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An experimental investigation on the properties of concrete containing manufactured sand & GGBS

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Abstract
Robo sand is manufactured sand which is eco-friendly solution that serves as perfect substitute for the fast depleting and excessively mined river sand. The effect of water cement ratio on fresh and hardened properties of concrete with partial replacement of natural sand by manufactured sand was investigated. Concrete mix design of M20 (2900 psi) grade was done according to Indian Standard code (IS: 10262). Concrete cube, beam and cylindrical specimens were tested for evaluation of compressive, flexural and split tensile strength respectively. Workability was measured in terms of slump and compacting factor. The concrete exhibits excellent strength also, so it can be used in concrete as viable alternative to natural sand. This paper puts forward the applications of manufactured sand as an attempt towards sustainable development in India. It will help to find viable solution to the declining availability of natural sand to make eco-balance.

Keywords: Manufactured sand, natural sand, aggregate, cement, fine aggregate, concrete, compressive strength, workability

1. Introduction

Concrete is the most widely used construction material in the world. It is a composite construction material made primarily with aggregate, cement and water. The word concrete comes from the Latin word “concretes” (meaning compact or condensed), the perfect passive participle of “concrescere”, from “con”-(together) and “crescere”-(to grow).

Concrete solidifies and hardens after mixing with water and placement due to a chemical process known as hydration. The water reacts with the cement, which bonds the other components together, eventually creating a robust stone-like material. There are many formulations of concrete, which provide varied properties and concrete is the most-used man-made product in the world.

There are many types of concrete available, created by varying the proportions of the main ingredients below. In this way or by substitution for the cementitious and aggregate phases, the finished product can be tailored to its application with varying strength, density, or chemical and thermal resistance properties.

Now a day’s concrete is being used for wide varieties of purposes to make it suitable in different conditions. In these conditions ordinary concrete may fail to exhibit the required quality performance or durability. In such cases, admixture is used to modify the properties of ordinary concrete so as to make it more suitable for any situation.

Admixture is defined as a material, other than cement, water and aggregates, which is used as an ingredient of concrete and is added to the batch immediately before or during mixing. Generally admixtures are of two types. Chemical admixtures and Mineral admixtures.

2. Literature Survey

Ozkan Sengul *et al.* replaced 50% of cement by finely ground fly ash and finely ground granulated blast furnace slag in concrete with water/binder ratios of 0.60 and 0.38 and tested rapid chloride permeability. The result indicated that incorporation of pozzolans are more effective than decreasing the water/cement ratio in rapid chloride permeability.

Ilangovan *et al.* (2006) [5] studies the strength and behaviour of concrete by using crushed rock dust as fine aggregate, they investigated the possibility of using crushed rock as 100 % replacement for sand, with varying compacting factors.

Nagraj T.S. (2000) [3] studied the proportioning concrete mixes with rock dust as fine aggregate.
Safiuddin *et al.* (2007) [4] carried investigation on utilization of quarry waste fine aggregate in concrete mixtures.
Misra (1984) [10] studied the effect of complete replacement of sand by stone dust in the cement – sand mortar cubes.

3. Materials and Its Properties
The materials used in our project and their physical properties are as follows
3.1. Cement
3.2. Coarse aggregate
3.3. Fine aggregate
3.4. Water
3.5. Robo sand
3.6. Ground Granulated Blast Furnace Slag (GGBS)

3.1. Cement
Cement is a binder and is defined as a finely ground inorganic material which, when mixed with water, forms a paste which sets and hardens by means of hydration reactions and processes which, after hardening retains its strength and stability even under water.

3.2. Coarse Aggregate
The coarse aggregate are granular materials obtained from rocks and crushed stones. They may be also obtained from synthetic material like slag, shale, fly ash and clay for use in light-weight concrete.

3.3. Fine Aggregate
The sand obtained from river beds is used as fine aggregate. The fine aggregate along with the hydrated cement paste fill the space between the coarse aggregate. The common shape of river sand is cubical or rounded with smooth surface texture.

3.4. Water
Combining water with a cementitious material forms a cement paste by the process of hydration. The cement paste glues the aggregate together, fills voids within it, and makes it flow more freely. The water should satisfy the requirements of Section 5.4 of IS:456 - 2000.

3.5. Robo Sand
Robo sand is manufactured sand which is eco-friendly solution that serves as perfect substitute for the fast depleting and excessively mined river sand. Robo sand with size 0-4.75 mm is suitable for all concrete preparations and is used across all segments such as independent houses, builders, concrete batching plants and infrastructure concrete works.
The robo sand generally contain more angular particles with rough surface texture and flatter face than natural sand that are more rounded as a result of weathering. The angular properties and rough surface of robo sand influences the workability and finish ability in fresh concrete.
Properties of robo sand used are as follows,

- Specific Gravity of Robo Sand = 2.84
- As per IS 383-1970 the Robo Sand is classified under grading zone II.

