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An Experimental Study on Strength Properties of Concrete by Using GGBS for the Construction of Rigid Pavement

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Abstract
The present study aims to identify the most suitable way to utilize the waste materials produced from industries as the replacement of cement for highway construction purposes. Several studies have been conducted across the world which identified the adverse effects of different waste materials on environment as well as on human health also. The basis of different studies, it was revealed that the production of cement on large scale is also responsible for causing several diseases to the human and the water pollution. Therefore, it is the need of the situation to utilize the different waste material as an alternative of cement. For the same purpose several studies were conducted across the world. Consequently, different waste materials were found to be appropriate ranging from 5% to 50% for the highway construction purposes. But, still there is a need to replace the cement completely by introducing another material by considering the chemical composition of cement. In the present study, an attempt has been made to aware the researchers and engineers to manufacture inexperienced concrete in order to attain the balance between environment, economical and technical aspects by highlighting different methods of utilizing the discarded materials.

Keyword- Cement, GGBS, LFS, Bagasse ash, Highway pavement, Environment.

Introduction

The economy of any country depend upon a good infrastructure which covers roads, bridges, buildings, warehouses, airports, harbors, instrumentality terminals etc. In today's life, a good infrastructure is a major requirement for the growth of a country which seems impossible to attain without using cement. Cement is a powdery substance which is made up of calcining lime and clay. Mainly cement is used as a binding material which is mixed with water, sand and aggregates for the construction purposes (i.e. highways or building). Though, it is an environmental concern because of the emission of several hazardous gases at various stages of cement manufacturing process. In a previous study (Mehraj et al 2014), it was mentioned that consumption of cement in India is increasing with the rate of 10% per year. It is to note that the cement is the second most consumable material after water across the world.

The global cement industry produces over four billion tonnes of cement annually. As per the latest report of Indian Bureau of mines (2015), production of cement in India in various companies is ranging from 0.83 to 43.8 million tons per year. Therefore, production of cement in so much quantity has become the point of interest for the researchers across the world as the waste produced (i.e. cement dust) from these cement plants is very harmful to the environment and human health also. Fly ash, steel slag, E-plastic and recycled concrete aggregate are the few examples waste materials which can be recycled and used as a polymer concrete mix

which will decrease the consumption of Ordinary Portland cement (OPC) and also help in utilization of energy without causing any environmental pollution. To preserve the natural resources some waste material should be used to maintain the sustainability of the environment. However, some guidelines have been provided regarding the use of fly ash in road construction.

Cement dust produced during the preparation of cement which is considered as waste material. This waste material affects the human as well as other species (i.e. animals and plants) upto a large extent. Both (animals and human) are badly tormented due to the pollution which was occurred by cement manufacturing plants and other waste materials. A brief discussion has been made regarding the consequences of cement waste on the atmosphere, human and other living beings. Mishra et al. (2014) studied the effect of cement manufacturing emissions on surroundings and living beings. In a survey, International Energy Agency (IEA), production of cement in India will manufacture will be reached upto or more than 2000 million tons up to 2050 which will result into global warming, ozone depletion, acid rain, biodiversity loss, reduced crop production, etc. Various diseases like tuberculosis, chest discomfort, chronic bronchitis, asthma attacks, and cardiovascular diseases will be caused by cement production in huge amount as the gases that emit while production of cement is NO2, SO2, CO, CO2, H2S, VOCs, etc very harmful for the health.

2. Literature Review

Sathiparan et al. (2018) measures the effect on cement block by partially replacement of sand by some agricultural waste. Open dumping of agriculture waste causes various health hazards and also pollute the environment. Cement block were made up of agricultural waste like rice husk. Cement, sand and waste materials were mixed in different proportion like (1:5:1), (1:4:2), (1:3:3) to make 400 sample. Test was conducted to determine the compressive strength and flexural tensile strength ”density, water absorption rate,” acid attack resistance and alkaline attack resistance of sample after done the curing of 28 days at room temperature. It was concluded that cement block of 1:5:1 gives equal strength of normal mix of block as all the properties were found similar the normal one. Zabihi et al. (2018) investigated that rice husk ash mix with geopolymer concrete assure 100% replacement of cement unless property like Water absorption, flexural strength and splitting tensile strength get compromise to some extent.

