Horizontal Shear Transfer between Concrete and Bricks

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Abstract

Horizontal Shear transfers through interfaces between two materials need to be studied accurately especially when the interface separates two different materials. In this study the two materials are concrete and bricks. This interaction can be formed in the regions where concrete is rested on brick walls in so many positions in construction. The study focuses on an experimental work through a series of push-off tests for (concrete to bricks, cement mortar to bricks) taking into consideration that the shear connectors are steel bars. Throughout push–off tests and due to the applied horizontal forces as slip had been attained. This forces and slips are recorded and graphically drawn. A statistical regression was made to find the most representative formula of the mechanism of shear transfer between concrete with bricks and between cement mortar with bricks. The predominant factor in shear transfer between concrete and bricks is the amount of shear connectors because as number of dowel bars increases the shear strength increases. The value of force recorded at 2mm slip for concrete to concrete was around three to four times that for concrete to bricks in existence of steel bars or steel dowels. This means that concrete to bricks is weaker than that between two concretes.

Key words: Aggregate interlock, Cement mortar, Dowels, Shear transfer.

Introduction

In so many contact regions of structural members (during construction) shear is transferred horizontally due to a limited movement of one part against other. These regions may be concrete to concrete or concrete to other materials. Concrete to concrete had been studied by so many researchers (Zheng L.X.&Burgoyne C.J., Husain M.H. et al,Yashiki Tanaka et al and K.F. et al) and yet the work still not finishes. Transferring horizontal shear is very complicated problem because of the effect of many variables like applied normal load, shape of the finish of contact area (smooth or rough), type of the materials forming contact area and the mechanism used to clamp the two parts through interface area.

An extensive statistical analysis of 88 push-off specimens were performed by Walraven et al (1978) to find the horizontal shear strength between two faces of concrete. This analysis yielded the following equation:

$$v_n = C_3(0.0007\rho_V f_y)^{C_4} \quad \text{Psi} \qquad (1)$$

where v_n =horizontal shearing stress. $C_3 = 16.8 f_c^{`0.303}$

$\rho_V f_y$ =clamping stress. $C_4 = 0.0371 f_c^{`0.303}$

$f_c^{`} = 0.85$ *times the compressive strength found using* 150 *mm cubes*.

Banta E.T. (2005) studied the media between the bridge decks to the top flange of the beams. Twenty-four push-off tests were performed to determine shear transfer design equations for shear strength of composite Ductal (R) and lightweight concrete sections. The results of his work were all found to be conservative but it was recommended that the equation from AASHTO-LRFD specifications (2004) be used for design.

The horizontal shear strength that was used by PCI on the work of Shaikh A.F. (1978). The simplified from of this equation is shown below:

$$v_n = \lambda\ \sqrt{1000\emptyset\rho_V f_y} \leq 0.25 f_c^{`}\lambda^2 \ and\ 1000\lambda^2 \qquad (2)$$

Where Ø=0.85 for shear.

λ =1.0 for normal weight concrete.

λ =0.85 for sand-lightweight concrete.

λ =0.75 for all-lightweight concrete.

The work of Mattock et al (1975) proposed the following linear equation to determine the horizontal shear strength of an initially cracked interface:

$$v_n = 400 + 0.8\rho_V f_y \quad \text{Psi} \qquad (3)$$

Where: $v_n \leq 0.3 f_c^{`}$ Psi

In concrete two mechanisms play as an active role in shear transformation namely aggregate interlock and dowel action. When the materials of the contact surfaces are changed these mechanisms need to be studied. In this work concrete was taken to be the first material whereas the second material was bricks. Connection between concrete and bricks can be fulfilled through interlock between concrete aggregates and brick material besides the concrete studs formed as a result of filling the brick holes by concrete. The present paper focused on this mechanism and another clamping mechanism using steel bars buried in brick holes and extended to the concrete layer as shear connectors.

Concrete to bricks can be seen in construction of brick walls constructed on concrete lintels , concrete beams rested directly on bearing walls or on partitions, concrete decks on brick walks and so on. The normal loads applied through concrete members try to push members under them. If the members beneath concrete are brick walls, so this normal load will create horizontal force (due to friction) making slip in the two members and forming an interface area. The present study focuses on this interaction without assuming an old crack or interface.