3.6. Ground Granulated Blast Furnace Slag (GGBS)
GGBS us a by-product from the blast-furnaces used to make iron. These operate at a temperature of about 1,500 degrees centigrade and are fed with a carefully controlled mixture of iron-ore, coke and limestone. The iron ore is reduced to iron and the remaining materials form a slag that floats on top of the iron. This slag is periodically tapped off as a molten liquid and if it is to be used for the manufacture of GGBS it has to be rapidly quenched in large volumes of water. The quenching, optimizes the cementitious properties and produces granules similar to a coarse sand. This “granulated” slag is then dried and ground to a fine powder
Concrete made with GGBS cement sets more slowly than concrete made with ordinary Portland cement, depending on the amount of GGBS in the cementitious material, but also continues to gain strength over a longer period in production conditions.

3.6.1. Effects of Slag on Fresh Concrete
Use of slag or slag cement usually improves workability and decreases the water demand due to the increase in paste caused by lower relative density of slag. Setting times of concretes containing slag increases as the slag content increases. The rate and quality of bleeding in concrete containing slag or slag cements is usually less than that in concrete containing no slag because of the relatively higher fineness of slag. However, slag unlike fly ash does not contain carbon, which may cause instability and air loss in concrete.

3.6.2. Effect on Strength of Hardened Concrete
In general, the strength development of concrete incorporating slag is slow at 1 to 5 days compared with that of the control concrete. Between 7 to 28 days approaches to control concrete, beyond this period, the strength of slag concrete exceeds the strength of concrete.

Table 3.6.1: Chemical composition of GGBS

Constituents	Percentage contents
CaO	40%
SiO_2	35%
Al_2O_3	13%
MgO	8%

Table 3.6.2: Physical Properties of GGBS

Color	Off white
Specific Gravity	2.9
Bulk Density	1200 kg/m^3
Fineness	1200 cm^2/gm

4. Mix Design for M2o Grade Concrete
Mix Design was done by Indian Standard Recommended Method (IS 10262 - 1982), after several trail mixes were conducted, we finally arrived the final mix proportion for M20 as 0.45:1:1.45:2.8.

5. Test Results& Graphs
The following are the test results of the fresh and hardened concrete.

5.1. Normal Concrete
5.1.1. Quantities of materials for M_{20} Grade of Normal Concrete

Table 5.1.1: Quantities of materials per m^3

Cement	Water	Fine Aggregate	Coarse Aggregate
400kg	180*lts*	580 kg	1120 kg

5.1.2. Fresh Properties

Table 5.1.2: Fresh Properties of Normal concrete

Slump	0
Compaction factor	0.911

5.1.3 Hardened Properties

Table 5.1.3: Hardened Properties of Normal concrete

No Of Days	Compressive Strength (N/Mm^2)	Tensile Strength (N/Mm^2)	Flexural Strength (N/Mm^2)
3 days	19	1.2	2.8
7 days	24.5	2.05	3.73
28 days	35.4	3.1	4.01

