Al-Azhar University Civil Engineering Research Magazine (CERM)
Vol. (41) No. (4) October, 2019

Study of Bond between Near-Surface Mounted Bars and frp strips and masonry

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ملخص البحث

تعتبر منشآت الحوائط الحاملة هي المنشآت الأكثر شيوعا في العالم نظرا لمميزاتها المتعددة مثل انها رخيصة ومتوفرة ومعمره ولكن مقاومتها لقوى القص ضعيفة جدا لذلك نلجأ الى تدعيمها لتتحمل تلك القوى؛ ومن أفضل طرق التدعيم وأكثرها انتشاراً هو التدعيم قرب السطح ومن ثم نحتاج الى دراسة هذا التدعيم ودراسة سلوك الرابطة بين مادة التدعيم والمادة الرابطة بين مادة التدعيم والطوب والتحقق ما اذا كانت تلك الرابطه تتحمل تلك القوى وتنقلها تماما ام هي فرضيه بعيده عن الواقع ولكن الأبحاث في هذا الاتجاه قليله جدا لذا يدرس هذا البحث سلوك الرابطة والتحقق من كفاءتها ودراسة ذلك عملياً ونظريا ومن ثم مقارنة ومناقشة النتائج والخروج باستنتاجات لمساعدة المهندس المصمم على فهم سلوك الحوائط المدعمه قرب السطح

Abstract:

this paper study the bond between masonry prism and the strengthening material. the study is divided into two main parts: the first one is setting up an experimental program for a certain number of specimens strengthened near surface mounted by using different strengthening materials such as: steel bars of different grades, CFRP strips, GFRP strips, then determination of the mode of failure for each one. the second part is studying them numerically by making numerical modeling using (ANSYS.15) program. Comparing the experimental and the numerical results, discussion and recommendations are presented in the paper.

Key words: bond, masonry, frp, near-surface mounted, steel bars, strengthening, numerical modelling.

Introduction

Masonry is one of the oldest construction methods used in the worldwide due to its advantages such as durability, sustainability, simplicity, wide availability of the material, and economy of construction, as well as its good mechanical and aesthetic properties .

Masonry has little strength in shear and tension, so it sometimes needs strengthening. Strengthening by near-surface mounted technique is a promising method has many advantages such as higher resistance, invisibility, minimum invasion, reversibility and reduced installation time [1]. it has few searches .

Published experimental research pointed out that the most common failure mechanism is the loss of bond between the strengthening element and the substrate, named as 'de-bonding failure', strongly affecting the effectiveness of the strengthening intervention [2]. Several investigations concern bond tests on masonry units and elements strengthened with Fiber Reinforced Polymer (FRP) [3, 4]. In most tests on retrofitted masonry elements, the performance of the strengthened element has been limited by the de-bonding of the FRP reinforcement at the extremity, if not adequately anchored, or along the FRP reinforcement [5].Also, experimental researches addressed the bond between masonry and steel bars used for post-strengthening of masonry elements as anchors or as NSM reinforcement [6-8]. The bond mechanism was shown to depend on the mechanical properties of masonry blocks, mortar joints, adhesive and reinforcement [9].De-bonding failure is observed to be very brittle and does not allow for attaining the full strength of the reinforcement. Therefore, accurate study of the bond strength at the interface level and the de-bonding mechanism is essential to provide correct design formulas. Numerical modeling was also attempted by several researchers with the objective of proposing theoretical models for design guidelines and standards [10-12].

This research study masonry strengthened by near surface mounted using different strengthening materials .an experimental program was conducted to a number of masonry prisms.

Masonry prism consisted of 2 clay blocks bonded together by mortar and strengthened near-surface mounted were prepared and subjected to tension tests, mechanical properties were determined and stress-strain curves for all materials. The strengthening material was subjected to tension force till failure then recording failure load and mode of failure.

