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Experimental Study of Brick Walls with Opening Strengthened During Construction by using Steel Bars Embedded into Bed Joint Mortar Above Lintel and Sill

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***Abstract*— Brick walls mainly constructed with solid and hollow clay or cement brick with mortar joints. These materials possess significant compressive strength but their ability to accommodate tension is limited. As a consequence, tension stress is develop cracking frequently. In addition, the appearance of openings in brick walls have an effect on the load capacity and cracking regime after construction under working loads. For these reasons, there is a need for strengthening brick walls with opening during construction. In the present study, a total of seven brick wall specimens having a wall dimensions (85*65) cm and thickness (10) cm with square opening (25*25) cm were tested. The brick wall specimens were divided into three groups according to the different methods of strengthening. Group one consisted of wall with R.C lintel 35 cm length as a control wall, group two consisted of three strengthened brick wall specimens by 3Ø8 steel bars embedded into bed joint mortar above lintel only with lengths (L = 50, 65, 85cm) and group three consisted of three strengthened brick wall specimens by 3Ø8 steel bars embedded into bed joint mortar above lintel and sill with lengths (L = 50, 65, 85cm). All brick wall specimens were tested under static loads in regular increments from zero up to the crack load then failure load. In addition, wall deformations have been measured by LVDT. The obtained test results show that using 3Ø8 steel bars embedded into bed joint mortar above lintel only with length (85cm) gives an increase in the load carrying capacity up to (179%) from the control ultimate capacity. However using 3Ø8 steel bars into bed joint mortar on lintel and sill with length (85cm) gives an increase in the load carrying capacity up to (223%) from the control ultimate capacity. However, ductility has been significantly increased. In addition, it was found that strengthening with this technique is durable, economic and easy to apply. The results suggest that using 3Ø8 steel bars into bed joint mortar on lintel and sill with the whole length of wall increases the load carrying capacity of wall as well as increasing ductility and prevent cracks a round opening.**

I.INTRODUCTION

Some of the important disadvantages of brick walls construction is its low resistance to tensile stresses and presence the opening in the walls. Thus, as a result of these reasons cracks in brick walls appears after construction under working load as shown in fig. 1. So, the purpose of the present study is strengthening brick walls with opening during construction to increase the load carrying capacity and ductility by using 3Ø8 steel bars embedded into bed joint mortar above lintel and sill with different lengths. Berkowski. P, Dmochowski .G (2001) presented examples of brick walls strengthening by two different methods. In the first method a self supporting reinforced jacket covering walls through all the building stories was used. The second method, connected to new concrete floor in a cellar and new story massive floors. The problem was solved by constructing self-supported lateral steel frames that had to carry over new floors. Behrokh H. Hashemi, et.al. (2002) collected information by various earthquake engineering professionals around the world. This is a typical confined brick masonry housing construction common in rural areas of Iran. This building type is often used as a single-family house. Brick masonry shear walls confined with concrete tie columns and beams were investigated to provide earthquake resistance in both directions. Hany Elshafie, et.al.(2002) carried out an investigation to study the behavior of masonry shear walls with openings through testing thirteen 1/3-scale reinforced concrete masonry shear walls and designed the test specimens to behave mainly in a flexural mode by forming plastic hinges at the member ends.

Fig. 1 Diagonal cracks over lintel and vertical cracks below window opening (Old building in elhagar city, El.fayoum) .

Elsamny, M.K., et.al. (2011) presented an investigation for strengthening solid brick walls by horizontal galvanized steel mesh embedded into bed mortar between bricks during