Experimental work

It was decided to achieve this work for the aim of finding out what will occur in the media between concrete and bricks interface. Practical work was including items of preparing molds, equipment's, materials and testing devices. A summary here can be given for the practical work of these items. Seventy tests were decided to be done. The first ten tests were for concrete poured on an old concrete without changing the surface shape between them. The second ten tests were for a concrete rested on bricks through two Ø12 mm dowels. In the third ten tests same procedure was consumed but with four dowel bars while fourth ten tests was done using six dowel bars. The remainders were thirty tests done on cement mortar and bricks because bearing walls are constructed through so many rows of bricks connected to upper and lower rows by cement mortar (cement paste). These thirty tests were divided also to three groups each group includes ten tests started by mortar and bricks with two dowel bars, four dowel bars and six dowel bars respectively. Table (1) shows the details of these tests.

Materials used

The materials used in this work include cement, gravel, sand and bricks. The cement used is Iraqi cement locally manufactured and it was coincided with Iraqi specifications (IQS, No.5, 1984) as in table (2). This specification is also coincided with Portland cement properties. Primary setting time of the cement used was (65 min.) and final setting time was (460 min.). The coarse aggregate used was rounded gravel of Max. size (19 mm) and it was found that it was coincided with Iraqi specifications (IQS, No.45, 1980) as in table (3). The fine materials were sand taken from Najaf quarries and whole of the tests were done which were gave results coincided with Iraqi specifications (IQS, No.45, 1980) as in table (4), zone no. 2.

The samples of bricks used were of class B manufactured in Iraqi factories in which their dimensions are 240X115X75 mm. The bricks are perforated by so many holes to achieve strong connection with mortar. The ratio of perforations was not more than 25% of the total size of brick. All of the tests include water absorption, density, fluorescent test and bearing in compression had been done. The steel bars used as dowels are of Ø13 mm bars and they were coincided with American specifications ASTM A615/ A615M-01b, as shown in table (5).

Mold, equipment and devices used

wooden molds were used to achieve the preparation of samples of push-off tests. The dimensions of each mold are illustrated in Fig. 1.The mold contains two parts the outside one called (A) which is a container prism of 41X24X12.5cm in dimensions whereas the internal part (B) manufactured from wood was used as a separator between the two materials during casting. This wood separator divide the mold into two pieces, piece one may be brick or it may be concrete while piece two was always from concrete as shown in Fig.2. The two pieces were erected in a manner as shown in the photos (1, 2, 3). A load cell and dial gage were used and assembled to measure the load applied and slip due to horizontal movement.

Ten samples of ordinary concrete (piece A) were casted and cured in water baths for 28 days. The average compressive strength of the cubes governed was 30.8 MPa. The ten upper pieces of concrete (piece B) were casted over lower pieces without connectors. The upper piece was reinforced by two bars of Ø10mm in the upper layer and 2 Ø8mm in the lower layer. The reinforcement of this assemblage (upper part B) can be shown in Fig. 3.

This procedure was used for the next ten .
samples with first piece of brick clamped to upper piece by two steel dowel bars Ø12mm inserted

in brick holes and fixed in their holes positions by the material of the upper part. The steps of the previous procedure were repeated for whole samples except the number of dowels was changed to four and six bars respectively. Another try was done to see the effect of the mortar because there are so many members constructed from cement mortar rested on bricks. The upper piece was prepared as mortar material from cement and sand by a ratio of (1:3) as used in construction of bearing walls. The average compressive strength of 5X5X5 cm molds was 21 MPa. Same procedure was done in push-off tests and all of the results of applied loads and slip were recorded.

Results and discussion

The results of the push-off tests were tabulated in Table (6) where the applied normal load is 1 KN. Each number of these results represents an average of ten readings. Seven cases were taken into consideration as previously mentioned. Against each slip measured the value of horizontal force applied was recorded.