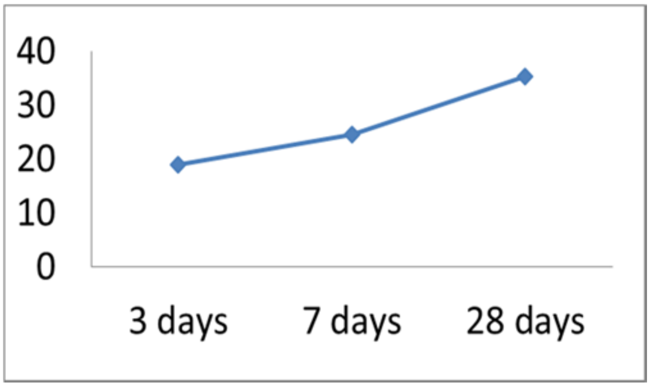

Plate 1: Compressive strength of Normal Concrete

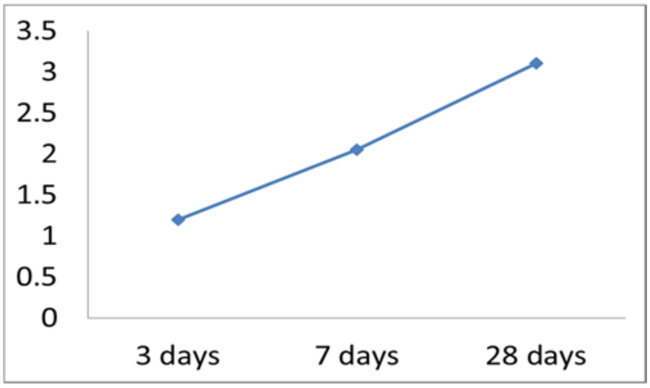

Plate 2: Tensile Strength of Normal Concrete

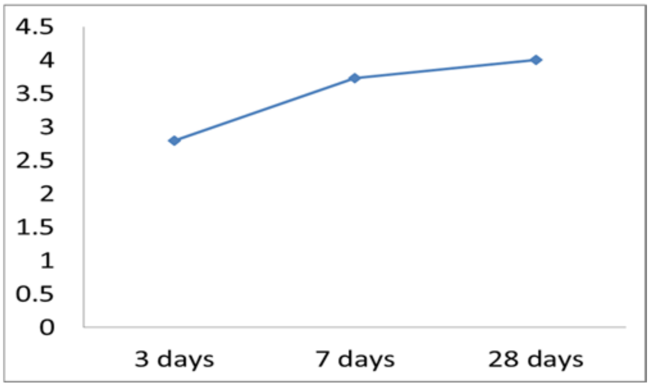

Plate 3: Flexural Strength of Normal Concrete

5.2. Trial Mixes of Normal Concrete with Ggbs

Cement was replaced with the GGBS in different proportions such as 5, 10, 15, & 20 percent.

5.2.1. Quantities of materials for Normal concrete with GGBS

Table 5.2.1: Quantities of materials

GGBS Proportion	Cement (kg)	GGBS (kg)	Water (lt)	Fine Aggregate (kg)	Coarse Aggregate (kg)
5%	380	20	180	580	1120
10%	360	40	180	580	1120
15%	340	60	180	580	1120
20%	320	80	180	580	1120

5.2.2. Fresh Properties

Table 5.2.2: Fresh Properties of Normal Concrete with GGBS

Ggbs Proportion	Slump	Compaction Factor
5%	25mm	0.911
10%	30mm	0.925
15%	36mm	0.94
20%	30mm	0.95

5.2.3. Hardened Properties

Table 5.2.3: Hardened Properties of Normal Concrete with GGBS

% Of Ggbs	Compressive Strength (N/Mm^2)			Tensile Strength (N/Mm^2)		
	3days	7days	28days	3days	7days	28 days
5%	14.4	17.2	28.5	0.5187	1.815	2.7935
10%	15.3	20.9	31.5	0.5187	1.815	2.834
15%	17.2	23	36.5	0.5187	1.8518	2.845
20%	22.2	27.6	42.3	0.778	1.9374	2.967

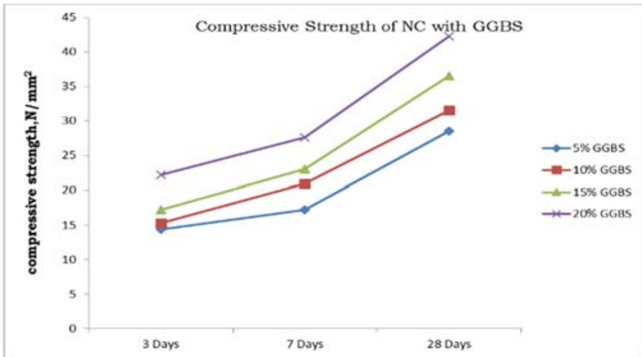

Plate 4: Compressive Strength of Normal Concrete with GGBS

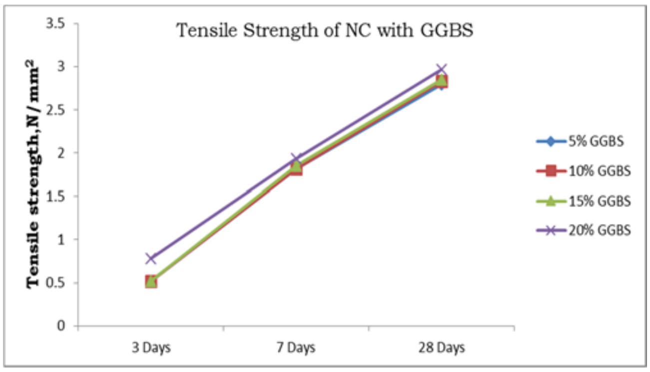

Plate 5: Tensile Strength of Normal Concrete with GGBS

5.3. Normal Concrete with Robo Sand

Sand was replaced with the Robo Sand in different proportions such as 25, 50, 75 & 100%.

