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To Analysis the Structural Behavior and Properties of Burnt Clay Brick and Fly Ash Brick

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ABSTRACT: Structural behavior of masonry unit is influenced by constituents units like bricks and mortar individually and as composite mass together. As bricks are made with locally available clay with different mineral composition properties of bricks vary widely from zone to zone. Thus average value of constituting material behavior may over estimate or under estimate the design and analysis of masonry structure. For safer and economical design of masonry structure the variability of constituting material properties is necessary to be considered. So the mathematical description of the randomness of constituting material is required, the variability of mechanical properties related to steel and concrete is well researched, while the same for brick masonry has not received proper attention.

In plane strength is an important aspect in sustaining with In plane forces for achieving better in plane strength soaking is very important, as bricks absorbs moisture from the mortar which leads to in habiting hydration of cement. In this study, for mechanical behavior a number of experiments are conceded for determining initial moisture absorption rate, moisture absorption, apparent dry density, crushing strength of units, crushing strength of mortar and of the composite unit.

I. INTRODUCTION

Every creature in this universe need a habitat where they live and evolve likewise for human being that habitat is their house where they lives and spend their life. A habitat must be comfortable and safe against natural agencies [1]. Among different types of masonries, brick masonry in India is one of the most widely used and thereby because of its low cost, the easy availability of raw materials, good strength, easy construction with less supervision, possesses good sound and heat insulation properties, and easily availability of man power [2]. The behavior of brick masonry is dependent on the structure properties of its constituents such as brick units and mortar separately and to gather as a unified mass [3]. Burnt clay non modular bricks are widely used around the globe but in recent years many other varieties of bricks have been developed. Among them the fly ash bricks have gained much popularity because of its large advantages over non modular burnt clay bricks.

A number of heavy engineering industries in our country are responsible for huge production of fly ash. It is a great challenge for the management to store the fly ash without polluting the environment. Around 143 thermal power stations consume nearly 500 million tons of coal and produce as much as 173 million tons of fly ash [10]. Every year in our country. The best ways for safe disposal and reuse of fly ash is to use in production of bricks. The government too emphasizes on the use of fly ash [4].

The property of fly ash depends upon the type and quality of coal from which it is produced, burning process of coal etc. The fly ash mostly consist substantial amount of silicon dioxide, aluminum oxide and calcium oxide apart from several heavy metals [5]. On the basis of chemical compounds present in the fly ash, it is classified broadly into two types: ClassF and Class C as per ASTM C-618. The physical and chemical requirements of fly ash are prescribed in Indian Standard IS: 3812-1981.

Class F: The burning of bituminous and anthracite coal produces Class F fly ash. This fly ash contains less than 20% of calcium oxide (CaO), so it requires a cement agent such as lime, Gypsum or Portland cement to react with glassy silica and alumina to produce cementing compounds [6]. In India, most of the coal deposits are of anthracite or bituminous type. So, the fly ash produced from these coal sources are of Class F type.

II. MATERIALS AND METHODS

For preparing the test sample burnt clay bricks and fly ash bricks, PPC cement and local sand is used. Formation of masonry units are arranged in the pattern of three brick units and single brick unit. Likewise PPC cement and local cement is utilized for mortar. Detailed decryption of the materials is described below.

Brick. Primary material used in this study is burnt clay bricks and fly ash bricks. Bricks used are of two variant one is clay and second is fly ash bricks. Clay bricks produced are form kiln nearby Sirsa and class standardized by IS 1077:1992. The bricks used are First class bricks having well smooth and shaped and selected based upon field tests as specified by general field practice. Two quality of fly ash bricks are used as shown in Fig. 1(A). One is F class which has high silica and alumina and colored grey from source-I second contain high iron oxide content with silica and alumina colored brown collected from source-II.

Source I and II are thermal coal based plants located at Hissar (Haryana) and Bhatinda (Punjab). Color and properties of fly ash depends upon the type of coal used and temperature at which coal is burnt.