Mazenan et al. (2017) analyzed a review study regarding the partial replacement of cement in place of palm oil fuel and ceramic waste. By reviewing past studies it was identified that the replacement of cement can be done by incorporating 20% of palm oil and 30 % of ceramic waste. Furthermore increment in the percentage of palm oil and ceramic waste, there must be reduction in the potency of concrete. Siddique et al. (2018) conducted a study by using bone china ceramic waste as a fine aggregate for the green concrete mix. It was concluded that 60% replaceable sample shows the maximum compressive strength due to similar composition to cement.

3. Methodology

After comparing the composition of various waste materials with OPC cement it was concluded that waste material like GGBS, LFS and Bagasse ash will be suitable for the partial replacement of cement as shown in table 1. In place of sand, stone dust will be used and for aggregate recycled aggregate will be used to some percentage. Different test that will be conducted is shown in table 3.3 to know the best suitable percentage of replacement of cement. In the end, the cost of conventional concrete will be compared with new green concrete.

Table 1: Sample to be made of different proportion.

Cement%	GGBS%
100	0
95	5
90	10
85	15
80	20
75	25
70	30
65	35

A) Different Type of Test

Normal Consistency test

The consistency of the cement test follows the IS 4031 (4) - 1988. The test for determining the consistency of cement was performed using Vicat's apparatus and consistency plunger. The water paste of cement was prepared using the water mix and was filled in the Vicat's mould. The water-cement ratio was taken as 25%. The gauging time should not be more than 5 minutes and should not be less than 3 minutes. The penetration value should lie between 7 to 5 mm and that water percentage is considered as the consistency of cement.

Initial & Final setting time

The initial & final setting time test for cement follows IS 4031 (5) - 1988. The test for determining the initial and final setting time of cement was performed using Vicat's apparatus and setting time needles. The water must be added, "0.85P" by weight of cement, where "P" is the standard consistency of cement. The initial setting time of cement was measured using 1mm penetration needle failed to penetrate at 5 -7"mm from the bottom of the mould. And, the final setting time of cement is the time at which"1mm penetration needle makes an impression on the mould 5 mm assembly failed to make any impression on the mould.

Specific gravity of cement

Fill the empty specific gravity bottle with cement and measure weight of it. After that remove half of the cement from bottle and measure its weight. Now fill the half empty bottle with kerosene and note down the weight of it. At last empty the density bottle and take weight. By some standard formula specific gravity was calculated.

Tensile strength of cement

Take 300g of cement, 900gm of sand and water (P/5 + 2.5) of water, then mix them properly. Put mix into briquette mould. After 24hr open the sample and put in curing tank for 3 and 7 days.

Compressive strength of cement

The cube of size of 7cm x 7cm x 7cm was constructed with the help of cement motor. This test was conducted after measuring the consistence of cement so that that much amount of water is used while making sample and

standard vibration machine is used for compaction. After constructing cube they were tested in CTM for 7, 14 and 28 days respectively.

Specific gravity of sand

Pycnometer method is used to determining the specific gravity of sand. Take weight of empty pycnometer. Fill pycnometer with sand and take weight of it, after that fill that bottle with half sand and half water and measure the weight of it. After taking readings fill pycnometer with water. Now with the help of formulas calculate the specific gravity.

Specific gravity of coarse aggregate

The test for determining the specific gravity of coarse aggregate follows IS 2386 (3) – 1963. Using the wire bucket, the specific gravity test for coarse aggregate was performed.

Compressive strength of concrete

The test for the compressive strength of concrete blocks can be checked by compression testing machine after 28 days curing. The concrete cubes are of dimension 150 mm x 150 mm x 150 mm were prepared using mix of grade M40. Before casting the cubes, the cubes mould should be cleaned properly and coat inside with oil and use fresh water for curing process. Mould should also subjected to vibration so that minimum number of void remain in sample.

Fig. 1: Compression test machine.

Split tensile strength of concrete.

Split tensile test was performed with the help of UTM on cylindrical sample. Load was applied on the horizontal surface at height of cylinder. Two wood strips will applies at top and bottom surface where load was applied so that crushing of concrete does not take place where plane surface of UTM and surface of specimen meets. Size of cylinder sample will be 150 mm dia and 300mm height.

