Compression and tensile strength of masonry wallets with near surface mounted steel reinforcement

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ABSTRACT

Unreinforced brick masonry has low tensile strength and hence vulnerable when subjected to out-of-plane and lateral loads. Mounting steel bars on the surface of masonry walls is a common strengthening method to mitigate the possible damage due to external forces. In this study, the effect of providing surface mounted steel bars on masonry wallets on compressive and diagonal tensile strength is studied. A total of 10 brick masonry specimens of size 600mm x 600 mm 110 mm were prepared. Out of the 10 specimens, 2 were unreinforced and remaining 8 were reinforced with surface mounted steel bars. The 6 mm diameter steel bars were provided in vertical and horizontal direction and also on both face of the masonry wallet. The surface mounted steel bar layers on either face of the masonry wallet were tied together with binding wire introduced through the bed joint. All masonry wallets were plastered. The test results of reinforced masonry wallet were compared with the corresponding test results of unreinforced masonry. The test results indicate that the masonry compressive strength and diagonal tensile strength can be increased by 62% and 193% by mounting surface reinforcement of 0.6%.

Keywords: Masonry, surface mounting, steel rebar, strengthening

1. INTRODUCTION

Brick masonry is one of the most popular and oldest construction methods in the world. Collapse of unreinforced masonry houses is the biggest cause of human causalities in under developed countries during an event of earth quake. The strengthening of existing brick masonry wall is important in seismic prone areas. The surface reinforcements can be provided

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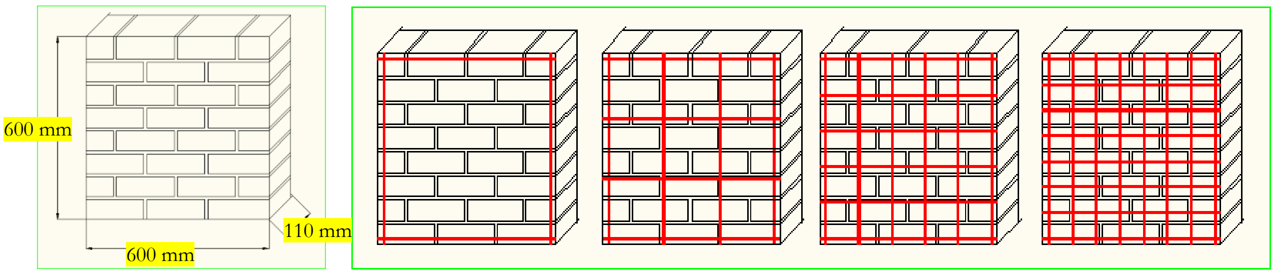
to mitigate in-plane and out-of-plane failure of masonry. In this study, the effect of providing different types of surface reinforcement cages on masonry wallets is investigated.

Strengthening existing unreinforced brick masonry can be achieved through several techniques. Demaj et al. (2022) experimentally assessed in-plane behavior of masonry walls both plain and reinforced. The in-plane shear strength of masonry wallets was found to increase from 0.75 to 1.56 MPa when the pre compressive stress is increased from 0.20 to 1.56 MPa. When 6 mm diameter steel bars are provided at the surface the in-plane shear strength was found to increase by 224 %. Casacci et al. (2019) carried out diagonal compression test on masonry wallets. The unreinforced masonry (URM) wallet, reinforced masonry wallets having two and four basalt bars and another specimen reinforced with glass ply were tested. The increase in strength for glass ply reinforced specimen was found to be 483 % when compared to the unreinforced masonry. Rezaee et al. (2019) investigated the efficiency of shotcrete retrofitting method for seismic rehabilitation of conventional unreinforced masonry wall. The diagonal tensile strength of the unreinforced specimen was found to be 0.45 MPa and the specimen having shotcrete overlay exhibited a strength of 550% more than unreinforced specimen. Debnath et al. (2023) reported that the out-of-plane flexural strength of masonry wallet increases about 200% when reinforced with polypropylene band and waste textiles. Hence, it can be concluded that the providing surface reinforcements can enhance the capacity of the masonry walls. In this study, the effect of adding surface mounted steel bars on the compressive and tensile strength has been explored.

The variation in the compression strength and diagonal tension of masonry walls with the variation in surface reinforcement ratio has not been studied in the literature. A systematic study on the effect of providing near surface mounted 6mm diameter steel rods in various spacing (reinforcement ratios) has not been investigated in the literature.

