Workability and Strength Analysis of Concrete with Brick Ballast as Coarse-Aggregate

Rakesh Ku Jena, Pratap Kumar Pani, Sudeep Kumar Singh, Prasant kumar Nayak

Abstract—The presented research focuses on the experimental investigation to calculate the suitability of using recycled brick ballast obtained as demolition debris to serve as partial substitute to coarse aggregates for concrete of different grades like M10, M15, M20, M25 and by varying the product mix in different replacement proportions as 0%, 25%, 50%, 75% and 100% by weight. The proposed methodology is based on a series of tests carried out, focusing mainly on the workability and characteristic strength analysis of concrete with graded brick ballast and comparing them with the conventional cement concrete. The experimental work included several types of concrete made keeping the water-cement ratio as 0.45 and with target slump value 70-100 mm. The influence of replacing different percentages of coarse aggregates to produce different concrete grades was closely observed. The conclusion drawn from the test results conforms, the possibility to use brick ballast in concrete for M25 grade with 25% by weight of the coarse aggregate as optimum value.

Keywords— Brick aggregate, Brick ballast, Non-conventional aggregate, Strength of concrete, Waste brick, Workability.

I. INTRODUCTION

CONCRETE is the most versatile material of modern civil construction works. It can be easily prepared, given any shape and will last long. The most commonly used coarse aggregate for concrete is the hard granite of igneous origin. Aggregates form 75% of concrete and provide better volume stability and durability compared to hydrated cement paste [1, 12]. There are places such aggregates that are not available or obtained with much difficulty and at a high cost. Also, there are some structures where the hardness, toughness, and strength required are less, and the hard stones can be substituted. There locally available bricks can be the first choice to replace the conventionally used crushed stone. But the pros and cons of the replacement of hard natural stones by brick have to be properly investigated to obtain a good matrix concrete product with the enhanced overall quality.

The broken but fully burnt bricks near the Kilns and clamps are used either as filling materials or left-outs near the burning place. These brickbats are of very low cost and difficult to be disposed-off from the site. To use such brickbats it is felt that they can replace fully or partly the coarse aggregates of concrete and can be used for temporary concrete structures or structures which bear less load. To study this concept, brick ballasts can be used after crushing to the required level**.**

In the present research, a series of tests were conducted to make comparative studies of various properties of fresh green concrete and hardened concrete with various mix proportions. The various replacement proportions used are 0%, 25%, 50%, 75%, and 100% with water-cement ratio 0.45 based on the results of the tests conclusions and recommendations have been made.

The hard stone chips are usually taken as the coarse aggregates as ingredients of concrete. Large scale construction and unavailability of stone chips in many places make the incurred cost skyrocketing. It is difficult to find a replacement of natural coarse aggregates fully or partially. But in many places, brick ballasts can be used as a supplement for construction. The present work investigates, the feasibility of replacing the naturally occurring coarse aggregates with brick ballast. The compressive strength and workability of concrete prepared from brick ballast have been studied. Brick ballasts with different proportions, with different water-cement ratios for different grades of concrete, are tested and compared with traditional concrete.

Although some of the earlier reported researches have considered different material properties like water absorption [6,3,5,4,10] compressive strength [6,3,2,4,10,11,12] frost resistance [3,4], density, flexural strength [6,10], drying shrinkage and creep [6], specific gravity test [5,11], for evaluating the suitability of reusable crushed bricks as coarse aggregate, they have not considered the workability criteria in their work.

Dhir, R. K. , Paine K.A.,(2007)[6] used recycled aggregate and found poor compressive & flexural strength, higher absorption and abrasion, resistance to freeze as some of the drawbacks, whereas in an experimental effort to find out the water absorption rate, compressive strength and frost resistance properties of concrete and conducting a similar research Poon, C. S. er.al.[12] recommends replacing a maximum 50% of coarse aggregate with recycled aggregate whereas Debieb, F., & Kenai, S. [10] considering both coarse and fine aggregates as replacement options suggested a blend of 25% coarse aggregate and 50% fine aggregate in the concrete mix. Ksenija Janković, Dragan Bojović, et al (2010)[3], recommends the use of recycled brick aggregates

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as ingredients of concrete for pavements, causeways, and other various non-structural construction. They have also concluded that the density of the aggregates correlates with the water absorption and frost resistance of the concrete. They are replacing brickbats (partially/fully) in different proportions in concrete. Dhir, R. K. , Paine K.A.,(2007)[6] also investigated physio-mechanical properties such as sulphide content, chloride content, alkali content and other physical properties such as resistance to wear and tear and freeze-thaw resistance, fragmentation and weather properties whereas physio-mechanical properties of the recycled mix has been investigated by Ksenija Janković, Dragan Bojović, et al (2010)[3].

