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Experimental Study on Bond Strength of Masonry by using Cement Mortar with Chemical Admixture

S.Sowbala, S.Kandasamy*

Department of Civil Engineering, SNS College of Technology, Coimbatore, India

Abstract : Masonry is a composite material with bricks as a building unit and the mortar as the joining material[6]. So the strength of masonry will depend on the strength of brick and mortar. The main aim of this investigation is to find the influence of various strength properties of mortar on the strength of masonry unit by using two types of bricks. In this investigation, mechanical properties like Tensile bond strength, shear bond strength and flexural bond strength properties of masonry was studied for mortar containing chemical admixture and it was effective compared with conventional mortar for both clay brick and fly ash brick[1,8].The test specimens were prepared for various cement-mortar ratios like H1 (1:3), H2 (1:4.5) and M1 (1:6). With this cement-mortar 8% of chemical admixture (styrene butadiene) was added to improve the strength of the mortar. The bond strength of masonry may determine by testing cross couplet brick specimen; shear strength of mortar was determined by triplet brick specimen and flexural strength was determined by stack bonded prism. The effect of different factors such as types of mortar and types of bricks on the strength of masonry was studied. It is observed that the mortar with chemical admixture gives improved strength properties when compared to conventional mortar mix. It is also observed that that the strength properties of masonry are affected by the bond strength of brick units.
Keywords : Mortar, Chemical admixture, tensile bond strength, shear strength, flexural strength.

1.0 Introduction

Masonry walls are used in almost all types of building construction in many parts of the world because of low cost material, good sound and heat insulation properties, easily available and locally available materials[2-5].Perfect bond between the masonry unit and the mortar is essential for the masonry to resist the stress due to different types of loading condition[11].Masonry wall provides higher resistance against compressive load but it can scarcely bear tensile stress. So the primary importance should give to improve the capacity of masonry to bear the tensile load. Masonry is a heterogeneous material and the mechanical property is purely based on the constituent material. It may not possible to alter the property of bricks but it is possible to improve the mechanical property of the mortar. This paper aims to improve the tensile strength of masonry by adding the chemical admixture Styrene butadiene.

Styrene butadiene rubber latex is a copolymer latex admixture that is designed as an integral adhesive for cement bond coats, mortars and concrete to improve bond strength and chemical resistance[9]. It will reduce cracking through increased mortar flexural strength and it will improve bond strengths to hardened cement paste.

2.0 Objective

This experimental study has been aimed at following objectives:

- To determine the tensile bond strength and shear bond strength of the masonry.
- To determine the flexural strength of masonry.
- To compare the shear strength with the bond strength of masonry.
- To investigate the influence of mortar and brick types on the bond strength of masonry.

3.0 Methodology

- Various types of mortar mixes were prepared with and without the addition of chemical admixture for two types of bricks for this study to investigate the influence of different types of materials on masonry strength.
- Bond strength was determined by crossed brick couplet method.
- Shear bond strength was determined by brick triplets.
- Flexural strength was determined a by beam element under Uniformly Distributed Load condition.

4.0 Material Properties

Clay bricks and fly ash bricks are used to study the properties of masonry unit. The properties of brick like compressive strength, water absorption, Initial Rate of Absorption and bulk density were found out and they were presented in the Table 1. Two types of mortar mix were used in this paper to find behavior of masonry element. As per IS 1905 three grades of mortar as H1(1:3), H2(1:4.5) and M1(1:6) were prepared for conventional mix and 8% bonding agent was used with these all mortar grades and they were tested. Mix proportioning for $1m^3$ of mortar was given in Table 2. The mortar specimens were prepared by using 70.6mm x 70.6mm x 70.6mm mould. They were tested after 28 days of curing [9]. The basic properties of mortar used in this project were presented in Table3.

