A Study on Compressive Strength of Normal Curing Concrete and Self Curing Concrete by Partial Replacement of Fine Aggregate with Crushed Spent Fire Brick

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Abstract - Concrete is one of the most important building materials, mixture of cement, aggregates and water with or without suitable admixtures. Concrete industry is particularly important as it is not only responsible for consuming natural resources but also for its capacity of absorbing other industrial wastes and by-products. The choice of aggregates is important and their quality plays a great role as they not only limit the strength of concrete but owing to their characteristics they affect the durability and performance of concrete. The consumption of sand as fine aggregate in concrete production is very high, and several developing countries have encountered difficulty to meet the increasing needs. To overcome the demand for river sand, researchers have identified some alternatives for sand, namely quarry dust, artificial sand, silica fume, furnace slag, welding slag, Fly ash, Bottom ash etc. The utilization of these locally available materials should achieve economy and required design strength. Spent fire brick is one such material. Generally the fire brick is used for inner lining of kiln meant for firing. Due to continuous exposure to high degrees of temperature about 1,000 to1,200ºC for a period of 10 to 15 days, fire bricks loose 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. (SFB)

Key words: spent fire brick, aggregate and concrete.

I. INTRODUCTION

The Spent Fire Brick being an industrial solid waste is to be disposed off properly without causing environmental problem. Usually most of 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 almost equal to fine aggregate used in concrete. As such the crushed spent fire brick can be used partially in place of fine aggregate while making the concrete.

Curing

As per IS 456:2000, Curing is defined as the process of preventing the loss of moisture from the concrete while maintaining a satisfactory temperature regime. Curing of concrete plays a major role in improving its durability and performance by developing the concrete microstructure and pore structure . Concrete can be cured using water or can be self cured using appropriate self curing agents.

II. PROPOSED PROGRAMME

The main objective is to compare the strength of concrete by normal curing and self curing in which sand is replaced by optimum % of crushed spent fire brick with nominal mix.

The materials used for experimental program is as follows.

1. Cement: KCP cement of 53 grades is used in this entire project work.
2. Fine aggregate: Locally available Godavari river sand conforming to Zone-II grade is used.
3. Coarse aggregate: Locally available coarse aggregate passing through 20 mm but retained on 10mm sieve are used.
4. Crushed spent fire brick: Crushed spent fire brick is procured from locally available Industries.
5. Water: Ordinary potable water without acidity and alkalinity available in the laboratory is used.
6. Super Plasticizer: Conplast SP 430 is used to reduce the frictional properties of concrete.

2.1.To verify the suitability of crushed spent fire brick as partial replacement to sand, the following material properties are 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	PH value	7.2	8.01
6	% of Silica	90-95%	37%
7	% of Alumina (Al_2O_3)	0.005-0.01%	50%
8	Water absorption	0.94%	1.50%
9	Porosity		25-30%

From the above, it is observed that,

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

Figure-1.Spent fire brick in kiln operation

To study this M30 concrete mix is considered.
The mix proportion per m³ of concrete is (M30)

Water	Cement(kg)	Sand(kg)	Coarse Aggregate(kg)
169.56	376.80	662.74	1258.31
0.45	1.00	1.76	3.34