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construction and investigated the effect of the number of horizontal steel mesh layers and the type of mortar used on walls carrying capacity. The experimental results showed that the use of this technique in strengthening has a great effect on walls carrying capacity depending on number of horizontal steel mesh layers and the type of mortar used. Elsamny, M.K., et.al. (2011) carried out an experimental study to investigate the strengthening solid brick walls using vertical galvanized steel mesh fixed at one side as well as both sides of the walls with different number of layers and investigated the effect of the number of vertical steel mesh layers and the type of mortar used on walls carrying capacity. The test results clearly demonstrate the efficiency of using this technique in strengthening brick walls and showed that increasing number of vertical steel mesh layers gives an increase in brick walls carrying capacity. Mahmoud .B.N.A (2011) tested thirty solid brick walls strengthened by different types of steel mesh, horizontal galvanized steel mesh into bed mortar between bricks , vertical galvanized steel mesh fixed at one side as well as both sides of the walls with different number of layers and combination of horizontal and vertical steel mesh . The results demonstrate that the use of horizontal, vertical and combination of horizontal and vertical steel mesh in strengthening brick walls gives an increase in brick walls carrying capacity. Masne, N. S., et.al. (2014) proposed a model to determine the behavior of confined masonry (CM) walls with opening under in-plane and out-of-plane loading. Elsamny, M.K., et.al. (2016) Tested ten unreinforced brick walls under uniform load up to 80% of failure load till cracks occurred. Then rehabilitated with different number of steel wire mesh layers only as well as with (1, 2 and 3Ø6) additional external steel bars then tested until failure. The results showed that the walls rehabilitated by a different numbers of steel wire mesh layers only gives an increase in the load carrying capacity up to (78.79%) of the control ultimate capacity. However, added external steel bars inside steel wire mesh gives an increase in the load carrying capacity up to (89.70%) of the control ultimate capacity. However, increasing the number of steel wire mesh layers or increasing the number of external steel bars used in rehabilitation increases the load carrying capacity of walls and increases ductility.

II. PROPOSED TECHNIQUE OF STRENGTHENING AND EXPERIMENTAL PROGRAM

In the present study, two different approaches well considered for strengthening brick walls with opening during construction to prevent cracks after construction and increase the load carrying capacity of wall as well as increasing ductility:

- Using 3Ø8 steel bars embedded into bed joint mortar above lintel only with variable lengths.
- Adding 3Ø8 steel bars embedded into bed joint mortar above lintel and sill with variable lengths.

A total of seven specimens of brick walls having a wall dimensions (85*65) cm and thickness (10) cm with square opening (25*25) cm were built. Fig.2 shows brick wall specimens during construction.

Fig. 2. Brick wall specimen during construction

The brick wall specimens were divided into three groups according to the different methods of strengthening as follows:

a) Group one consisted of one brick wall with R.C lintel 35 cm as a control wall as shown in fig.3.

b) Group two consisted of three strengthened brick wall specimens by using 3Ø8 steel bars embedded into bed joint mortar above lintel only with lengths (L = 50, 65, 85cm) as shown in fig.4 to fig.6.

c) Group three consisted of three strengthened brick wall specimens by using 3Ø8 steel bars embedded into bed joint mortar above lintel and sill with lengths (L = 50, 65, 85cm) as shown in fig.7 to fig.9.

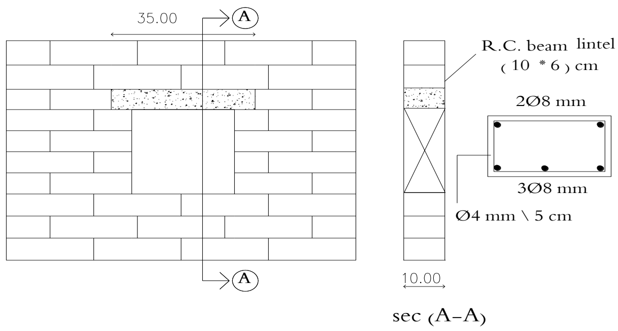

Fig. 3. Brick wall with R.C.lintel 35 cm (control wall)