5.3.1. Quantities of materials for Normal concrete with GGBS

Table 5.3.1: Quantities of materials per m^3

Robo Sand Proportion	Cement (kg)	Water (lt)	Fine Aggregate (kg)	Robo Sand (kg)	Coarse Aggregate (kg)
25%	400	180	435	145	1120
50%	400	180	290	290	1120
75%	400	180	145	435	1120
100%	400	180	0	580	1120

5.3.2. Fresh Properties

Table 5.3.2: Fresh Properties of Normal Concrete with Robo sand

Robo Sand Proportion	Slump (Mm)	Compaction Factor
25%	20mm	0.892
50%	30mm	0.893
75%	80mm	0.924
100%	70mm	0.903

5.3.3. Hardened Properties

Table 5.3.3: Hardened Properties of Normal concrete with Robo sand

% Of Robo Sand	Compressive Strength (N/Mm^2)			Tensile Strength (N/Mm^2)			Flexural Strength (N/Mm^2)		
	3days	7days	28days	3days	7days	28days	3days	7days	28days
25%	16	22	29.5	0.5187	1.78	2.85	2.9	3.5	3.9
50%	19.5	27.6	32.5	1.0374	1.83	2.896	3.01	3.75	4.05
75%	23.5	30.6	39.3	1.29	2.07	3.17	3.15	3.89	4.15
100%	18	25	32	0.778	2.07	2.9	3.25	4.01	4.30

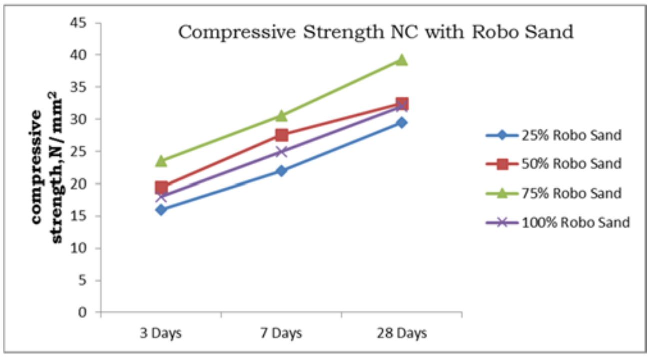

Plate 6: Compressive strength of Normal concrete with Robo Sand

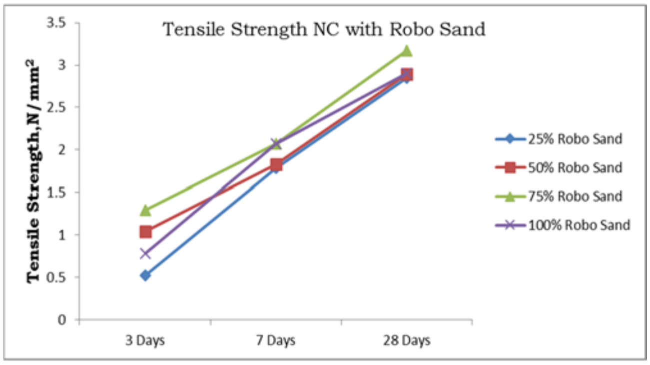

Plate 7: Tensile Strength of Normal Concrete with Robo Sand

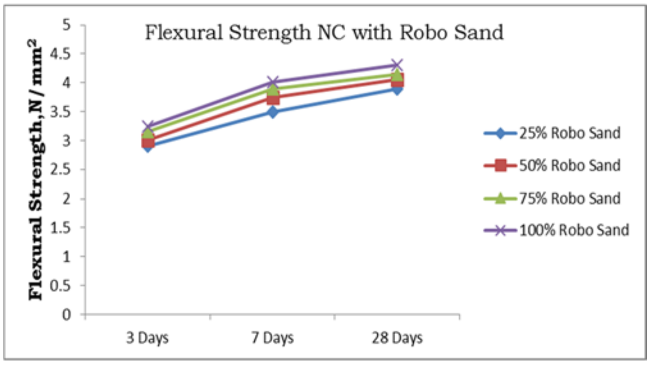

Plate 8: Flexural Strength of Normal concrete with Robo Sand

5.4. Optimized Mix of Ggbs

From the results obtained, the optimized value obtained is 20% of GGBS is convenient.

5.4.1. Quantities of materials of optimized GGBS Mix

Table 5.4.1: Quantities of materials per m^3

GGBS Proportion	Cement (kg)	GGBS (kg)	Water (lt)	Fine Aggregate (kg)	Coarse Aggregate (kg)
20%	320	80	180	580	1120

5.4.2. Fresh Properties

Table 5.4.2: Fresh Properties of optimized GGBS Mix

Slump	36mm
Compaction Factor	0.95

5.4.3. Hardened properties

Table 5.4.3: Hardened Properties of Optimized GGBS Mix

No of days	Compressive strength (N/mm^2)	Tensile strength (N/mm^2)	Flexural strength (N/mm^2)
3 days	22.2	1.2	2.8
7 days	27.66	2.05	3.73
28 days	42.3	3.1	4.01

