EXPERIMENTAL STUDY ON EFFECT OF MORTAR AND BASE TO HEIGHT RATIO ON COMPRESSIVE STRENGTH OF BRICK PRISM

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Abstract*—The compressive strength of masonry is the most important material property for the design of structural masonry. The behavior and strength of masonry prisms under compressive loading has been a fundamental research topic. In most practical applications, the compressive forces are applied normal to the masonry bed joint and thus the masonry compressive strength is obtained by subjecting the masonry prisms in compression normal to the bed joint in the experimentation. However, there are other masonry members that rely on the compressive strength of masonry either parallel or inclined with an angle to bed joints such as masonry beams or masonry infills. The main objective of the present study is to determine the optimum mix ratio of cement-sand mortar to obtain maximum compressive strength. Bricks are used to determine the compressive strength of brick prisms. Conventional red brick of size 225x100x75 are used for test. Bricks are arranged in English bond pattern with too many layers as per requirement. Each layer of bricks is bonded with the 12mm thickness mortar. We made three number of sample of height of 30cm, 60cm, 120 cm, and 180cm. For the average value of compressive strength is taken into account we made prism for 1:4 and 1:8 ratio of cement mortar. Brick prism is cured using gunny bags. Compressive strength is determined at 28 days curing time, by using "Universal Testing Machine".

***Index Terms*—Bricks Prism, Cement Mortar, Compressive Strength Test.**

I. 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, easy availability, and locally available material and skilled labor. Mathematical modeling of structures with masonry walls requires the material properties and constitutive relationships of masonry and its constituents, i.e., bricks and mortar, which are not easily available because of scarcity of controlled experimental tests and significant variation in material properties geographically.

Housing is one of the basic need for human beings. Masonry is an unavoidable component in of housing. Masonry has been use to construct significant structure since the beginning of civilization. Among all other types of masonries, brick masonry is widely used through-out the world because of easy availability of raw material, good strength, easy construction and heat insulation property. However, the structural use of masonry experienced a decline in the past 100 years due to the slow development and implementation of rational design standards. Brick masonry is a composite material of systematic arrangement of brick units and mortar joints. The behavior of masonry is dependent on the properties of its constituents such as brick units and mortar separately and together as a unified mass.

The performance of brick masonry depends on its compressive strength as well as on the bond strength at brick mortar joint. The bond strength is affected by brick properties such as initial rate of absorption, moisture content in bricks at the time of laying and mortar grade. Initial rate of absorption is often neglected by the design codes although it is an important factor for deciding strength of brick-mortar bond. The optimum moisture content in bricks at the time of laying with mortar to achieve good bond strength is not well documented.

II. LITERATURE REVIEW

Hegemier et al. (1978) investigated the compressive strength of concrete masonry prisms normal to the bed joint. The authors found that prism strength was primarily a function of the number of bed joints and not the h/t ratio. Bond pattern was observed to have an effect on strength. The authors recommended that prisms be constructed from four or five courses with either three or four mortar bed joints.

Drysdale and Hamid (1979) performed 146 axial compression tests on concrete block masonry prisms and established that a 3-course block prism is preferred to 2-course high block to represent the behavior close to a real wall. It was found that Type N mortar, which has lower strength than Type S mortar, only resulted in a 10% decrease in prism strength and a large increase in grout strength resulted in a relatively small increase in prism capacity.

Boult (1979) aimed to determine a relationship between the compressive strength and the height of concrete masonry prisms made of different types of masonry blocks. A series of stack bonded prisms with h/d (height-to-least lateral dimension) of 2 to 5 were constructed for each masonry unit type. Test results showed that the compressive strength decreased as the prism height increased and the rate of decline was dependent on the block type. Results also showed that the decrease in strength as height increased appeared to be insignificant between the 5-course high prisms and the 12- course high columns. Boult suggested that careful consideration of the material properties of the units and grout should be taken into account when assembling the prisms.

Drysdale and Hamid (1980) studied the failure modes and strength of both the concrete and brick masonry prisms when subjected to compression applied at designated angles in relation to the bed joint. Axial compression both parallel and normal to the bed joint was considered as well as θ of 15º, 45º and 75º. Regular flat ended concrete blocks, Type S mortar and a medium strength grout was used for all prisms. Results showed that grout had a maximum contribution for θ= 15º and no significant contribution for θ= 75º. It was observed that two major failures were exhibited for both ungrouted and grouted prisms; a shear mode failure along the bed or head joint and a tensile failure of the prism. For θ=15º, large shear stresses and small normal stresses were developed along the bed joint resulting into a shear-slip failure. For θ= 75 º, high shear stresses and low normal stresses along the head joint resulted in a shear-tension failure. For θ= 45º, a mixed shear-tension mode of failures was developed since shear and normal stresses were balanced along the bed and head joints. The maximum prism strength was achieved when prisms were compressed at an angle normal to the bed joint. The authors underlined the importance of considering the effects of the stress orientation along the bed joint when determining the strength of masonry in design.

