EXPERIMENTAL APPROACH TO INVESTIGATE CONCRETE–MASONRY INTERFACE

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Abstract: A masonry infill wall is a common cell in a concrete framed building. More importantly the bond between concrete and masonry has considerable effect to the performance of infill masonry walls and hence to the frame structure itself. Therefore, understanding of the element interaction between concrete and masonry become very important and has become a topic of considerable research interest in the past few decades. Many researchers have tried to represent this interaction numerically. However, reliable numerical analysis can be achieved only with the correct mechanical properties which are obtained experimentally.

This paper presents the results of a series of experimental studies carried out to determine the tensile and shear behaviour of concrete masonry interface relevant to the Sri Lankan brick masonry. Tests were carried out in accordance with ASTM standards. In this study, the effect of the mortar designation and the joint thickness on the bond was also investigated. From the results, it can be concluded that properties of the bond is significantly affected by the roughness of the brick used and workmanship apart from the mortar designation and joint thickness. Also it can be recommended to use 10 mm mortar joints in construction, since both shear and tensile strength of the joints get reduced when the joints become thicker, irrespective of the mortar designation.

Keywords: Concrete–masonry interface, Bond Strength of Mortar, Shear strength, Mortar joint thickness, Mortar designation

1. Introduction

In Civil Engineering practice, there are varieties of structures with interface discontinuities where the assumption of rigid interconnection between the contact surfaces is questionable. Since the bond between concrete and masonry is not easy to recognize, interface between concrete and masonry also falls into the above category. The bond between the concrete masonry at their interface depends on number of factors such as the method of construction, the strength of mortar and masonry units, etc.

Although the infill panels significantly enhance both the stiffness and strength of the frame, their contribution is often not considered mainly because of the lack of knowledge of composite behaviour of the frame and the infill [1]. Since the interface between concrete and masonry represents the weakest plane, in some cases due to their low resistance to shear and tensile, it tends to crack when loading is applied. Therefore, it is necessary to conduct detailed studies to understand the mechanical behaviour and the effect of different parameters to the bond between concrete and masonry at their respective interfaces. Objective of this paper is to present the knowledge of the shear and tensile behaviour of concrete masonry interface.

In order to determine the shear strength of masonry assemblages, a number of both experimental and theoretical researches have been performed. In these many different test techniques have been used to investigate the shear strength of masonry assemblages because of the difficulty in simulating experimentally, the actual load and boundary conditions of a structural masonry component in a building. Ghazali and Riddington (1988) [2] presented a simple method for assessing the shear strength of the brick/mortar interface by using a triplet test specimen tested without the complication of adding a pre-compression force. From this work it was shown that the Mohr-Coulomb failure envelope could be established by conducting tests with zero pre-compression and then by measuring the coefficient of friction at the joint.

To test brick triplets dynamically, the drop hammer testing method for triplet was subsequently developed by the Liverpool University. Molyneaux (1994) and later Beattie, Bouzeghoub *et al* (1995) [3] did assess a similar testing in their study with some modifications. Additionally several other testing methods are available in British standards to assess the initial shear strength of masonry [4, 5].

Tensile strength of bond is defined as the maximum stress that the masonry prisms can withstand while being stretched or pulled. Unlike in shear strength testing, very few testing methods are used in practice for tensile strength of the masonry bond. Fouad and Khala (2005) [6] developed a new testing method with Z-shaped specimens and his method was based on some standard testing methods such as BS 5628 [7] and the bond wrench test developed in Australia AS 3700[8]. In this study the brick couplet test proposed in ASTM C 952 – 02 - Standard Test Method for Bond Strength of Mortar to Masonry Units [9] was adopted for the concrete-brick couplets.

