Study on Behaviour of Masonry Walls using Different Masonry Unit and Mortar Combinations

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Abstract — **Masonry is one of the most important components of a structure which is under the action of compression and lateral loads. There are many types of masonry units available in the market and different types of mortars which can be used with them. However, the behavior of different combinations of these masonry units and mortars under different loadings is not well known. In the present study, three types of masonry units and mortars are used to test the behavior of different masonry combinations under compression and shear bond loading. Stack bonded prisms and English bonded prisms are used for experiment. The results obtained, describe the suitability of different masonry combinations under different conditions.**

Keywords —Masonry; mortar; compression; shear bond; burnt clay brick; concrete block; stabilized mud block; fly ash; polypropylene fiber; prism;

I. INTRODUCTION

Masonry is one of the most significant components of structure made from individual units which are laid in and bound together by mortar [1]. Masonry is one of the oldest building technologies known to man and used to construct significant structures since the beginning of civilization for its durability and aesthetic purposes. At present, in our country, about 45% of residential buildings are made of burnt clay brick and about 10% is of natural stone [2]. Hence, it is crucial to know the strength characteristics of masonry.

Unreinforced Masonry (URM) Structures are susceptible to damages mainly due to lateral seismic loads and compression loads [3]. The shear behaviour of URM is characterized by their resistance to in-plane loads and the bond between masonry unit and mortar whereas, the compression behavior of URM is characterized by resistance to vertical gravity loads. The compressive strength and the shear bond strength of the masonry depends on the type of masonry unit and type of mortar used [4]. Different combinations of masonry units and mortars behave differently under different loading conditions. In present study an attempt is made know the behavior of masonry of different mortar and masonry block combinations under compression and shear bond loading to know the suitability and applicability of each type. This will help in selecting type of masonry block and type of mortar for a given loading condition and situation. Suitable tests were performed for materials as per the IS codes [5-7].

II. EXPERIMENTAL PROGRAM

A. Materials

Masonry prisms and masonry triplets were made using three different types of masonry units namely burnt clay brick, stabilized mud bock (SMB) and concrete block. The sizes of the different masonry units and the compression test prisms prepared using them are given in Table 1. Three types of mortars are used in the study namely cement mortar, cement mortar with fly ash and cement fiber reinforced cement mortar. Cement mortar with fly ash mortar is formed by replacing 30% of cement with fly ash [8]. Fiber reinforced cement mortar is prepared by introducing polypropylene fibers [9] into the mix. The quantity of fibers is taken as 1.5% in the mix. M-sand is used as fine aggregate for the preparation of mortar. The grade of cement used is 53 grade. The proportion considered is 1:4.

The properties of the 53-grade cement used in the study are presented below

- Specific gravity – 3.14
- Normal consistency – 31%

The fly ash used in mortar type 2 is procured from the paper mill at Thandavapura, Mysuru. The properties of the fly ash are presented below

- Specific gravity – 1.82
- Density – 610 kg/m^3
- Water absorption – 65.11%

M - sand used as fine aggregate have the following properties

- Specific gravity – 2.65
- Density – 1690 kg/m^3
- Fineness modulus – 3.23

The polypropylene fibers used in fiber reinforced mortar have the following properties

- Diameter – 0.4 mm
- Average length – 10 mm

TABLE I – TYPES OF MASONRY UNITS

Masonry unit	Unit size in mm (L x W x H)	Prism size in mm (H x W x T)
Burnt brick	220 x 100 x 75	415 x 220 x 100
Stabilized mud block	300 x 140 x 100	540 x 300 x 140
Concrete block	400 x 150 x 200	470 x 400 x 200

- Tensile strength – 29.9 N/mm^2
- Density – 930 kg/m^3
- Elongation – 50-70 %

B. Construction of masonry prisms and masonry triplets

In the present study, the prisms are tested for compression and shear bond. For compression testing, stack bonded prisms and English bonded prisms are considered [10]. For shear bond tests, stack bonded prisms are considered which are called as masonry triplets [11].

The compression test specimen consists of masonry units in stack bonded or English bonded structure with height to width ratio between 2 to 5 [12]. For testing of shear bond specimen, masonry triplets were used with staggering in burnt brick and stabilized mud blocks. Staggering was not used in concrete blocks. The arrangement of compression and shear bond specimen is shown in Fig. 1.

