An Investigation on Flexural Behaviour of Concrete with Fine Aggregate Partially Replaced with Grog

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Abstract:- One of the major challenges of our present society is the protection of environment. Some of the important elements in this respect are the reduction of the consumption of energy and natural raw materials and consumption of waste materials. It conserves natural resources and reduces the space required for the landfill disposal.

The reduction in the sources of natural sand and the requirement for reduction in the cost of concrete production has resulted in the increased need to identify substitute material to constituent materials as aggregates in the production of concretes. Several types of waste materials have been investigated for this purpose both in developing and developed countries and the outcome of success has been varying. The materials usually researched for this purpose are either by-product materials or even sometimes manufactured aggregates. The advantages of utilization of byproducts or aggregates obtained as waste materials are pronounced in the aspects of reduction in environmental load and waste management cost, reduction concrete production cost and enhancement in some properties of concrete.

In order to solve this problem, reliable source and continuous supply of alternative material for these ingredients should be thought of and their use should be recommended. It is essential that this recommended alternative material should be eco-friendly and they should be available at cheaper cost without an interrupted supply on to the construction industry.

Key Words: Grog, Flexural Strength

I. CRUSHED SPENT FIRE BRICK (GROG)

Fire brick is the product made of highly purified clays generally fired at 1300 - 1400 ^{0}C used as one of the construction materials for metallurgical based industries such as manufacturing and processing of Iron and steel, Alloy castings etc. Ex. Rastreeya Ispath Nigam Limited, Visakhapanam. There are number of such industries processing steel and allied products in India. The quantum of Fire bricks usage per annum is very high and depends on capacity of the industry.

Usually the Fire bricks are used for inner lining of kiln meant for firing. Due to continuous exposure to high degrees of temperature about 1,800 to2,100ºC for a period of 10 to 15 days, fire bricks lose some of the physical and mechanical properties and need to be replaced by fresh fire bricks. The usage and replacement of fire bricks is periodical in nature in metallurgical based industries. The fire bricks disposed off after use are called as Spent Fire Bricks.

The Spent Fire Brick being an industrial solid waste to be disposed off properly without causing environmental problems in the vicinity of dump. Usually the waste materials are disposed by land filling. In the similar manner the spent fire bricks are also used as land filling material.

The fire bricks so generated as waste are physically cleaned and mechanically crushed to grade conforming to fine aggregates. The fineness modulus of crushed spent fire brick powder is nearly equal to river sand used in concrete. As such, the crushed spent fire brick can be used in place of river sand partially in making the concrete.

In East Godavari District of Andhra Pradesh there are number of refractory kilns working. They manufacture different types of refractory products for Metallurgical Industries. Some of the products include different shapes of Fire Bricks, Bottom Poring Sets etc. These manufacturing industries are concentrated in Rajahmundry and Jaggampeta Mandals. For the present study the Crushed Spent Fire Brick is procured from industries located in Jaggampeta Mandal**.**

II. OBJECTIVE OF PRESENT WORK

The objective of present work is to study the behavior of concrete where sand is partially replaced with crushed spent fire brick in flexure.

At the outset the study was made for optimized value of replacement and standard cubes, cylinders and prisms are to be cast for studying the compressive strength, split tensile strength and flexural strength for the optimized results.

Based on these values arrived at beams of size110 x 210 x 1600 mm with Area of Steel of 0.97 percent were prepared. It was proposed to study the behavior of concrete with and without replacement under flexure till failure

The physio-chemical properties of sand and crushed spent fire brick

To verify the suitability of crushed spent fire brick as partial replacement to sand, the following material properties were compared.