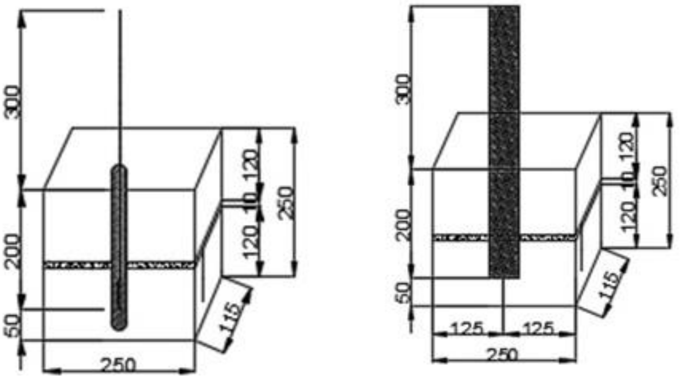
The main goal of this research is to investigate the efficiency of the bond between the masonry and strengthening material. The study was done by using different strengthening materials such as steel bars, GFRP and CFRP strips. numerical models were done to achieve experimental analysis results .

Experimental program

Specimens preparation

Pull-out test was carried out for 24 prism specimens. Prism specimen consists of two block units (250x115x120) bonded together with mortar layer with mix proportion 1:3 according to Egyptian code of practice [1]. prisms were prepared and cured for three weeks. specimens shapes and dimensions are as shown in Fig.1. specimens are such as:

- 3 specimens for steel dia.(10mm) imbedded in mortar.
- 3 specimens for steel dia.(8mm) imbedded in mortar.
- 3 specimens for steel dia.(10mm) imbedded in epoxy.
- 3 specimens for steel dia.(8mm) imbedded in epoxy.
- 3 specimens for GFRP imbedded in grout.
- 3 specimens for CFRP imbedded in epoxy.
- 3 specimens for GFRP externally bonded with grout.
- 3 specimens for CFRP externally bonded with epoxy.



(a) (b)

Fig.1. specimens shape and dimensions,(a) specimen with steel bar,(b) specimen with frp

Materials properties

Compressive strength test was done for 3 mortar cubes of dimensions (100x100x100)mm, 3 block units of dimensions(250x120x115)mm.and 3 prism specimens of dimensions(250x250x115)mm. and the results as shown in table 1:

Table 1. experimental results for compressive strength test

Test sample		Failure load (kN)	Area (mm2)	Compressive strength (MPa)
block unit	1	104.1	28750	3.62
	2	115.2	28750	4
	3	124.9	28750	4.34
	Average compressive strength			3.98
Mortar cube	1	195.3	10000	19.53
	2	197.9	10000	19.79
	3	178.6	10000	17.86
	Average compressive strength			19.06
Masonry prism	1	110.4	28750	3.84
	2	96	28750	3.33
	3	125.9	28750	4.37
	Average compressive strength			3.85

Pull-out test

The reinforcement is attached to the upper fixed part of the machine and the prism is attached to the under movable part of the machine. When applying loads; the reinforcement will be under tension load. failure load has been recorded , elongation ,cracks and the mode of failure . test setup is shown in Fig.2.

Fig.2. pull-out test set-up

Experimental results

Specimens with steel bars

1. Steel bar of dia.10mm. embedded in mortar

The failure loads for the three specimens MS1#10, MS2#10, and MS3#10 are 8.1, 16.5 and 19.55kN, respectively, with an average value of 14.71kN for the three specimens. The failure modes for two specimens MS2#10, MS3#10 is splitting of bars from mortar and de-bonding between mortar and masonry, and specimen MS1#10 is de-bonding between mortar and masonry led to taking off the bar with the mortar from the groove as shown in fig.3.

Fig.3. mode of failure of specimens with steel bar 10mm embedded in mortar

2. Steel bar of dia.8mm. embedded in mortar

The failure loads for the three specimens MS1#8, MS2#8, and MS3 #8 are 11.5, 12.5 and 15kN, respectively, with an average value of 13kN for the three specimens. The failure modes for two specimen MS1#8, MS2#8 is de-bonding between mortar and the specimens led to taking off the mortar with the bar from the groove, elongation for the bar by distance equal 10cm and fracture of the prism as shown in Fig.4.

Fig.4. mode of failure of specimens with steel bar 8mm embedded in mortar

3. Steel bar of dia.10mm. embedded in epoxy

The failure loads for the three specimens ES1#10, ES2#10, and ES3 #10 are 48.20, 44.85 and 50.50kN, respectively, with an average value of 47.85kN for the three specimens. The failure modes for all three specimens no failure for the epoxy with the bars but the failure happened to the block such as specimens ES1 &ES2 or rupture of bar only such as ES3, as shown in Fig.5.