Fig. 2: Splitting tensile setup.

Figure shows a typical failed sample. The splitting tensile strength of a cylinder specimen was calculated using the following equation:

$T=2P/\pi LD$, Where

T = splitting tensile strength of cylinder (mm^3);

P = maximum applied load (N);

L = average length of cylinder (mm); and

D = average diameter of cylinder (mm).

4. Results Analysis

The cube with standard size of 150 X 150 X 150 mm was used to find the compressive strength of concrete by using waste material in them. Place cubes inside the plates of CTM and apply a constant rate of loading until failure of cube will occur. The ultimate load was measured as shown below in table 2.

Table 2: Compressive strength by using GGBS for 7 days.

% Replacement of GGBS	Casting–I (MPa)	Casting–II (MPa)	Casting–III (MPa)	Average (MPa)
0%	26.42	27.41	27.21	27.01
5%	30.08	28.22	29.64	29.31
10%	30.22	30.66	31.02	30.63
15%	27.77	28.00	28.17	27.98
20%	26.53	26.35	25.91	26.26
25%	23.77	24.71	24.22	24.23
30%	21.33	20.57	20.84	20.91
35%	18.66	19.22	19.73	19.20

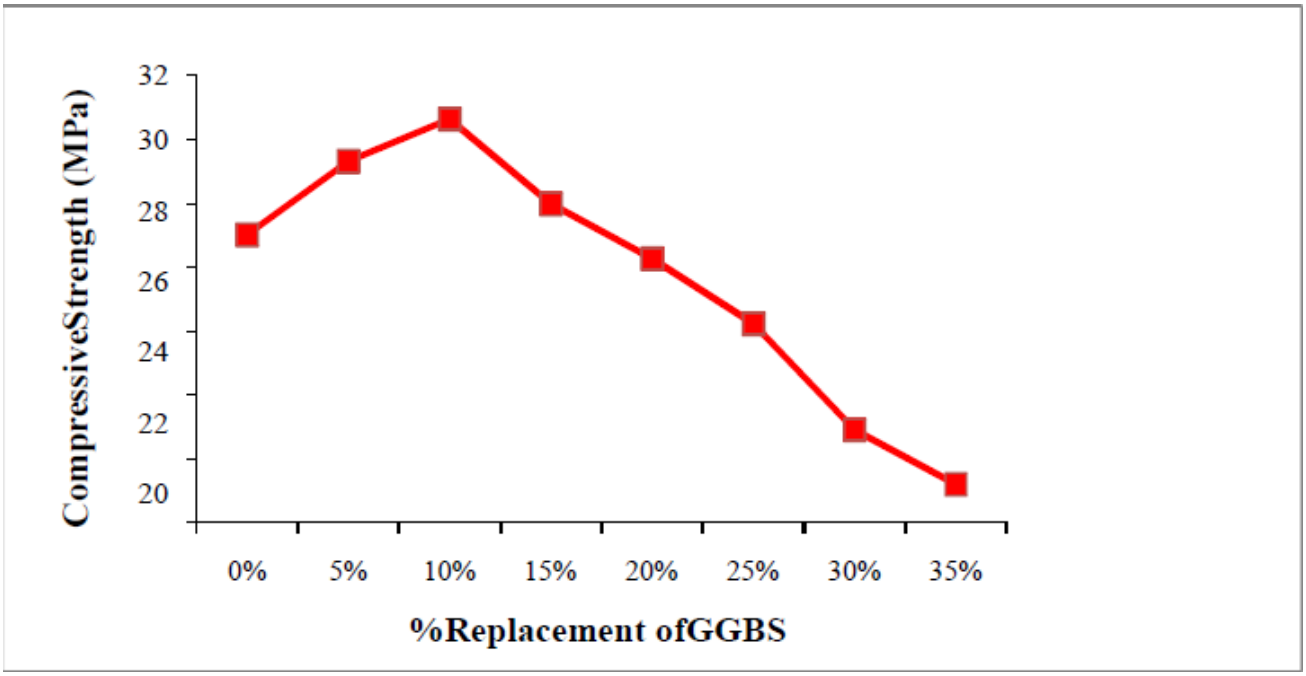

Fig 3: Fluctuation in compressive strength with the % of GGBS for 7 days.