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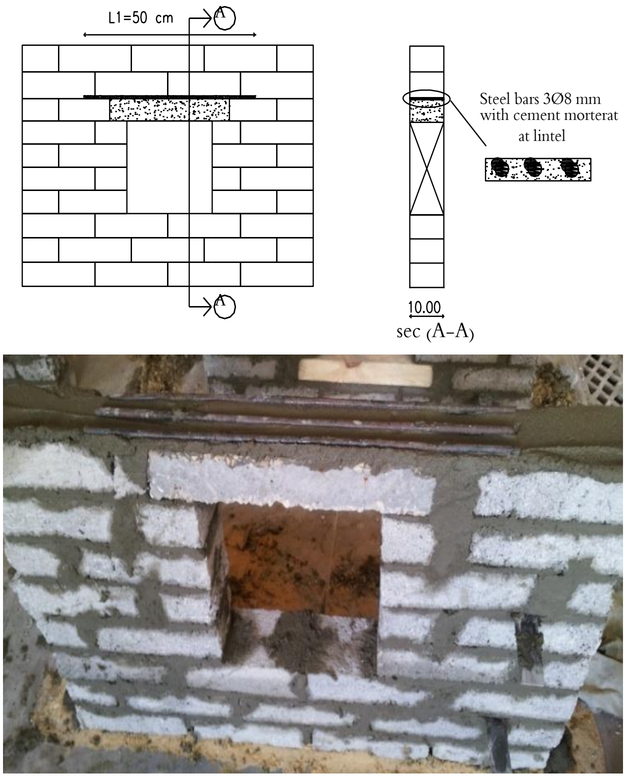

Fig. 4. Strengthening brick walls with opening using 3Ø8 steel bars embedded into bed joint mortar above lintel only with length (L1 = 50 cm)

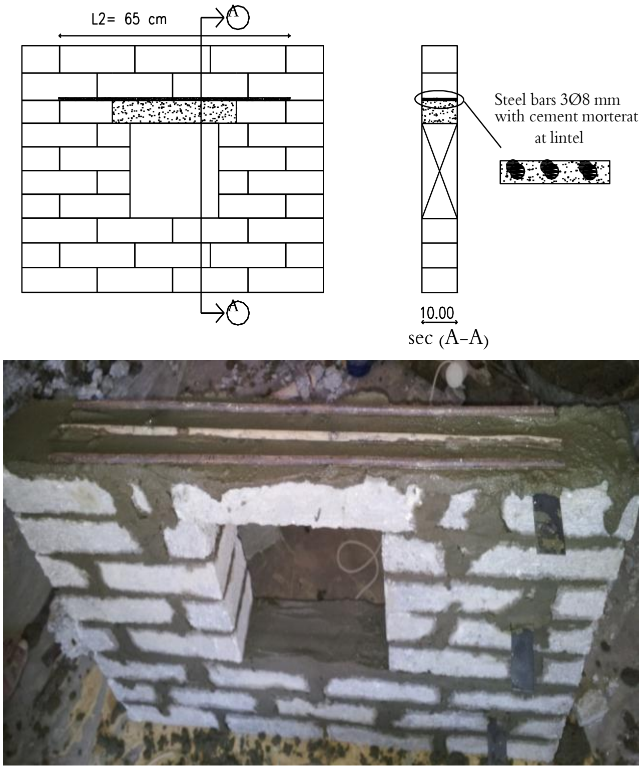

Fig. 5. Strengthening brick walls with opening using 3Ø8 steel bars embedded into bed joint mortar above lintel only with length (L2 = 65 cm)