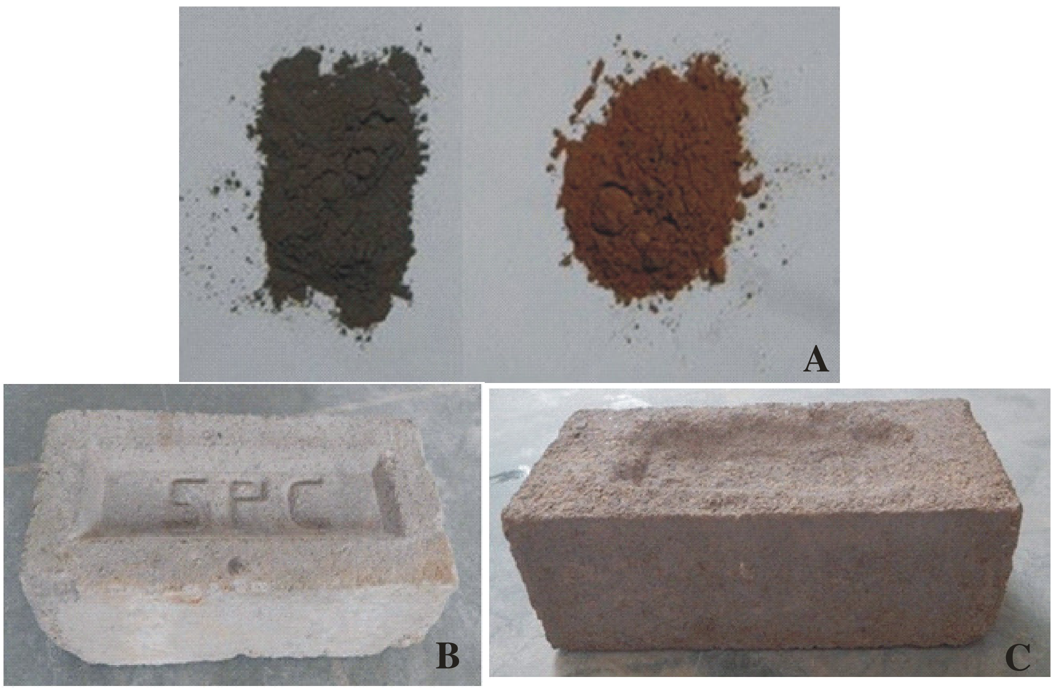


Fig. 1. (A) Quality of fly Ash. (B) BFA-1 fly ash brick. (C) BFA-2 fly ash brick.

These two verities of bricks are mainly used in the building construction work in nearby area of Sirsa and Hissar. The proportion of fly ash and other constituting material is in the usual range of. Fig. 1 (B) and (B) show the two types of fly ash bricks used in the study.

The composition and the dimensions of the bricks are presented in Table 1. the burnt clay bricks are designated as BCB, fly ash bricks from source one are designated as BFA-1 and the fly ash bricks form the second source are designated as BFA-2. Indian standard code of practice IS 3495 (part-1) is referred as standard for determining physical properties of bricks.

Table 1: Mix proportions and dimensions of brick specimens.

Designation	Mix proprtion (FA:S:C)	Dimensions in mm (Length × Breadth × Height)
BCB	constituent : Clay	235mm×110mm×75mm
BFA-1	60:30:10	235mm×110mm×75mm
BFA-2	50:40:10	235mm×110mm×75mm

Sand. Sand which is used for mortar is locally available from nearest query i.e. Panipat, and IS 2116:1980 is referred as standard specification.

Cement. Cement used is confirming to the IS 8112:1989. Type of cement used is PPC of Ultra Tech brand.

Test Procedure and Detailed Briefing

Section deals with the detailed test procedure and brief. Various other tests are conducted on the masonry units for determining the initial moisture absorption rate, moisture absorption and compression strength. Detailed description is as follow:

(i) Initial rate of moisture absorption

It is the measurement of water absorbed by a brick when immersed in water for 1 minute at a three millimeter depth. It express the area of brick wetted by amount of water in one minute, unit of measurement is Kg/M^2/min. In simple term we can say moisture absorption capacity of brick. American society of testing material Code 67 – 14 standardized the test procedure. The test procedure is described as below.