Table.1 Physio-Chemical Properties of Sand and Crushed spent fire brick

S.No	Properties of Material	Sand	crushed spent fire brick
1	Specific Gravity	2.53	2.53
2	Fineness Modulus	2.36	2.65
3	Bulk Modulus in loose state	1548	1437
4	Bulk Modulus in compact state	1696	1696
5	p^H value	7.2	8.01
6	Percentage of Silica	90-95%	37%
7	Percentage of Alumina	0.005-0.01%	50%
8	Water absorption	0.94%	1.50%
9	Stability and Reactivity	No	No

1. Both sand and crushed spent fire brick aggregate have almost the same specific gravity, fineness modulus, bulk density (at both the states), porosity and pH value.
2. Whereas % of Silica, % of Alumina, % of water absorption were found to be different.
3. The crushed spent fire brick was made of very fine clay material, exposed to very high temperature during manufacturing process as such it may not as inert as sand, but does not affect the quality of concrete when used as an ingredient.
4. The suitability of crushed spent fire brick aggregate as an ingredient in making concrete was investigated for in this study proved good.

III. OPTIMIZATION OF MATERIALS

The natural sand was partially replaced by different % of crushed spent fire brick for arriving at the optimum % of replacement that gives maximum strength. As per the mix design, the river sand was partially replaced by Crushed Spent Fire Brick in 10%, 20%, 30% 40% and 50% and specimen were cast as per the procedure laid down in IS 456-2000. After 24 hours, the test specimens were demoulded and cured and tested after 7 days for Compressive Strength. The test results are tabulated as follows.

Table 2 7 days Compressive Strength of concrete for different % of crushed spent fire brick

S.No	% of crushed spent fire brick replaced	7 days Compressive Strength in N/mm^2

1	0%	22.15
2	10%	22.67
3	20%	27.33
4	30%	28.74
5	40%	26.59
6	50%	27.03

Observations: It was observed that concrete with 30% replacement gave maximum strength and the maximum 7 days compressive strength is 28.74 N/mm^2. Comparison of Gradation curve of sand and crushed spent fire brick
Final mix proportion per m^3 of concrete is given in table.
Table 3 Mix Proportions

Water (Lt)	Cement(kg)	Sand(kg)	Coarse Aggregate (kg)
174	348	679	1236
0.50	1.00	1.95	3.55

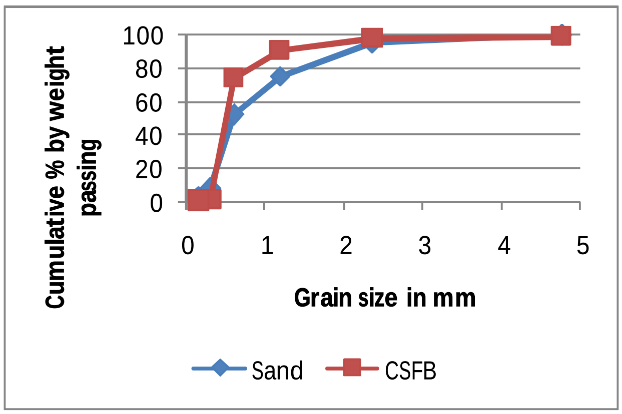


Fig.1 Gradation curve of sand and crushed spent fire brick

IV. THE QUANTITY OF MATERIALS PER M^3 OF EACH TYPE OF CONCRETE

The quantity of materials for each type of concrete mix is given in the table.

Table 4. Quantity of materials per m^3 of concrete for different types of concretes

Details	Nominal Mix	Mix with crushed spent fire bricks
Cement Kg	348	348
Sand Kg	679	475
Crushed spent fire brick Kg	--	204
Coarse Aggregates Kg	1236	1236
Water Lt	174	174
Super Plasticizer (Conplast) ml	870	870

Specimens for each type of concrete

A Total of 18 Cubes, 18 Cylinders and 18 Prisms 6 beams were cast to carryout the experimental study. Minimum of 3 specimens were cast as stipulated by IS Code 456:2000 for 3 days, 14 days and 28 days results..

Preparation of specimens

The scheme of experimental program was to cast of Cubes of size 150×150×150mm, Cylinders of size 150×300mm Prisms of size 100×100×500mm and RCC beams of size110×210×1600mm, curing them in water for 7days, 14 days and 28 days. After curing the specimens were tested for compression strength, split tensile strength and flexural strength. The test were done as per specifications in IS 516-1959.