III. TEST SETUP

The different combination of masonry units and mortars were constructed in laboratory conditions. Three specimens were constructed for each masonry unit and mortar combination and for each loading case. The specimens are named based on type of bonding, type of masonry unit, type of mortar and type of loading. P1 and P2 represent Stack bonded and English bonded prisms. Burnt bricks, stabilized mud blocks and concrete blocks are represented as BB, SB and CB. Cement mortar, cement mortar with fly ash and fiber reinforced cement mortar are represented as CMR, CFA and CFR. Compression and shear bond loading are represented as C and L.

A. Compression test

Masonry prisms were tested for compression in Universal testing machine after 28 days of curing as shown in Fig 2. Specimen with different masonry units and different mortars with 10mm average mortar thickness were tested with gradually applied load [13]. Masonry units with frogs were filled with 1:4 mortars and cured before testing. The failure load and the failure pattern of the specimen were noted.

- Five numbers of locally available burnt clay bricks of size 220mm x 75mm x 100mm are used.
- Three numbers of concrete blocks of size 400mm x 200mm x150mm are used.

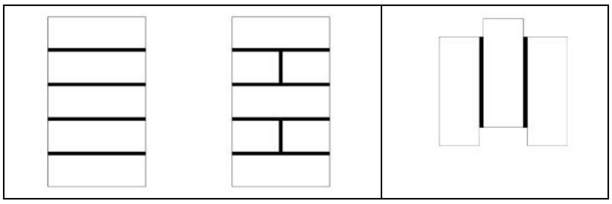

Fig. 1. Masonry prisms and masonry triplet

Fig. 2. Compression testing of (a) Stack bond and (b) English bond prisms

- Five numbers of stabilized mud block of proportion 1:12:18 (cement: soil: dust) and of size 300mm x 100mm x 140mm are used.

B. Shear bond test

Shear bond strength of specimen is tested using masonry triplets [14] as shown in Fig. 3. In case of burnt bricks and stabilized mud blocks, the center masonry unit of the triplet is staggered as shown in figure [15]. This is to facilitate testing of specimen kept vertically in universal testing machine. In case of concrete blocks, triplets are stack bonded without staggering. Lateral confinement is provided to burnt brick and stabilized mud block specimens to simulate the practical site condition [16]. To achieve this, a vertical steel plate as wide as the specimen is firmly fixed on both sides with help of bolts as shown in Fig. 3. In actual masonry, the load of the overlying masonry layers act on the masonry and provide extra resistance to the lateral strength of the masonry. During laboratory testing, vertical load was applied to the staggered middle brick to impart shear force to brick mortar interface at the joint. The ultimate shear load was noted and the shear bond strength is then calculated considering the resisting area. The resisting area are the two mortar joints between the masonry units.

- Three numbers of locally available burnt clay bricks of size 220mm x 75mm x 100mm and mortar thickness 10mm are used to construct masonry triplets with different mortars keeping the middle unit 40mm staggered along length to the other two bricks.
- Three numbers of stabilized mud block of proportion 1:12:18 (cement:soil:dust) and of size 300mm x 100mm x 140mm using mortar thickness 10mm are used to construct masonry triplets with different mortars keeping middle one 50mm forward along length to the other two bricks.
- Three numbers of concrete blocks of size 400mm x 200mm x150mm are stack one above the other using mortar thickness 10mm are used to construct masonry triplets with different mortars without any staggering.

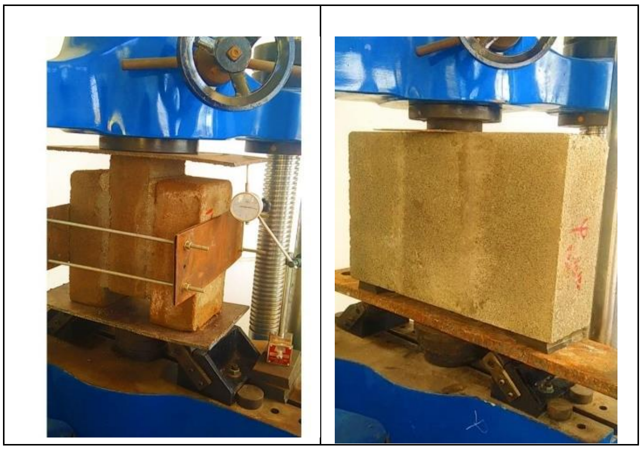

Fig. 3. Shear bond testing of masonry triplets

IV. RESULTS AND CONCLUSIONS

The experimental test results of different masonry unit and mortar combinations for compression and shear bond loading are presented below.