2. Experimental Details

2.1 Model preparation

For the preparation of shear testing specimens, wire cut bricks of standard size 215mmx105mmx65mm were used and for the tensile strength testing both wire cut bricks and normal handmade bricks having approximate dimensions of 205mmx95mmx55mm were used. The other half of each couplet specimen consisted of a concrete block with similar dimensions to the brick used in each type. The Selected Grade of concrete for the blocks was Grade 25 since it's the most commonly used in the normal constructions.

In constructing the prisms, the bricks were first pre-wetted by totally immersing in water basin for 20 min before laying them in position as recommended by Jayasinghe (1998), to achieve a good bond with Sri Lankan bricks. Then using three different mortar designations of 1:5, 1:6 and 1:8 cement-sand, mortar joints with thicknesses of 10mm and 15mm were cast to obtain three couplet specimens for each type. The water cement ratio of mortar was maintained at the consistency level of 0.5 as obtained by the Cone penetration test which was carried out according to ASTM C780. For the tensile strength test, cross brick couplet specimens were constructed according to ASTM C 952 – 02. The prepared specimens were cured for 28 days at room temperature.

2.2 Shear strength test

For the shear testing, a fully fixed base was made and on top of that, the shear specimens were placed. When placing specimens, they were kept so that concrete portion of the specimen is fixed against the base. A hydraulic ram controlled through an air regulator was used to apply a shearing load to the couplet at a rate of 0.1kN/s until the shear failure of the specimen occurred. This shear strength test was carried out under a pre-compression of 0.5kN.

Two Linear Variable Displacement Transducers (LVDTs) were attached to the brick and mortar faces of the specimens for the determination of shear displacement while the exerted load was read through a 200kN load Cell.

Fig.1 (a)

Fig.1 (b)

Fig.1 (c)
Fig.1 (a) Shear test setup; (b) Deformation while applying load; (c) After the failure of the shear specimen;

2.3 Tensile strength test

Specimens were kept centrally on the lower plate of the specially made loading jigs so that the concrete surface touched the lower plate and on top of the brick upper plate was kept to apply the load. Two digital dial gauges were attached in either side of brick to read the displacement and a 1 ton proving ring was kept on the upper plate of the loading jigs to read the applied load.

The specimen was loaded by means of a compression testing machine and loading rate was controlled so that the failure occurred within 2 minutes except for the specimens made using wire cut bricks. For wire cut made specimens, loading was applied using weights as the failure load was less compared to the Normal handmade-brick specimens.

Fig.2 (a)

Fig.2 (b)
Fig.2 (a) Tensile testing setup; (b) After the failure of the tensile specimen

3.0 Results and Discussion

3.1 Shear strength test

The mode of failure for all the shear specimens was slip at the brick-mortar interface as seen in Figure1(c) and from the obtained results displacement Vs stress relationships are plotted and represented in figures below. Figure 3 shows the stress Vs displacement relationship for 10 mm mortar joint with 1:5 cement-sand mortar.

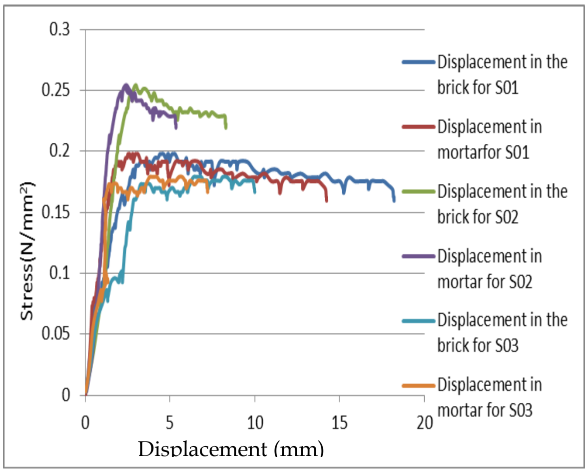

Figure 3: 10 mm thick mortar joint with 1:5 cement-sand mortar

Llinear elastic loading followed by linear softening and residual shear strength of the interface is clearly seen and the mechanical behavior of the interface is very stiff in the elastic domain. The order of the total shear deformation was only a fraction of a millimeter. From Figure 3, it can be clearly seen that the maximum bond strength is 0.25 N/mm^2 and minimum value is about 0.16 N/mm^2. Hence the average shear strength of the bond for 10mm joint with 1:5 mortar designation is about 0.2 N/mm^2.