Mix proportion is given as 0.45: 1: 1.76: 3.34

2.2. Poly Ethylene Glycol – 400

Polyethylene glycol (PEG)is a condensation polymer of ethylene oxide and water with the general formula H(OCH2CH2)nOH, where n is the average number of repeating oxy ethylene groups typically from 4 to about 180. One common feature of Polyethylene glycol appears to be the water-soluble nature. Polyethylene glycol is non-toxic, odorless, neutral, lubricating, non-volatile and non-irritating and is used in a variety of pharmaceuticals. Polyethylene glycol 400 is strongly hydrophilic
Depend on molecular weight the wide range of the physical property such as solubility,
Hygroscopic, Vapour pressure, melting or freezing point and viscosity are variable.
Solubility- Increasing the molecular weight of Polyethylene glycol results in decreasing solubility in water and solvents. Polyethylene glycol is also soluble in many polar organic solvents such as acetone, alcohols.
Hygroscopic-Polyethylene glycol is hygroscopic, it means that they attract and retain moisture from the atmosphere. Hygroscopic capacity decreases as molecular weight increases.
Viscosity-Polyethylene glycol can be considered Newtonian fluids, so the kinematic viscosity of Polyethylene glycol is 83-105 centistokes.
Stability- PEGs have low volatility and are thermally stable.
The use of Polyethylene Glycol (PEG400) in conventional concrete as an admixture helps better hydration and hence the strength of concrete. Rate of evaporation of water from concrete during hydration depends up on molecular weight of self curing agent. Low molecular weight self-curing agent possess low rate of evaporation, hydroxyl value and effects blockage of pores in concrete. If molecular weight increases, the solubility in water decreases. Low molecular weight self-curing agent has remarkably good effect on surface quality. For this reason, the low molecular weight Poly Ethylene Glycol (PEG-400) is used in the project.
REACTION OF SELF CURING AGENT WITH WATER

When self-curing agent added to water it forms hydrogen bond. Hydrogen bonds the attractive interaction of a hydrogen atom with an electronegative atom such as Oxygen, fluorine that comes from another molecule or chemical group. These hydrogen bonds reduce water evaporation from concrete.

Table – 2 Properties of Poly Ethylene Glycol – 400

S.No.	Specification	Value
1	Molecular weight	380 – 420
2	Appearance	clear liquid
3	Colour	white
4	Moisture	0.2% max
5	Hydroxyl value	264 - 300 (mg KOH/g)
6	pH	4.5 – 7.5
7	Specific gravity	1.12 - 1.13

2.3. Water

Ordinary potable water without acidity and alkalinity available in the laboratory was used. The pH value of water is 7.1 i.e., neutral in nature.

III. EXPERIMENTAL RESULTS

3.Optimization of Materials

The natural sand is partially replaced by different % of crushed spent fire brick for arriving at the optimum % of replacement that gives maximum strength. Similarly, the self curing agent Poly Ethylene Glycol - 400 is used in different % dosages by weight of cement that gives maximum strength.

3.1. Optimization of crushed spent fire brick

As per the mix design, the river sand is partially replaced by Crushed Spent Fire Brick in 10%, 20%, 30% and 40% and specimen are cast as per the procedure laid down in IS 456-2000. After 24 hours, the test specimens are demoulded and placed in fresh water tank for curing. After 7 days, they are tested for Compressive Strength. The test results are tabulated as follows. Graph is also drawn.

Observations: It is observed that concrete with 30% replacement gave maximum strength and the maximum 7 days compressive strength is 31 N/mm2. A graph is also drawn.

Table 3.1 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%	28.60
2	10%	28.31