Fig.5. mode of failure of specimens with steel bar 10mm embedded in epoxy

4. Steel bar of dia.8mm. embedded in epoxy

The failure loads for the three specimens ES1#8, ES2#8, ES3#8 are 20.85, 22 and 21.15kN, respectively, with an average value of 21.33kN for the three specimens. The failure modes for all three specimens are splitting of the bar from epoxy as shown in Fig.6.

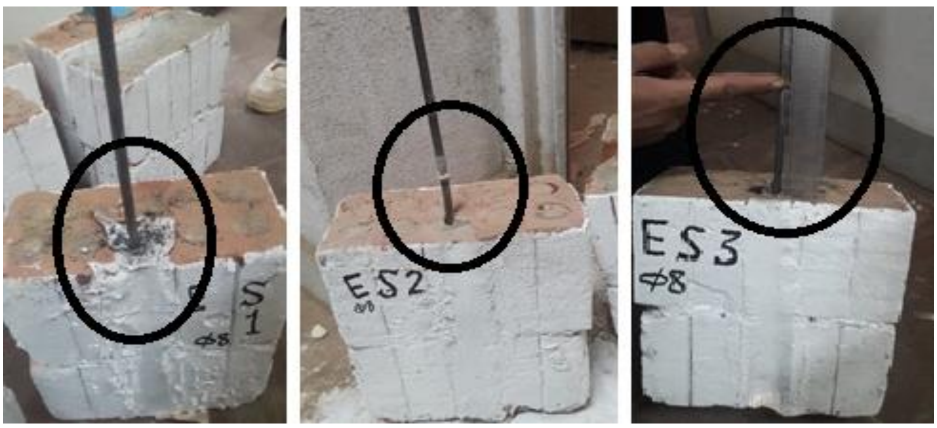


Fig.6. mode of failure of specimens with steel bar 8mm embedded in epoxy

Specimens with GFRP strips

1. Externally bonded

The experimental results for three specimens of GFRP strips of width 50mm externally bonded with grout are as follow: The failure loads for the three specimens EEF1, EEF2, EEF3 are 1.25, 0.46 and 0.52kN, respectively, with an average value of 0.743kN for the three specimens. The failure modes for all three specimens are failure of the interface between the GFRP strips and masonry as shown in Fig.7.

Fig.7. mode of failure of specimens with GFRP bonded externally

2. Near-Surface Mounted

The experimental results for three specimens of GFRP strips of width 35mm inside epoxy are as follow: The failure loads for the three specimens EIF1, EIF2, EIF3 are 2.90, 2.43 and 4.02kN, respectively, with an average value of 3.11kN for the three specimens. The failure modes for all three specimens are rupture of GFRP strips as shown in Fig.8.

Fig.8. mode of failure of specimens with GFRP NSM

Specimens with CFRP strips

1. Externally bonded

The experimental results for three specimens of CFRP strips of width 50mm externally bonded with adhesion material are as follow: The failure loads for the three specimens EEF1, EEF2, EEF3 are 1.11, 2 and 2.73kN, respectively, with an average value of 1.95kN for the three specimens. The failure modes for all three specimens is de-bonding the CFRP strips with the adhesion material and apart of the surface of the blocks as shown in Fig.9.