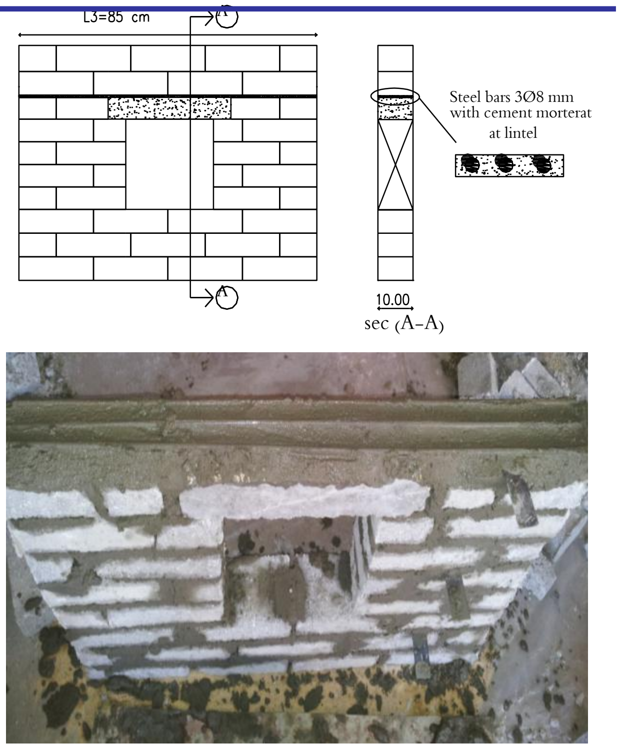

Fig. 6. Strengthening brick walls with opening using 3Ø8 steel bars embedded into bed joint mortar above lintel only with length (L3 = 85 cm)

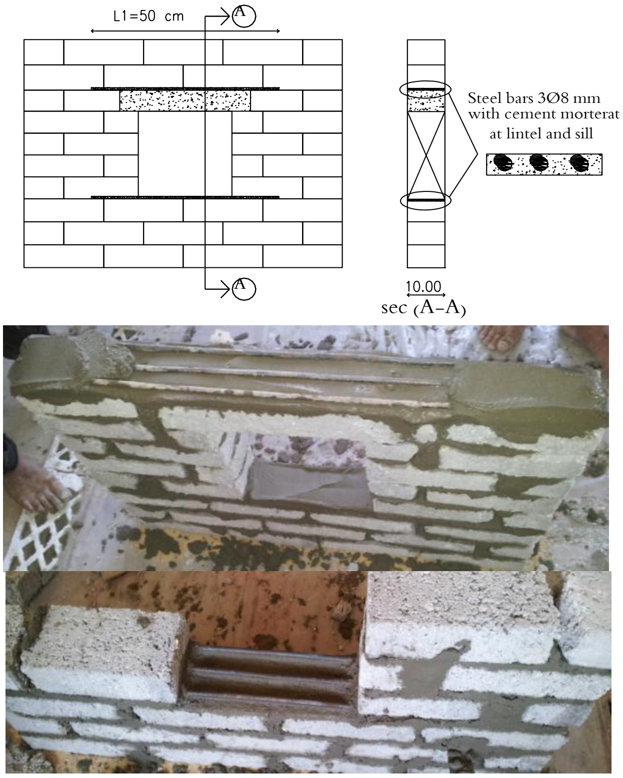

Fig. 7. Strengthening brick walls with opening using 3Ø8 steel bars embedded into bed joint mortar above lintel and sill with length (L1 = 50 cm)

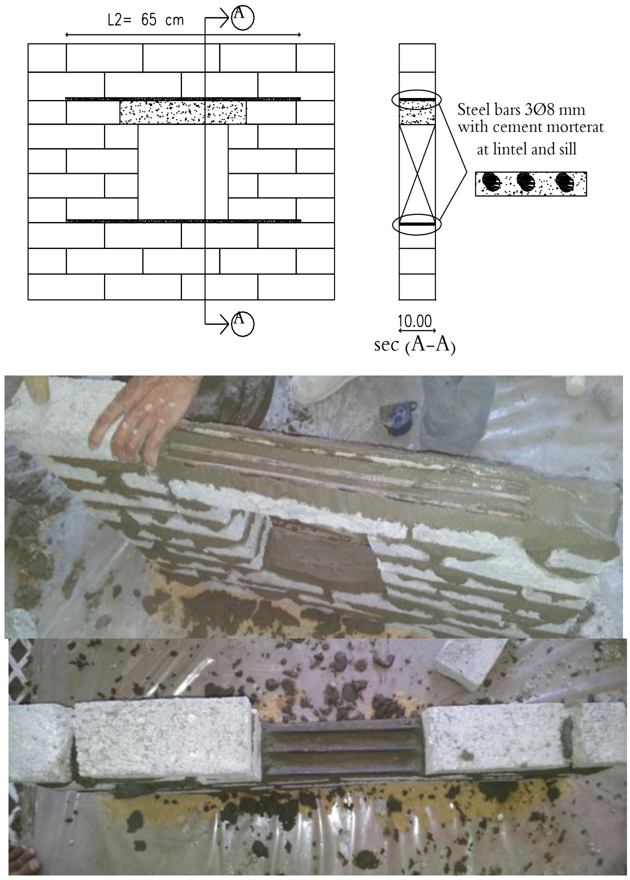

Fig. 8. Strengthening brick walls with opening using 3Ø8 steel bars embedded into bed joint mortar above lintel and sill with length (L2 = 65 cm)