3	20%	27.15
4	30%	31.00
5	40%	26.86

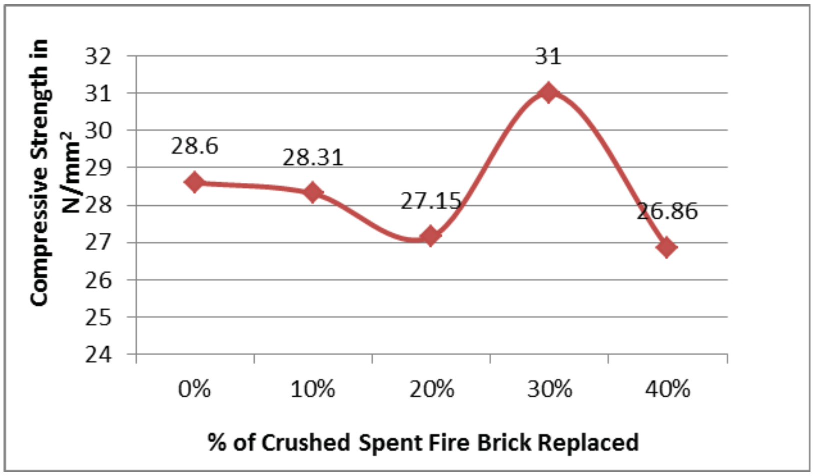

Figure-2 7 days Compressive Strength Vs % of Crushed Spent Fire Brick

3.2 Optimization of Self Curing Agent PEG- 400

Similar procedure is followed to find out the optimum dosage of the self curing agent Poly ethylene glycol- 400. PEG-400 is used in dosages of 0.5%, 1%, 1.5% and 2% by weight of cement. Specimens are cast as per the procedure laid down in IS 456. After 24 hours, the test specimens are demoulded and placed in open atmosphere in lab for self curing. They are then tested for 7 days Compressive Strength. The test results are tabulated as follows.

Table 3.2 7 days Compressive Strength of concrete for different % of PEG

S.No	% of PEG - 400	Compressive Strength in N/mm^2
1	0%	28.60
2	0.5%	30.78
3	1.0%	25.26
4	1.5%	29.04
5	2.0%	28.46

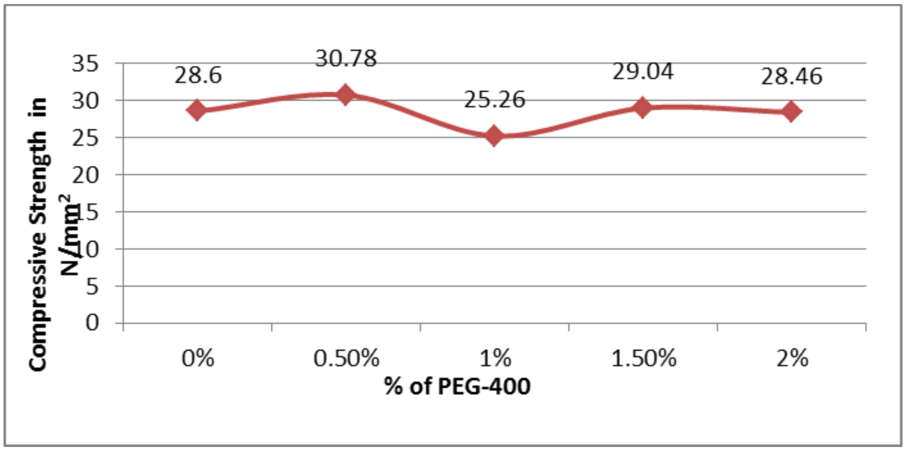

Figure-3 7 days Compressive Strength Vs % of PEG 400

Table 3.3 Specimens for each type of concrete mix

Type of Test	No. of Cubes for Compression Test		
Mix/Age	**7 days**	**14 days**	**28 days**
Nominal Mix Water cured (NMW)	3	3	3
Mix with crushed spent fire brick Water cured (SBW)	3	3	3
Mix with crushed spent fire brick Self cured (SBS)	3	3	3

3.3 Properties of hardened concrete

The specimens so cast is tested for compression as per specifications of are 516-1959 using appropriate testing equipment.

3.4 Cube compression strength test

Compression test is the most common test conducted on hardened concrete, because it is an easy test to perform and most of the desirable characteristic properties of concrete are qualitatively related to compressive strength.

The cube specimen is of the size 150 X 150 X 150 mm is used in the present study as the largest nominal size of the aggregate not exceeded 20mm.

