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Effect of reinforcement in perforated brick arrangement for determining flexural strength and corrosion loss

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ABSTRACT

Brick masonry walls consist of the main elements that responsible for the global stability of brick masonry buildings when subjected to lateral loads such as wind and seismic forces. These elements are subjected to gravity forces, bending moments and shear forces due to the horizontal loading. The application of reinforcement increases the deformation capacity, controls the crack opening and allows a better distribution of stresses. Longitudinal reinforcements increase the flexural strength, even if they seem not to influence the shear behavior. Effectiveness of reinforcement on the increase of the resistance of brick masonry wall is highly related to the failure mode of the element. This paper shows the flexural strength of reinforced perforated brick masonry wall and weight loss of reinforcements for corrosion after a certain period of time. Several reinforce bar arrangements into the perforated brick masonry walls show the variety of possible applications.

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1. Introduction

Brick work strengthened by the introduction of mild steel flats, hoop iron, expanded mesh or bars is termed as reinforced brick masonry (Hossain et al., 1997). This reinforced brick masonry is capable of resisting both compressive as well as tensile and shear stress. On account of its ability to resist lateral forces, reinforced brick masonry is extensively used in seismic areas. It is essential to use first class bricks with dense cement mortar in the reinforced brick work. The reinforcement should be effectively embedded and surrounded with mortar cover of 15 to 25 cm. This is necessary to protect the reinforcement against corrosion (Cabrera, 1996).

Reinforced perforated brick masonry is frequently adopted for the construction of retaining walls especially in places where exposed brick work is necessary from architectural considerations. In another case, brick work has been restricted for compression members (Kumar, 2006).

2. Experimental Program

2.1. Preparation of specimen

During the experimental study, a total of 40 brick masonry specimens (each having dimension: 10"×10"×18") were constructed where 20 specimens (1st batch) have been used for determining strength test and other 20 (2nd batch) have been used for determining strength and corrosion in rebar. An English bond arrangement of bricks was followed giving a cross-sectional area of 10"×10". The height of the specimens was 18" achieved through 10 mm mortar thickness and by laying six bricks one after another. However, masonry with mortar bond is difficult to predict for masonry flexural bond which is generally not practical (Maroliya, 2012).

The specifications for required specimen cover minimum construction requirements for masonry structures such as requirements for materials, the placing, bonding and anchoring of masonry, the placement of grout and of reinforcement (Lumantarna et al., 2014).

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Before using in specimen construction, bricks were kept immersed in clear water for about 24 hours and then cleaned with a cloth. The ratio of cement and sand was fixed for particular brick strength. The water-cement ratio was varied to suit the fixed cement and sand ratio. The required amount of cement and sand were measured by a cylinder type vessel. A 1000 ml plastic cylinder graduated to 10 ml was used to measure water.

To obtain the mortar mix of a certain proportion, required volumes of sand and cement were mixed in dry condition. Water was gradually added to the mixture until workability of cement and sand of different proportions comes in order to construct the specimens. The workability of concrete depends on the factors like grading and proportioning of aggregates, proportion of cement, the efficiency of mixture (Aziz, 2012).

Two pieces of required diameter rod and trowel were used to facilitate spreading of mortar in a proper thickness. Bricks were then firmly embedded on this mortar. 10 mm rebar were placed vertically through the holes of perforated bricks. The vertical joints between bricks were filled up with mortar by the help of a trowel. Alternative layers of mortar of required thickness and bricks were laid up to the six layers. Each layer contains two bricks.

A final 10 mm layer of definite proportion of mortar was placed on the top of six layers. The mortar used in the top was finished smooth with steel trowels. Finally, all the mortar joints were flushed jointed. After performing these operations, all specimens were cured for 7 days before testing (Grimm, 1975). Then 10% NaCl solution was also applied for 28 days for the 2nd batch only before testing because 2nd batch was used for determining strength as well as corrosion (difference between 1st and 2nd batch).