Figure (4) shows the results tabulated before in graphical form. It is clearly evident that concrete to concrete failed at values of shear force higher than concrete to bricks. This leads to the truth that concrete to concrete has more strength against shear and that is due to the interlock of aggregate and high coefficient of friction. The value of force recorded at 2mm slip for concrete to concrete was about three to four times that for concrete to bricks in existence of steel bars or steel dowels

From the same figure it can be seen that the results of the shear transfer between mortar and bricks are very low and they are approximately coincided. This is due to the weakness of the bricks materials as a major reason and low coefficient of friction between the skin of bricks and cement mortar. Concrete to bricks with two dowels samples were failed at very small slip (2mm) while that cases (with four or six dowels) were failed at values of 8.5mm.

Figures (5, 6, and 7) show that as number of dowels exceeds two bars the value of maximum shear strength increases. So the predominant factor here in shear transfer is the amount of shear connectors. For two dowels the maximum value of shear force was 14 KN while increasing two bars more, the force jumped to 20.4 KN and it was jumped to 32.1 KN for six dowel bars. A statistical regression was made to find the most representative formula of the mechanism of shear transfer between concrete and bricks. The governed formula was as follows:

$$S_{ft} = 0.0038S^6 - 0.1003S^5 + 0.9907S^4 - 4.3157S^3 + 6.7428S^2 + 4.4572S \qquad (4)$$

Where S_{ft}=Shear force transferred in kN.

S=Slip in mm.

The results of shear transfer between cement mortar and bricks can be seen in figures (8,9,10). These three figures show that if the numbers of dowels are two or four and even if it is six, there is no any improvement in shear force. Shear force for the three cases was not more than 4.5 KN. So it is advised not to use dowel bars between cement mortar and bricks. The governed formula covering the behavior of the shear transfer between cement mortar and bricks was as follows:

$$S_{ft} = 0.0038S^6 - 0.1003S^5 + 0.9907S^4 - 4.3157S^3 + 6.7428S^2 + 4.4572S$$

Which is the same as previous formula used for concrete rested on bricks.

Conclusions and recommendations

The following conclusions can be drawn in the present study:

1. It is advised to use shear connectors as dowel bars between concrete and bricks to prevent and minimize the harmful slip between the two adjacent surfaces.
2. The value of force recorded at 2mm slip for concrete to concrete was around three to four times that for concrete to bricks in existence of steel bars or steel dowels. This means that concrete to bricks is weaker than that between two concretes. The values of forces corresponding to 2 mm can be seen in table (6).
3. The predominant factor in shear transfer between concrete and bricks is the amount of shear connectors because as number of dowel bars increases the shear strength force increases. The ratio of the increase of shear force corresponding to slip recorded can be determined from Eq. (9).
4. The results of the shear transfer between mortar and bricks are very low and they are approximately coincided. So it is advised not to use dowel bars between cement mortar and bricks. The ratio of the increase of shear force corresponding to slip recorded can be determined from Eq. (5).
5. The work needs testing prototypes to see the truth as it and build the most correct opinions about the real behavior between concrete and bricks.

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Table (1): Details of the tests done.

Materials used	Number of tests	Number of dowels	Tests done
Concrete to concrete	10	---	Push-off, compressive strength of concrete.
Concrete to bricks	10	2	Push-off, compressive strength of concrete, compressive strength of bricks.
Concrete to bricks	10	4	Push-off, compressive strength of concrete, compressive strength of bricks.
Concrete to bricks	10	6	Push-off, compressive strength of concrete, compressive strength of bricks.
Mortar to bricks	10	2	Push-off, compressive strength of cement mortar, compressive strength of bricks.
Mortar to bricks	10	4	Push-off, compressive strength of cement mortar, compressive strength of bricks
Mortar to bricks	10	6	Push-off, compressive strength of cement mortar, compressive strength of bricks

Table (2): Results of used cement.

Test		Ordinary Portland cement
Fineness (m2/kg)		230
Sitting	Initial (min.)	45
	Final (hr.)	10
Stability (%)		0.8
Compressive strength MPa	3 day	15
	7 day	23

Table (3): Grain size distribution of coarse gravel.

