Strength and durability of crushed fire bricks by partial replacement with fine aggregate

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ABSTRACT

The main objective of this investigation is to examine the properties of CSFB concrete. Partial or full replacement of fine aggregates by the other compatible materials like fly ash, crushed rock dust, quarry dust, glass powder, and recycled concrete dust."Spent Fire bricks" (SFB) for partial replacement of fine aggregate in concrete Fire bricks are the products manufactured from refractory grog, plastic, and non plastic clays of high purity. M25 grade of concrete is designed as per code. Conventional concrete is taken as control mix CSFB is to be added in various proportions and concrete specimens are casted. The different raw materials are properly homogenized and pressed in high capacity pressesto get the desired shape and size. In most structural applications concrete is used primarily to resist compressive stress. In those cases where strength in tension or in shear is of primarily importance, the compressive strength is frequently used as a measure of these properties. Conventional concrete is taken as control mix Conventional concrete specimens are also to be casted for comparison. Various tests for hardened concrete such a Compressive strengths, Split tensile strength, Flexural strength, Modulus of elasticity, Bulk density are to be performed.

I. INTRODUCTION

Aggregates are the important constituents in the concrete composite that help in reducing shrinkage and impart economy to concrete production. Most of the aggregates used are naturally occurring aggregates, such as crush rock, gravel and sand which are usually chemically interactive or inert when bonded together with cement. On the other hand, the modern technological society is generating substantially high amounts of solid wastes both in municipal and industrial sectors; posing an engineering challenging task for this effective and efficient disposal. Hence, partial or full replacement of fine aggregates by the other compatible materials like sintered fly ash, crushed rock dust, quarry dust, glass powder, recycled concrete dust, and others are being researched from past two decades, in Asian countries could not gear up to that level to match with those countries . Therefore, resource exploitation and waste disposal problems are currently rocking the sustainable development in those countries. The main objective of this investigation is to examine the properties of CSFB concrete. Which is produced by adding in the concrete in various proportions.M25 and M30 grade of concrete isdesigned as per code.

A. Fire Bricks

Fire bricks are the products manufactured (as per IS: 6 and IS: 8 specifications) from refractory grog, plastic, and non plastic clays of high purity. The different raw materials are properly homogenized and pressed in high capacity presses to get the desired shape and size. Later, these are fired in oil-fired kiln at a temperature of 1300°C. Table 1 shows the physio-chemicalproperties of the fire bricks.

Table 1: Physio- Chemical Properties of the Fire Bricks

Property	**Result**
Physical	
Bulk density	2000 kg/m^3
Porosity	25-30%
Size tolerance	±2%
Working temperature	1300-1400ºC
Crushing strength (cold)	24.5-27 N/mm^2
Chemical	
Aluminum as Al_2O_3	30-40%
Iron as Fe_2O_3	2-2.5%
Silica as SiO_2	57-65%
Alkalis	Trace

Fig.1.Fire Bricks Samples

B. Spent Fire Bricks (SFB)

Due to the exposure to continuous high temperature (i.e. 1000-1200ºC) for a period of 10 to 15 days, they lose some of the physical and mechanical properties and need to be replaced by fresh fire bricks, and is being done usually done once in fortnight. Then, the SFB is an industrial solid waste to be disposal off properly.

II. LITERATURE REVIEW

Silvia Fiore and Maria Chiara Zanetti. 2011, The industrial process of a cast iron foundry plant located in the North of Italy was analyzed in order to determine the amount and kind of produced wastes. The main fractions are core and moulding sands, muds and powders from dust abatement plants, furnace and ladle slags, and exhaust lime, making about 750-800 t/d of residues for a production of about 800 t/d of globular and grey cast iron. All wastes were sampled and characterized by means of particle-size distribution and chemical analyses to evaluate the best reuse and recycling solutions.

