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Manufactured sand with silica fume, an alternative to river sand and in concrete industry

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Abstract
Scarcity of good quality Natural River sand due to depletion of resources and restriction due to environmental consideration has made concrete manufactures to look for suitable alternative fine aggregate. One such alternative is "Manufactured sand". Though manufactured sand has been in use in concrete manufacturing in India, the percentage of its contribution is still very negligible in many parts of the country. Except in Kerala and in some pockets in Southern and Western India, real processed manufacture sand is not available and this makes manufacturing of good quality of concrete very difficult. The application of concrete meeting the specification is of paramount importance, to ensure construction of durable R.C.C. structure. Hence durable concrete covers and bears the responsibility of sustaining the entire R.C.C. structure throughout it service life. 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.

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 behavior 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) [9] 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. Silica fume

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. Silica Fume
Silica fume is a by-product resulting from the reduction of high purity quartz with coal or coke and wood chips in an electric arc furnace during the production of silicon or Ferro silicon alloys. The silica fume, which condenses from the gases escaping from the furnaces has very fine spherical particles having diameter of 0.1 micro meter.
Ferro silicon alloys are produced with nominal silicon contents of 61% to 98%. As the silicon content increases in the alloy, the SiO_2 content increases in the silica fume. Generally more than 85% SiO_2 in Silica fume is satisfactory for the use of silica fume in concrete.
Precipitated silica, fumed silica, and gel silica are purposely made forms of silica. While these materials are amorphous and would be expected to perform well in concrete, they are typically too expensive for such use. Colloidal silica is a stable dispersion of discrete synthetic amorphous particles of silicon dioxide. Colloidal silica may also be referred to as silica gel. Again because of the expense, colloidal silica is not being used in concrete. Silica flour is a crystalline form of silica that may perform as a filler material in concrete. It will not contribute as a pozzolan.

3.6.1. Physical Properties
Color: Generally the color of silica fume ranges from light to dark grey. Because SiO_2 is colorless, the color is determined by non-silica components. This includes carbon and iron oxide. Higher the carbon content in silica fume, the darker the color of silica fumes.

Bulk density: Bulk densities of different types of silica fume have the values as shown below. Normal silica fume or as
Produced silica fume -- 130 to 430kg/m^3
Slurried silica fume -- 320 to 1440kg/m^3
Densified silica fume -- 500 to 600 kg/m^3
Undensified silica fume -- 200 to 300 kg/m^3

Fineness, Particle size and over shape material
Silica fume consists primarily of very fine smooth spherical particles with a surface area of approximately 20,000 m^2/kg. It is measured by nitrogen adsorption method.
The particle size distribution of a typical silica fume shows most particles to be smaller than 1 micro meter with an average diameter of about0.1 micrometer. The particle size distribution of a typical silica fume shows most particles to be smaller than 1 micro meter with an average diameter of about 0.1 micro meter, approximately 1/100 of the size of an average cement particle.

Table 3.6.1: The general chemical composition of silica fume

Chemical composition	Percentage
SiO_2	85-95
Al_2O_3	0.25-0.7
Fe_2O_3	0.58-3.86
CaO	0.2-0.7
MgO	0.2-1.0
Na_2O+K_2O	0.5-2.0
S	0.05-0.2
SO_3	0-0.3
C	0-3.5
LOI	2-4

Table 3.6.2: Chemical Composition of Silica Fume

Content	% by mass
Loss on ignition	8.33
SiO_2	67.18
Fe_2O_3	9.58
Al_2O_3	7.90
CaO	3.50
MgO	2.00
TiO_2	0.13
Na_2O	1.08
K_2O	0.02
Blains fineness, cm^2/gm	9265