Sieve opening (mm)	Percentage passing
37.5	100
20	95-100
10	30-60
5	0-10

Table (4): Grain size distribution of fine gravel.

Sieve opening (mm)	Percentage passing
10	100
4.75	95-100
2.36	75-100
100	55-95
0.600	35-59
0.300	8-30
0.15	0-10

Table (5): specification of steel bar used.

Standard requirement	Specification
Nominal mass (kg/m)	0.994
Diameter (mm)	12.7
Cross section area (mm^2)	129
Parameter (mm)	39.9
Deformation height (mm)	0.51
Deformation spacing (mm)	8.9
Tensile strength (MPa)	620
Yield strength (MPa)	420
Elongation per 200 mm length at least (mm)	9

Table (6): Results of push-off tests.

Horizontal displacement (mm)	Concrete to concrete	Concrete to bricks using steel bars as shear connectors of:			Mortar to bricks using steel bars as shear connectors of:		
	No. Reinf.	2Ø12mm	4Ø12mm	6Ø12mm	2Ø12mm	4Ø12mm	6Ø12mm
	Force kN	Force kN	Force kN	Force kN	Force kN	Force kN	Force kN
0	0	0	0	0	0	0	0
0.5	14.0	1.0	2.0	2.3	0.4	0.6	0.6
1	23.6	1.2	7.6	7.6	1.3	1.4	1.4
1.5	35.3	3.4	14.0	16.2	2.1	2.0	2.3
2.0	56.7	14.0	14.0	18.3	3.3	3.5	3.7
2.5	110.6		14.0	24.7	3.6	3.8	4.1
3.0			16.2	32.1	3.8	4.3	4.4
3.5			16.2	25.1	4.0	4.5	4.5
4.0			16.2	18.3			
4.5			16.2	18.3			
5.0			16.2	22.6			
5.5			16.2	22.6			
6.0			18.3	20.4			
6.5			18.3	20.4			
7.0			18.3	18.3			
7.5			18.3	16.2			
8.0			20.4	14.0			
8.5			20.4	14.0			

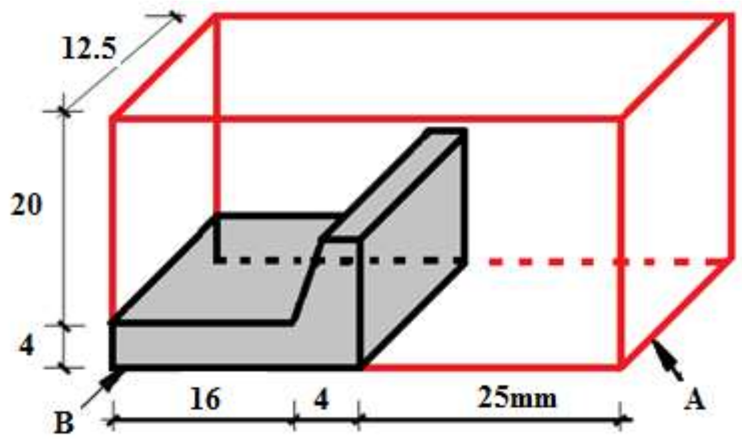

Figure (1): Shape and dimensions of the wooden molds used.

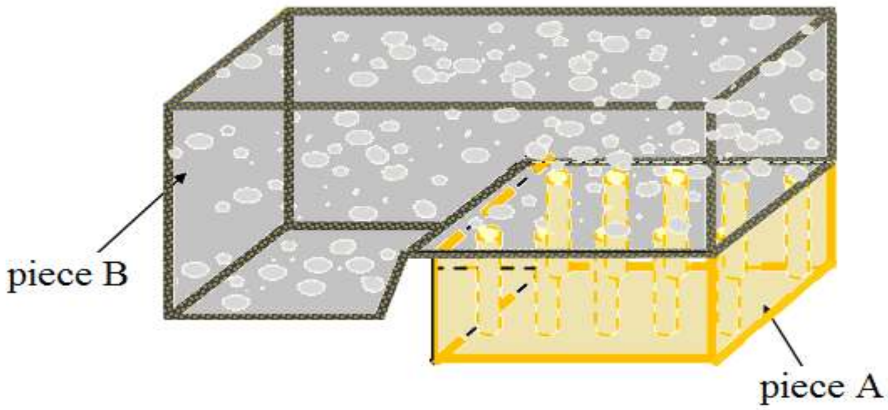

Figure (2): Lay out of the materials in the mold.

