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Evaluation of Compressive Strength and Basic Compressive Stress of Clay Brick Unreinforced Masonry by Prism Test

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Abstract: ***The compressive behavior of clay brick unreinforced masonry has been studied. As Masonry is normally provided for resisting compressive forces, compressive strength is the basic and important property of masonry and it is always required for design, repair or retrofitting of Masonry structures. Masonry constitutes of two different materials; bricks and mortar. The experimental results of bricks, mortar and brick masonry prisms are presented here with brief description of testing procedure. The basic compressive stress of unreinforced masonry prisms determined experimentally have been compared with the basic compressive stress of the same obtained by using IS 1905-1987. The failure mechanism of prisms under uniaxial compressive load has been discussed.***

Keywords: Bricks, Mortar, Masonry, Compressive Strength.

1. Introduction

Brick Masonry is heterogeneous, nonelastic material. It is composed of two very different materials; bricks and mortar. Further the large variety in basic materials; bricks and mortar makes the behavior of masonry more complex to characterize. The properties of bricks vary from region to region depending on the nature of available soil and technique adopted for moulding and burning. The mortar grade basically depends on the properties of constituents such as cement, sand, lime etc.

Masonry is very week in resisting tension therefore it is normally provided for resisting compressive forces only. Hence compressive strength of masonry is very important property required for design, strengthening and retrofitting of masonry structures or elements such as walls, columns or arches. One of the objectives of this study is to add reliable experimental data base.

2. Literature Survey

Literature survey reveals that less research work on masonry has been carried out as compared to concrete, all over the world. In India, work on characterization of mechanical properties of brick masonry [1].

Bricks are the basic masonry units used in masonry construction. Bricks have the advantage over stone of easy construction and require less labour for laying. Properties of bricks depend on the soil used and it varies from places to places. The normal strength of bricks in India is in the range of 7 to 10 N/mm^2. Krevaikas et al. have reported the experimental results of compressive strength of bricks as average 23.5MPa in Greece region [2]. In Germany bricks which are used for masonry structures are of compressive strength of order 20MN/m^2 [3]. Borri et al. have found the compressive strength of bricks in Italy region of the order 20MPa [4]. In many Western countries bricks of even medium quality have crushing strength in the range of 30 to 50 N/mm^2 [5]. It has been reported by BIS (Bureau of Indian Standards) that recently manufactured brick plants have been set up at a few places in country which are producing bricks of strength 17.5 to 25 N/mm^2 [5].

3. Compressive Strength of Basic Materials

Masonry constitutes of Bricks and Mortar. The properties of masonry depend on properties of Bricks and Mortar. Hence it is essential to determine the compressive strength of basic materials first.

3.1 Compressive Strength of Bricks

Five brick specimens from 'Maharashtra' state were tested for compressive strength as per IS 3495 (Part 1): 1992 [6]. The test included two stages as 'Specimen Preparation' and 'Testing'. Unevenness in bed faces was removed to have smooth and parallel faces by grinding. Grinding had to be done very carefully as bricks breaks easily. Specimens were immersed in water at room temperature for 24 hrs. The frog on bricks was filled by cement mortar (1: 1). Specimens were kept inside damp jute bags for 24 hrs. Then specimens were immersed in clean water for 3 days. After completing the above tasks, specimens were ready for testing. Exact dimension of each brick specimen was noted before test. Specimen was placed horizontal, filled face upwards between 3mm thick ply pieces in Compression Testing Machine (CTM) of capacity 200 Tonnes (Figure 1). Load was applied axially till failure and maximum load was noted for each brick specimen. Figure 1 shows the values of compressive strength of five brick specimens.

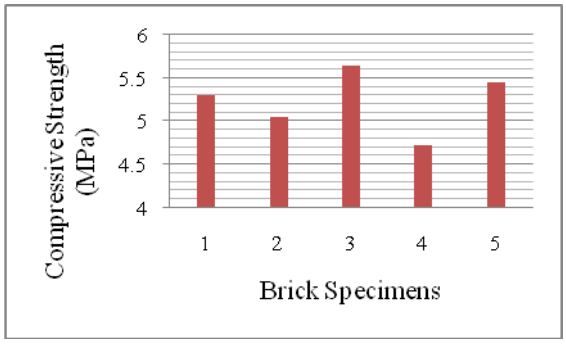

Figure 1: Compressive Strength of Brick Specimens

The average experimental strength calculated experimentally is 5.328 MPa which goes in line with the compressive strength stated by BIS in SP20 for Maharashtra state [5].

The IS 3495 (Part 1 to 4): 1992 [6] gives the test procedure for determination of various properties of bricks such as compressive strength, water absorption, efflorescence and warpage respectively. Test procedure for determination of Modulus of Elasticity of brick is not provided in this Indian Standard.

3.2 Compressive Strength of Mortar

Mortar is a mixture with water of a binder such as cement or lime and some inert material such as sand in the form of smooth paste. Mortars play important role of binding masonry units together into one mass. There are various types of mortars such as cement-mortar, lime-mortar, cement-lime mortar and lime pozzolana mortar. IS 2250: 1981 [7] gives a table for standard mortar mixes for masonry commonly used. The mortar types are designated as H1, H2, M1, M2, M3, L1 and L2 with different proportions and combinations of ingredients; minimum compressive strengths of these groups are also specified in the table. Such 26 mixes are provided in IS code. Guidelines for proper choice of mortar are also provided in this code.