Brown and Whitlock (1982) showed that high strength grout and mortar, high tensile strength brick and low brick coring percentage are several factors that increased prism strength. For most prisms tested, it was found that the simple superposition of the strength of grouted core and the hollow brick prisms overestimates the strength and the contribution from the grout.

Lee et al. (1984) tested 82 grouted and ungrouted concrete masonry prisms under compression both parallel and perpendicular to the bed joints. The effects of several parameters on the compressive strength in the two different loading orientations considered were the mortar and grout strength, and head mortar joint detail. The authors noted that for prisms loaded parallel to the bed joint, the head joint had a significant effect on the behavior of the prism and was recommended that the head joints be completely filled. The mortar strength was found to be an important parameter in affecting the strength of prisms loaded parallel to the bed joint; a maximum increase in prism strength of 52% is noted with the use of a stronger mortar. A significant increase in grout strength is found to have a small effect on prism strength.

Wong and Drysdale (1985) tested prisms made from hollow, solid and grouted concrete block units subjected to compression both normal and parallel to the bed joint. Prisms of 2 to 5 courses high were tested for both hollow and grouted concrete block units. Two types of blocks were used to build the prisms, a 190 mm two-cell stretcher unit and a solid 190 mm block. Type S mortar and a medium strength grout were used in all prisms. The authors found that the compression parallel to the bed joint is 25% lower than the compression normal to the bed joint. In addition, they confirmed that grouted and solid prisms exhibited 35% lower strength than hollow prisms and this is valid for both loading directions. Wong and Drysdale recommended that design standards should take into account the properties of the prisms for all directions of compression forces and treat the prisms separately.

McNary and Abrams (1985) evaluated the strength and deformation of clay brick masonry under uniaxial compressive force. The constitutive relations of bricks and mortar were established by performing biaxial tension-compression tests on brick units and triaxial compression tests on mortar. The force-displacement relation for stack-bonded prisms was derived from a numerical model. The results were then compared with experimental values and a relation was established. The failure pattern of the masonry was also well recorded in the study. The mechanics governing the failure in a stack-bonded prism was analysed and explained. It was found from the analysis that mortar initiates the tensile stresses that cause tensile splitting of masonry prisms. The masonry prism strength was found to depend upon the strength of brick unit under biaxial tension-compression stresses.

afat Siddique (2003) performed experimental investigation to study the effects of replacement of cement (by mass) with three percentages of fly ash (35 %, 45 % and 55 %) and the effects of addition of natural san fibers on the slump, vebe time, compressive strength, splitting tensile strength, flexural strength and impact strength of fly ash concrete. The test results indicated that the replacement of cement with fly ash increased the workability (slump and vebe time), decreased compressive strength, splitting tensile strength and flexural strength and had no significant effect on the impact strength of plain (control) concrete. Addition of san fibers reduced the workability, did not significantly affect the compressive strength, increased the splitting tensile strength and flexural strength and tremendously and enhanced the impact strength of fly ash concrete as the percentage of fibers increased.

Bouzoubaa et al (2001) examined the mechanical properties and durability of concrete made with a high-volume fly ash (HVFA) blended cement using a coarse fly ash that does not meet the fineness requirement of ASTM C 618. The results were compared with those of the HVFA concrete in which ungrounded fly ash had been added at the concrete mixer. The results showed that except for the resistance of the concrete to the deicing salt scaling, the mechanical properties and the durability of concrete made with this blended cement were superior to the concrete in which the ungrounded fly ash and the cement had been added separately in the mixer. Therefore, the production of HVFA blended cements offers an effective way for the utilization of coarse fly ashes that do not otherwise meet the fineness requirements of ASTM C 618.

The strength of roller-compacted concrete with high volume fly ash (HFRCC) is examined by Cheng Cao et al (2000). From the experimental results it was concluded that (1) The strength at early ages of HFRCC is poor, while the fly ash effect is low or negative. (2) The strength of HFRCC increases rapidly following its curing age; meanwhile, the fly ash effect gradually improves and is more beneficial to raising flexural strength. (3) With increasing proportion of fly ash, its effect on HFRCC at long curing age becomes more remarkable.