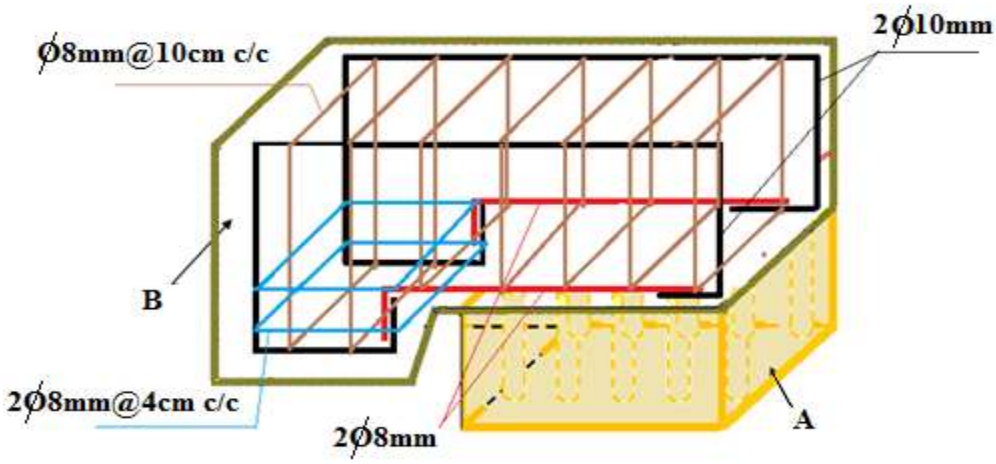

Figure (3): Reinforcement of the concrete part B.

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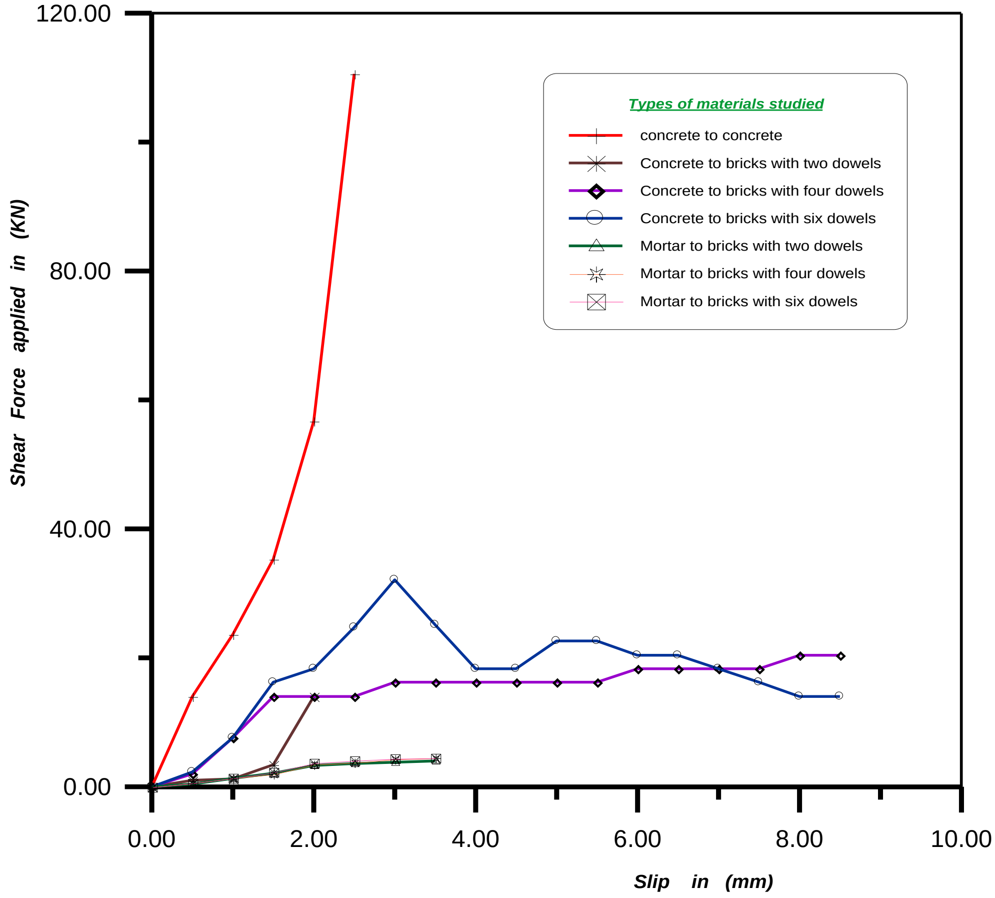