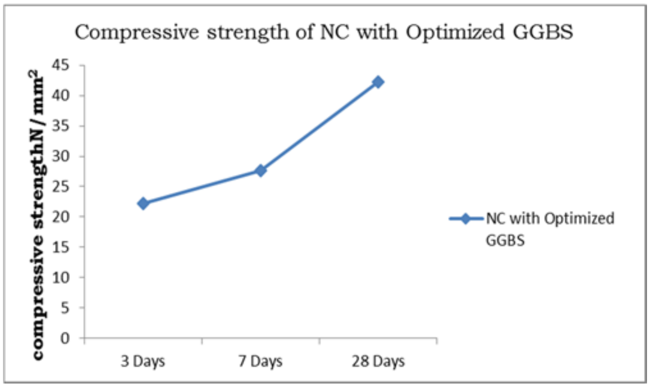

Plate 9: Compressive Strength of NC with Optimized GGBS

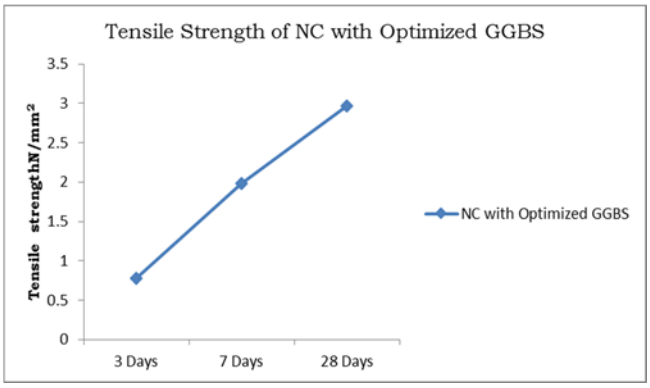

Plate 10: Tensile Strength of NC with Optimized GGBS

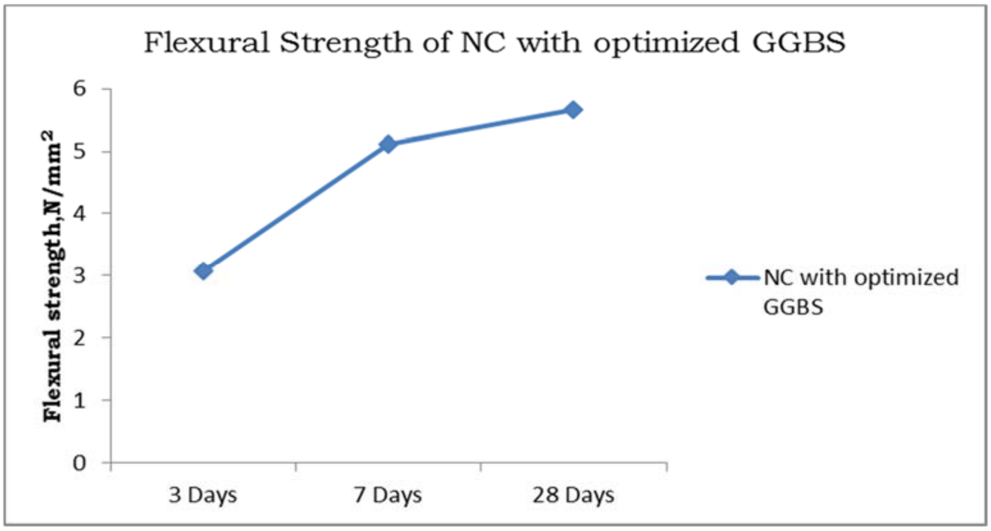

Plate 11: Flexural Strength of NC with Optimized GGBS

5.5. Normal Concrete with Optimized Ggbs and Robo Sand

Optimized value of GGBS is mixed with the different proportions of the Robo Sand

5.5.1. Quantities of materials for Normal concrete with Optimized GGBS and Robo sand

Table 5.5.1: Quantities of materials per m^3

Robo Sand Proportion	Cement (kg)	Water (lt)	Fine Aggregate (kg)	Robo Sand (kg)	Coarse Aggregate (kg)	Optimized GGBS (kg)
25%	320	180	435	145	1120	80
50%	320	180	290	290	1120	80
75%	320	180	145	435	1120	80
100%	320	180	0	580	1120	80

5.5.2. Fresh Properties

Table 5.5.2: Fresh Properties of NC with Optimized GGBS & Robo sand

Robo Sand Proportion	Slump (Mm)	Compaction Factor
25%	50mm	0.86
50%	70mm	0.88
75%	80mm	0.889
100%	60mm	0.877