The bricks are firstly oven dried at a temperature range of 100°C to 105°C for 24 hr's. after 24 hr. bricks are allowed to cool down till they are not liable to hand operation. A metallic tray with high edge surface area greater than the brick size is filled with water to the level of 3 millimeter. After preparing the test tray oven dried bricks are placed in the tray and stop watch is started. Bricks are allowed to stay in tray for one minute along with maintain the water level equal to three millimeter during the whole duration of test. As the test time is completed the bricks are taken out of the test tray and bricks are surface dried with a cotton cloth.

Fig. 2. Test setup for determining IMAR.

These surfaced dried bricks are then weighted with a precision of 0.01 g on a weighting balance.

The weight gained in one minute is divided by the surface area wetted gives the initial rate of moisture absorption. Fig. 2. shows the test setup of initial rate of moisture absorption.

Moisture Absorption. Indian standard code of practice IS 3495:1992 standardized the test procedure. Moisture absorption is the amount of water absorbed by the bricks within 24 hr when fully immersed in water. Firstly bricks are oven dried at a temperature of 100°C to 104°C for 24 Hr. then bricks are allowed to cool down for five to six hours. Then they are weighted dry with a recession of 0.01g. after taking the dry weight. Bricks are then immersed in water for 24 hours. After completion of 24 hours the wetted bricks are taken out of water bath and excess water is wiped out and with a help of a cloth the surface is dried. The surface dried bricks are weighed again. The moisture absorption is calculated by dividing the weight of wetted brick to weight of dry brick.

Dry Density (γ_d). Density is defined as the ratio of weight of the body to volume occupied. The dry density defines the dry weight to the volume of the body. The determination of dry density is performed by Firstly calculating the dimensions of the brick with the help of venire caliber and then volume of the brick is calculated. The dry weight is calculated as describe in the moisture absorption calculation. Dry density is calcialted by dividing the dry weight of brick to the volume calculated of the brick.

Crushing Strength. Crushing strength is the measurement of the load per unit area carring ability of the bricks under the static compressive load. Indian standard code of practice IS 3495:1992 standardized the test procedure. For testing the crushing strength of a brick and masonry unit a standard mortar mix is prepared with the help of standard and with cement, ratio of 1:3 is prepared then bricks are wetted, frog of bricks are filled with this standard mix of sand and cement. Then they allow setting for 5 hours then this test specimen is allowed to cure for 24 hours with a wetted cloth. After 24 hours surface area of test sample is measured then it is placed in the compression testing machine with two ply wood planks of thickness 5mm to distribute the load uniformly over the surface areas of the bricks and allowed to break under constant compressive loading. The loading is continued till first crack is appeared in the test sample. The load is noted and by dividing the surface area with this crushing load the crushing strength is calculated. The bricks and masonry units are test by following the same test procedure. Figure 3 shows the test performance.

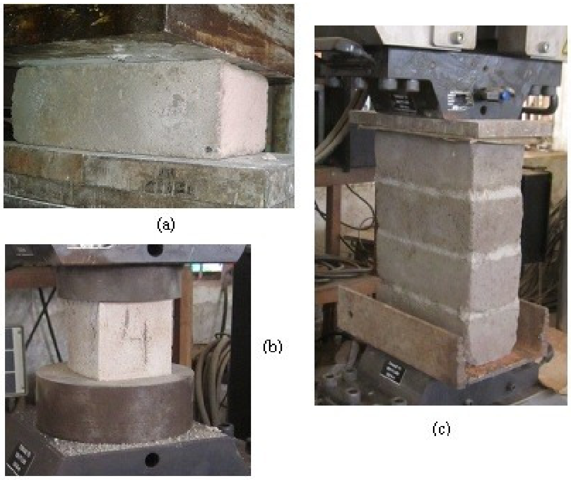


Fig. 3. Test setup for Crushing strength.