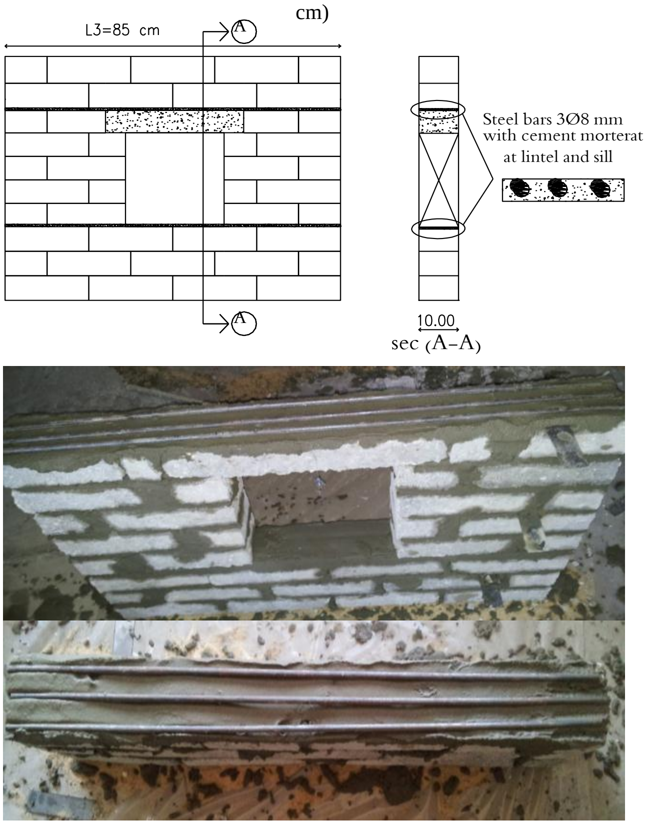

Fig. 9. Strengthening brick walls with opening using 3Ø8 steel bars embedded into bed joint mortar above lintel and sill with length (L2 = 85 cm)

All specimens were tested under static loads in regular increments from zero up to the cracking load then failure load. All groups are shown in Table (1) and fig.3 to fig.9 .

Table 1

Group	Wall no.	Steel bars above lintel only (cm)	Steel bars above lintel & sill (cm)	Failure Loads (kN)	Failure Stress kg\cm2	% Wall carrying capacity from control	Average vertical Strain
1	W1	-	-	135	15.88	100 %	0.0008
2	W2	50	-	180	21.18	133 %	0.0014
	W3	65	-	203	23.89	150 %	0.0015
	W4	85	-	241	28.35	179 %	0.0022
3	W5	50	50	211	24.82	156 %	0.0016
	W6	65	65	252	29.65	187 %	0.0016
	W7	85	85	301	35.41	223 %	0.0024

III.USED MATERIALS

- Solid concrete bricks with dimension (20 * 10 * 6) cm. The average of bricks compressive strength is (200.87 kg/cm2) .Concrete mix consisted of crushed stone which has a maximum nominal size of (10.0mm) was used as the coarse aggregate in the mix. Graded sand having sizes in the range of (0.3 mm) was used as the fine aggregate in the mix. Ordinary Portland cement and clean drinking fresh water were used for mixing and curing.

- Cement mortar mix used in building the brick wall specimens was made of water-cement ratio = 0.50 and cement sand ratio of 1:3 Natural sand passing through JIS sieve designed no. 1.2 (1.19 mm). Standard mortar cubes were taken during construction with average compressive strength (90.82 kg/cm2).