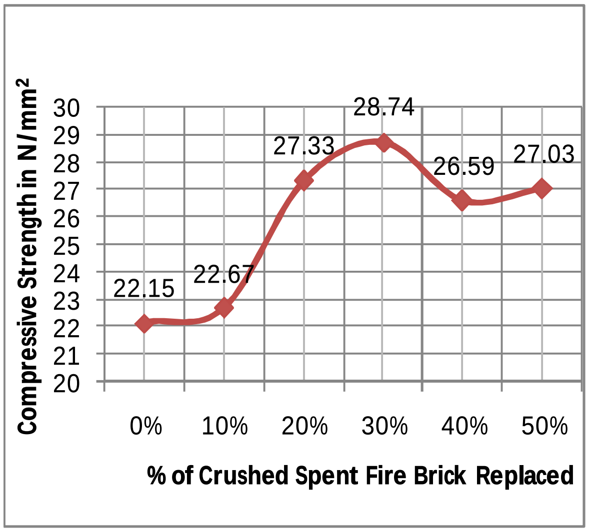


Fig. 2. 7 days Compressive Strength Vs % of Crushed Spent Fire Brick

Strength of Optimized Materials

The experimental investigation has been carried out on the test specimens to study the strength properties of concrete by replacing the fine aggregate by crushed spent fire brick in various percentages viz 10%, 20%, 30% 40% and 50% for arriving optimum % of crushed spent fire brick that gives maximum strength. The test specimens were cast in steel moulds. The inside of the mould was greased with oil to facilitate the easy removal of specimens. The raw materials were weighed accurately. The concrete was mixed thoroughly in dry condition.

The mixing was continued until a uniform colour was obtained. Fresh concrete was placed in the mould in three layers, and each layer was compacted using vibrator. After 24 hours from casting, the test specimens were taken out and placed in a curing tank, for 7 days age of the specimens. The specimens were tested for compression in UTM for arriving optimum % of crushed spent fire brick that gives maximum strength.

1. The optimum % of crushed spent fire brick that has given maximum strength was found to be at 30% replacement.
2. Maximum 7 days Compressive strength achieved was 28.74 $N/mm^2 \approx 29 N/mm^2$

Testing and tabulation of experimental results

The experimental work has carried out with optimum quantity of crushed spent fire brick powder so arrived above to produce for Nominal mix and Mix in which sand was partially replaced by optimum % of crushed spent fire brick. The strengths of different types of concretes at 7, 14 and 28 days Compressive strength of different types of concrete at 7, 14 and 28 days are tabulated below. The results are also shown graphically.

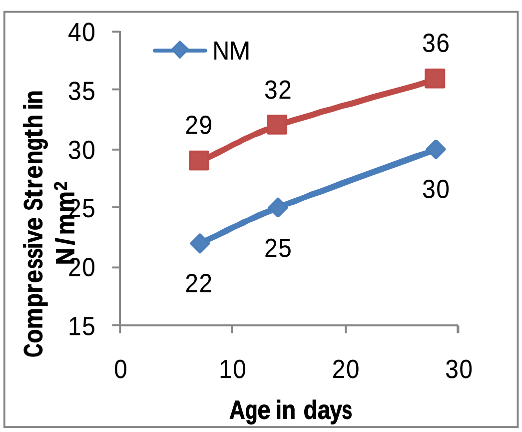


Fig. 3. Compressive Strength Vs type of concrete

Table 5 Split tensile strength of different types of concrete with age

Type of Concrete	Split tensile strength in N/mm^2		
	7 days	14 days	28 days
Nominal Mix(NM)	1.64	1.81	1.97
Concrete mix in which sand is replaced by Optimum % of crushed spent fire brick(SFBM)	1.89	2.28	2.72