All the specimens were numbered for identifying before the testing. From Fig. 1, we can see the arrangement of rebars clearly where different water cement ratios were taken constant for arrangement. For example, for water cement ratio 0.3, five arrangements were made. Here, arrangement no. 4 and 5 were nearly same excepting that they generated slightly different load value due to machine fault or the position of the arrangement. Fig. 2 shows steps of constructing the specimens before testing. Fig. 3 shows the application of 10% NaCl solution on specimen's surface.

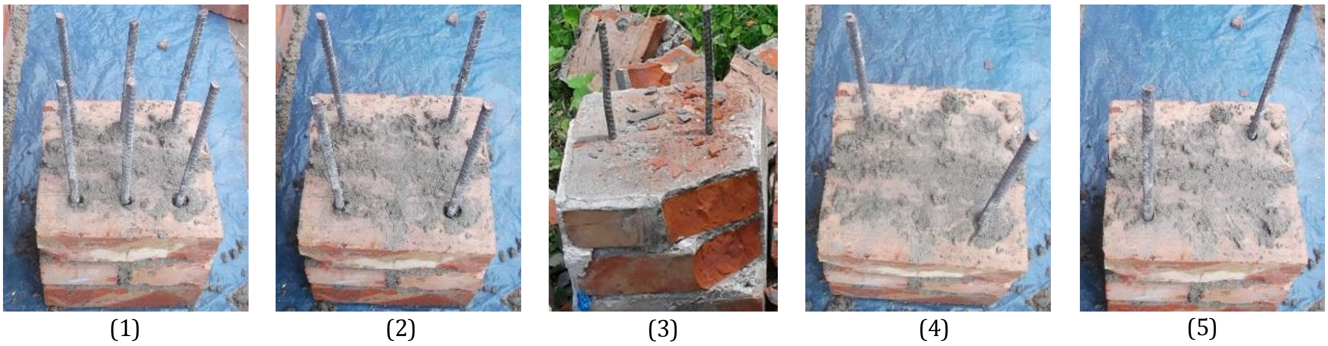
(1) (2) (3) (4) (5)

Fig. 1. Different rebar arrangements.

Fig. 2. Photos of constructing specimens for testing.

The specimens were mounted on the testing machine and centred (Haach, 2011). Typical load was applied initially at a rate of 1000 kN or 224810 lbs per minute. At this loading rate, the specimens took about 1 minute to 2 minute to fail. Gradually, the 40 specimens with different number and arrangements of rebar were broken one after another. There also be the two supports were arranged on the two sides of the specimens for determining the flexural strength of the specimens at the time of testing shown in Fig. 4. Calculation for specimen flexural strength was done by dividing the ultimate load by the area of specimen (10"x10"). Here, we used 3-point loading because load measurement was easy using the machine's crosshead position sensor (typically a digital encoder), whereas the 4-point bend test had been measured using a deflectometer. In our instrument, we had a digital encoder that's why we used 3-point loading.


(a) (b)

Fig. 3. Applying 10% NaCl solution into specimens: (a) NaCl solution on top surface; (b) Covering the specimens (for curing).

2.2. Numerical details

Out of total 40 specimens, 1st batch was made for determining flexural strength only (Table 1, Fig. 5), and 2nd batch was made for determining both flexural strength of specimens (Table 2, Fig. 6) and weight losses of rebar due to corrosion (Table 3, Fig. 7).

Fig. 5(a, b, c, d) and Fig. 6(a, b, c, d) are showing the comparison of rebar arrangements and flexural strength for strength and strength with corrosion respectively. For example, for water cement ratio 0.3, arrangement no. 1 gives higher strength than other arrangements and arrangement no. 4 and 5 give the lowest nearly values.

The reason behind this occurrence is the amount of rebar. No. 1 arrangement has 6 rebars whereas no. 4 and 5 similarly have 2 rebars. So, no. 1 arrangement needs higher value of load to break whereas no. 4 and 5 need lower value of load to break. In other cases, if we change the water cement ratio then the strength value will be changing. Generally, we know that an increase in water cement ratio reduces the value of mechanical properties and increases the workability but here, by increasing water cement ratio, we have got higher strength. This is due to high temperature reason and fault of machine.