Figure 4 shows the stress Vs displacement relationship for 15 mm mortar joint with the same mortar designation (i.e. cement sand mortar). One specimen out of three failed even before applying any load on the brick.

Observing the rest of results, the average shear strength of the interface for 15 mm thick joint with 1:5 mortar designation is 0.18 N/mm².

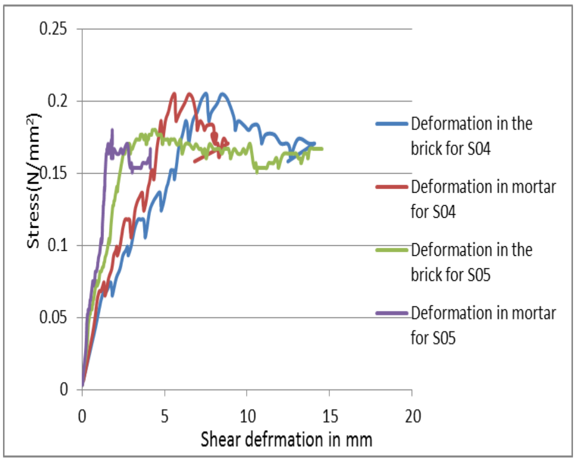

Figure 4: 15 mm thick mortar joint with 1:5 mortar designations

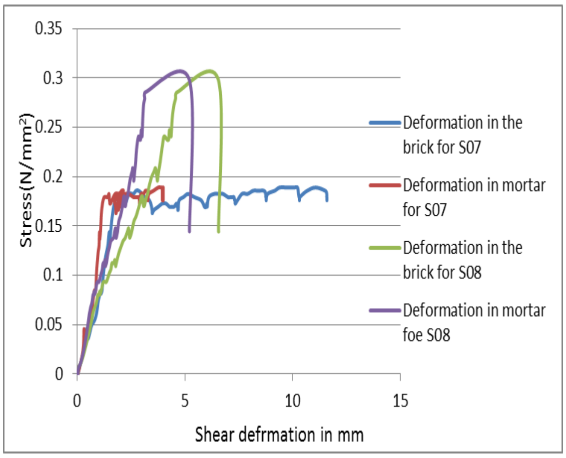

Figure 5: 10 mm thick mortar joint with 1:6 mortar designations

Figure 5 shows the stress Vs displacement relationship for 10 mm thick mortar joint with 1:6 cement-sand mortar.
In these specimens also one specimen was failed during handling. In this case, there is a considerable difference in strength values. Therefore we cannot take the average value as the shear strength of the bond. But we can conclude that shear strength of the bond is 0.18 N/mm² and it is lower than same joint thickness with 1:5 mortar designations.

Figure 6 shows the stress Vs displacement relationship for 15 mm mortar joint with 1:6 mortar designation.

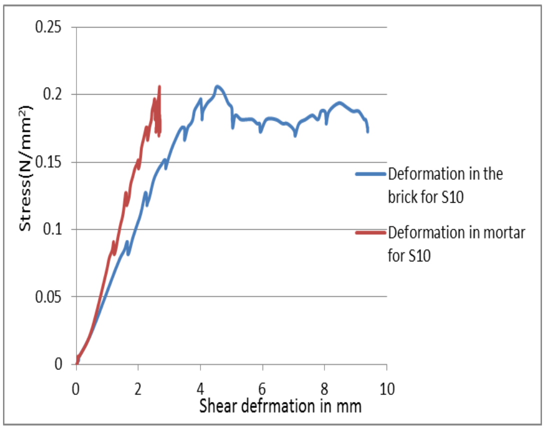

Figure 6: 15 mm thick mortar joint with 1:6 designation

Two specimens out of three were failed before applying load and the failure stress of remaining specimen was 0.2 N/mm². In this case specific bond strength value cannot be determined.