III. RESULTS AND DISCUSSION

Results obtained from various test experiments to determine the properties of materials are statically analyses. The test procedure and specimen preparation is explained to determine the properties of the material, as per the standard test procedure and keeping in mind the precautions tests are performed to find IRMA, MA, CS etc for the bricks and mortar. The results obtained are discussed in the following sections.

The casing of sample and test experiments is conducted in the laboratory of JCD College. The tests to determine IRMA, MA, CS etc are conducted in the observation of lab technician. For each type of brick BCB, BFA-1, BFA-2 ten numbers are taken into consideration, for mortar five samples are considered for each mix type and for masonry work also there are five samples are taken into account. The test results are expressed in a tabular form with mean and standard deviation and co-efficient of variation for each type of test. The inconsistency in the results of each type of test sample is detailed in the subsequent sections.

A. IRMA Variation

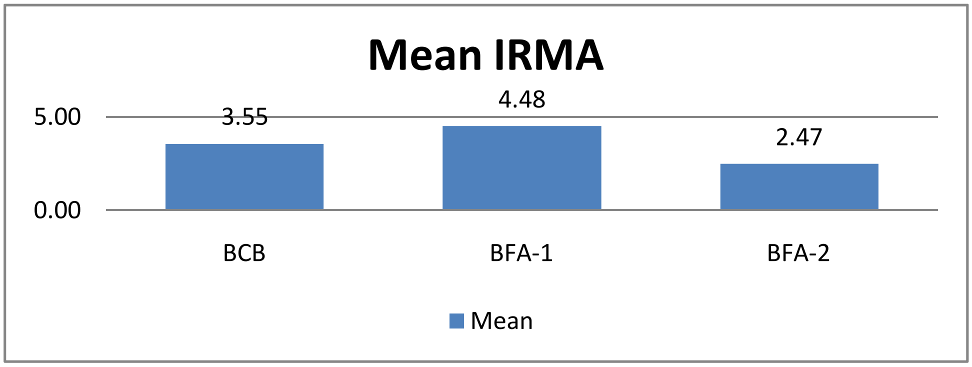
Initial rate of moisture absorption is a critical property of joint constructed by using cement mortar. IRMA represents the ability of brick to absorb water for the mortar which leads to reduction in water in mortar resulting greater influence on hydration of cement. Whereas less ability of moisture absorption leads to week bond between mortar and brick. Hence it's a general practice to pre wet the bricks before get used in masonry thus IRMA provides us an estimate of time for pre wet.

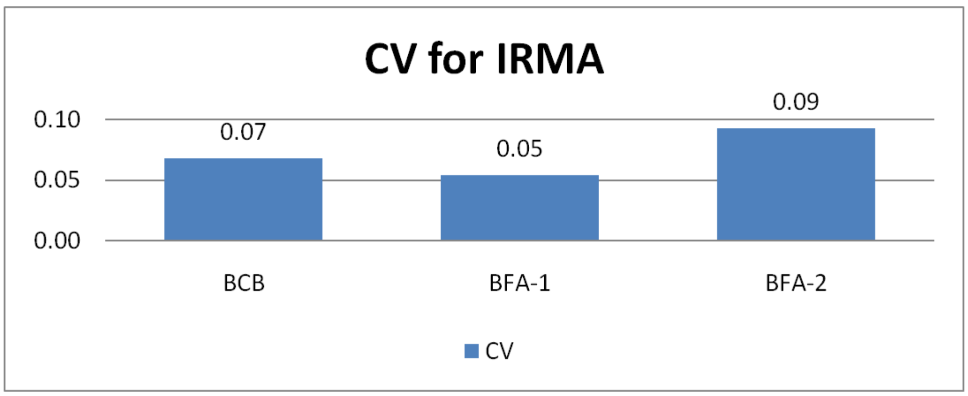
Table 2.