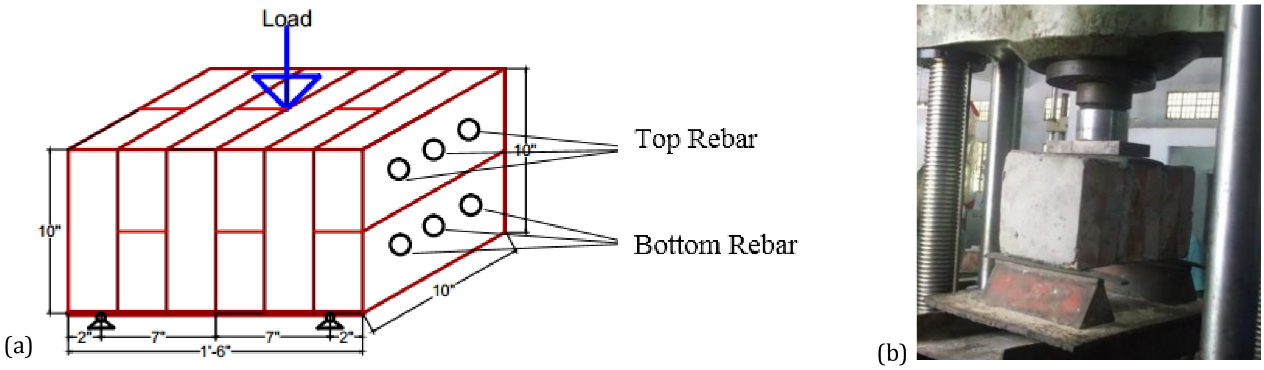

Fig. 4. Testing of specimens: (a) Horizontal loading; (b) Specimens during testing.

Table 1. Flexural strength of reinforced perforated brick masonry specimens (10"x10") (for strength test only).

SL. No.	Rebar Arrangement	Water/Cement Ratio	Failure Load (kN)	Strength (psi)
1	1	0.60	67.49	151.72
2	2		53.28	119.78
3	3		46.17	103.79
4	4		39.06	87.81
5	5		36.02	80.98
6	1	0.50	64.45	144.89
7	2		51.25	115.22
8	3		45.16	101.52
9	4		37.03	83.25
10	5		35.00	78.68
11	1	0.40	61.40	138.03
12	2		44.14	99.23
13	3		40.08	90.10
14	4		36.02	80.98
15	5		32.97	74.12
16	1	0.30	58.35	131.18
17	2		41.09	92.37
18	3		39.06	87.81
19	4		33.99	76.41
20	5		30.94	69.56