5.5.3. Hardened Properties

Table 5.5.3: Hardened Properties of NC with Optimized GGBS & Robo Sand

% Of Robo Sand	Compressive Strength (N/Mm^2)			Tensile Strength (N/Mm^2)			Flexural Strength (N/Mm^2)		
	3days	7days	28days	3days	7days	28days	3days	7days	28days
25%	18.2	22.3	30.1	0.778	1.987	3.012	2.56	3.05	3.95
50%	21.8	26.2	39.8	0.785	2.05	3.125	2.57	3.14	3.85
75%	24	29.8	45.1	0.82	2.16	3.125	2.72	3.38	4.07
100%	22.4	27.6	40.5	0.88	2.1	3.01	2.68	3.17	3.75

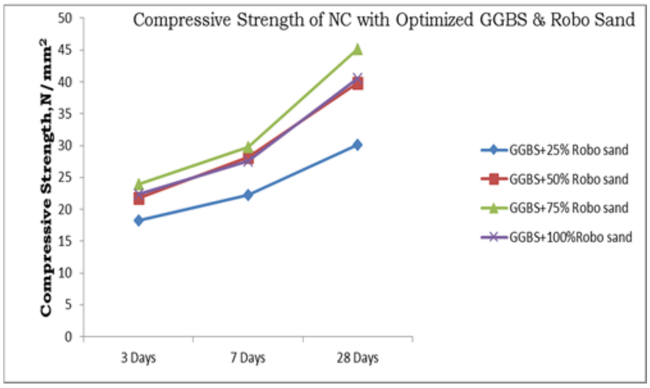

Plate 12: Compressive Strength of NC with Optimized GGBS & Robo Sand

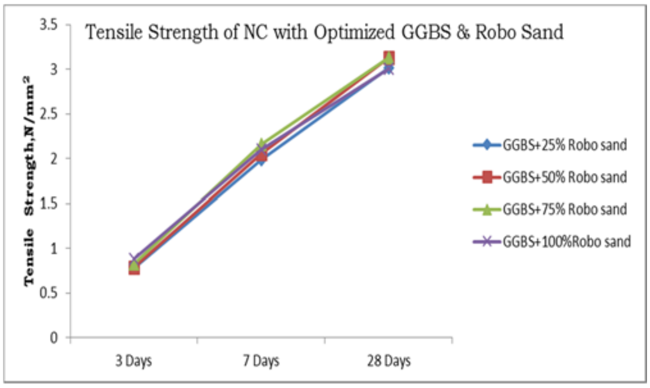

Plate 13: Tensile Strength of NC with Optimized GGBS & Robo Sand

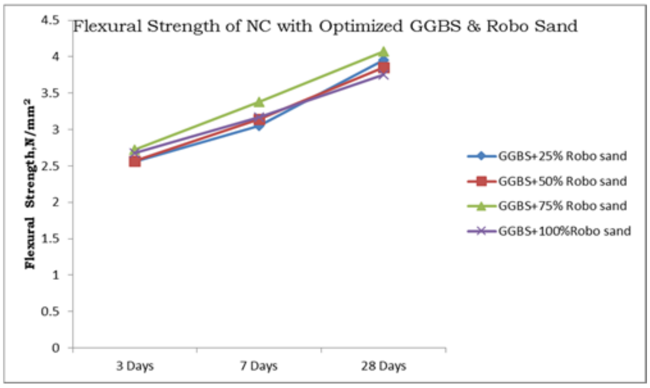

Plate 14: Flexural Strength of NC with Optimum GGBS & Robo Sand

5.6. Acid Durability Test

Initial strength is measured after 28 days curing in water; Final strength is measured after immersion in acid solution after 7days, 14days and 28day

5.6.1 Weight loss and compressive strength loss for normal concrete M20

Acid	% Wt and % CS loss	Days		
		7	14	28
2% Hcl	% Wt loss	1.47%	1.53%	1.72%
	% CS loss	12.42%	15.53%	21.75%

5.6.2. Weight loss and compressive strength loss for normal concrete with 75% Robo sand

Acid	% Wt and % CS loss	Days		
		7	14	28
2% Hcl	% Wt loss	0.88%	1%	1.3%
	% CS loss	11.19%	14.7%	18.0%

5.6.3. Weight loss and compressive strength loss for normal concrete with 20% GGBS

Acid	% Wt and % CS loss	Days		
		7	14	28
2% Hcl	% Wt loss	0.88%	1%	1.3%
	% CS loss	11.1%	14.6%	19.14%

5.6.4 .Weight loss and compressive strength loss for NC with 75% Robo sand and 20% GGBS

Acid	% Wt and % CS loss	Days		
		7	14	28
2% Hcl	% Wt loss	0.07%	0.18%	0.30%
	% CS loss	9.9%	12.3%	16.4%