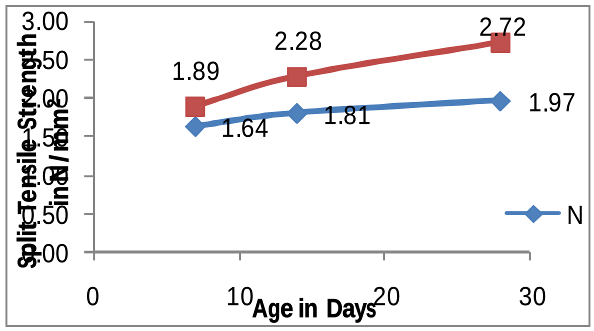


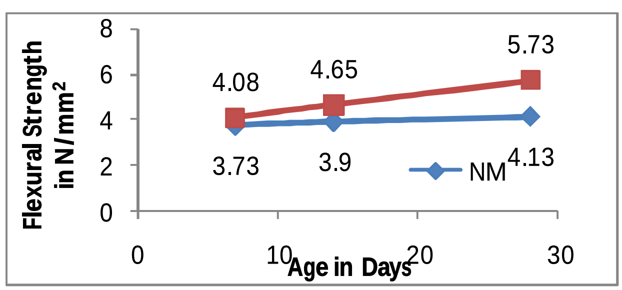
Fig. 4. Split tensile strength Vs type of concrete

Observations: From the above results, it is observed that The 28 days Split tensile strength of crushed spent fire brick concretes was more than nominal concrete by 38.07%.

Flexural Strength of different types of concrete at 7, 14 and 28 days are tabulated below. The results are also shown graphically.

Table 6. Flexural Strength of different types of concrete with age

Type of Concrete	Flexural strength in N/mm^2		
	7 days	14 days	28 days
Nominal Mix (NM)	3.73	3.9	4.13
Concrete mix in which sand is replaced by Optimum % of crushed spent fire brick(SFBM)	3.85	4.65	5.73



Graph 5. Flexural strength Vs type of concrete

Observations: From the above results, it is observed that The 28 days Flexural strength of crushed spent fire brick concrete was more than nominal mix by 38.74%.

Deflection of beams: Beams are tested for deflections and the observations were tabulated as follows.

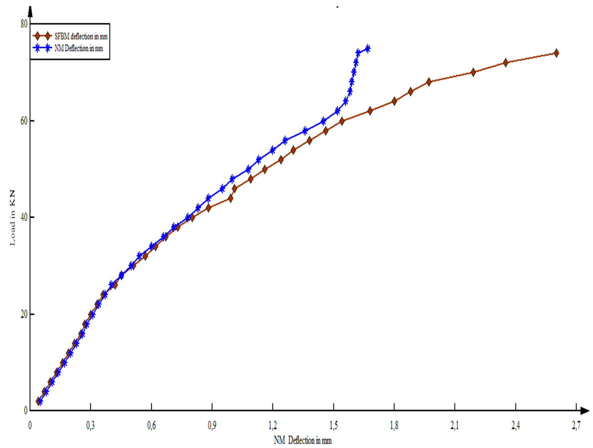


Fig. 5 Load Deformation test result

Table 7 Ultimate Load of beams with different concretes

S.No	Type of concrete mix	Ultimate Load (kN) (Des)	Ultimate Load (kN) (Expt)
1	Nominal mix (NM)	61.74	67.50
2	Replaced mix (SFBM)	61.74	74.00

Table 8 Flexure capacity of different concrete

S.No	Type of mix	Designed ultimate moment (kN-m)	Experimental ultimate moment (kN-m)
1	Nominal mix (NM)	15.43	16.87
2	Replaced mix (SFBM)	15.43	18.50

Design Of Under Reinforced Beam

RCC Beams are Designed as Under reinforced sections having Size of Beam as 110 x 210 x1600 with Bottom reinforcement 2 numbers 12 mm, Hanger bars of 2 numbers of 10 mm and Shear reinforcement having 6 mm diameter bars at 200 mm spacing c/c

Flexure Test on R.C.C Beam:

The beam specimens of size 110 x 210 x 1600 mm with M20 grade concrete were cast 3 Nos with nominal mix and 3Nos with replaced mix. After completion of 28 days curing, the beams were tested under central point load. As the existing beam specimen is of 1.60m length and the testing span was restricted to 1.00m,central point load is adopted. All the beams were simply supported over the span of 1000 mm and test loading frame of capacity 1000kN.