- R.C lintel was reinforced with steel bars 5Ø8 mm and stirrups Ø4 \ 5 cm , cross section is (10x6) cm with length of 35cm. The concrete mix consisted of crushed stone which has a maximum nominal size of (1.0 mm) as the coarse aggregate in the mix, graded sand having

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sizes in the range of (0.3 mm) used as the fine aggregate in the mix. Ordinary Portland cement and clean drinking fresh water were used for mixing and curing.

- Normal mild steel bars St24/37 diameter 8 mm were used embedded into bed joint mortar on lintel and sill with lengths (L = 50, 65, 85cm).

IV.TEST SETUP AND PROCEDURE

All wall specimens were tested under static loads using the testing machine mounted on the material laboratory of Al-Azhar University which has an ultimate compressive load capacity of 2000kN. Two u-steel beams were used for distribution the load on the wall specimens as shown in fig. 10 .Carrying the wall specimen with wood panels as shown in fig.11. Loads have been measured by the testing machine and wall deformation have been measured with LVDT under the applied loads as shown in fig.12 .The readings of loads and wall deformation were recorded through the data acquisition system. The data acquisition system consisted of a laptop computer, a Keithley-500a data acquisition system and the lab tech notebook software package .Test setup is shown in fig.13.

Fig. 10 Two U-steel beams for distribution the load on walls

Fig.11 Carrying wall on testing machine by wood panels

Fig. 12 Wall deformations measured with LVDT

Fig. 13 Test set up

V.EXPERIMENTAL TEST RESULTS

Table (1) shows the failure loads, deformation, ultimate stress and strain as well as increasing in ultimate capacity for control and strengthened brick walls with different types of strengthening. Strengthened brick walls with 3Ø8 steel bars embedded into bed joint mortar above lintel only with varying lengths made the failure almost started by appearance of vertical cracks under opening this was followed by appearance corner cracks above opening at the end of steel bars embedded into bed joint mortar above lintel even the load reaches its peak value. However, strengthened brick walls with 3Ø8 steel bars embedded into bed joint mortar above lintel and sill made the failure almost started by appearance corner cracks above opening at the end of steel bars even the load reaches its peak value and there are no cracks when steel bars above lintel or sill equal the length of wall.

Failure pattern shows that:

- Increasing the length of steel bars embedded into bed joint mortar above lintel during construction overcome the corner cracks above opening.

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- Adding steel bars embedded into bed joint mortar above sill under opening during construction has a great effect and it overcome the cracks occur in the wall under opening.

Fig.14. shows The relationship between stress and strain for control and strengthened brick walls by by3Ø8 steel bars embedded into bed joint mortar above lintel only with lengths (L = 50, 65, 85cm).

Fig.15. shows the relationship between stress and strain for control and strengthened brick walls by by3Ø8 steel bars embedded into bed joint mortar above lintel and sill with lengths (L = 50, 65, 85cm).

Fig.16. shows the relationship between ultimate stress (%) from control wall with R.C. 35 cm lintel and length of lintel and sill for strengthened brick walls by3Ø8 steel bars embedded into bed joint mortar above lintel and sill with different lengths.

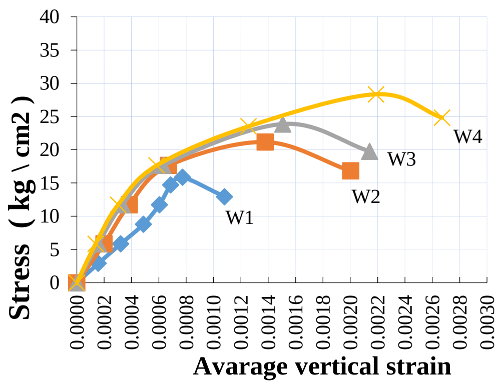


Fig. 14 The relationship between stress and strain for control and strengthened brick walls by using 3Ø8 steel bars embedded into bed joint mortar above lintel with lengths (L = 50, 65, 85cm)