The test is carried out using UTM of capacity 300 M.T applying a uniform stress of 140 kg/cm²/minute. The loading is continued till the dial gauge needle just reverses its direction of motion. The maximum compressive strength of the cube is calculated by dividing the maximum load (P) applied to the specimen during the test by its cross sectional area (A).

$$fc = P / A.$$

Where, fc– Compressive Strength in N/ mm²

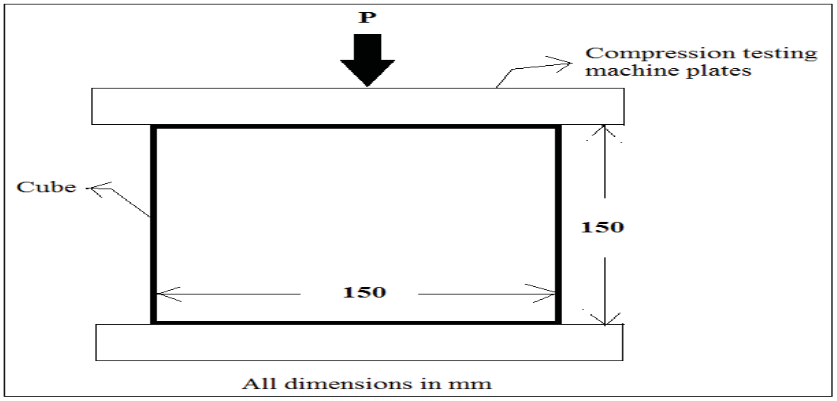

Figure – 4. Testing of cube in UTM

3.5. The strengths of different types of concretes at 7, 14 and 28 days

.Table 3.4 Compressive strengths of different types of concrete with age

Type of Concrete	Type of Curing	Compressive strength in N/mm^2		
		7 days	14 days	28 days
Nominal Mix (NMW)	Water Cured	30.92	34.55	41.67
Concrete mix in which sand is replaced by Optimum % of crushed spent fire brick	Water Cured	33.28	38.18	42.39
	Self Cured	22.65	29.33	31.36

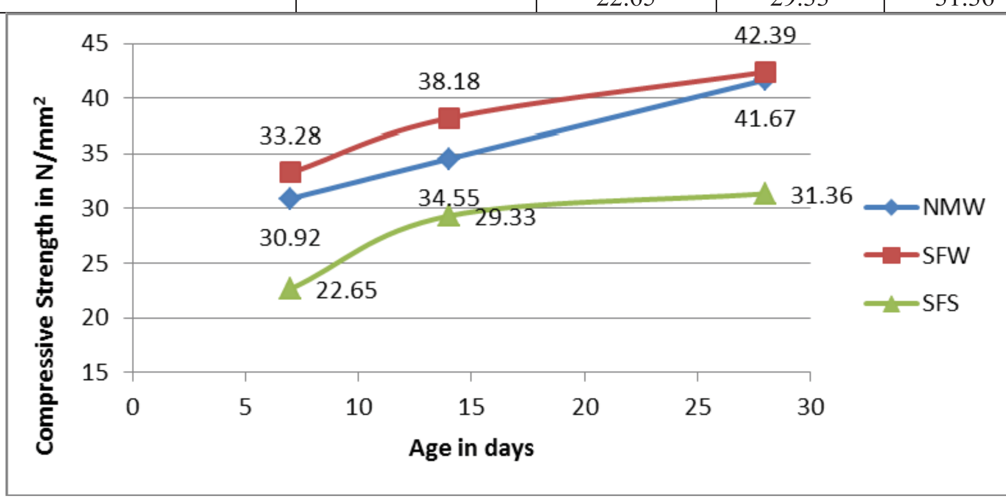

Figure - 5. Compressive Strength Vs type of concrete

3.6. Compressive Strength of different types of concrete at 28 days is tabulated below.

Table 3.5 Compressive Strength of different types of concrete at 28 days

Type of Concrete	Type of Curing	Compressive Strength
Nominal Mix	Water Cured (NMW)	41.67 N/mm^2
Concrete mix in which sand is replaced by Optimum % of crushed spent fire brick	Water Cured (SFW)	42.39 N/mm^2
	Self Cured (SFS)	31.36 N/mm^2
Target Strength		38.25 N/mm^2