Table 1 Properties of brick

Property	No of specimen tested	Clay brick	Fly ash brick
Size (mm)	10	228X104X70	230X107X75
Water absorption (%)	6	9.037	4.975
IRA (kg/m^2/minute)	6	0.7	0.169
Compressive strength(N/mm^2)	6	5.7	7.12
Bulk Density (kg/m^3)	6	1875.32	1709.42

Table 2 Mortar mixture proportion for $1m^3$ (kg/m^3)

Mixture	Conventional mortar H1 (1:3)	Conventional mortar H2 (1:4.5)	Conventional mortar M1 (1:6)	Mortar with Bonding agent (1:3)	Mortar with Bonding agent (1:4.5)	Mortar with Bonding agent (1:6)
Water/cement	0.45	0.45	0.45	0.45	0.45	0.45
Water	247.5	180	141.429	203.5	148	116.286
Cement	550	400	314.286	550	400	314.286
Sand	1650	1800	1885.714	1650	1800	1885.714
Bonding Agent	-	-	-	44	32	25.143

Table 3 Properties of mortar

Specimen	Mix proportion	compressive strength28 days(N/mm^2)f_{ck}	Water Absorption	Bulk Density (Kg/m^3)
Conventional mortar	1:3	18.056	6.467	2154.047
	1:4.5	13.04	8.571	1991.12
	1:6	8.359	10.133	1978.805
Mortar with Bonding Agent	1:3	19.394	3.519	2183.411
	1:4.5	14.378	5.073	2133.207
	1:6	10.031	7.700	2019.537

5.0 Testing Procedure

Three types of test like tensile bond strength, shear bond strength and flexural bond strength of the masonry specimens were carried out. The three types of specimens were prepared by using two types of bricks (clay, fly ash) and two types of mortar (conventional mortar, mortar with chemical admixture) with variousmortar grades like H1(1:3), H2(1:4.5) and M1(1:6). For each type of test 3 specimens were prepared, totally 36 specimens were prepared. The mortar thickness was maintained as 12mm for all types of specimen. The prepared specimens were cured for 28 days before testing. The prepared specimens were tested by using UNIVERSAL TESTING MACHINE having capacity of 1000kN.

1. Tensile Bond strength

To find the bond strength between two bricks crossed brick couplet specimens were prepared. The brick couplet specimen model was shown in Fig1

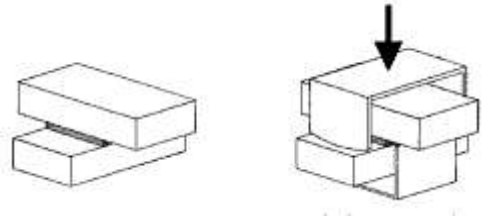

Figure 1: Brick Couplet

2. Shear bond strength

To find the shear strength of the masonry specimen, brick triplet specimens were prepared. Three bricks were joined in the long face by mortar[3]. The middle one was 75mm above than the other two. Shear force was applied on the top of the middle brick. The triplet specimen model was shown in Fig 2.

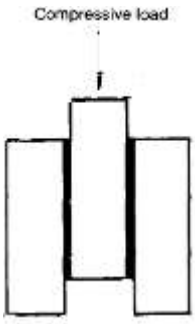

Figure 2: Brick Triplet

3. Flexural bond strength

To find the flexural strength of mortar 10 courses of stack bonded prism was used. The prism was placed horizontally under UDL. The specimen model was shown in Fig 3.

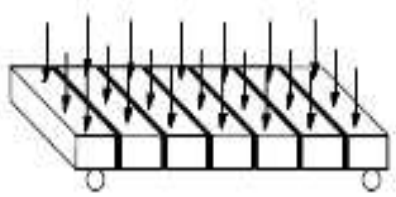

Figure 3: Stack bonded prism

6.0 Result and Discussion

6.1Tensile Bond strength

Bond strength of brick masonry was calculated by using brick couplet specimen. Compressive load was applied to create a tensile force on the mortar joint. Bond strength was calculated by finding the ratio between ultimate load and mortar area. The average bond strength values of all specimens were presented in table 4.