A. Results

Table II shows the compressive strength of different masonry unit and mortar combinations for two different bonding patterns namely stack bonded and English bonded prisms.

From the results, it is seen that for both stack bonded prisms and English bonded prisms, the compressive strength is higher for the concrete block and fiber reinforced mortar combination. The strength is almost 2 to 3 times the masonry strength of specimen with burnt bricks and stabilized mud blocks. Burnt brick masonry specimen gave least compressive strength results among the three masonry unit types. This can be attributed to the higher compressive strength of concrete blocks and low compressive strength of burnt bricks. However, we see that among different masonry specimen, the masonry having fiber reinforced mortar yielded higher compressive strengths than other mortar types. In case of stabilized mud blocks, masonry containing cement mortar with fly ash yielded higher compressive strength.

Comparing the results of stack bonded and English bonded prisms, we can observe that the type of bond does not strongly affect the compressive strength in case of masonry prisms.

TABLE II – COMPRESSIVE STRENGTH OF MASONRY

Specimen	Masonry Unit	Mortar	Average compressive strength (N/mm^2)
P1_BB_CMR_C	Burnt brick	Cement mortar	1.097
P2_BB_CMR_C	Burnt brick	Cement mortar	1.105
P1_BB_CFA_C	Burnt brick	Cement mortar with fly ash	0.852
P2_BB_CFA_C	Burnt brick	Cement mortar with fly ash	0.999
P1_BB_CFR_C	Burnt brick	Cement mortar with fibers	
P2_BB_CFR_C	Burnt brick	Cement mortar with fibers	
P1_CB_CMR_C	Concrete block	Cement mortar	3.255
P2_CB_CMR_C	Concrete block	Cement mortar	3.009
P1_CB_CFA_C	Concrete block	Cement mortar with fly ash	3.289
P2_CB_CFA_C	Concrete block	Cement mortar with fly ash	3.004
P1_CB_CFR_C	Concrete block	Cement mortar with fibers	3.813
P2_CB_CFR_C	Concrete block	Cement mortar with fibers	3.046
P1_SB_CMR_C	SMB	Cement mortar	1.882
P2_SB_CMR_C	SMB	Cement mortar	1.541
P1_SB_CFA_C	SMB	Cement mortar with fly ash	1.975
P2_SB_CFA_C	SMB	Cement mortar with fly ash	1.447
P1_SB_CFR_C	SMB	Cement mortar with fibers	1.525
P2_SB_CFR_C	SMB	Cement mortar with fibers	1.276

TABLE III – SHEAR BOND STRENGTH OF MASONRY

Specimen	Masonry Unit	Mortar	Average shear bond strength (N/mm^2)
P1_BB_CMR_L	Burnt brick	Cement mortar	0.275
P1_BB_CFA_L	Burnt brick	Cement mortar with fly ash	0.311
P1_BB_CFR_L	Burnt brick	Cement mortar with fibers	0.312
P1_CB_CMR_L	Concrete block	Cement mortar	0.098
P1_CB_CFA_L	Concrete block	Cement mortar with fly ash	0.141
P1_CB_CFR_L	Concrete block	Cement mortar with fibers	0.126
P1_SB_CMR_L	SMB	Cement mortar	0.208
P1_SB_CFA_L	SMB	Cement mortar with fly ash	0.268
P1_SB_CFR_L	SMB	Cement mortar with fibers	0.201