Rashid M A et al (2012)[2] have found a 33% reduction in compressive strength. They also observed that the variation in tensile strength up to 50% replacement is insignificant, but there is a 28% reduction in elastic modulus properties. Using brick waste of size 25mm to 38mm as coarse aggregate Reza Farhad (2013)[5] has recommended the use of 10% of old used brick aggregates with virgin aggregates of concrete. Using gravel and crushed, over burnt bricks as coarse aggregates N S Apebo, M B Iorev uab et al (2013) [4] also recommend bricks in an effort to make comparative analysis of compressive strength of concrete using a higher cement water mix using 10% broken bricks available as stockpiles mixed with virgin aggregates, whereas in another research Jian Yang et. al.[11] suggests 20% of coarse aggregate for good compressive strength and cautions 50% or more in the mix.

Cavalin T, David et al in their work [8] obtained high absorption properties, lower strength and less durability as the property which limited the use of brick as coarse aggregate in concrete and advocated the use of higher water-cement ratio to achieve good workability for recycled aggregate concrete. The prepared recycled brick masonry aggregate and tested its suitability in pavement works.

As reported in this article, most researchers have suggested optimum values for one grade of concrete mix, the current experimental investigation deals with the compressive strength and workability of concrete with graded brick ballast as coarse aggregate for all four nominal mix grades (M10, M15, M20 & M25) The results obtained has been compared with the conventional concrete and their suitability has been evaluated from experimental findings.

II. METHODOLOGY

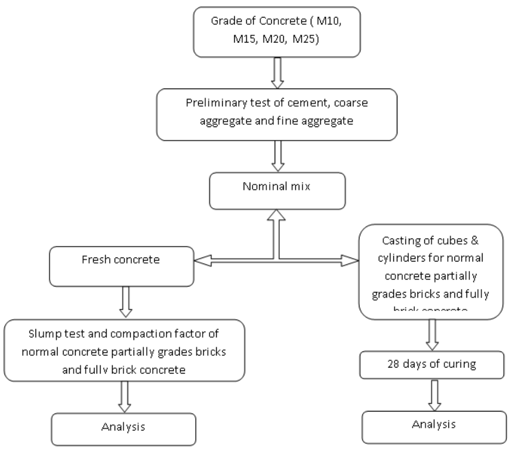

Fig: 1 Working methodology

A. Materials and Methodology

Materials: Kiln burnt local Bricks are collected from nearby kilns. They are made from local earth, sand, and lime available nearby. Such bricks were taken as materials for the replacement of coarse aggregates. These bricks were hand broken to ballasts and passed through 20mm by 100% and retained by 4.75mm size sieves. Bulk density measured to be 810 Kg/m3. These brickbats were well sorted from Jhama bricks, cleaned and cured for 24hours before use. Simultaneously the other ingredients taken for preparation of concrete are Ambuja Cement of grade 43 with standard consistency 34 percentage, Specific gravity 3.15, soundness 3mm with initial and final setting time 115minute and 410minutes respectively. The fine ingredient used is river sand of zone III confirming IS 373 - 1972. The major coarse aggregate is 20mm and 12mm HG chips free from weathered skin and deleterious materials. The water used is a portable and water-cement ratio used at various proportions as per the recommendation of IS 456 – 2000. The different grades of Concrete prepared are M-10 (1:3:6), M-15 (1:2:4), M-20 (1:1.5:3), and M-25 (1:1:2).The mix of concrete is Nominal Mix and the ingredients used are Cement (OPC 43 Grade), Fine aggregate (sand, Zone-III),Coarse aggregate (crusher broken Hard Granite chips in the ratio above 10mm is 75 percent and above 4.75mm 25 percentage) and replacement of graded clay bricks added by weight 0 percentage, 25%, 50%, 75% and 100%. The water-cement ratio used for the concrete is at 0.45. The properties of the ingredients are given below.