Fig.9. mode of failure of specimens with CFRP bonded externally

2. Near-Surface Mounted

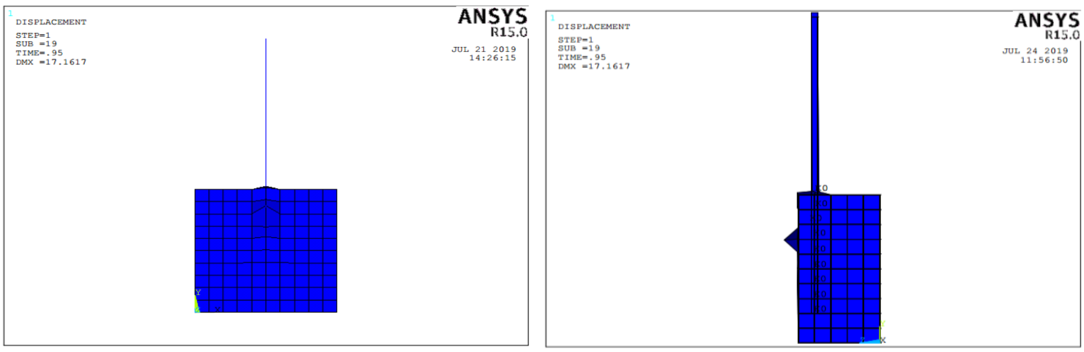
The experimental results for three specimens of CFRP strips of width 35mm inside epoxy are as follow: The failure loads for the three specimens EIF1, EIF2, EIF3 are 2.56, 2.22 and 2.8kN, respectively, with an average value of 2.52kN for the three specimens. the first two specimens didn't show any deformation or failure however the last one the prism broken without any failure or deformation for the fiber or the adhesion material as shown in Fig.10.

Fig.10. mode of failure of specimens with CFRP NSM

Numerical models

1. Prisms strengthened by 10mm steel bar embedded in mortar

failure load is determined and recorded 18.57kn. results of the model are presented as follow: deformed shape, stresses, crack pattern and load-displacement curve as shown in fig.11 to fig.15.



(a) (b)

Fig.11. deformed shape

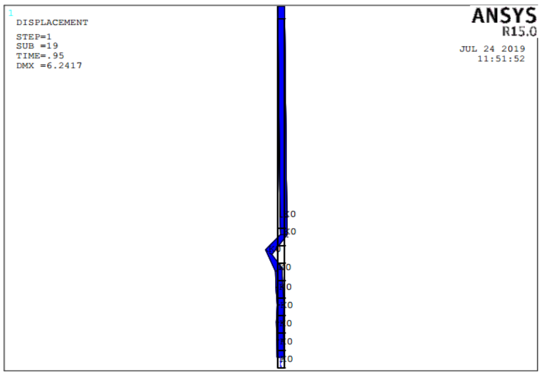


Fig.12. deformed shape of bar

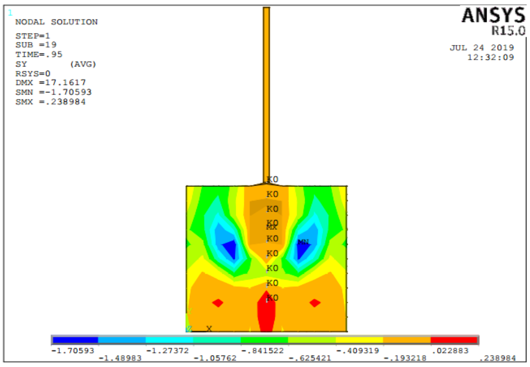


Fig.13. stresses of specimen

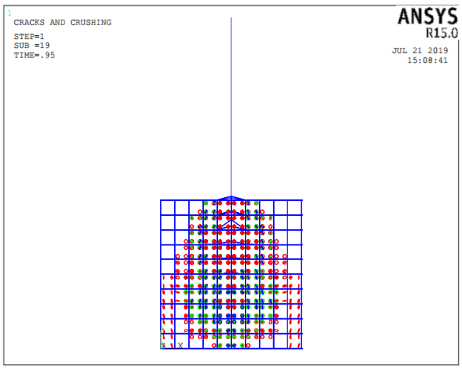


Fig.14. crack pattern

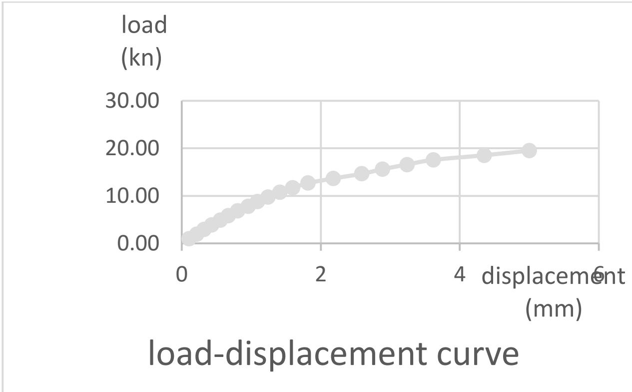


Fig.15. load-displacement curve

2. Prisms strengthened by 10mm steel bar embedded in epoxy

failure load is determined and recorded 50kn. results of the model are presented as follow: deformed shape, stresses, crack pattern and load-displacement curve as shown in fig.16 to fig.20.