IRMA ($kg/m^2/min$)			
SAMPLE	**BCB**	**BFA-1**	**BFA-2**
1	3.56	4.89	2.12
2	3.45	4.52	2.78
3	3.62	4.65	2.21
4	3.40	4.23	2.25
5	3.23	4.78	2.36
6	3.25	4.12	2.58
7	3.41	4.36	2.54
8	3.89	4.63	2.45
9	3.95	4.25	2.85
10	3.78	4.35	2.60
Mean	3.55	4.48	2.47
σ	0.24	0.24	0.23
CV	0.07	0.05	0.09

From the observation table it can be seen that the IRMA for the BCB varies from 3.56-3.78 $Kg/m^2/min$ with a Co efficient of variation of 0.07, that for the BFA-1 it varies from 4.12- 4.89 $Kg/m^2/min$ with a Co efficient of variation of 0.05 and for BFA-2 IRMA varies from 2.12-2.85 $Kg/m^2/min$ with a Co efficient of variation of 0.09. Higher the value of IRMA results in decrease in joint strength so, it's better to cure the bricks before lying in the mortar.

However, From the mean values it can be seen that the mean values for the BCB,BFA-1 and BFA-2 are 3.55, 4.48 and 2.47 kg/ m^2/min respectively which are within the limits of 3-7 kg/m^2/min with an average of 5.1kg/ m^2/min and Co- efficient of 0.19. it can also seen that the means value for BFA-1 is much higher than BFA-2 almost double and the mean value for BCB is in between the BFA-1 and BFA-2 The CV for BCB, BFA-1 and BFA-2 is 0.07, 0.05, 0.09 respectively.



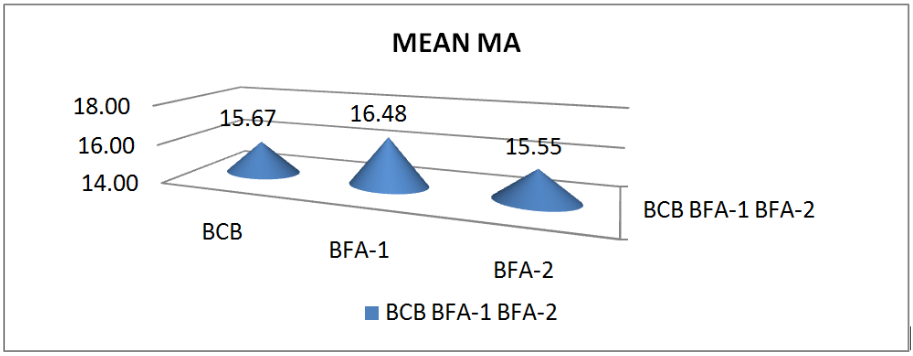


B. Moisture absorption variation

Moisture absorption is a critical parameter in masonry work. It represents the total amount of water absorbed by bricks, which effects the joint strength between masonry as excess water leads to formation of cracks when gets evaporated from the bricks and also it aided efflorescence. Good quality bricks shouldn't absorb water more than 20% by its weight. Table 3 shows the variation in MA for various brick sample. As table is showing that value for BCB varies from 15.02% to 16.32%, BFA-1 value varies from 16.20% to 16.98 % and for BFA-2 values in between 15.22% to 15.98 %. With a co efficient of variation 0.03, 0.01, 0.02 respectively. The mean value for BCB, BFA-1and BFA-2 is 15.67, 16.48 and 15.55 respectively which is lower than the permissible value specified by IS 12894:2002. And for fly ash bricks it is listed as 12.5 to 37 %. The variation in the mean MA value for the BAF-1 is higher than the BFA-2 due to the reason of Fly ash content and its grading. More the finer grading of fly makes bricks denser and less moisture absorbent.

Table 3.