Table 3: Average Compressive strength by using GGBS for 28 days.

%Replacement by GGBS	Casting–I (MPa)	Casting–II (MPa)	Casting–II (MPa)	Average (MPa)
0%	40.65	42.17	41.87	41.56
5%	42.77	44.09	46.52	44.46
10%	43.12	45.90	46.86	45.29
15%	42.57	40.66	40.73	41.32
20%	39.17	40.34	40.18	39.89
25%	38.97	38.15	38.74	38.62
30%	37.41	35.80	36.85	36.68
35%	34.00	35.80	30.50	33.43
40%	31.67	33.39	32.80	32.62
45%	32.45	30.22	30.54	31.07
50%	29.41	28.32	26.19	27.97

In fig 4. Compressive strength for 28 days by using GGBS gives optimum results, when cement was replaced up to 15%. At 10 % replacement there was an increment of 12% compressive strength.

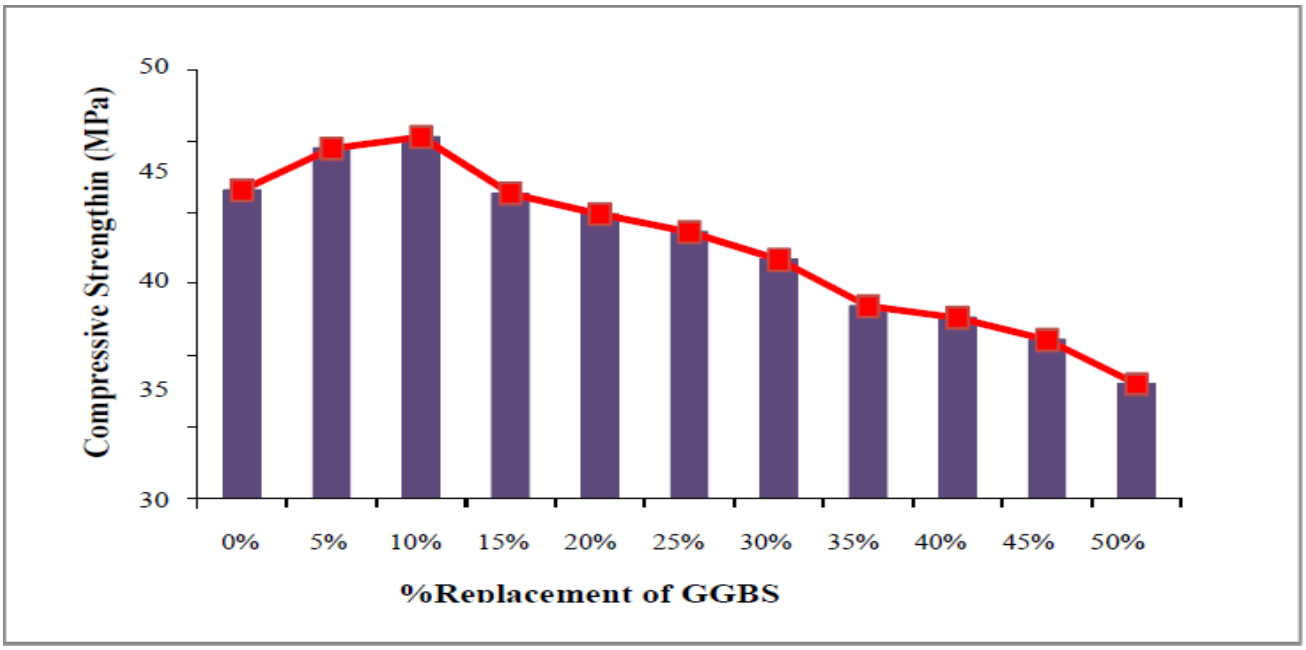

Fig 4: Fluctuation in compressive strength with the % of GGBS for 28 days.

Split tensile test was performed with the help of CTM on cylindrical sample. Load was applied on the horizontal surface at height of cylinder. Two wood strips will applies at top and bottom surface where load was applied so that crushing of concrete does not take place where plane surface of CTM and surface of specimen meets. Size of cylinder sample will be 150 mm dia and 300mm height. In table 4. split tensile strength of various materials was calculated.