Sivasundaram et al (1990) monitored the strength development of high volume fly ash concrete over a period of 3 years, and it reached a maximum compressive strength of 70 MPa at 1/2 years. The modulus of elasticity of this concrete at 2 years was 47 GPa. Following its excellent performance in the laboratory investigations, this concrete was utilized in a field application.

III. MATERIALS USED FOR PRESENT INVESTIGATION

Cement

Cement is the most important ingredient in construction. The characteristics of cement on water demand is more noticeable. Some of the important factors which play vital role in the selection of cement are compressive strength at various ages, fineness, heat of hydration, alkali content, tricalcium aluminate (C3A) content, tricalcium silicate (C3S) content, dicalcium silicate (C2S) content etc. Ordinary Portland Cement, 43 Grade conforming to BIS: 12269-1987. The properties of cement were determine as per IS 4301:1968 & results of the tests on cement sample are listed in Table 1.

Table 1 Test results for Ultratech 43 OPC

S.No.	Tests	Results
1	Normal consistency	29%
2	Initial Setting Time	85 Minutes
3	Final Setting Time	195 Minutes
4	Specific Gravity	3.10
5	7 days compressive strength of cement	46.7 N/mm^2

Fine Aggregate

River sand of BINAWAS was used as fine aggregate. Properties of natural aggregates. The properties should comply with the norms laid down in IS 383:1970 specifications for fine aggregates from natural sources for concrete. Aggregates should be chemically inert strong, hard, durable of limited porosity free from the properties of the fine aggregates are in table 2.

Table 2 Sieve Analysis Test results for fine aggregate (sand)

No.	Sieve Size	% passing	from table IS 383-1970 for Zone II% Passing
1.	4.75 mm	97.3	90-100
2.	2.36 mm	94.0	85-100
3.	1.18 mm	81.4	75-100
4.	600 micron	64.4	60-79
5.	300 micron	41.6	12-40
6.	150 micron	5.0	0-10
7.	Pan	0.0	-

Above sieve analysis conforms to fine aggregate of zone III and specific gravity 2.48 and voids content 32.6%.

Bricks

Bricks are the most commonly used construction material. Bricks are prepared by moulding clay in rectangular blocks of uniform size and then drying and burning these blocks. Compressive strength of normal red brick are variable for different classes. It may vary from 30 kg/ cm^2 to 70 kg/cm^2. In this investigation used bricks having compressive strength are 42kg/cm^2 and water absorption of bricks are 19%. The bricks used are second class brick.

IV. EXPERIMENTAL PROGRAM

The design of this thesis experiment was developed to get knowledge of response of brick masonry under the compressive loading when the sand and cement ratio of mortar is different with change in slenderness ratio and to get answer of a question that under compression the bond between brick and mortar is durable.

Methodology

Bricks are used to determine the compressive strength of brick prisms. Conventional red brick of size 225x100x75 are used for test. Bricks are arranged in English bond pattern with too many layer as per requirement. Each layer of bricks are bonded with the 12mm thickness mortar. We made three number of sample of height of 30cm, 60cm, 120 cm, and 180cm. For the average value of compressive strength is taken into account we made prism for 1:4, 1:8 ratio of cement mortar. Brick prism is cured using gunny bags. Compressive strength is determined at 28 days curing time, by using “Universal Testing Machine”.

Mix Proportion

The cement mortar mix used for the experimental study was 1:4 and 1:8. The quantity of materials required to make three number of brick prism are in the given Table 3.

Table 3 Mix Proportion Details

BRICK PRISM Ht.	MIX RATIO	FINE AGGREGATE IN Kg	CEMENT IN Kg
30CM	1:4	20	5
60CM	1:4	40	10
120CM	1:4	80	20
180CM	1:4	120	30
30CM	1:8	24	3
60CM	1:8	48	6
120CM	1:8	96	12
180CM	1:8	144	18

Identification of the Brick Prism

W I/D- 4A1, 4A2, 4A3, 4B1, 4B2, 4B3, 4C1, 4C2, 4C3, 4D1,4D2, 4D3, 8A1, 8A2, 8A3, 8B1,8B2, 8B3, 8C1, 8C2, 8C3, 8D1, 8D2, 8D3
4= cement sand ratio 1:4
8= cement sand ratio 1:8
A= 30 cm specimen
B= 60 cm specimen

C= 120 cm specimen
D= 180 cm specimen
1, 2 and 3 numbering on specimen of same height.