	MA		
Sl. No.	**BCB**	**BFA-1**	**BFA-2**
1	15.23	16.21	15.26
2	15.56	16.56	15.23
3	15.46	16.54	15.65
4	15.02	16.36	15.45
5	15.24	16.52	15.22
6	15.89	16.2	15.65
7	15.98	16.32	15.68
8	16	16.55	15.48
9	16.02	16.58	15.98
10	16.32	16.98	15.89
Mean	15.67	16.48	15.55
SD	0.43	0.23	0.27
CV	0.03	0.01	0.02



Whereas for BCB bricks have silently higher value to BFA-2 reason may be the source of earth having silt content higher.

C. Dry Density Variation

Dry density is index to represent the weight per unit volume of the material, higher the density higher the weight per unit volume resulting in high dead load of the masonry unit.

The dry density for the BCB varies from 15.10-15.32 KN/m^3, for BFA-1 its values are in between 15.01 -15.24 KN/m^3 and for BFA-2 values are 16.21- 16.25 KN/m^3. With a co efficient of variation of 0.01.

Dry density for the BCB, BFA-1 and BFA-2 bricks varies 15.10-15.32 ,15.01-15.23 and 16.10-16.32 KN/m^3 respectively. Shows that the BCB and BFA-1 have lesser density w.r.t BFA-2 which is due to presence of less content of silica in BFA-1 and in BCB.

As compared in the mean values as shown in the graph the mean value for BFA-2 is greater due to high sand content and less fly ash content. Whereas the density for BCB Less due to the specific gravity of clay used to make the whole clay bricks.

Crushing strength variation. Table 5 shows that the values for the BCB varies from 7.10-7.80 with a CV of 0.03 and for BFA-1 its value varies from 4.71-5.90 along with CV of 0.09 also for BFA-2 crushing strength varies form 9.50-9.87 with CV of 0.03.

Table 4.

DRY DENSITY			
Sl. No.	BCB	BFA-1	BFA-2
1	15.1	15.01	16.11
2	15.1	15.03	16.29
3	15.1	15.02	16.1
4	15.1	15.02	16.19
5	15.3	15.24	16.21
6	15.1	15.23	16.12
7	15.2	15.12	16.24
8	15.2	15.16	16.28
9	15.1	15.1	16.32
10	15.3	15.11	16.32
Mean	15.2	15.1	16.22
SD	0.08	0.09	0.09
COV	0.01	0.01	0.01

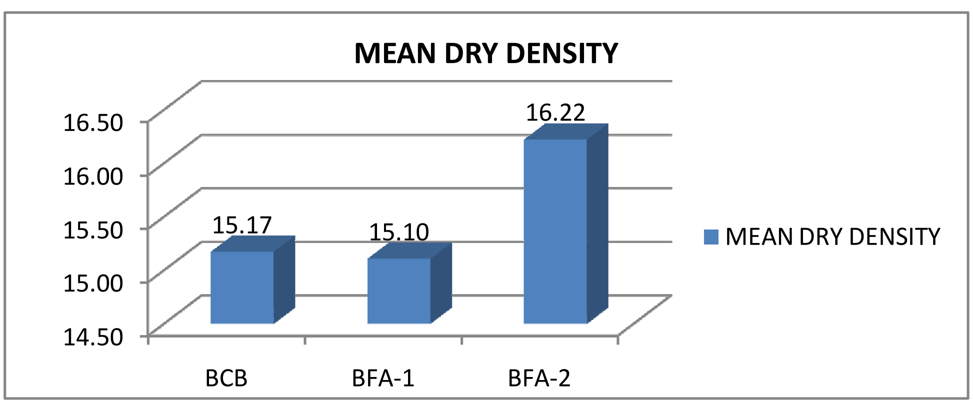


Table 5.

CRUSHING STRENGTH			
SL.NO	BCB	BFA-1	BFA-2
1	7.1	4.71	9.65
2	7.21	4.73	9.23
3	7.23	4.79	9.65
4	7.25	4.78	9.21
5	7.35	4.98	9.32
6	7.32	5.23	9.23
7	7.4	5.65	9.45
8	7.6	5.3	9.65
9	7.8	5.65	9.78
10	7.5	5.9	9.87
Mean	7.38	5.17	9.5
σ	0.21	0.44	0.25
COV	0.03	0.09	0.03

As specified by many researchers' values for fly ash brick varies from 4.3-80 MPa and for clay brick value varies from 3.2-18.0 MPa, bricks used shows good quality and standard and data bound with the studies. Mean values also satisfies the same.