Table 4: Split tensile strength of GGBS after 28 days.

% Replacement by GGBS	Casting–I (MPa)	Casting–II (MPa)	Casting–III (MPa)	(Average) (MPa)
0%	3.05	2.99	3.02	3.02
5%	3.18	3.24	3.22	3.21
10%	3.25	3.30	3.34	3.29
15%	3.35	3.40	3.38	3.37
20%	3.31	3.28	3.30	3.29
25%	3.25	3.18	3.24	3.22
30%	3.18	3.11	3.15	3.14
35%	3.13	3.07	3.05	3.08

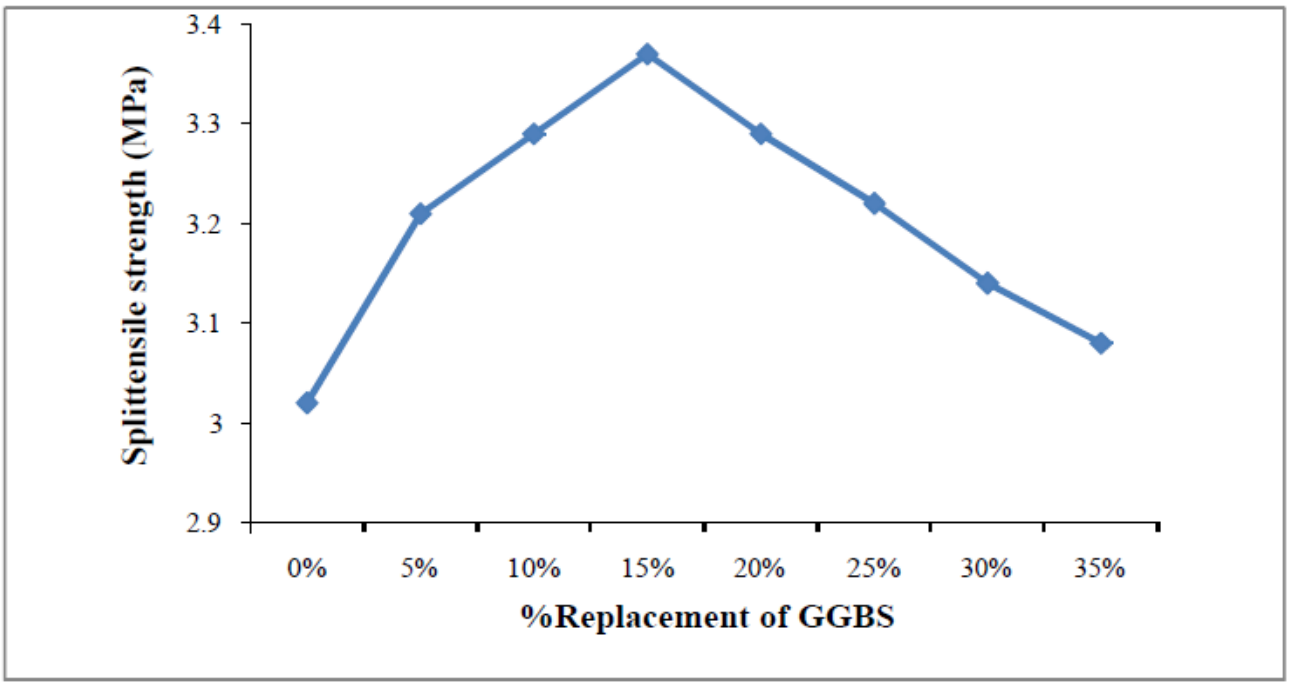

Fig 5: Deviation in Split tensile strength with the percentage of GGBS for 28 days.

5. Conclusions

1. variation in compressive strength with the percentage of GGBS for 7 and 28 days, which results 15% replacement of cement by GGBS optimally.
2. At 10 % replacement there was an increment of 12% compressive strength.
3. Compressive strength for 28 days by using GGBS gives optimum results, when cement was replaced up to 15%. At 10 % replacement there was an increment of 12% compressive strength.
4. Different combinations of these three waste materials were prepared during the study. On the basis of the results it was observed that 5% of GGBS in the mix exhibit maximum compressive strength.
5. Split tensile strength of GGBS is slightly higher than the conventional concrete.

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