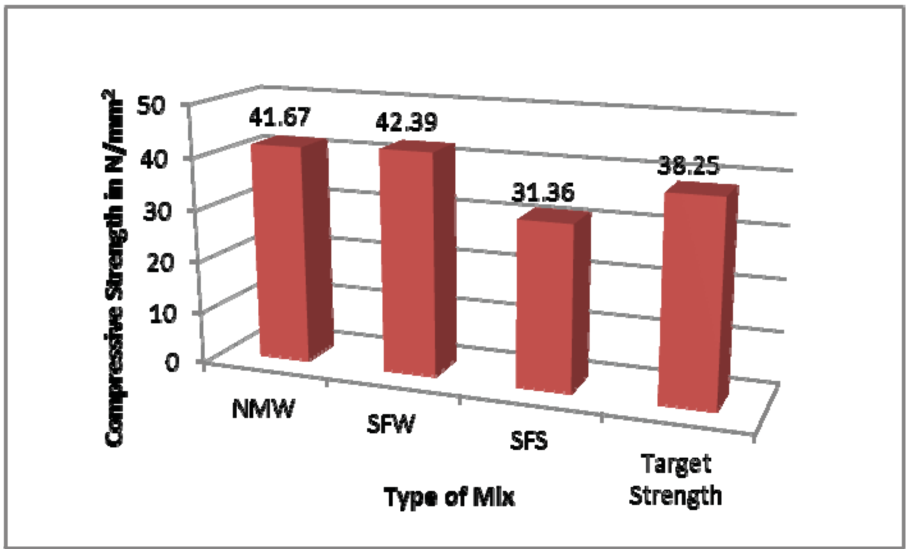

Figure – 6 28 days Compressive Strength Vs type of concrete

Observations: From the above results, it is observed that

1. The 28 days compressive strength of nominal mix and crushed spent fire brick concrete have reached above the target strength of 38.25 N/mm^2.
2. The compressive strength of self cured concrete is 31.36 N/mm^2, below the target strength of 38.25 N/mm^2 by 18%.

IV. CONCLUSIONS

4.0. Conclusions

4.1. General

The properties of fresh and hardened concrete are compared. The compatibility of materials for replacements is observed. The optimization of material is done. The compressive strengths of hardened concrete so arrived are compared with respect to each other.

4.2. Specific

1. The specific gravity and fineness modulus, bulk density (at both the states) and pH value of crushed spent fire brick are nearly equal to that of river sand. Hence, sand can be suitably replaced by crushed spent fire brick.
2. By varying the crushed spent fire brick content from10% to 40%, the optimum quantity of crushed spent fire brick is found to be 30% of sand by weight based on 7 days compression test.
3. High early strengths are observed due to replacement of sand by optimum % of crushed spent fire brick.

4. It is found that the crushed spent fire brick is suitable and economical alternative for the natural sand, as it gives the required strength and shown better results.

Properties of water cured Concrete with river Sand	**Vs**	**Properties of water cured Concrete with partial replacement of sand by crushed spent fire brick**

5. The compressive strength has shown marginal increase to that of concrete with the river sand at the age of 7 days, 14 days, and 28 days when water cured.
6. The increase in 7 days, 14 days and 28 days compressive strength is 14.10 %, 10.51% and 1.73% respectively.

Properties of self cured Concrete with partial replacement of sand by crushed spent fire brick	**Vs**	**Properties of water cured Concrete with partial replacement of sand by crushed spent fire brick**

7. The method of curing has effect on the strength of concrete. Water cured concrete mixes showed better results compared to self cured concrete.
8. The compressive strength of self cured concrete have shown lower values compared to water cured concrete (both with replacement of sand by optimum % of crushed spent fire brick) at the age of 7 days, 14 days, and 28 days.
9. The decrease in 7days,14 days and 28 days compressive strength is 35.80 %, 23.18 % and 26.02 % respectively

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