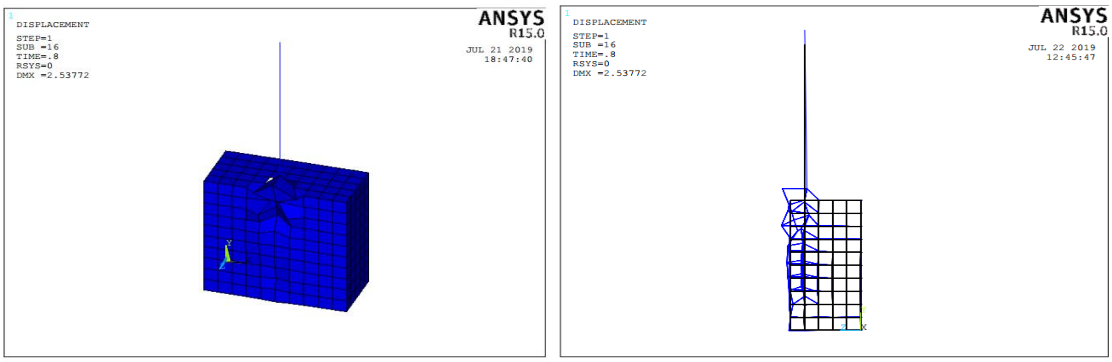


Fig.16. deformed shape

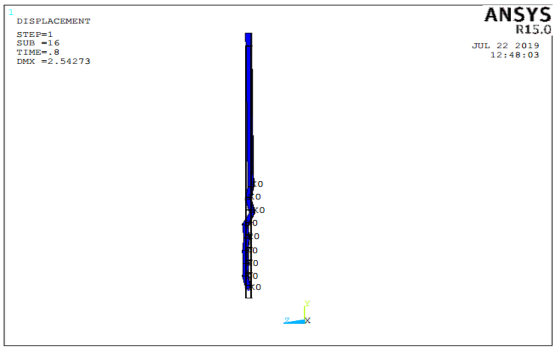


Fig.17. deformed shape of bar

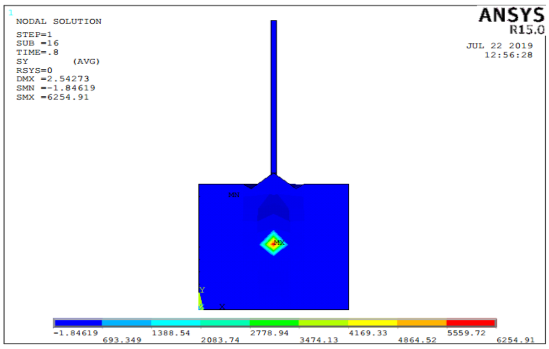


Fig.18. stresses of specimen

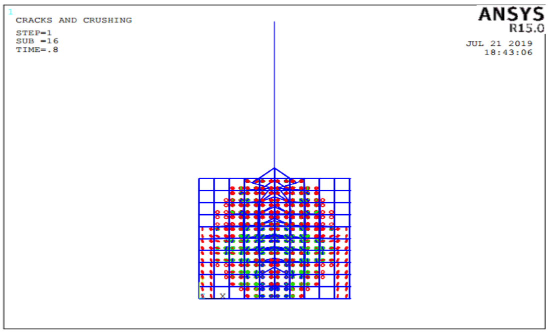


Fig.19. crack pattern

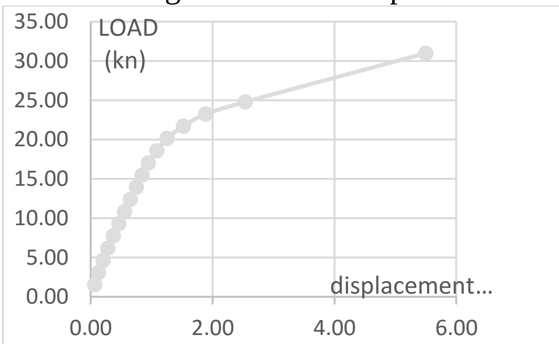
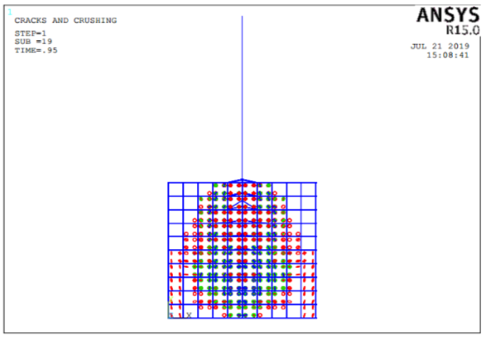
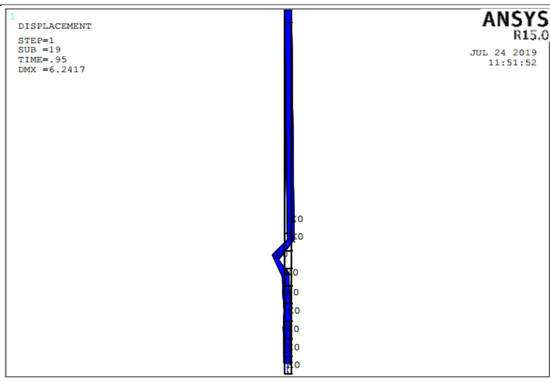


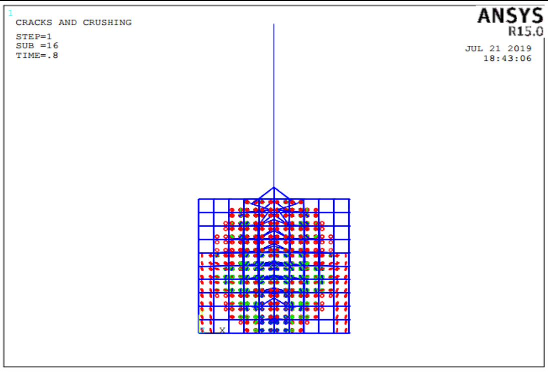
Fig.20. load-displacement curve

Comparison between Numerical and Experimental Results

1. Steel bar of dia.10mm. embedded in mortar

	experimental	numerical
Failure load	14.71kN	18.57kn.
Failure mode of specimen		
Failure mode of bar		

2. Steel bar of dia.10mm. embedded in epoxy

<table>
<tr><td></td><td>experimental</td><td>numerical</td></tr>
<tr><td>Failure load</td><td>47.85kN</td><td>50kn</td></tr>
<tr><td>Failure mod of specimer</td><td></td><td>
