonry wallets.

Keywords: Polypropylene, Shear strength, Flexural strength, Stiffness, Diagonal Compression.

I. INTRODUCTION

MASONRY is an assemblage of masonry units (Bricks, Blocks, and Stones, etc.) and mortar. The masonry infill is very vulnerable to lateral (Seismic and Cyclonic) loads [1]. The masonry infill exhibits orthotropic behavior and very low ductility under lateral loads. Because of this, leading to brittle failure seen in unreinforced masonry infill. The various factors influencing the performance of masonry are the main type of masonry unit and type of mortar used in construction. The higher the strength of mortar does not contribute to the compressive strength of masonry but it effects on failure crack pattern of masonry infill [1, 2]. Brick masonry is widely used as an infill material in reinforced concrete (RC) frames from thousands of years. These traditional constructions are relatively economical and quick to construct in stipulated time. In recent, several experimental works have been done to understand the performance of masonry. All analysis reveals that to strengthen the infill because to overcome the poor performance under shear consideration. The stiffness and strength of masonry over time depends on the quality of workmanship and materials used for construction. In most cases, un-reinforced masonry failed because of insufficient ability to withstand load under flexure and shear [1, 2]. The various reinforcing and retrofitting techniques are adopted to overcome these effects during disasters. To overcome the drawback with un-reinforced masonry, several researchers carried experimental studies on strengthened masonry wallets to overcome the effect of shear and flexure behavior [2, 3]. The various strengthening techniques have been developed-binding of strengthening material [4, 5, 6], application of additional fabric reinforced cementitious matrix (FRCM) [7, 2], strengthening of mortar joints [1,8], etc. were tested and analyzed to propose the most suitable method to increase the flexure and shear capacity of masonry infill. The Geo-fabrics are new generation reinforcing materials widely used in civil engineering infrastructural works. Geo-synthetics are extensively used in the field of highway and soil stability strength enhancing projects. Therefore, in this present paper, an attempt is made to study the polypropylene type of geo-fabric as reinforcing the material in masonry infill.

II. EXPERIMENTAL SEQUENCES

A. Basic material characterization

The various tests are conducted on brick units as per IS: 1077-1992 and IS: 3495-1992 (part 1-4). The results are tabulated in table I. The properties of cement mortar are studied by casting cube mould as per IS: 2250-1981 and ASTM-C-190. The results are tabulated in table II. The biaxial polypropylene (PP) types of rigid geo-fabrics are used in this study. The various properties are determined under 25kN universal testing machine results are represented in table III and Geo-fabrics used in this study are shown in Figure 1.

Manuscript published on 30 September 2019
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Fig.1. Polypropylene geo-fabric and testing arrangement in UTM

Table I. Mechanical properties of Bricks

Dimension (mm)	Weight Density (kN/m^3)	Water Absorption (%)	Modulus of rupture (Mpa)	Compressive strength (Mpa)
210x 100 x 70	14.20	13.10	1.15	3.6

Table II. Properties of Mortar

Proportion	Tensile Load (kN)	Tensile strength (MPa)	Compressive Load (kN)	Compressive strength (MPa)
1:4	1.727	2.75	130	26.53

Table III. Basic properties of Polypropylene (PP) Geo-fabric

Ultimate Load (N)	Ultimate Tensile Strength (N/mm^2)	Breaking Load (N)	Breaking Stress (N/mm^2)	Young's Modulus (N/mm^2)
1016	172.083	970	189.4	$1.85x10^{6}$

B. Compressive strength of masonry Prism

The compressive strength test was performed according to IS 1905 – 1987. The five brick unit stack bonded with and without polypropylene Geo-fabric bed joint reinforced prisms are considered to evaluate the compressive strength. The polypropylene Geo-fabrics are sandwiched between mortar bed joint of thickness 12 mm in each bed joints of masonry prism and specimens were cured under wet gunny bags for a period of 28 days before the test. The compressive strength of the prisms is tabulated in Table-4 and testing specimens are shown in Figure-2.