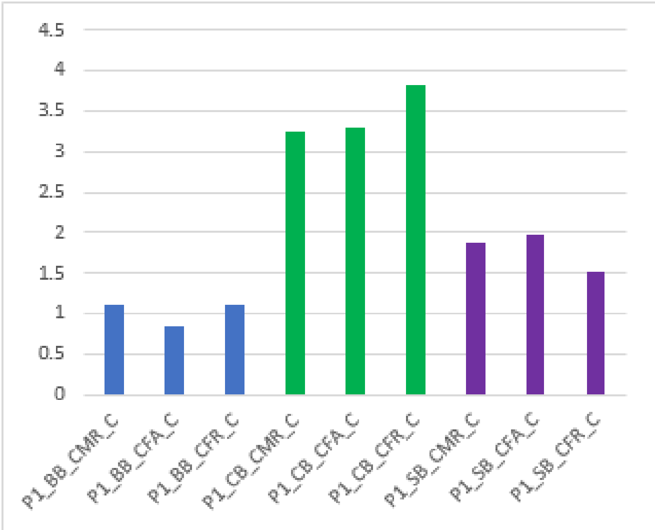

Fig. 4. Compressive strength comparison of Stack bonded prisms

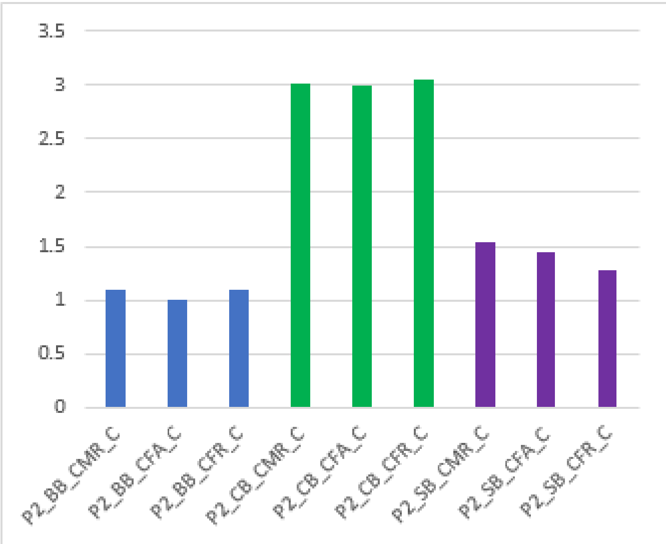

Fig. 5. Compressive strength comparison of English bonded prisms

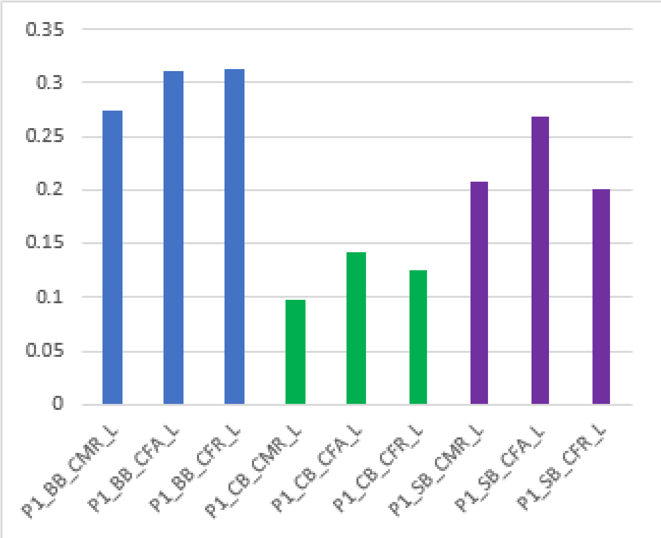

Fig. 6. Shear bond strength comparison

Table III shows the shear bond strength of different masonry unit and mortar combinations for stack bonded prisms (staggered for burnt bricks and SMB, unstaggered for concrete blocks).

From the results, it can be observed that the masonry specimen with burnt brick and fiber reinforced cement mortar yielded marginally higher shear bond strength compared to other cases. Also, specimen with cement mortar with fly ash showed better bond strength compared to specimen with cement mortar and fiber reinforced mortar. The shear bond strength on concrete block masonry was found to be lower than stabilized mud block and burnt brick specimen which can be attributed to the dead load of concrete blocks and absence of lateral confinement playing a role in early failure of the shear bond specimen. Specimen with cement mortar performed comparatively poor than other type of mortars.

B. Failure pattern

The behavior of masonry specimen containing burnt brick, stabilized mud blocks and concrete blocks were similar to each other. In most of the compression testing cases, masonry prisms were failed by splitting with vertical cracks or by crushing of the prism as shown in Fig 7. In rare cases there were instances of spalling of specimen as shown in Fig 8. In case of shear bond test, specimens failed by failure of one of the mortar and masonry unit joints as shown in Fig 9.