** Cement/sand ratio is 1:3*

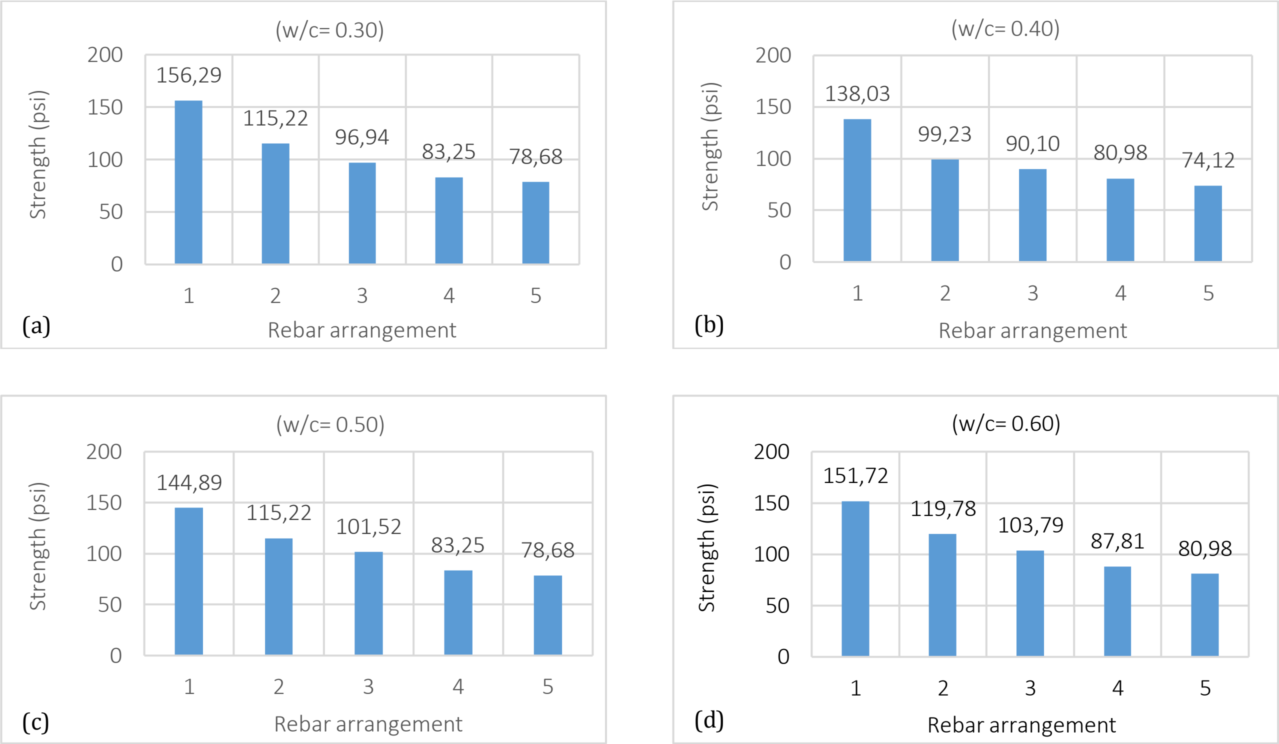

Fig. 5. Relationship between rebar arrangement and flexural strength.

Table 2. Flexural strength of reinforced perforated brick masonry specimens (10"x10") (for strength and corrosion test).

SL. No.	Rebar Arrangement	Water/Cement Ratio	Failure Load (kN)	Strength (psi)
1	1	0.30	69.52	156.29
2	2		51.25	115.22
3	3		43.12	96.94
4	4		37.03	83.25
5	5		35.00	78.68
6	1	0.40	73.58	165.42
7	2		54.29	122.05
8	3		48.20	108.36
9	4		46.17	103.79
10	5		39.06	87.81
11	1	0.50	74.60	167.71
12	2		56.32	126.61
13	3		50.23	112.92
14	4		45.16	101.52
15	5		42.11	94.67
16	1	0.60	76.63	172.27
17	2		59.37	133.47
18	3		49.22	110.65
19	4		47.19	106.09
20	5		43.12	96.94

** Cement/sand ratio is 1:3*

From Figs. 5 and 6, it is observed that the 1st arrangements have higher flexural strength with higher number of rebars. So, higher number of rebar blocks gives higher values and lower number of rebar blocks gives lesser values with the positions of rebar.

The reason behind this is the number of rebars. Specimens containing more rebars need more loads because rebar needs extra load to resist the load. In the other case, specimens containing less rebars will need less load.