Fig.2. Compression test on masonry Prism

Table IV. Compressive strength Masonry Prisms

Material	Dimension (mm)	Load (kN)	Compressive Load (N/mm2)	Correction Factor	Corrected Compressive Stress N/mm2
Conventional	210×100 ×435	55.4	2.63	0.968	2.55
PP Geo-fabric	210×100 ×435	65.1	3.10	0.968	3.00

C. Load Bearing capacity of masonry wallets

The test was performed according to IS 1905 (BIS 1987). The load bearing test was performed on three sets of variety by considering 3 numbers (0.7m×0.7m×0.23m) in each category. The test was carried under 2000kN loading frame; the strengthening of unreinforced masonry wallet was done by two methods. The bed joint reinforcement and face reinforcement on both sides by applying the cementitious matrix. The results were compared with unreinforced controlled specimens. The experimental setup is represented in Figure-3 and Figure-4. The modulus of Elasticity of Conventional masonry wallets, PP geo-fabric parallel to bed joint and PP reinforced on Face of masonry wallet is 2389.3Mpa, 2734.9Mpa, and 8689.2 Mpa respectively. The reinforcing way of bed joint reinforcement of PP geo-fabric is shown in Figure-5 and Stress-strain curves for normalized values of 3 wallets in each category are presented in Figure-6(a, b and c).

Fig.3. Load Bearing capacity test on Masonry wallet

Fig.4. PP Geo-fabric Face strengthened wallet

Fig.5 PP Geo-fabric Bed reinforcement

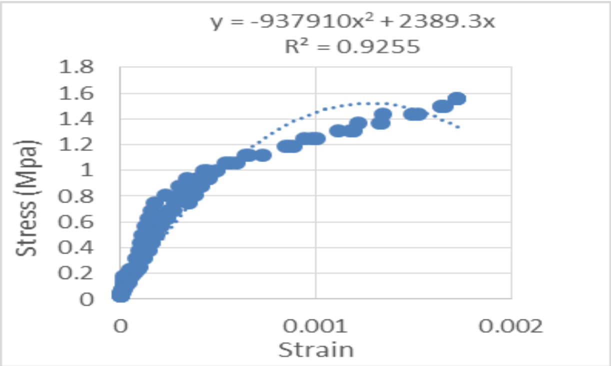

Fig.6 (a).Conventional wallet

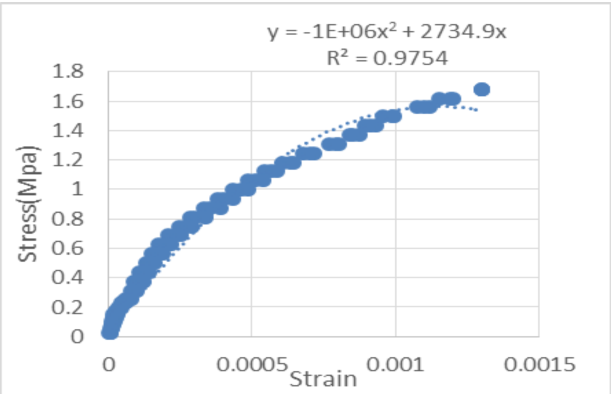

Fig.6 (b).PP geofabric face Reinforcement

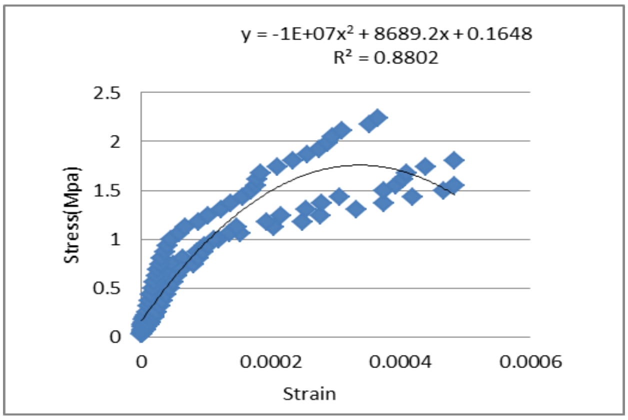

Fig.6 (c).PP geofabric Bed Joint Reinforcement

Fig.6.Stress/Strain Curves for Masonry Wallets

D. Shear strength of Masonry wallets by Diagonal Compression

Diagonal Compression test was performed in six masonry specimens (0.7m×0.7m×0.23m) in order to evaluate the diagonal tensile (shear) strength. As referred, three masonry specimens built with 1:5 mortars Conventional, whereas the other three specimens were based on Polypropylene bed joints at each course of Brick masonry and three specimens reinforced with polypropylene on face of the Brick masonry. All panels were built in the following techniques and were positioned in the testing machine with a diagonal axis in the vertical direction. The compressive load has been applied along the direction of diagonal axis shown in Figure-7. According to ASTM standards (ASTM 519:2010), the test setup is composed of steel loading shoes which were fixed in opposite corners of a diagonal of masonry specimens. The shear stress (τ) assured by equation (1).