Table 1 Properties of Cement for 43 Grade Opc

Sl NO	TEST	RESULT
1	fineness	5% Residue
2	Standard Consistency	34%
3	Initial Setting Time	115 min
4	*Final Setting Time*	410 min
5	Specific Gravity	3.15
6	Soundness	3mm Expansion

For the purpose of experiment crusher-broken, HG chips and hand broken brick ballast have been used as coarse aggregate out of which the HG chips used are a mixture of 75% by volume having size 10-20 mm and rest 25% by volume having a size greater than 4.75mm. The crushing value for the HG chips used is 18.26%, fineness modulus of 3.48% and specific gravity 2.66. The hand broke clamp burnt brick ballast used is having water absorption 13.83% and compressive strength 8.05 N/sq.mm. River sand of Zone-III have been used as fine aggregate having fineness modulus 1.8% and specific gravity 2.66.

The concrete is mixed in the laboratory by a Concrete Mixer at a temperature of 200C to 260C. The chips and the brick ballasts are sieved by 4.75mm sieve, well sorted and the proportions as mentioned are taken. The coarse aggregates and the fine aggregates are well cleaned and well dried before 48 hours to make it free from debris, dust, and silts. The sand is well dried before use to avoid the bulking of sand. The molds of the laboratory are well cleaned and oiled properly of shape cubes (150mmX150mmX150mm), cylinders (radius 150mm and height 300mm) and Prisms (275mmx75mmx75mm).

Different grades of concrete are prepared in batches with the replacement of a different percentage of brick ballasts at a different water-cement ratio.

After the preparation of fresh concrete, the in situ laboratory tests conducted are slump Test and Compaction factor test to know the workability of the fresh concrete. The values are recorded and those concrete were allowed for experimental purposes which pass through the recommended values (IS 456-2000, 7.1, 7.1.1). The concrete is cast in the prepared molds in layers and well compacted by using Table vibrator and vibrated for 3 minutes till the concrete is well compacted.

B. The texture of Coarse Aggregates

The brick ballasts are rough, angular and elongated. Since the concrete quality is influenced by the shape and size of the coarse aggregate, the replaced concrete has needed a higher water-cement ratio to achieve the same workability. The void ratio is higher in the replaced concrete which needs more graded fillers.

Fig: 2 Coarse aggregates

C. Laboratory Test Conducted

Compressive Strength Test

Each set consisting of nine cubes of standard size and nine cylinders were cast. compressive strength was determined after curing for 28 days. The size of the cube is as per the IS 10086 – 1982.

Flexural Strength Test:

Four prisms were cast and cured properly before testing to determine the flexural strength of concrete.

Flexural strength = PL/BD2.

Where P is load

L= Length of Prism. B = Breadth of Prism. D = Breadth of Prism

Workability of Concrete

The concrete mix was ensured to have adequate workability such that the concrete. (Cl. 7.1pp-17 IS 456:2000)

Durability

A durable concrete performs well in the working environment during its estimated service life. The materials and mix used should maintain the integrity and, also protect the embedded metal from corrosion (Cl. 8 pp-17 IS 456:2000).

SLUMP TEST & COMPACTION FACTOR TEST

Slump test and Compaction factor test were of different grade with different percentage of replacement of coarse aggregate. The coarse aggregate by brick ballast was determined using (referring IS 456: (2000)).

III. RESULTS AND DISCUSSIONS

A. Tests on Fresh Concrete

By slump test and Compaction factor test of different grade with different percentage of replacement of coarse aggregate by brick ballast with W/C ratio- 0.45 were tabulated below in

Fig :3 Mixing process of aggregates

Table 2

Sl. No	Grade	% of aggregate replace by brick ballast by weight	Slump value in mm	Compaction factor
1		0	0	0.70
2		25	0	0.73
3	M10	50	2	0.72
4		75	1	0.71
5		100	1	0.71
6		0	32	0.72
7		25	8	0.78
8	M15	50	8	0.76
9		75	0	0.76
10		100	0	0.73
11		0	31	0.85
12		25	180	0.85
13	M20	50	195	0.83
14		75	152	0.84
15		100	198	0.80
16		0	195	0.90
17		25	205	0.89
18	M25	50	201	0.88
19		75	198	0.88
20		100	176	0.86