6. Comparative Study

Normal Concrete with natural sand and that of with 75% robo sand

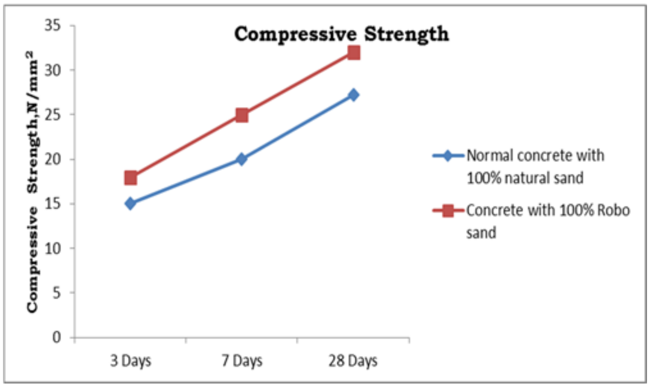

Plate 15: Compressive strength of NC with normal sand and Robo sand

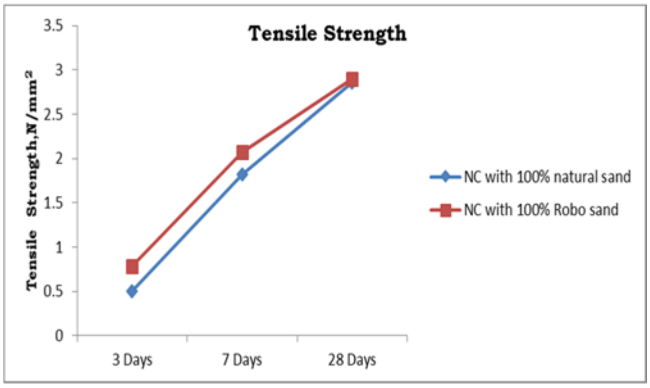

Plate 16: Tensile Strength of NC with normal sand and Robo sand

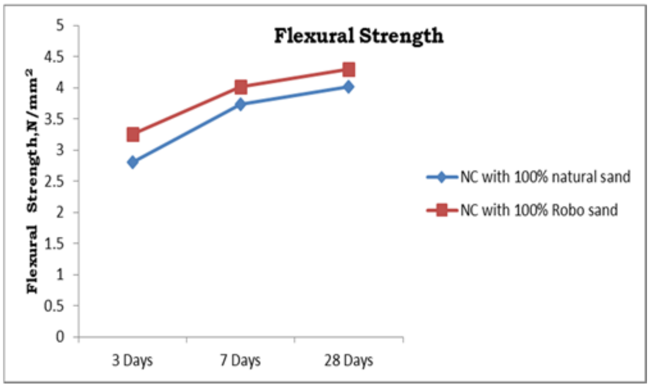

Plate 17: Flexural Strength of NC with natural sand and Robo Sand

Normal Concrete with optimized GGBS with natural sand and that of with 75% robo sand

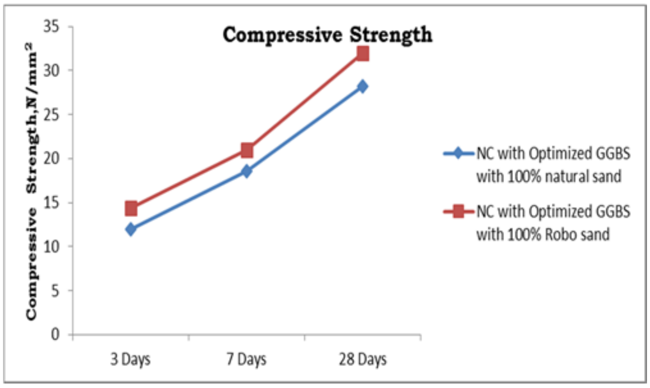

Plate 18: Compressive Strength of NC with Optimized GGBS with natural sand and robo sand

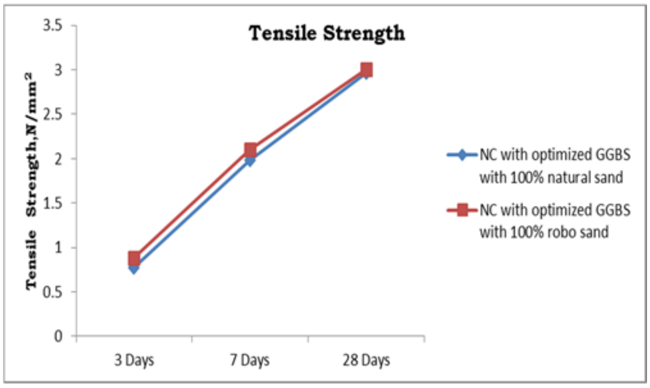

Plate 19: Tensile Strength of NC with Optimized GGBS with natural sand and Robo sand