Crushing strength variation of mortar: The crushing strength value for the mortar variation can be easy observed form the table 6 shows that the mortar having higher cement content have high value of crushing strength. Total 15 cubes were tested three specimen of each kind C1 have the least amount of cement and C2 have the medium amount of cement and C3 have the maximum amount of cement. Rest all the condition of curing and other conditions kept same for all the samples. The Co efficient of variation for C1 and C2 are 0.15 where for C3 is .016. Shows the variation in result is not much influencing.

The variation in value in C1 mortar is from 8.54-5.85, for C2 is 12.54-8.50, and for C3 it varies from 23.56-17.98 MPa shows that higher cement content results higher strength.

Table 6.

MORTAR CRUSHUNG STRENGTH			
Sl. No.	C1	C2	C3
1	5.85	8.5	17.98
2	6.23	10.47	20.36
3	6.54	12.54	21.54
4	7.23	12	21.9
5	8.54	11.89	23.56
Mean	6.88	11.08	21.07
σ	1.06	1.63	3.39
CV	0.15	0.15	0.16

Mean values of mortar crushing strength shown in figure below.

Crushing strength variation of masonry units: 4 Bricks units are casted using three brick varieties using three different mortar mixtures, five sets of every unit are tested and results are formulated in individual table. A graft representing individual unit mean strength is shown.

Table 7.

Brick Type	BCB		
mortar			
Sl. no	C1	C2	C3
1	1.56	2.45	3.12
2	1.65	2.23	3.23
3	2.45	3.23	3.89
4	2.89	3.18	4.12
5	3.2	3.56	4.65
Mean	2.35	2.93	3.8
σ	0.73	0.56	0.64
COV	0.31	0.19	0.17

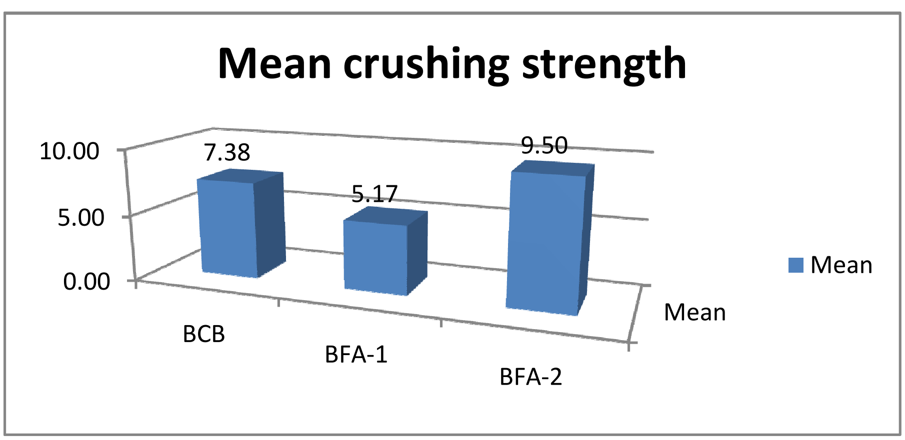


Table 7 represents the crushing value of masonry unit in MPa for BCB which varies from 3.2-1.56, 3.56-2.45 and 4.65-3.12 for C1, C2and C3 respectively with a Co efficient of variation of 0.31, 0.19 and 0.17. The mean values shows that the BCB C3 has maximum mean crushing strength value of 3.80 MPa.