Dial gauges were arranged to the bottom of beam and hydraulic load is applied linearly. Dial gauge readings measure the deflection of beam at each interval of 2KN load, and also observed the first crack and the load and corresponding deflection. This process was continued for all beams and also noted the ultimate load with corresponding deflection for all beam sections. The testing arrangements of the beam specimens were shown in figure.

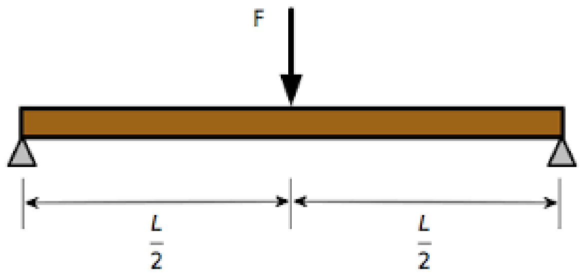


Fig. 6. Simply Supported Beam with Central Point Load

Observations:

1. Mode of failure: All beams have failed in flexural mode.
2. Deflection: The maximum deflection reached was 2.60mm less than the deflection stipulated in IS Code 456:2000 i.e., 20 mm
3. Crack pattern: The flexure cracks initiated in the pure bending zone at mid span. As the load increases further, the cracks propagated up wards and new cracks are developed at the bottom of the span. The initially formed cracks were at the mid span, has increased in width when failure has reached. The bottom of beam deflected significantly, indicating that the tensile steel might have yielded at failure.
4. Width of Crack: The width of all the cracks formed are well within the limit stipulated in IS code 456:2000 i.e 0.30 mm
5. The ultimate load reached was 67.50 kN & 74.00 kN for nominal mix and replaced mix as against the designed load of 61.74 kN.
6. The ultimate moment reached was 16.87 kN-m & 18.50 kN-m for nominal mix and replaced mix as against the designed moment of 15.43 kN-m.

5.5 Conclusions

- The specific gravity and fineness modulus, bulk density (at both the states) and pH value of crushed spent fire brick were nearly equal to that of river sand.
- The slump decreases with increase in % of crushed spent fire brick.
- By varying the crushed spent fire brick content from10% to 50%, the optimum quantity of crushed spent fire brick was found to be 30% of sand by weight based on 7 days compression test.
- High early strengths were observed due to replacement of sand by crushed spent fire brick.
- It is found that the crushed spent fire brick was suitable and economical alternative for the natural sand, as it gives the required strength and shows better results.
- The compressive strength, Split Tensile Strength and Flexural Strength of concrete with partial replacement of sand by crushed spent fire brick were shown good amount of increase to that of concrete with the river sand at the age of 7, 14 and 28 days.
- The increase in compressive strength was 29.75 % at 7 days 31.03 % at 14 days and 19.82 % at 28 days respectively
- The increase in Split tensile strength was 15.24 % at 7 days, 25.97 % at 14 days and 38.07 % at 28 days
- The increase in Flexural strength was 0 % at 7 days, 19.23 % at 14 days and 38.74 % at 28 days
- The 28 days compressive strength of nominal mix and crushed spent fire brick replaced concrete reached the target strength of 26.60 N/mm^2
- The flexural strength of all types of concrete was more than the values computed based on IS 456 formula: 0.7 √fck.
- All the beams were failed in the flexural zone
- At failure, the flexural crack propagated from the tension zone towards compression zone.
- Increased deflection was observed for the beam with SFBM compared to the nominal mix.
- The deflections at mid span at service load were within the prescribed limits as per codal provisions.

- The ultimate load reached by both nominal mix and SFBM was higher than the designed load.
- The ultimate moment reached for both nominal mix and SFBM was higher than the designed moment.

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