Akindahunsi, A. and Ojo, O. Billet 2011 scales are by-products from steel rolling mills in Nigeria that presently constitute environmental pollution. This paper reports studies carried out using these solid wastes as a partial replacement for sand in the production of concrete. Various percentages of billet scales were used in a concrete mixture of 1: 2: 4 by weight to cast concrete specimens. The compressive and tensile strengths developed were tested after 7, 14, 21, and 28 days of curing. The result of the compressive and splitting tensile strengths tests indicated that concrete strength increased with curing age. The compressive strength of 0%, and 15% replacement of sand with billet scales as obtained at 28 days are 26.0N/mm2, 26.2N/mm2. 15% optimal replacement of sand with billet scales had similar results as the control mixture of 0%, which could be used in reinforced concrete structures

Shahul Hameed and A. S. S. Sekar.2013 Green concrete capable for sustainable development is characterized by application of industrial wastes to reduce consumption of natural resources and energy and pollution of the environment. Marble sludge powder can be used as filler and helps to reduce the total voids content in concrete. An attempt has been made to durability studies on green concrete compared with the natural sand concrete. It is found that the compressive, split tensile strength and durability studies of concrete made of quarry rock dust are nearly 14 % more than the conventional concrete. The concrete resistance to sulphate attack was enhanced greatly. Application of green concrete is an effective way to reduce environment pollution and improve durability of concrete under severe conditions.

Ronaldo S. GALLARDO and Mary Ann Q. ADAJAR 2015.,In this study, researchers have focused their investigations on the viability of using paper mill sludge, an industrial waste generated by paper mills factories as an alternative material applied as partial replacement of fine aggregates in manufacturing fresh concrete intended to be used for low cost housing projects. The investigations cover the following criteria; comparison of physical properties which includes moisture content, specific gravity and absorption of paper sludge versus ordinary river sand, the chemical properties, and the quality and durability of concrete with paper sludge in terms of compressive strength and splitting tensile strength. Based from results of the study, the most suitable mix proportion is the 5% to 10% replacement of paper sludge to fine aggregates.

III. TESTS ON CONCRETE

A. Casting and Curing Of Specimens

For ordinary concrete, fine aggregate and cement were weighed and mixed thoroughly; the coarse aggregate was then added and mixed with the above. The required amount of water was added and mixed the thoroughly to get uniform concrete mass. For preparing the specimens for determining the compressive tensile, flexural strength, and impact strength, permanent steel moulds, of standard size were used. The fresh concrete was filled in the mould. Care should be taken to see that the concrete was compacted perfectly. The compaction was carried but bymeans of vibrators and the top surface was leveled and finished.

B. Tests on Fresh Concrete

Fresh concrete (or) plastic concrete is freshly mixed materials, which can be moulded in to any shape. The relative quantities of cement, aggregates and water mixed together control the properties in the wet state as well as in hardened state. Workability is the important quality of fresh concrete, workability is defined as the ease with which a given set of material can be mixed into concrete and subsequently handled, transported, placed and compacted with minimum loss of homogeneity. The word workability or workable concrete signifies much wider and deeper meaning than other terminology consistency often used loosely for workability. Consistency is the general term to indicate the degree of fluidity or the degree of mobility.

C. Slump test

The mould for the slump test is in the form of frustum of a cone of bottom diameter 20cm, top diameter 10cm and height 30cm. The mould is filled with fresh concrete in four layers, each approximately one quarter of height of the mould. Each layer shall be tamped with 25 strokes of the rounded end of the tamping rod. After the top layer has been rodded and top surface leveled, the mould is removed from the concrete by raising it slowly in vertical direction. The Concrete subsides and the slump is measured immediately by determining the difference between the height of the mould and of the highest point of the specimen being tested. The test determines theconsistency of the fresh concrete and given comparable results in the case of wet mixes.

D. Compacting factor test

Compacting factor test is more precise and sensitive than the slump test and is useful for concrete mixes of very low workability, which may fail consistency fail to slump. The sample of concrete is placed gently in the upper hopper. The hopper is filled with concrete and trap door is opened so that the concrete falls in to the lower hopper. Immediately after the concrete has come to rest, the trap door of the lower hopper is opened and the concrete is allowed to fall into the cylinder. The top of cylinder is leveled and the cylinder with concrete is weighted. The cylinder is then refilled with same concrete, the layers being heavily rammed or vibrated so as to obtain full compaction.