Figure (4): Results of push-off tests

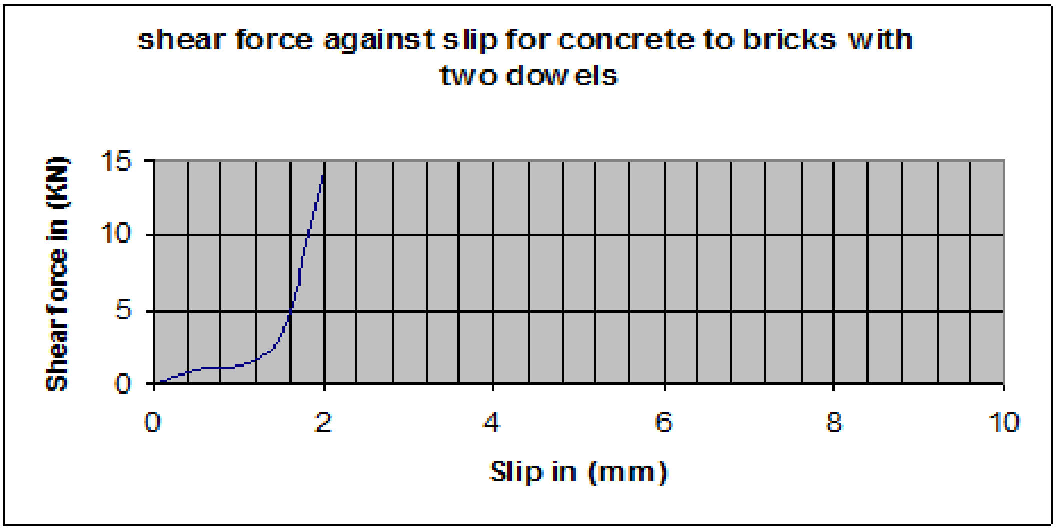

Figure (5): Concrete rested on bricks with two dowel bars.

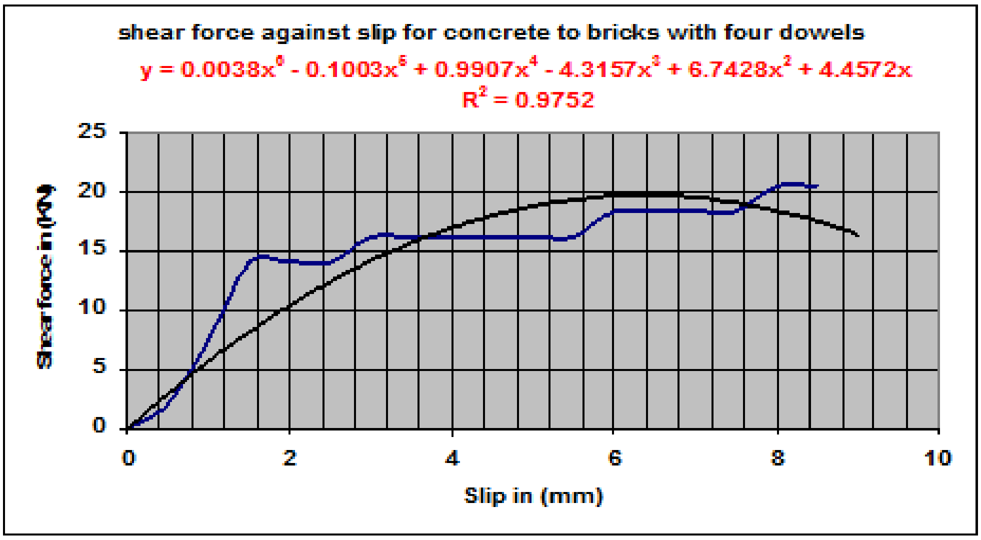

Figure (6): Concrete rested on bricks with four dowel bars.