Casting of the Brick Prism

Locally available second class bricks were used to construction of brick prisms. The prisms are divided in two type of cement sand ratio i.e.1:4 &1:8. Four different height prisms are constructed for each ratio i.e. 30 cm, 60 cm, 120 cm, 180 cm.

The required quantity of sand and cement is calculated previously according to the required cement mortar ratio. Then they mixed properly. Then brick cube prepared. The casted brick prisms were kept under normal atmosphere for next one day. Then it was kept under curing using gunny bags, process for a period of 28 days. The photograph of the specimens of brick prisms shown in fig. 1.

Figure 1 Brick Prisms

V. TEST PROGRAM AND RESULT DISCUSSION

Compressive Strength Test for Brick Prisms

The compressive strength test is the most common test conducted because most of the desirable characteristic properties of mortar and the structural design purpose are quantitatively related to compressive strength. The test was conducted in calibrated compression testing machine of 50 ton capacity as per the specifications given in IS-3495. The prisms were properly held in position to apply axial load gradually till the crushing load is reached. The test specimen with flat face horizontal and mortar filled face facing upward between ply wood, and carefully centered between ply wood were tested for compression by axially applied load at the rate of 5 KN per minute till the failure. The crushing load was noted.

Compressive Strength Test Results

As the height of bricks prism was increase the compressive strength of prism decrease. As the ratio of cement and sand was change the strength of brick prisms changed. Initially the brick masonry prism of 1:4 & 1:8 mortar in normal red bricks was constructed. The curing was done with the help of gunny bags with water for 28 days. Then the specimens were tested for compressive strength in the Universal testing Machine shown in fig. 2.

The results found after the testing of the bricks prism are given below.

Figure 2 Preparations for Test with Universal Testing Machine

Table 4 Compressive Strength of 1:4 Mix Prism of Different Height

I/D	Size	Load	Area	Strength	Avr. Compressive Strength
	Cm²	Tons	Cm²	Kg/Cm²	
4A1	21.5x22	14.8	473	31.29	31.89
4A2	22x22	15.5	484	32.02	
4A3	21.5x21.5	15.3	462.25	33.10	
4B1	21.75x22	13.8	478.5	28.84	28.89
4B2	21.5x21.75	14	467.63	29.94	
4B3	22x22	135	484	278.93	
4C1	21.5x22	11.5	473	24.31	24.39
4C2	21.5x22	11.3	473	23.89	
4C3	22x22	11.8	484	24.38	
4D1	22.5x22	10.6	495	21.41	22.09
4D2	21.5x22	10.8	473	22.83	
4D3	21.75x21.5	10.3	467.63	22.03	

Table 5 Compressive Strength of 1:8 Mix Prism of Different Height

I/D	Size	Load	Area	Strength	Avr. Compressive Strength
	Cm²	Tons	Cm²	Kg/Cm²	
8A1	22x22	12.13	484	25.06	26.35
8A2	21.5x22	12.71	473	26.87	
8A3	21.5x21.5	12.54	462.25	27.13	
8B1	21.5x22	11.32	473	23.93	23.61
8B2	21.75x22	11.5	478.5	24.03	
8B3	22x22	11.07	484	22.87	
8C1	22x22	9.43	484	19.48	19.72
8C2	21.5x22	9.3	473	19.66	
8C3	22x22	9.7	484	20.04	
8D1	21.75x21.5	8.7	467.62	18.60	18.35
8D2	21.5x22	8.9	473	18.82	
8D3	21.75x21.5	8.5	467.62	18.18	

Table 6 Comparison of Compressive Strength of 1:4 to 1:8 Mortar Ratios for Different Height

Specimen	Avg. Compressive Strength Of 1:4 Mix	Avg. Compressive Strngth Of 1:8 Mix	% Variation
A	31.89	26.35	-17.37
B	28.89	23.61	-18.27
C	24.39	19.72	-19.14
D	22.09	18.35	-16.93

Table 7 Variation in Strength of Bricks Prisms with Change in Slenderness Ratio for 1:4 Mortar Mix.

Specimen	Avg. Compressive Strength Kg/ Cm²	% Change With Specimen "A"
A	31.89	-
B	28.89	-9.40
C	24.39	-23.52
D	22.09	-30.73

Table 8 Variation in Strength of Bricks Prisms with Change in Slenderness Ratio for 1:8 Mortar Mix.