E. Compressive strength

The compressive strength of concrete is one of the most important and useful properties of concrete. In most structural applications concrete is used primarily to resist compressive stress. In those cases where strength in tension or in shear is of primarily importance, the compressive strength is frequently used as a measure of these properties. For practically the compressive strength increases as the specimen size decreases. At least three cubes of 15 cm x 15 cm x 15 cm are cast for each age, usually 7 and 28 days. The specimens are air cured for one day and in water for rest of the days. Specimens are tested in saturated condition. Cubes are placed in such a manner in testing machine that the line of loading is perpendicular to direction it was cast. Constant load of 140 $kg/cm^2/min$ is applied till failure. Compressive stress = Ultimate load / bearing area

F. Split tensile strength

The test specimens shall consist concrete cylinders of 150mm in diameter and 300mm long. Specimens if dry are kept for 24 hrs before testing. Plywood strip of size 12mm x 3mm is centered along the center of the lower pattern. The wet cylinder specimen is placed on the strip horizontally with its axis perpendicular to the loading direction. The second plywood strip is thenplaced lengthwise on the cylinder centrally. The load is then applied without shock and increasedcontinuously at a rate to produce approximately a splitting tensile stress of 14 to 21 $kg/cm^2/min$ until failure.

G. Modulus of rupture

Direct measurement of tensile strength of concrete is difficult. Neither specimens nor testing apparatus have been designed which assure uniform distribution of the pull applied to the concrete. While a number of investigations involving the direct measurement of tensile strength have been made, beam test are found to be dependable to measure flexural strength property of concrete. The value of the modulus of rupture extreme fibre stress is bending/ depends on the dimensions of the beam and manner of loading. The size of the specimen used in 150 x 150 x 750 mm.

H. Modulus of elasticity

The test specimens shall consist of concrete cylinders 150 mm in diameter and 300 mm long. Alternately, other size of cylinders or square prisms may be used provided that the height/diameter or height/width ratio is at least 2.The tests were carried out when the specimens reached the age of 28 days. Compressive Strength (N/mm^2) = Load/Contact area of thespecimen Strain = Dial gauge reading/Gauge length. Finally the results are tabulated and stress versus strain plot is prepared with the readings. The stress is calculated in MPa. The initial tangent modulus which is the slope of the tangent drawn to the stress-strain curve at the initial point is the Modulus of Elasticity.

IV. TEST RESULTS

The results of compressive strength, Bulk density, split tensile strength, flexural strength, andModulus of elasticity are tabulated and discussed as follows.

A. Compressive Strength

The compressive strength of concrete is one of the most important and useful properties ofconcrete. In most structural applications concrete is used primarily to resist compressive stress.

Table 1: Compressive strength of cube at 28 days-M25

S. No	Replacement in Percentage	Load in Divisons	Ultimate compressive Strength in MPa	Average Compressive strength of concrete in MPa
1	10	61	598410	26.3
		58	568980	
		62	608220	
		59	578790	
		60	588600	
		62	608220	
2	20	64	627840	28.1
		65	637650	
		65	637650	
		64	627840	
		66	647460	
		63	618030	
3	30	67	657270	29.7
		65	637650	
		69	676890	
		69	676890	
		70	686700	
		69	676890	
4	40	58	568980	25.9
		60	588600	
		60	588600	
		61	598410	
		59	578790	
		58	568980	

B. Bulk Density of Concrete

Bulk density is weight of concrete in a given volume. It is normally expressed in kg/m^3.

Table 2: Bulk density of concrete cubes at 28 days-M25

S. No	Replacement in Percentage	Weight in kg	Bulk Density in kg/m^3	Average Bulk Density in kg/m^3
1	0	8.4	2488.9	2501.2346
		8.5	2518.5	
		8.4	2488.9	
		8.4	2488.9	
		8.5	2518.5	
		8.45	2503.7	
2	10	8.35	2474.1	2410.3704
		8.01	2373.3	
		8.1	2400.0	
		8.15	2414.8	
		8.2	2429.6	
		8	2370.4	
3	20	8.12	2405.9	2401.9753
		8.14	2411.9	
		8.13	2408.9	
		8.15	2414.8	
		8	2370.4	
		8.1	2400.0	
4	30	8.2	2429.6	2395.0617
		8.15	2414.8	
		8.1	2400.0	
		8	2370.4	
		8	2370.4	
		8.05	2385.2	
5	40	8.28	2453.3	2387.6543
		8	2370.4	
		8.12	2405.9	
		7.95	2355.6	
		7.9	2340.7	
		8.1	2400.0	

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C. *Split Tensile Strength*

Direct tensile strength of concrete cannot be determined owing to difficulty in preparation of test specimen and applying a truly axial tensile load. This test is an indirect method of finding out thetensile strength of concrete .The split tensile strength is determined using cylinders of 150mm diameter and 300 mm long. The test results of various proportions at 28 days are given below.