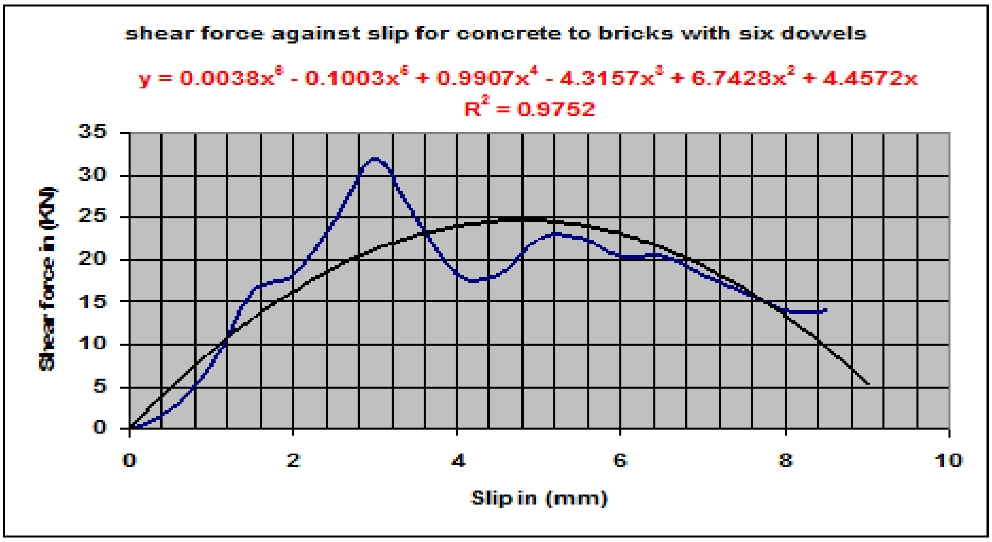

Figure (7): Concrete rested on bricks with six dowel bars.