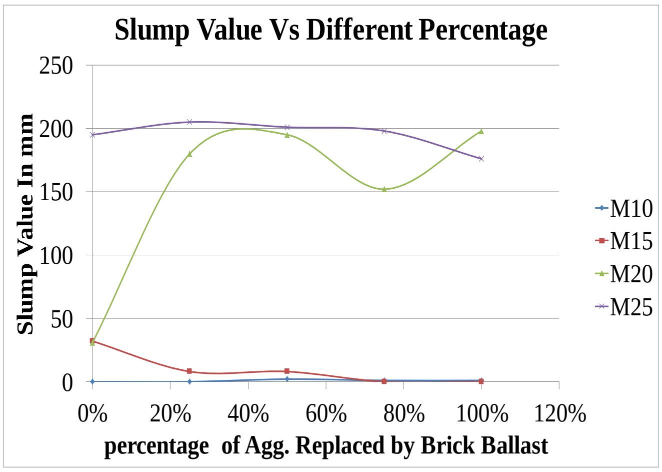

Fig. 4 Slump Value for W/C-0.45

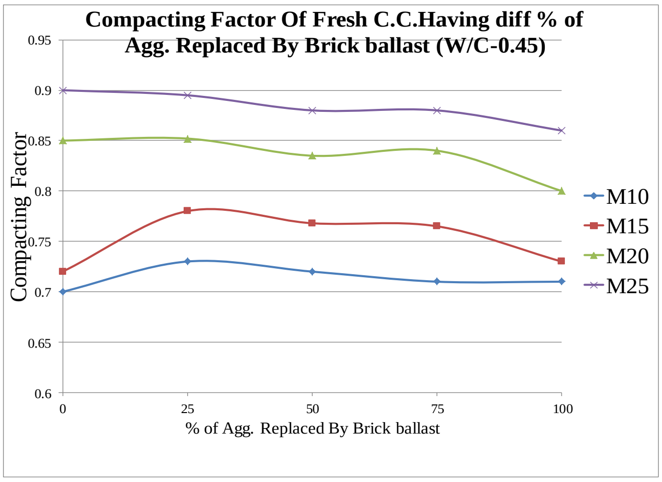

Fig. 5 Compaction Factor for W/C-0.45

4.3 Compressive strength tests of cement concrete Cubes, Cylinders and Flexural strength tests of different grade with different percentages of replacement of coarse aggregate by brick ballast were determined using the following procedure.
Referring to IS 516 (2000):

Compressive strength test of cement concrete Cubes and Cylinders test of different grade with different percentages of replacement of coarse aggregate by brick ballast with W/C ratio- 0.45 were tabulated below in Table No. 4.3.

Table 3 Compressive Strength of Cement Concrete Cubes

Sl. No	W/C	% of aggregate replace by brick ballast by weight	Compressive Strength after 28 Days Curing (N/mm^2)			
			M10	M15	M20	M25
1	0.45	0	16.1	18.3	24.12	29.08
2		25	13.87	15.87	22.44	25.52
3		50	12.45	12.7	16.9	17.25
4		75	9.83	10.76	14.28	14.55
5		100	8.13	9.68	12.26	12.88

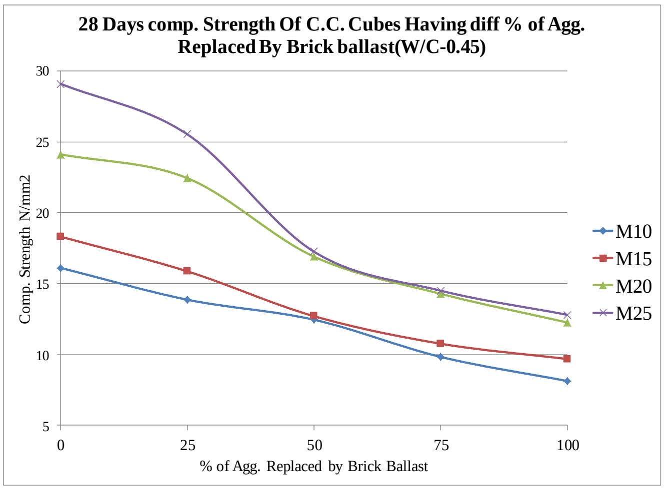

Fig. 6 Comp. Strength values for 28 Days of C.C. Cubes (W/C-0.45)