Table 3: Split tensile strength of concrete cylinders at 28 days-M25

S. No	Replacement in Percentage	Ultimate load in divisions	Split Tensile Strength in MPa	Average Split Tensile Strength in MPa
1	0	18	2.4993631	2.3489384
		16	2.2216561	
		17	2.3605096	
		17.5	2.4299363	
		16	2.2216561	
		17	2.3605096	
2	10	18	2.4993631	2.4762208
		16	2.2216561	
		19	2.6382166	
		17	2.3605096	
		18	2.4993631	
		19	2.6382166	
3	20	20	2.7770701	2.8464968
		19	2.6382166	
		21	2.9159236	
		21	2.9159236	
		22	3.0547771	
		20	2.7770701	
4	30	22	3.0547771	2.9159236
		21	2.9159236	
		20	2.7770701	
		21	2.9159236	
		22	3.0547771	
		20	2.7770701	

D. *Flexural strength of concrete*

In this test, a plain (unreinforced) concrete beam is subjected to flexure using symmetrical two point loading until failure occurs. Because the load points are placed at 1/3rd of the span, the test is also called as third point loading test. The theoretical maximum tensile stress reached in the bottom fiber of the test beam is called Modulus of Rupture. The Flexural strength is determined using prisms of 150mm x 150mm x 750mm. The test results of various proportions at 28days aregiven below:

Table 4:Flexural strength of concrete at 7 days-M25

S. No	Replacement in Percentage	Load in divisions	Flexural Strength in MPa	Average Flexural Strength in MPa
1	0	0.63	2.1	2.2
		0.675	2.25	
		0.66	2.2	
		0.693	2.31	
		0.705	2.35	
		0.684	2.28	
2	10	0.72	2.4	2.5
		0.75	2.5	
		0.765	2.55	
		0.792	2.64	
		0.765	2.55	
		0.795	2.65	
3	20	0.825	2.75	2.8
		0.84	2.8	
		0.885	2.95	
		0.855	2.85	
		0.8295	2.765	
		0.855	2.85	
4	30	0.945	3.15	3.2
		0.9	3	
		0.975	3.25	
		1.005	3.35	
		0.945	3.15	
		0.9855	3.285	

E. Modulus Of Elastisity

The value of strain corresponding to different stresses for various percentages of CSFB and thecorresponding Young's Modulus are tabulated in below Tables.

Table 5: Modulus of elasticity for 10% Replacement

Load	Stress	Deflection	Strain
0	0.000	0	0
1	0.555	10	0.000417
2	1.111	16	0.000667
3	1.666	22	0.000917
4	2.222	31	0.001292
5	2.777	39	0.001625
6	3.332	46	0.001917
7	3.888	56	0.002333
8	4.443	71	0.002958
9	4.999	84	0.0035
10	5.554	96	0.004
11	6.110	110	0.004583
12	6.665	120	0.005
13	7.220	136	0.005667
14	7.776	142	0.005917
15	8.331	155	0.006458
16	8.887	161	0.006708
17	9.442	165	0.006875
18	9.997	172	0.007167
19	10.553	176	0.007333
20	11.108	180	0.0075
21	11.664	181	0.007542
22	12.219	183	0.007625

Modulus of Elastisity, E= 1602.49N/mm^2

Conclusion

Based on limited experimental investigation on the compressive and split tensile strength of concrete, the following observations are made The SFB is a locally available, low cost, and inertindustrial solid waste whose disposal is a matter of concern likes construction waste, On an overall, the CSFB is comparable to natural river sand. The CSFB satisfies the zone II gradation for not only to partially replace the sand, but for making good The SFB is locally available, low cost, and inert industrial solid waste whose concrete.Unit weight of CSFB is higher than that of river sand aggregate in dense condition which, in turn contributes to the increase in the unit weight of concrete containing CSFB as a fine aggregate. From the results we observe that the maximum strength is achieved by 30% of CSFB replacement in concrete. The 40th % of CSFB replacement in concrete indicates there is no strength gaining after increasing the proportion. Thecompressive strength of partial replacement of CSFB aggregate concrete is marginally higher than that of the river sand aggregate concrete at age 7 days, 14 days, and 28 days respectively,

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