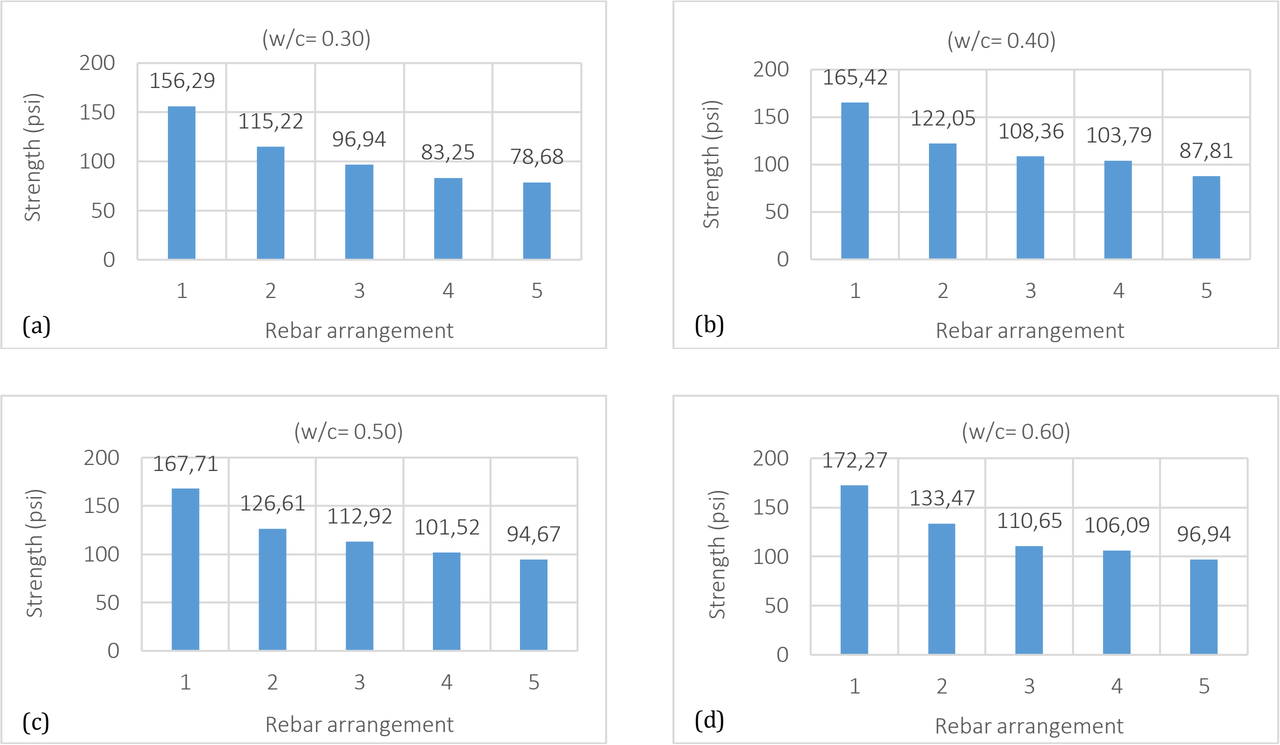

Fig. 6. Relationship between rebar arrangement and flexural strength with corrosion.

Table 3. Weight losses of rebar.

SL. No.	Rebar Arrangement	Water/Cement Ratio	% of Weight Loss (top rebar)	% of Weight Loss (bottom rebar)
1	1	0.30	0.25	0.22
2	2		0.54	0.32
3	3		0.51	0.34
4	4		0.33	0.12
5	5		0.39	0.32
6	1	0.40	0.54	0.44
7	2		0.50	0.47
8	3		0.50	0.33
9	4		0.41	0.28
10	5		0.39	0.39
11	1	0.50	0.42	0.40
12	2		0.49	0.45
13	3		0.50	0.45
14	4		0.44	0.39
15	5		0.51	0.40
16	1	0.60	0.56	0.54
17	2		0.72	0.60
18	3		0.80	0.49
19	4		0.63	0.53
20	5		0.58	0.56

3. Results and Discussion

To get accurate results, we can see the following figures (Fig. 7) where corrosion is less in arrangement no. 5. So, in fine we can say that arrangement no. 5 (for all water cement ratio: 0.3, 0.4, 0.5, 0.6) has the lowest corrosion as well as the highest strength.

From Fig. 7, it is observed that rebar arrangement 5 is comparatively less corrosive and more economical than any other rebar arrangements.