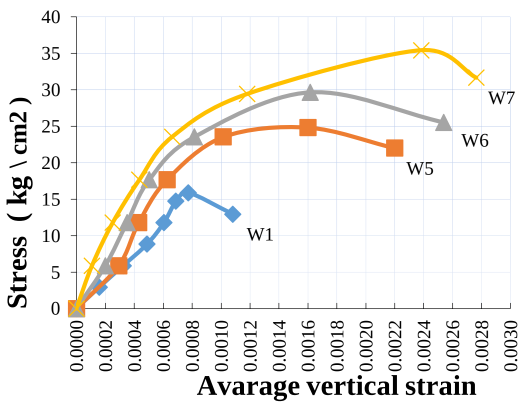
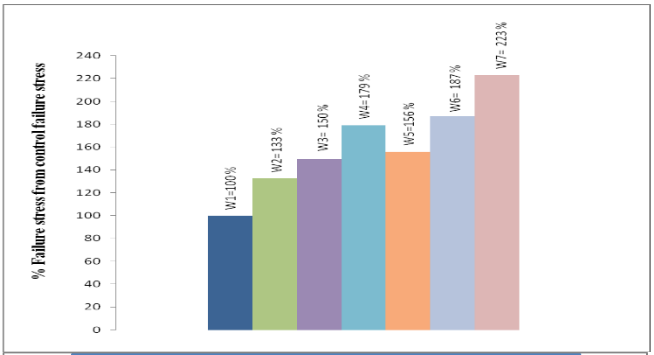


Fig. 15 The relationship between stress and strain for control and strengthened brick walls by using 3Ø8 steel bars embedded into bed joint mortar above lintel and sill with lengths (L = 50, 65, 85cm)



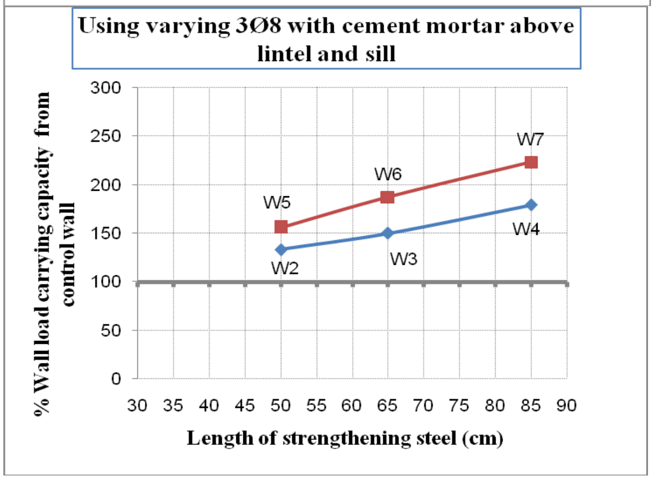


Fig. 16 The relationship between failure stress (%) from control for strengthened brick walls and length of using 3Ø8 steel bars embedded into bed joint mortar above lintel and sill with lengths (L = 50, 65, 85cm).

VI. CONCLUSIONS

From the present study, the followings have been concluded:

1) Using steel bars embedded into bed joint mortar above lintel during construction increases the load carrying capacity of wall as well as increasing ductility.
2) Increasing the length of steel bars embedded into bed joint mortar above lintel increases significantly the load carrying capacity of wall as well as ductility.
3) Adding steel bars embedded into bed joint mortar above sill during construction increases significantly the load carrying capacity of wall as well as increasing the ductility.
4) The percentage of increasing the ultimate stress for strengthened brick walls with 3Ø8 steel bars embedded into bed joint mortar above lintel only with different lengths was found to be between 133 % and 179 %.as well as increase the ductility.
   The percentage of increasing the ultimate stress for strengthened brick walls with 3Ø8 steel bars embedded into bed joint mortar above lintel and sill with different lengths was found to be between 156 % and 223 %.as well as increase the ductility.
5) Failure pattern of using 3Ø8 steel bars embedded into bed joint mortar above lintel and sill with length of wall shows more ductile behavior.

Finally, the results suggest that strengthening brick walls with opening during construction by using 3Ø8 steel bars embedded into bed joint mortar above lintel and sill with complete length of wall is the most efficient and economic method for increasing the load carrying capacity and ductility as well as prevent cracks under working load conditions.

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