$$\tau = \frac{0.707P}{A_n} \qquad (1)$$

Where, P is axial load applied with jack and A_n is the net area of Specimen.

$$A_n = \left(\frac{w+h}{2}\right) \times t \times n \qquad (2)$$

Where w is the specimen width, h is the specimen height, t is the thickness of the specimen and n is the percentage of the unit's gross area that is solid. In this work, n=1 was adopted. The average values of maximum load and shear stress are tabulated in Table-5.

Fig.7. Diagonal Compression Test

Retrieval Number C4181098319/19©BEIESP
DOI: 10.35940/ijrte.c4181.098319
Journal Website: www.ijrte.org

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Table V. Shear stress of Masonry Wallets

Specimen	Specimen Dimension m	Axial Load (kN)	Shear Stress (τ) (Mpa)
Without Polypropylene Geo-grid	0.7 × 0.7 × 0.23	255	0.52
With Polypropylene Bed Joint Reinforcement	0.7 × 0.7 × 0.23	315	0.66
With Polypropylene on Face of Masonry	0.7 × 0.7 × 0.23	295	0.61

E. Failure Mechanism of Masonry Wallets

Experimental results, which were obtained in this experimental analysis, showed that all controlled specimens (Without PP Geo-fabric) have similar failure pattern. It is seen that in all specimens the main crack started in the middle of the specimens, developing towards the bottom and upper corners (only through mortar, without damaging the bricks), Causing the collapse of wallets represented in Figure 8 (a). Due to the different mechanical property of mortar, the specimens showed different behavior at the failure in polyester geo-fabric bed joint wallets represented in Figure 8 (b). In the case of PP reinforced on the face of masonry, the masonry fails first and after PP geo-fabric showed the pattern of cracks at middle strips represented in Figure 8 (c). The geo-fabric helps to make ductile behavior of wallet by contributing tensile strength at bed joints and avoid the collapse of wallets. The typical crack behaviors developed in all cases represented in Figure 8(a, b, and c).

Fig.8 (a).Conventional wallet

Fig.8 (b).PP geofabric face Reinforcement

Fig.8 (c).PP geofabric Bed Joint Reinforcement

Fig.8 (a, b, and c). Crack pattern in masonry wallets

III. SUMMARY AND CONCLUSIONS

An experimental study was carried out to investigate the behavior of Polypropylene geo-fabric reinforcement in masonry. The geo-fabrics possess better interlocking behavior with aggregates and help to make stiffer under any kinds of loads. The geo-fabrics are eco-friendly, economical and recyclable materials. This study focuses on the strengthening of masonry with polypropylene (PP) type of geo-fabric as reinforcement. Based on present experimental investigation some of the primary conclusions were drawn are as follows.

1. Application of PP geo-fabric as bed joint reinforcement and face reinforcement on masonry helps to make masonry wallets as stiffer under loads compare to conventional wallets.
2. From the load bearing test it is evident that PP reinforcement on bed joint and face of brick masonry significantly increased the load carrying capacity by 45% and 30% compare with conventional masonry wallets.
3. The diagonal compression of masonry wallets shows in the increment of shear carrying capacity by 25% in bed joint PP reinforcement and 20% by face PP reinforcement compare with unstrengthen brick masonry wallets.
4. The PP geo-fabric is a ductile material and having very good bonding with cementitious matrix. This makes the masonry infill as single integral unit. It helps to avoid the sudden brittle failure of brick masonry.
5. The failure mechanisms also showed that, the significance of PP reinforcements in brick masonry in bed joints and on the face of the masonry by avoiding the primary cracks and collapse of masonry wallets.

ACKNOWLEDGMENT

Authors would like to acknowledge Strata India Pvt. Ltd for providing Geo-fabric material for the strengthening of Masonry sub assemblages.

Also we acknowledge CIIRC, Jyothy Institute of Technology campus, Bangalore for providing laboratory facility.

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