In the present work, cement mortar of proportion 1:8 and 1:8 (cement: sand) are used for casting of masonry prisms. The compressive strength of mortars has been obtained by testing the mortar cubes of dimension 70 x 70 x 70 mm as per IS 2250:1981 [7]. Photograph of mortar cube being tested in CTM and of failed specimens has been provided here (Figure 2).

Figure 2: Testing of Mortar

The average compressive strength obtained from testing for 1:8 mortar is 1.53 MPa.

4. Compressive Strength of Masonry by Prism Test

Compressive behavior of masonry depends on both bricks and mortar. The value of compressive strength of masonry is always required for design, repair or retrofitting of masonry structures or elements. The basic compressive stress of masonry can be obtained experimentally or from IS code tables. In present study the compressive strength of masonry is determined experimentally by prism test and results of basic compressive stress are compared with IS code tables.

4.1 Compressive Strength of Masonry by Prism Test

IS 1905-1987 [8] gives the procedure for testing of masonry prism for determination of compressive strength of masonry. Also ASTM C 1388-97 [9] is for standard test method for compressive strength of Laboratory Constructed Masonry Prisms and ASTM E447- ASTM standard test methods for compressive strength of masonry assemblages [10]. Details about specimen sizes, material properties, instrumentation for the tests are discussed herewith.

- **Specimen Sizes**

As per IS1905-1987 [8], assembled specimen shall be at least 40cm high and shall have a height to thickness ratio (h/t) of at least 2 but not more than 5. As per ASTM E447 the specimen should have height at least twice the thickness or a minimum of 15 inch (381 mm). The height should not exceed 5 times the thickness [10]. Hence in both codes h/t ratio should be between 2 to 5 and minimum height 381mm as per ASTM E447 [10] and 400 mm as per IS1905-1987 [8]. Considering all these code provisions and dimensions of bricks; the specimen size were finalized as 215 x 215 x 470 mm and 200 x 200 x 470 mm. Figure 3 shows the cast masonry prisms which were tested after 28 days.

Figure 3: Brick Masonry Prisms

- **Materials**

Bricks and cement mortar of earlier mentioned properties were used for casting the masonry prisms.

- **Instrumentation**

The tests were conducted on Universal Testing Machine (UTM) of 100T capacity. Figure 4 shows the brick masonry prism in UTM.

Figure 4: Testing of Brick Masonry Prism

5. Results and Discussion

- **Compressive Strength of Masonry**

Experimental value of Compressive strength of masonry was calculated as, maximum load taken by prism divided by the cross sectional area. However a correction factor for different values of h/t ratio is to be applied; which is suggested by IS1905-1987 [8] (Table 12). The correction factor is 1 for h/t ration of 5 and it is less than one for other values of h/t for brick masonry. The correction factor in present study was 0.76 as the prism height was 480 mm. The values of compressive strength of masonry, obtained experimentally are provided in Table 1.

Table 1: Compressive Strength of Masonry by Prism Test

Sp. No	Max Load (kN)	P / A (MPa)	Compressive Strength in MPa (after applying correction factor : 0.76)	Average Compressive Strength (MPa)
1	48	1.088	0.827	0.781
2	43	0.975	0.741	
3	45	1.020	0.775	

- **Mode of Failure**

It has been observed for each specimen that vertical cracks initiated the failure of masonry. Vertical splitting cracks were seen on all four sides of prism (Figure 5). In some of the cases the cracks caused breaking of strain gauges for the higher loads. This failure pattern has been reported by other researchers also.

Figure 5: Vertical Splitting Cracks

- **Basic Compressive Stress of Masonry**

Basic compressive stress of masonry has been calculated by using experimental value of compressive strength of masonry and by refereeing IS 1905-1987 [8]. Clause B.2.1 [8] states that to calculate basic compressive stress, the value obtained from prism test should be multiplied by 0.25. The alternative method is by using Table 5 of IS 1905-1987 [8]. The average value of basic compressive stress of masonry obtained by prism test is 0.2 MPa and by IS1905:1987 [8] is 0.29 MPa, for the clay bricks of 5 MPa compressive strength and cement mortar of 1:8 proportion.

6. Conclusions

Experimental investigations on compressive strength of clay brick unreinforced masonry are carried out by prism test. The bricks used, are from Maharashtra region and mortar of proportion 1:8 (cement:sand). The average compressive strength of bricks obtained experimentally is 5.328 MPa which matches with the BIS value of compressive strength of bricks of Maharashtra region (5 MPa). The average compressive strength of masonry obtained by prism test is 0.781 MPa. This value has been compared with the results obtained by other researchers considering the strength of bricks and mortar. Further validation of these experimental results have been done by calculating basic compressive stress from experimental compressive strength by prism test and comparing it with the basic compressive stress obtained from IS1905:1987 [8] based on crushing strength of bricks and grade of mortar. The average value of basic compressive stress of masonry obtained by prism test is 0.2 MPa and by IS1905:1987 [8] is 0.292MPa.

7. Future Scope

In the present work only one mortar proportion has been used. Similar experimentation can be carried out by considering other proportions of mortar mixes. Further more experimental and analytical work is required to be carried out to study behavior of elements of masonry structures which is very much essential for developing new techniques for strengthening of Masonry Structures.

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