Similarly most of the specimens with 1:8 cement-sand mortar with both 10 mm and 15 mm joint thicknesses failed at handling and indicating very low shear strengths at the bond.

3.2 Tensile strength test

For the Sample no.1 (M1) i.e. Normal brick with 1:5 mortar designation, applied stress vs. average displacement was shown in Figure 7. From that graph it is evident that the average displacement is linearly varying with the applied stress and the tensile strength of the specimen is 0.085N/mm² with an average displacement value of 0.135mm at failure.

Figure 8 shows the variation of the average displacement of the concrete masonry interface with the applied stress in specimens made out of normal brick for different mortar designation. From that graph we can conclude that the bond strength is increasing with the usage of higher cement content in the mortar (bond strength is higher in 1:5 than that of 1:6 mortar designation).

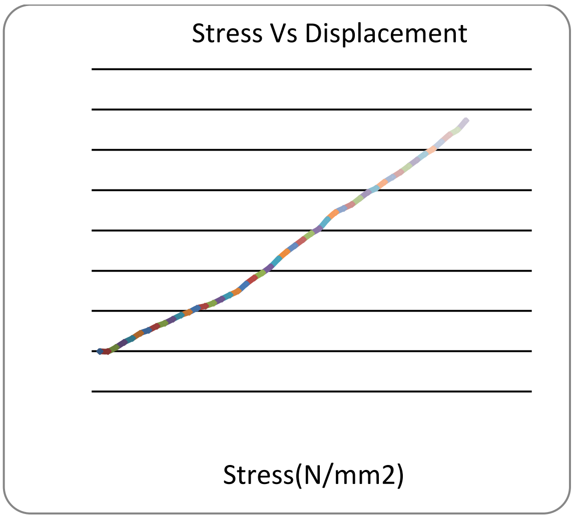

Figure 7: Stress vs. Average Displacements in M1

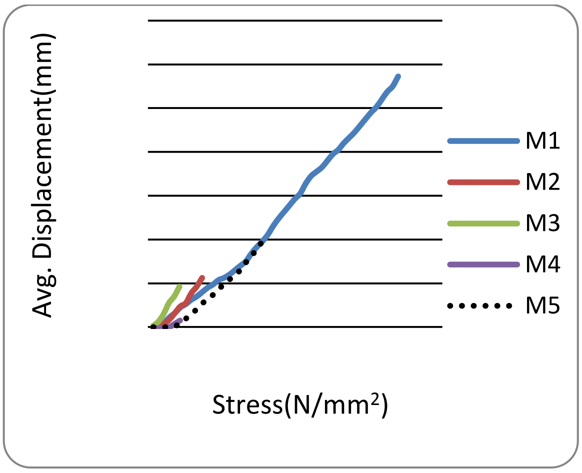

Figure 8: Stress vs. Average Displacements in for Normal brick with different mortar designations