2. EXPERIMENTAL STUDY



(a) UR/0.00 (b) SR/0.15 (c) SR/0.30 (d) SR/0.45 (e) SR/0.60

Figure 1. Details of the masonry wallets

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Two types of masonry wallet specimens, namely, unreinforced and reinforced specimens were prepared. Four sets of reinforced specimens having a reinforcement ratio of 0.15, 0.30, 0.45 and 0.60 % were prepared. The details of the specimens are given in Figure 1.

Country burnt clay bricks having a strength of 7.1 MPa were used for the preparation of bare masonry wallets of size 600 mm x 600 mm x 110 mm. Mortar mix of 1:5 having a strength of 5.0Mpa was used for the preparation of bare masonry. The 6mm nominal diameter bars having yield strength of 544 MPa was used for reinforcing the masonry specimens. The reinforcements were provided on the surface of the specimens on opposite face of 600 mm x 600 mm side and tied together using binding wire at 200 mm interval along the bed joints. The unreinforced specimen is designated as UR/0.00 and the steel reinforced specimens are designated as SR/0.15, SR/0.30, SR/0.45 and SR/0.60. The SR indicates the steel reinforced specimen and the number 0.15, 0.30, 0.45 and 0.60 indicate the percentage of reinforcement in the specimen. The bare masonry specimens were cured for 28 days using moist burlap. In the case of reinforced specimens, the surface reinforcements were provided and the surface was plastered using 1:5 mortar. The reinforced masonry specimens were cured for another 28 days using moist burlap. All specimens were tested using a compression testing machines of capacity 1000kN. The set-up of the compression and diagonal test are given in Figure 2.

(a) Compression testing

(b) Diagonal tensile strength

Figure 2. Test set-up

The compression testing specimens are placed directly on the platform of the testing machine. A steel beam was placed at the top to spread the load. The diagonal tensile specimens are placed using a bracket on top and bottom. The load was applied gradually and the failure load was noted. The diagonal tension test was carried out in accordance with ASTM E519/E519M-10.

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The compressive strength (f_m) and diagonal tensile strength (f_{dt}) of the masonry wallet is calculated using the equations (1) and (2) respectively.

$$f_m = \frac{P_{uc}}{Lt} \qquad (1)$$

$$f_{dt} = \frac{0.707\,P_{udt}}{0.5t(L+H)} \qquad (2)$$

where P_{uc} is the ultimate load in compression and P_{udt} is the ultimate load in diagonal tension. L , H and t are the length, height and thickness of the specimen respectively.

3. RESULTS AND DISCUSSION

A total of 10 masonry wallets were tested. Five specimens were tested to determine the compressive strength and another five specimens were tested to determine the diagonal tensile strength. All specimens were tested to determine the ultimate failure load.

3.1. Compressive Strength

(a) UR/0.00 (b) SR/0.15 (c) SR/0.30 (d) SR/0.45 (e) SR/0.60

Figure 3 Crack pattern in compression specimens

The uniaxial compressive load was applied on the specimens as shown in Figure 2(a). The compressive strength of the masonry prism was calculated using the equation (1). The crack pattern in the compression test specimens are given in Figure 3. In the initial stages of loading, no cracks were observed and in the subsequent stages of loading vertical cracks could be seen. At the ultimate stage, both vertical and horizontal cracks were available in unreinforced specimen UR/0.00. In steel reinforced specimens, the peeling of the surface plaster along with the reinforcement mesh could be observed at the ultimate stage. This indicates that the tying of surface reinforcement with binding wire is not sufficient withstand the peeling of reinforcement layer.

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The variation of compressive strength of masonry wallets due to the addition of surface reinforcement is given in Figure 4. The compressive strength was found to increase with the increase in the reinforcement ratio. The increase in compressive strength was found to be 62% for a specimen having reinforcement ratio of 0.6% (SR/0.60) when compared to control specimen having no surface reinforcement (UR/0.00). Similarly, the increase in compressive strength for wallet having a reinforcement ratio of 0.3% is 29%.