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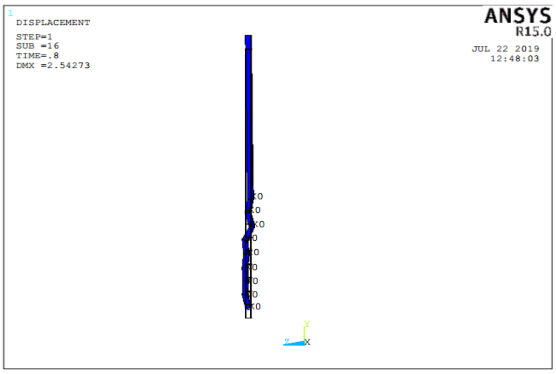
<tr><td>Failure mod of bar</td><td></td><td>
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Conclusion

Full bond case could be achieved experimentally and numerically in case of epoxy with steel bar of dia.10mm. as epoxy has high strength comparing with mortar and high tensile steel (rough surface) affected on increasing the load capacity. numerical approach is in agree with experimental results.

there are some factors affecting on the bond behavior :

1. Bonding material , high strength bonding material increase load capacity, tensile strength and bond behavior

2. Surface condition; rough surface increases the load capacity and tensile strength due to friction

3. embedded length; increasing imbedded length increasing the strength

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