Table 8

Brick Type	BFA-1		
mortar			
Sl. no	C1	C2	C3
1	1.25	2.23	2.78
2	1.56	2.65	3.25
3	1.89	2.89	3.87
4	2.56	3.23	4.56
5	2.54	3.5	4.2
Mean	1.96	2.9	3.73
σ	0.58	0.5	0.72
COV	0.3	0.17	0.19

The crushing strength table 8 of BFA-1 shows the sample with different cement proportion have variation of value from 2.56-1.25 for C1 with CV of 0.3, for C2 values are from 3.50-2.23 with CV of 0.17 and for C3 crushing values are 4.56-2.78 MPa with CV of 0.19. Where the mean crushing strength value shows the BFA-1 with C3 mortar shows the maximum value of crushing strength of 3.73 MPa and BFA-1 with C2 mortar gives the value of 2.90 MPa and BFA-1 with BFA-1 with C1 yield the minimum value of 1.96 MPa.

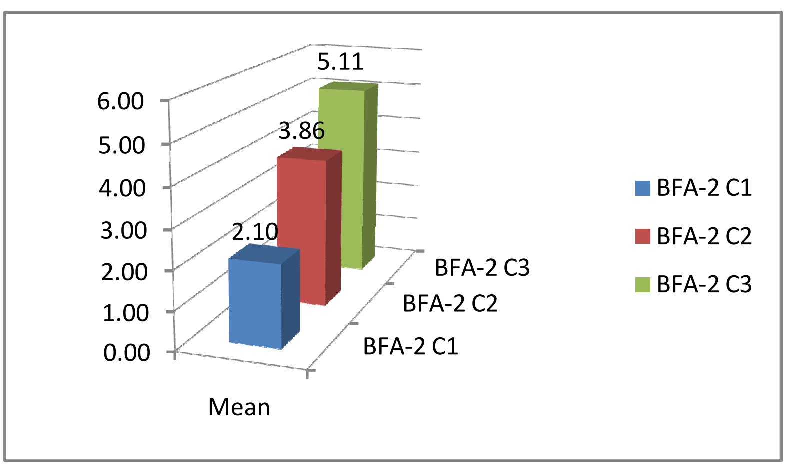
Table 9

Brick Type	BFA-2		
mortar			
Sl. no	C1	C2	C3
1	1.45	3.51	4.56
2	1.98	3.54	5.21
3	1.56	3.89	5.54
4	2.74	3.78	5.12
5	2.78	4.56	5.1
Mean	2.1	3.86	5.11
σ	0.63	0.42	0.35
COV	0.3	0.11	0.07

The crushing strength table 9 of BFA-2 shows the sample with different cement proportion have variation of value from 2.78-1.45 for C1 with CV of 0.31, for C2 values are from 4.56-3.51 with CV of 0.11 and for C3 crushing values are 5.54-4.56 MPa with CV of 0.07. Where the mean crushing strength value shows the BFA-2 with C3 mortar shows the maximum value of crushing strength of 5.11 MPa and BFA-2 with C2 mortar gives the value of 3.86 MPa and BFA-1 with BFA-1 with C1 yield the minimum value of 2.10 MPa.

(i) It can be observed from the data that if the proportion of cement sand is increased the strength of mortar increases

(ii) The CV data for individual material and for compositing material have very high variation; it shows that when two different specific gravity materials are used to form a composite material high degree of precision should be used.



V. CONCLUSION

The Following conclusions are made for the present work:

1. BFA-1 has more value than BFA-2 and BCB bricks.
2. BFA-2 has less moisture absorption value than BFA-1 due to more percentage of fly ash.
3. Dry density for BFA-2 is highest among BFA-1 and BCB due to high specific gravity of fly ash.
4. BFA-2 has highest Crushing strength as compare to BFA-1 and BCB.
5. Crushing strength for mortar C3 has good strength as compared to C1 and C2.
6. As pozzolanic material reacts with cement in better way and results in good strength the co efficient of variation for masonry unit has least variation in CV
7. The crushing strength trend for the masonry unit shows that as the mix proportion of mortar increases the crushing strength of unit increases and among all BFA-2 has the highest value on C3.

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