Table 4: Tensile bond strength

Type of brick	Type of mortar	Mix proportion	Tensile Bond strength N/mm^2 (f_{tb})	f_{tb}/f_{ck}
Clay brick	Conventional mortar	1:3	0.4222	0.0233
		1:4.5	0.4037	0.0309
		1:6	0.3698	0.0442
	Mortar with bonding agent	1:3	0.4684	0.0241
		1:4.5	0.4006	0.0278
		1:6	0.3821	0.0380
Fly ash brick	Conventional mortar	1:3	0.4192	0.0232
		1:4.5	0.3726	0.0285
		1:6	0.3639	0.0435
	Mortar with bonding agent	1:3	0.4309	0.0222
		1:4.5	0.3726	0.0259
		1:6	0.3202	0.0319

From the table no. 4 it was observed that the H1 grade mortar having higher bond strength than H2 and M1grades on both conventional mortar and mortar with admixture. When the sand content was increased the bond strength value gets reduced. While comparing conventional mix and the mortar with chemical admixture, it is observed that the mortar with chemical admixture shows some improved strength. At the same time the bond strength of the masonry was purely based on the type of brick. Because clay brick shows improved bond strength property than fly ash brick.

From the test results an approximate relation was arrived for each type of mix between tensile bond strength of masonry specimen and compressive strength of the mortar. They were

For H1 grade - $f_{tb}= 0.0232\ f_{ck}$-------- (1)
For H2 grade - $f_{tb}= 0.0282\ f_{ck}$-------- (2)
For M1 grade - $f_{tb}= 0.0394\ f_{ck}$-------- (3)

By using the above relationship we may easily find the tensile bond strength value of the specimen for various compressive strength of mortar.

Figure 1: Test arrangement and failure mode of brick couplet

By observing the fig 1, the brick was failing before the mortar failure. This behavior was observed in clay brick with mortar with chemical admixture.

6.2 Shear bond strength

Compressive load was applied on the top of the center brick and the maximum load was noted. Shear strength was calculated by finding the ratio between load and area parallel to the mortar joint. Theaverage shear bond strength values of the specimens were presented in table 5.

Table 5: Shear bond strength

Type of brick	Type of mortar	Mix proportion	Shear bond strength N/mm^2 f_{sb}	F_{sb}/f_{ck}
Clay brick	Conventional mortar	1:3	3.0952	0.1714
		1:4.5	2.6666	0.2044
		1:6	1.9238	0.2301
	Mortar with bonding agent	1:3	3.0666	0.1581
		1:4.5	2.7428	0.1907
		1:6	2.7238	0.2715
Fly ash brick	Conventional mortar	1:3	2.2952	0.1271
		1:4.5	2.0000	0.1533
		1:6	1.6190	0.1936
	Mortar with bonding agent	1:3	3.0476	0.1571
		1:4.5	2.6476	0.1841
		1:6	1.9047	0.1898

From the table it was observed that the H1 grade mortar having higher shear strength than H2 and M1 grades. While comparing the conventional mix and the mortar with chemical admixture, the mortar with chemical admixture shows some improved strength.

Figure 2: Failure mode of brick triplet

While applying the load on the triplet specimen various types of failures are occurred. In 50% specimen's only one face was failed without any crack on brick while applying the load. In 30% specimens both the faces were failed without any cracks on bricks. Remaining 20% of specimens mortar was failed after the cracks appeared in bricks. But these results were not observed in fly ash brick.

From the test results similar to equations (1), (2), (3) an approximate relation was arrived for each type of mix between shear bond strength of masonry specimen and compressive strength of the mortar. They were

For H1 grade - f_{sb}= 0.0232 f_{ck}-------- (4)
For H2 grade - f_{sb}= 0.0282 f_{ck}-------- (5)
For M1 grade - f_{sb}= 0.0394 f_{ck}-------- (6)

By using the above relationship we may easily find the shear bond strength value of the specimen for various compressive strength of mortar.

6.3 Flexural bond strength

Uniformly Distributed load was applied on the top of the brick specimen and the maximum load was noted. Flexural strength was calculated by finding the ratio between Bending Moment and Moment of Inertia. The average flexural bond strength values of the specimens were presented in table 6.