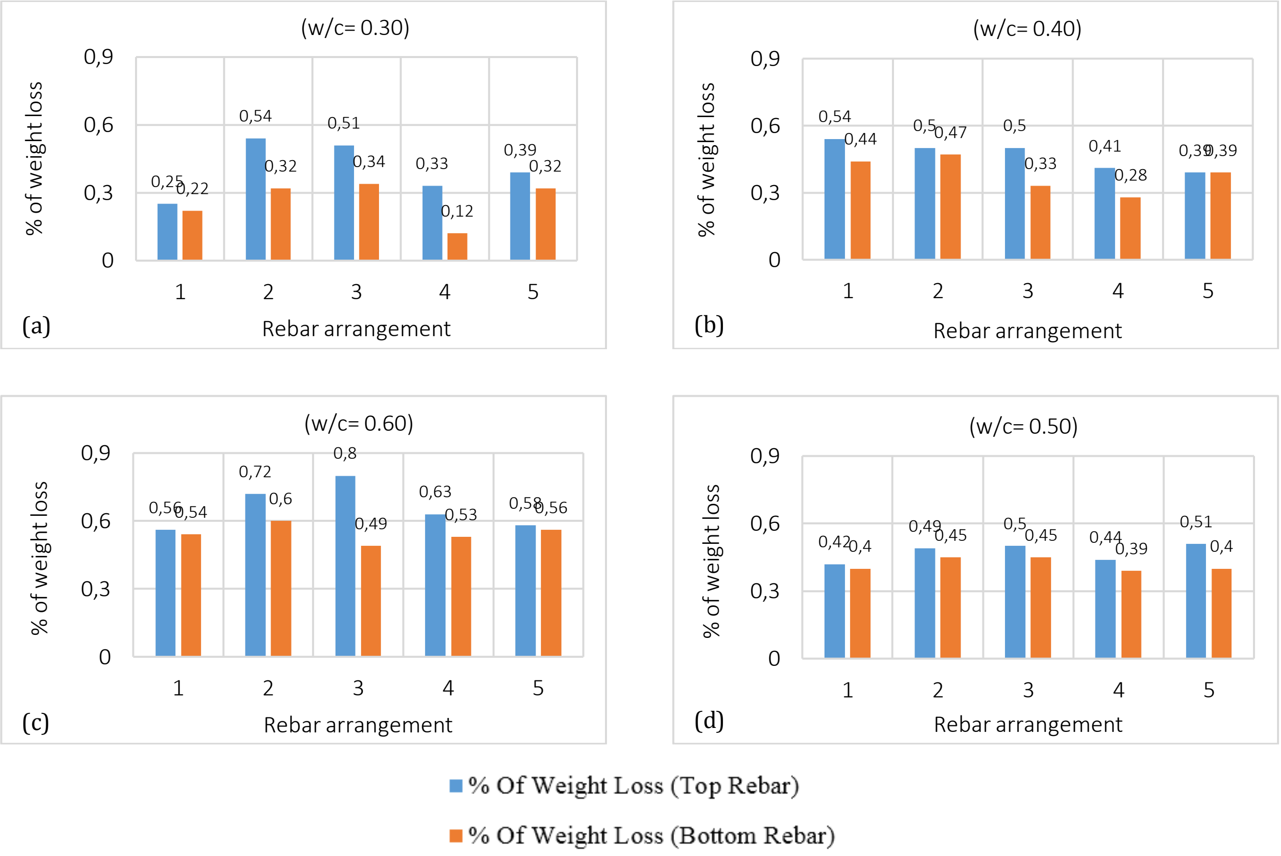

Fig. 7. Relationship between rebar arrangements and % of weight loss.

4. Conclusions

The following conclusions are drawn from the present experimental study:

- The behaviour of Reinforced Perforated Brick Masonry works to loads was observed. Arrangement 1 (6 #3 bar & w/c= 0.60) was carried the maximum flexural strength comparatively.
- Flexural strength of masonry works increases with the strength of brick, number of rebar and different rebar arrangements.
- Flexural strength of masonry works also depends on water cement ratio and mortar.

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