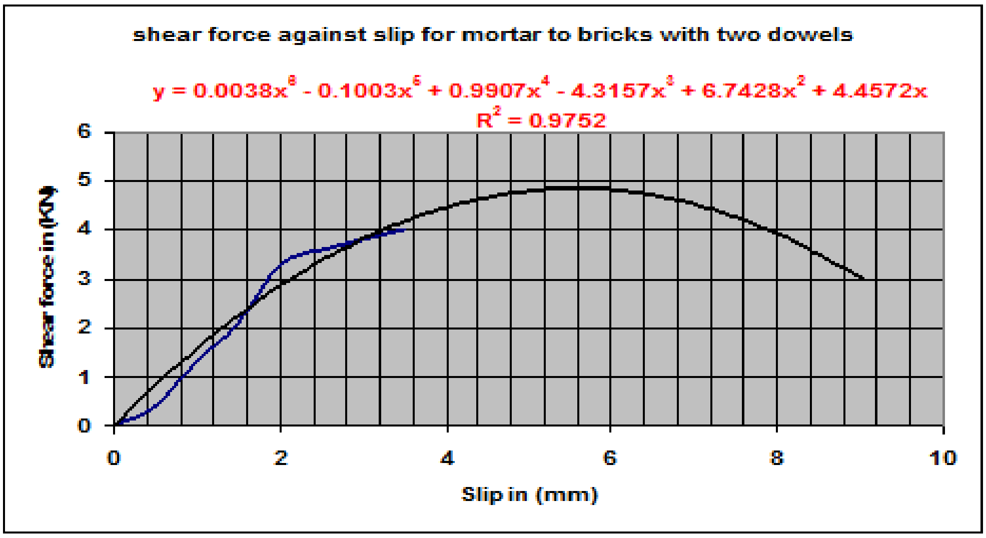

Figure (8): Mortar rested on bricks with two

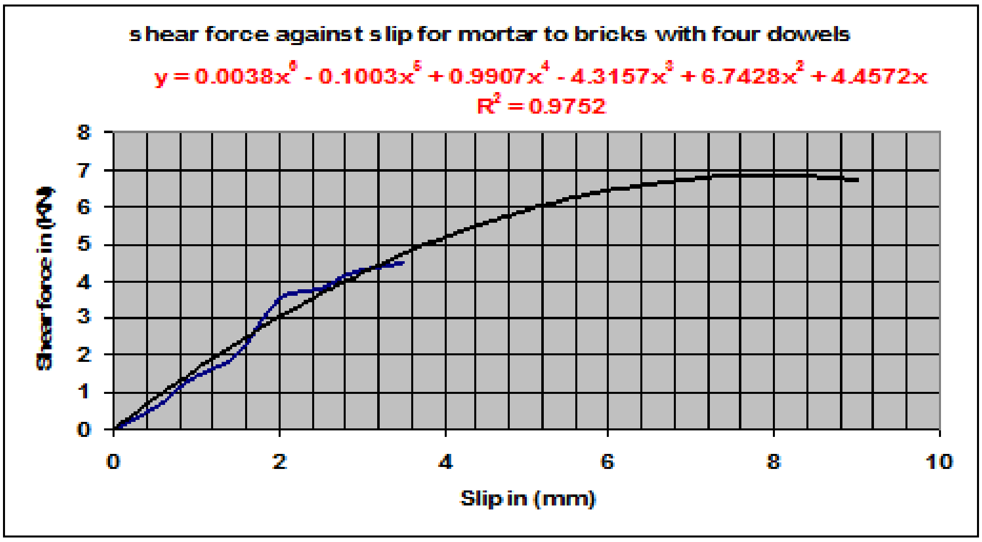

Figure (9): Mortar rested on bricks with four dowel bars.

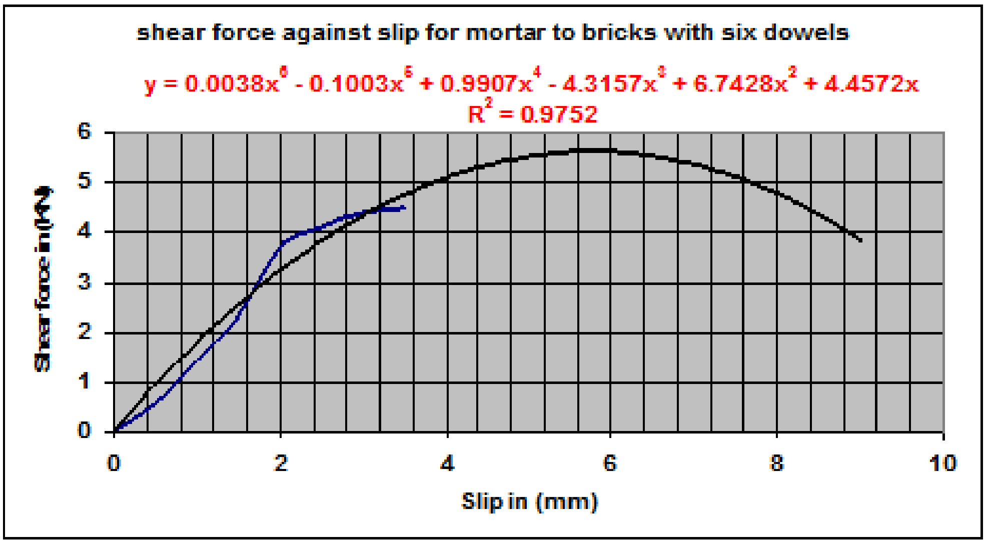

Figure (10): Mortar rested on bricks with six dowel bars.

Photo (1): Concrete to concrete shear test

Photo (2): Concrete to Bricks shear test

Photo (3): Failure of concrete to Bricks with six dowels