Specimen	Avg. Compressive Strength Kg/ Cm²	% Change With Specimen "A"
A	26.35	-

B	23.61	-10.39
C	19.72	-25.16
D	18.35	-30.36

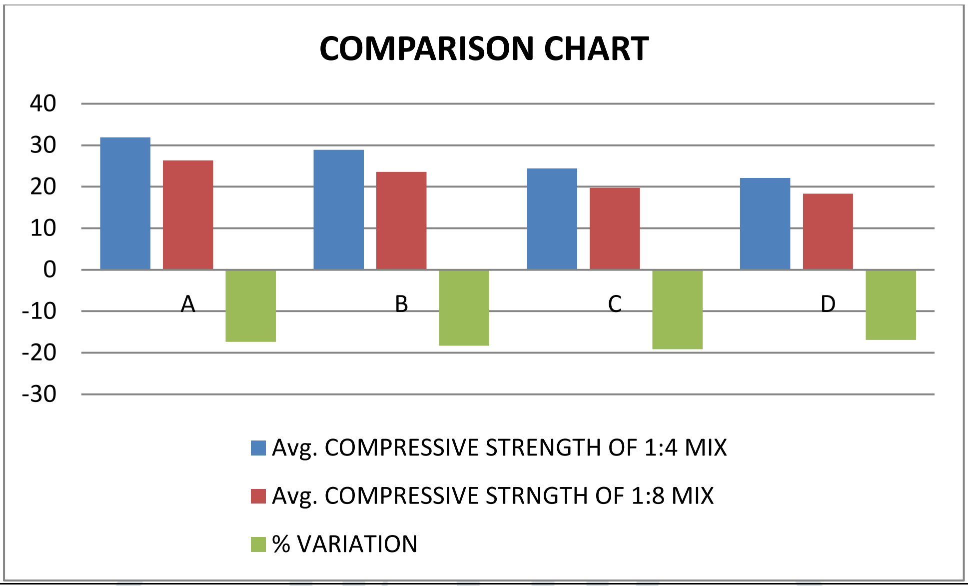

Figure 3 Comparisons between Compressive Strength of 1:4 and 1:8 Cement Mortar Mix with Percentage Variation

The result shows that the compressive strength of the brick masonry prisms are more when the height of the prism is short. As the height of prisms increases the compressive strength will decreases. These results also show that the height of brick masonry prism was increase the deflection was increase.

Results also show that as the ratio of cement sand mortar change the compressive strength will also affected. The strength of brick masonry prism with 1:4 mortar is higher than the strength of brick masonry prism of 1:8 ratio. The result of the deflection is also varies with the change in mortar ratio. The deflection in 1:8 mortar prisms is relatively more as compare to the deflection in 1:4 mortar prisms.

Its means that the rich mix mortar have higher strength in bonding and also in compression. The height of the masonry increase the deflection which provide low strength in compression. In the high length prism the deflection increases with high amount as shown in result.

VI. Conclusions

In this investigation from the above experimental Study, Following conclusions are observed.

1. Strength of first specimen “A”(30cm height) of 1:4 mortar ratio is 17.37% more than that of 1:8 mortar ratio
2. Strength of second specimen “B”(60cm height) of 1:4 mortar ratio is 18.27% more than that of 1:8 mortar ratio.
3. Strength of second specimen “C”(120cm height) of 1:4 mortar ratio is 19.14% more than that of 1:8 mortar ratio.
4. Strength of second specimen “D”(180cm height) of 1:4 mortar ratio is 16.93% more than that of 1:8 mortar ratio.
5. By above all four the result shows that the strength of 1:4 mortar mix masonry is better than the poor one
6. Result shows that the compressive strength of small brick masonry prisms (30cm) is comparatively good than the other height (60cm, 120cm, and 180cm) in 1: cement-sand mortar mix
7. Compressive strength of 30cm brick masonry prism is higher than 60cm, 120cm and 180cm with the cement-sand mix mortar of 1:8
8. The result shows that as the height is increases compressive strength decease whatever the mix proportion is
9. As the height of specimen of 1:4 and 1:8 mix mortar increases the deflection also increase.

As per all above, compressive strength of bricks masonry is depend on individual compressive strength of bricks and mortar. Also depend on the height of masonry because first the masonry go through the pure compression and afterward it go through bending with compression. It’s also depend on the mortar mix ratio as the mix is rich it bear more load as compare to the less cement contain mortar.

Limitation of work

1. The compressive strength of individual brick affects the compressive strength of masonry.
2. Voids between mortars affect the strength of masonry.
3. The irregular shape of brick affects the strength.
4. Impurities present in bricks affects compressive strength.
5. Mortar not mix properly will also affect the strength

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