Table 6: Flexural bond strength

Type of brick	**Type of mortar**	**Mix proportion**	**Flexural bond strength (N/mm^2) f_{fb}**	**f_{fb}/f_{ck}**
Clay brick	Conventional mortar	1:3	14.8653	0.8232
		1:4.5	10.6181	0.8142
		1:6	10.6181	1.2702
	Mortar with bonding agent	1:3	15.5732	0.8029
		1:4.5	14.1575	0.9846
		1:6	12.7417	1.2702
Fly ash brick	Conventional mortar	1:3	15.5920	0.8635
		1:4.5	11.3397	0.8696
		1:6	9.9222	1.1870
	Mortar with bonding agent	1:3	19.8444	1.0232
		1:4.5	12.7571	0.8872
		1:6	11.3397	1.1304

By observing the table 6, mortar with chemical admixture gives the higher value than conventional mortar mix.While applying the load the stack bonded prism was failed into three numbers of pieces. Sudden failure on the mortar joint was observed in all types of specimens.

From the test results similar to equations (1) to (6) an approximate relation was arrived for each type of mix between flexural bond strength of masonry specimen and compressive strength of the mortar. They were

For H1 grade – f_{fb}= 0.8782 f_{ck}-------- (7)
For H2 grade – f_{fb}= 0.8889 f_{ck}-------- (8)
For M1 grade – f_{fb}= 1.2144 f_{ck}-------- (9)

By using the above relationship we may easily find the shear bond strength value of the specimen for various compressive strength of mortar.

7.0 Comparison of Results

A comparison between tensile bond strength and shear bond strength was made to find the relationship between tensile and shear bond strength values. A model graph was plotted between bond strength and shear

strength as shown in fig no 4. Likewise a model graph was plotted between tensile bond strength and flexural bond strength as shown fig no 5.

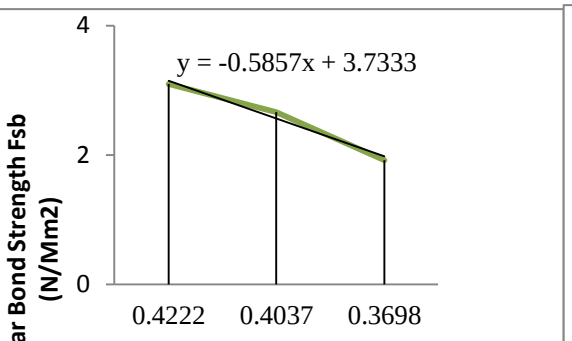

FIG 4: tensile bond strength vs shear strength

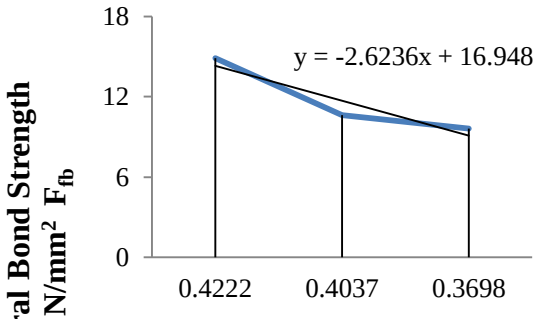

Fig 5: Flexural Bond Strength Vs Tensile Bond Strength

From the graph it is observed that the shear bond strength and the flexural bond strength values will depend on the tensile bond strength of masonry specimen. An equation also arrived for the model graph to find the shear bond strength and flexural bond strength by using tensile bond strength of masonry.

8.0 Conclusion

Based upon this study following conclusions were arrived.

- The strength property of the masonry was mainly influenced by the strength of the mortar.
- The mortar with chemical admixture shows improved strength than the conventional mortar.
- Comparing the test results, the bricks and mortar with higher tensile bond strength gives higher shear strength and higher flexural strength.
- While comparing the clay brick and fly ash brick, clay brick shows good bonding property, with the mortar so the strength of clay brick masonry is higher than the fly ash brick masonry.
- Based on the equation 1 to 9, the approximate value for tensile bond strength, shear bond strength and flexural bond strength of masonry can be obtained with respect to the compressive strength of mortar.

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