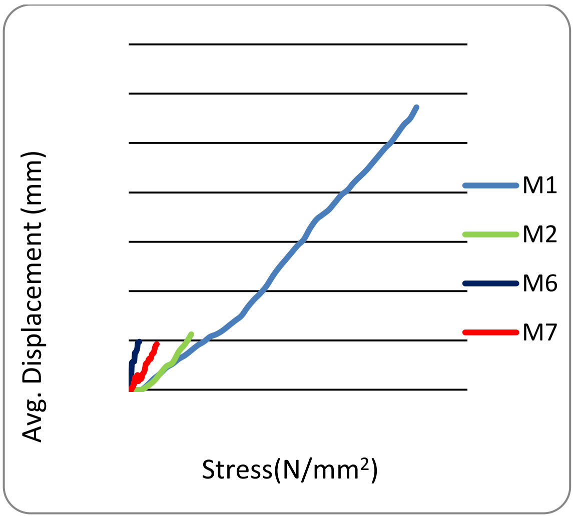

Figure 9: Stress vs. Average Displacements in for mortar designation 1:5

In the Figure 9, M1 and M2 represent the specimens made with Normal handmade bricks and other 2 are Wire cut brick specimens. From the results, it can be seen that the tensile bond strength is higher in the Normal brick specimens. As well as the average Displacement before the failure is almost same except in the case of M1. In specimen M1 the failure load is very much higher (460% higher than M2) and this may be due to some factor other than the mortar designation or brick type used.

Roughness of the bonding surface crucially affects the bond strength of the interface than most of the other factors. At the initial stage of this study, specimens for the tensile testing were prepared only using wire cut bricks and without making the surfaces rough. All the specimens failed at handling indicating a very low tensile strength.

Figure 10: Effect of roughness

Figure 10 shows a failure of a specimen that was created at the initial stage of the study. It can be clearly seen that the mortar is hardly attached to the brick surface and proper bond between brick and the mortar is not there. The main reason can be due to low roughness of the wire cut brick surface.

After roughening the wire cut brick surface, failure load of the specimens were increased. But normal brick made specimens showed comparatively higher tensile strength than that of wire cut specimens since the influence of surface roughness is considerably higher in normally available bricks.

For all specimens, similar behaviour were obtained and in most cases linear variation can be seen in the tensile stress Vs. Average displacements graphs. Summary of the result are given in Table 1.

Table 1: Summary of the tensile test result

Speci-men No:	Mortar type	Failure stress N/mm²	Failure plane
M1	1:5	0.08	Brick-mortar
M2	1:5	0.02	Brick-mortar
M3	1:6	0.01	Brick-mortar
M4	1:6	0.01	Concrete- mortar
M5	1:6	0.04	Concrete- mortar
M6	1:5	0.003	Concrete- mortar
M7	1:5	0.009	Concrete- mortar
M8	1:6	0.02	Concrete - mortar
M9	1:6	0.09	Concrete - mortar
M10	1:6	0.002	Brick-mortar

M1- M5 are made of Normal handmade bricks
M6- M10 are made using Wire cut bricks

In the above results it can be seen that the tensile strength of the bond between concrete and masonry is considerably affected by the brick type used. However, it is difficult to find any relation between the tensile strength of wire cut brick made specimens. Reason for that result may be some other factor other than the mortar designation. But in Normal brick made specimens, tensile bond strength is relatively same for same mortar designation and values are higher for the 1:5 designation.

Theoretically, tensile strength of specimen M1 and M2 should be higher than others as the mortar designation used is 1:5 and the surface is relatively rough. But it is deviated in some cases as specimen M9 which gives the highest failure load. But if we consider factors like mortar designation, brick type M9 and M10 should give the least breaking loads. As well as failure loads of M3, M4 and M5 should be almost same as all the governing factors are same. (Especially surface roughness factor is same for all these as additional roughening was not done for those specimens). Therefore it can be concluded that the workmanship is a critical factor affecting the tensile strength of the concrete masonry interface.

3.3 Conclusion

From the experimental results it can be concluded that both tensile and shear strength parameters of the bond between masonry and concrete are dependent on the mortar designation and the mortar thickness. Higher cement content in the mortar mix and the lower thickness of mortar joint give high bond strength. In addition, until the failure occurs, displacement is linearly varied with the applied stress.

The dispersion of results for all the cases was considerable and also some of the specimens failed even before the testing was carried out. Hence, it can be conclud that the factors such as roughness of the brick, degree of roughness and workmanship are strongly affecting the bond strength between concrete and masonry joints apart from mortar designation and mortar joint thickness.

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