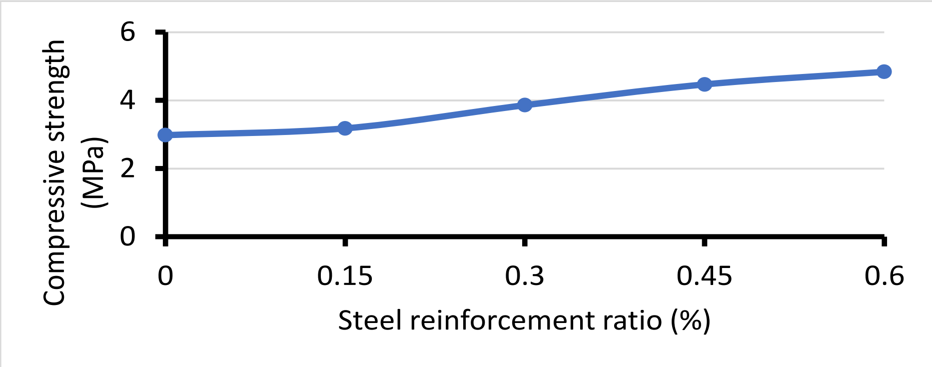

Figure 4. Variation of compressive strength of masonry wallets

3.2. Diagonal Tensile Strength

The diagonal tensile strength of the five masonry wallets was determined. In diagonal tension test, a major crack was formed in the vertical direction and the width of the crack was found to increase with the increase in subsequent stages of loading. In masonry wallets having reinforcements, the steel were found to bridge between the crack interfaces. The reinforcement mesh and the surface plaster peeled off from the brick masonry at ultimate stage. The crack pattern in the diagonal tension test specimen is shown in Figure 5.

(a) UR/0.00 (b) SR/0.15 (c) SR/0.30

(d) SR/0.45 (e) SR/0.60

Figure 5. Crack pattern in diagonal tension test specimens

The effect of mounting surface steel reinforcement cage on the diagonal tensile strength of the masonry wallet is shown in Figure 6

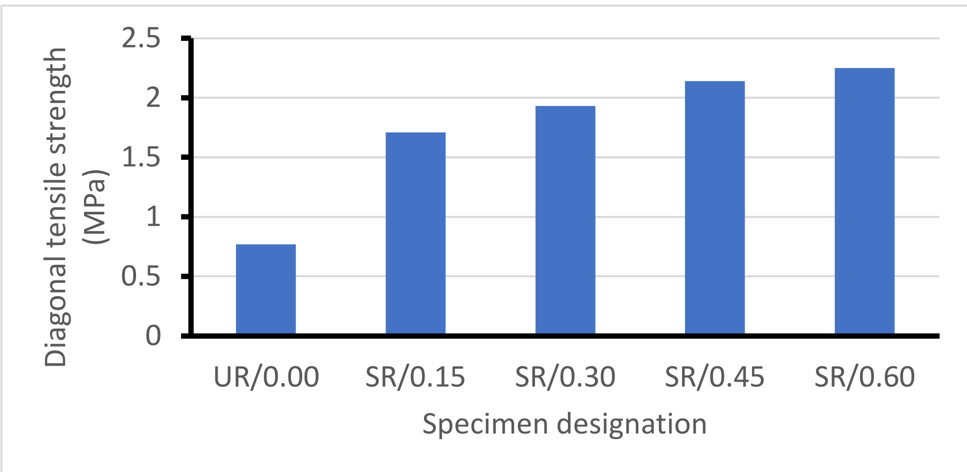

Figure 6. Diagonal tensile strength of masonry wallets

The diagonal tensile strength of the masonry wallet was found to increase with the increase in the reinforcement ratio. The bridging of steel reinforcement across the crack was found to be effective up to certain stages of loading which enhanced the diagonal tensile strength of the

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specimens having greater reinforcement ratio. The increase in the diagonal tensile strength was found to be 151% and 193 % for specimens SR/0.30 and SR/0.60 respectively.

4. CONCLUSION

Compressive strength of the masonry wallet can be increased by 62 % by mounting cage having a steel reinforcement ratio of 0.60%. By mounting the reinforcement mesh of steel ratio of 0.60%, the diagonal tensile strength of the masonry wallet can be improved by 193%. Hence, the surface mounting of steel reinforcement mesh can be recommended for improving the load carrying capacity of masonry wallets. It is expected that the test results will give an insight to the practicing engineers to adopt the proposed methodology of surface mounting for strengthening of masonry structures. The research can be carried out in the following areas in further scope of the study. For enhancement of strength properties, the combination of steel rod with weld mesh can be studied. Effect of changing the properties of binding material for tying the reinforcement with the masonry wallets can be studied. The effect of placing of steel rod in the surface grooves of wallets can be studied.

CONFLICT OF INTEREST

The authors do not have any conflict of interests.

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