Fig. 7. Failure pattern (cracking) in compression test specimen

Fig. 8. Failure pattern (spalling) in compression test specimen

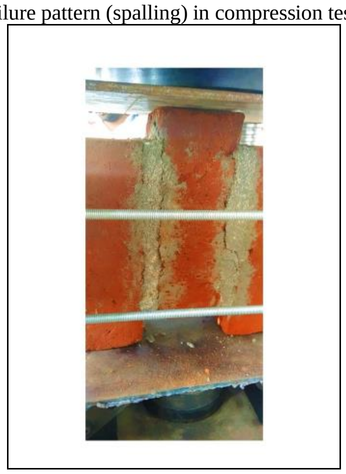

Fig. 9. Failure pattern in shear bond test specimen

V. CONCLUSION

From the experimental program the following conclusions can be drawn.

- Compressive strength of masonry largely depends on the compressive strength of the masonry unit.
- Compressive strength of the masonry can be marginally improved by introducing polypropylene fibers into the mortar mix.
- Considering masonry test prisms, the type of bond does not influence the compressive strength of the masonry prism.
- Shear bond strength of masonry can be significantly improved by using fly ash or polypropylene fibers in the mortar mix.
- Shear bond strength is influenced by the vertical pressure from overlying masonry layers.
- The shear bond strength of the masonry is influenced by the type of mortar used rather than the compressive strength of the masonry unit used.

REFERENCES

[1] Muskan Sharma Kuinkel, Sona Sukubhatu, Rameswor Shrestha, “Physical performance of traditional brick mud masonry”, International Conference on Earthquake Engineering and Post Disaster Reconstruction, April 2019.

[2] Kamu Iyer, Shibani M Kulkarni, Shantanu Subramaniam, C V R Murthy, “Build a safe house with confined masonry”, Gujrat State Disaster Management Authority, Gandhinagar, Sept 2012.

[3] Chuanlin Wang, Vasilis Sarhosis, Nikolaos Nikitas, "Strengthening/Retrofitting Techniques on Unreinforced Masonry Structure/Element Subjected to Seismic Loads: A Literature Review", The Open Construction and Building Technology Journal, Vol 12, Pg 251-268, 2018.

[4] Sabapathy, T Nithila, k Vaishnavi, A Srinidhi, V Srilekha, A Jai Vigneshwar, "In-Plane shear behaviour of unreinforced brick masonry strengthened by Bio-composite fabrics", International Journal of Recent Technology and Engineering, ISSN:2277-3878, Vol 7, Issue 5S3, Feb 2019.

[5] IS 2116:1980, Indian Standard Specification of Sand for masonry mortars.

[6] IS 269:2013, Indian Standard Specification of Ordinary portland cement.

[7] IS 2250:1981, Indian Standard Specification of Practice for preperation and use of masonry mortars.

[8] Rahul Bansal, Varinder Singh, Ravi Kant Pareek, "Effect on compressive strength with partial replacement of fly ash", International Journal on Emerging Technologies, ISSN: 2249-3255, Jan 2015.

[9] Hui Chen, Xin Huang, Rui He, Zhenheng Zhou, Chuanqing Fu and Jiandong, "Mechanical Properties of Polypropylene Fiber Cement Mortar under Different Loading Speeds" Sustainablitiy 2021, Vol 13, 2021.

[10] K S Gumaste, K S nanjunda Rao, B V Ventakatrama Reddy, K S Jagadish, " Strength and elasticity of brick masonry prisms and wallettes undere compression", Materials and Structures, Vol 40, Pg 241-253, July 2006.

[11] Megashree M, G A Satheesh, "Shear strength of pond ash mortar brick masonry", International journal of Engineering Reasearch and Technology, ISSN: 2278-0181, Vol 2, Issue 9, Sept 2013.

[12] IS 1905:1980, Code of practice for structural use of unreinforced masonry.

[13] Nassif Nazeer Thaickavil, Job Thomas, "Behaviour and strength assessment of masonry prisms" Case studies in construction materials, Vol 8, pp. 23-28, 2018.

[14] S.B. Singh, Pankaj Munjal, "Bond strength and compressive stress-strain characteristics of brick masonry" Journal of Building Engineering, Vol 9, pp. 10-16, 2017.

[15] Owino Stephen, Dr. Kyakula Michael, Dr. Mugume Rodgers Bangi, "Assessing the Effect of Different Mortar Mixes on Strength of Burnt Clay Brick Masonry Wall" International Journal of Engneering Research and Technology, vol. 9, Issue 05, May 2020.

[16] G S Pavan, nanjunda Rao Kenkere, "Behavior of Brick–Mortar Interfaces in FRP-Strengthened Masonry Assemblages under Normal Loading and Shear Loading", Journal of Materials in Civil Engineering, 28(2), Aug 2015