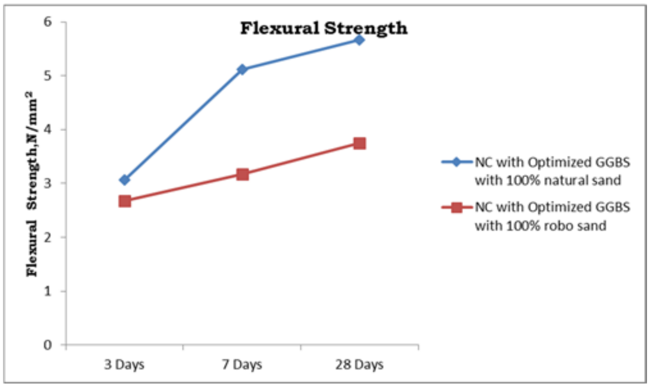

Plate 20: Flexural Strength of NC with optimized GGBS with natural sand and Robo sand

7. Discussions

7.1. GGBS

1. With the replacement of GGBS, there is an improvement in workability. The strength at early ages, there is a reduction in strength of concrete with GGBS.
2. This is because the setting action may be delayed with GGBS. At 28days, there is little hike in 16.67% compressive strength when compared to normal concrete.
3. The tensile strength values with GGBS are nearer to normal concrete at same age.

7.2. Normal Concrete with Robo Sand

1. It is observed that replacement of Robo sand in normal concrete shows an improvement in workability up to 75% beyond that the workability is slightly decrease in workability.
2. Replacement of Robo sand in normal concrete shows an increase in compressive strength of 6.66%-23.6% at 3 days, 10%-22.4% at 7days and 1.09%-11.18% at 28 days at different percentages of replacement.
3. Similarly there is a little hike in tensile strength is observed due to replacement of Robo sand with normal sand in normal concrete at 3,7,28 days.

7.3. Normal Concrete with Optimized Ggbs and Robo San

1. With Robo sand in mix of normal concrete with GGBS there is an improvement in workability by 15-30 mm as compared with the normal concrete with GGBS.
2. There is an improvement in compressive strength by 8.33%-22.5% at 3days, 2.1%-7.75%at 7days, 2.8%-6.61% at 28 days for different percentages of Robo sand.
3. Similarly there is a considerable increase in tensile strengths with the replacement of natural sand with Robo sand in Normal concrete with GGBS and Robo sand mix.
4. Similarly there is also an improvement in flexural strength with the replacement of natural sand with robo sand in optimized GGBS mix.

7.4. Compressive strength loss and weight loss for normal concrete

1. The strength loss for 7days, 14days and 28days are 12.42%, 15.53% and 21.5% respectively.
2. The weight loss for 7days, 14days and 28days are 1.47%, 1.53% and 1.72% respectively

7.5. Compressive strength loss and weight loss for normal concrete with 75% Robo sand

1. The strength loss for 7 days, 14 days and 28days are 11.19%, 14.7% and 18.0% respectively
2. The weight loss for 7 days, 14 days and 28days are 0.88%, 1.00% and 1.35% respectively

7.6. Compressive strength loss and weight loss for normal concrete with 20%GGBS

1. The strength loss for 7days, 14days and 28days are 11.1%, 14.6% and 19.14% respectively
2. The weight loss for 7days, 14days and 28days are 0.88%, 1.00% and 1.3% respectively

7.7. Compressive strength loss and weight loss for normal concrete with 75% Robo sand and 20%GGBS

1. The strength loss for 7days, 14days and 28days are 9.9%, 12.3% and 16.4% respectively
2. The weight loss for 7days, 14days and 28days are 0.07%, 0.18% and 0.30% respectively

8. Conclusions

The following conclusion can be drawn from this work.

1. The optimum percentage replacement level of GGBS in ordinary Portland cement based on the concrete maximum compressive strength and water/cement ratio of 0.45 was 20%.
2. The addition of GGBS provides high compressive strength development, comparative normal concrete. The 28 days strength increase in the 20% GGBS specimen was higher by 3.6%.
3. The admixture concrete has shown improvement in workability with GGBS.
4. Hence, observed that mineral admixtures varies the workability and strength upto certain limit.
5. Addition of Robo sand shows improvement in workability and strengths.
6. Concrete modified with robo sand perform comparatively better than normal concrete with and without admixtures like GGBS.
7. It is observed that percentage weight loss and strength loss is less in admixture concrete with robo sand as compare to normal concrete. This show that admixture concrete with robo sand compared to normal concrete has better resistance against acidic solutions

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