COMPRESSIVE STRENGTH TEST OF CEMENT CONCRETE CYLINDER (150mm*300mm) (W/C-0.45)

TABLE 4 Compressive Strength of C. C. Cylinders

Sl. No	W/C	% of aggregate replace by brick ballast by weight	Compressive Strength after 28 Days Curing (N/mm^2)			
			M10	M15	M20	M25
1	0.45	0(Normal concrete)	14.53	15.83	21.27	25.7
2		25	12.13	13.94	19.8	21.53
3		50	10.9	11.27	17.29	17.73
4		75	8.8	9.4	11.73	12.07
5		100	6.8	8.53	11.63	11.76

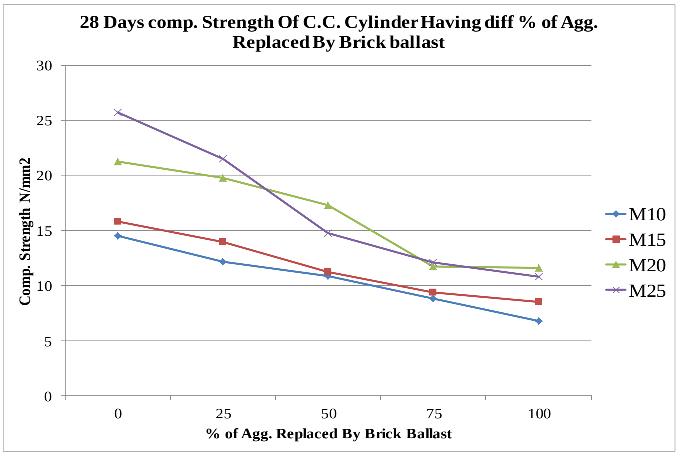

Fig. 7 Comp. Strength of 28 Days Cement Concrete Cylinder (W/C-0.45)

IV. DISCUSSION

The experimental results are discussed for the workability and strength of the concrete. For lean and lower grades, the workability decreases for concrete replaced with brick ballast for coarse aggregates partially. For higher grades, the workability improves. For 25 percentages replacement and water-cement ratio of 0.45 for M10 grade the slump value decreases from 1 to 0 and for M15 grade it decreases 32 mm to 08 mm, This is mainly due to the higher amount of coarse aggregates per unit volume of fresh concrete in these grades comparing the amounts in M20 and M25 grades. When the amount of coarse aggregates is more, the corresponding substituted brick ballast is also more. This absorbs more water because of higher porosity leaving lesser amount for lubrication. For M20 and M25 grades, the observed slumps are 90mm and 205 mm, This is because the amount of water absorbed by brick ballast is less.

The important aspect of this replaced brick ballast concrete is its strength. As observed, the strength is reduced by replacing coarse aggregates by brick ballast. However, limited replacement may be accepted where the reduction in strength is not putting the strength below the recommended value. For the water-cement ratio of 0.45 up to 50 percentage replacement is possible M10 M15 grades. The strength reduces by 13 to 30 percentages but remains higher than the recommended strength. For M20 and M25 grades, a replacement can be up to 25 percentages and a reduction in strength is 7 percentages. The reduction in strength is due to the differential absorption quantity between the brick and the stone which affects the creep and shrinkage of concrete and thereby develops internal stresses in concrete.

Further by adding brick ballast the non-homogeneity advances further though we assume concrete to be homogeneous. The SI unit for magnetic field strength *H* is A/m. Magnetic flux density *B* or magnetic field strength $\mu_0 H$ can be used for using the units of T.

V.CONCLUSION

The following inferences are drawn based on the experimental investigation on the strength and workability of concrete with partial replacement of coarse aggregates by brick ballast.

a. On average 25 percentages, of course, aggregates may be replaced with brick ballasts.

b. The most suitable water-cement ratio for preparation of the concrete is

0.45 for grades of concrete of M15, M20, and M25.

c. Replacement by brick ballasts should not be made beyond M25 grade of concrete.

5.2 EXTENSION

Before the recommendation for use in the field, a number of tests should be conducted for the concrete with replaced coarse aggregates of different proportions.

The following aspects which have not been studied should be investigated

i. The creep and shrinkage of concrete
ii. The modulus of rupture of concrete.
iii. The durability of the concrete
iv. The cost analysis of the concrete.

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