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

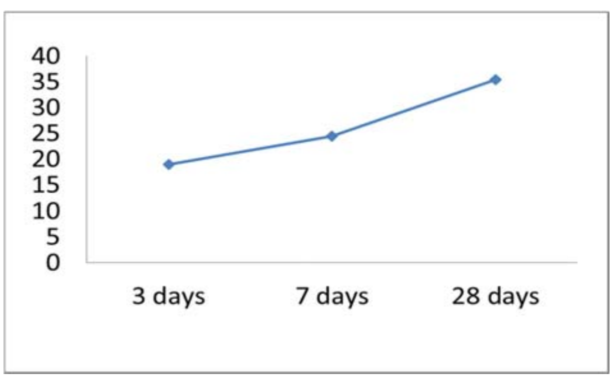

Plate 1: Compressive strength of Normal Concrete

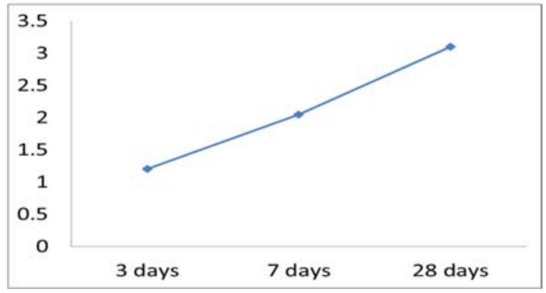

Plate 2: Tensile Strength of Normal Concrete

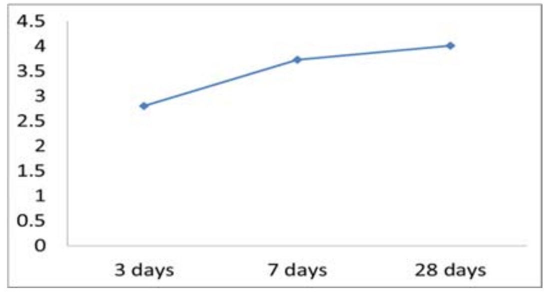

Plate 3: Flexural Strength of Normal Concrete

5.2. Trial Mixes of Normal Concrete with Silica Fume

Cement was replaced with the silica fume in different proportions such as 5, 10, 15, & 20%.

5.2.1. Quantities of materials for Normal concrete with silica fume

Table 7.2.1: Quantities of materials

Silica Fume Proportion	Cement (kg)	Silica fume (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 silica fume

Silica fume proportion	Slump (mm)	Compaction factor
5%	0	0.82
10%	0	0.80
15%	0	0.80
20%	0	0.78

5.2.3. Hardened Properties

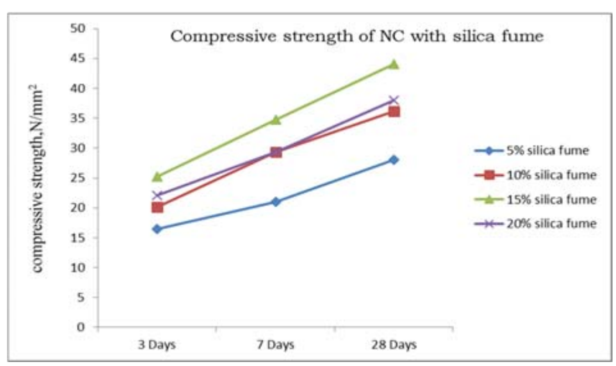

Plate 4: Compressive Strength of NC with Silica fume

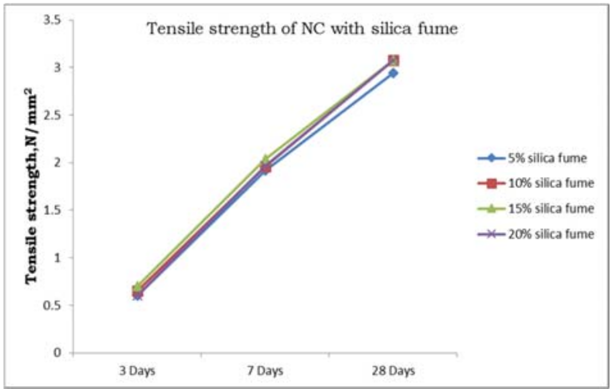

Plate 5: Tensile Strength of NC with Silica fume

Table 5.2.3: Hardened Properties of Normal Concrete with Silica fume

% of Silica Fume	Compressive Strength (N/mm^2)			Tensile Strength (N/mm^2)		
	3days	7days	28days	3days	7days	28 days
5%	16.5	21	28	0.6	1.92	2.94
10%	20.1	29.3	36.2	0.65	1.96	3.0748
15%	25.25	34.7	44.1	0.7	2.0374	3.0748
20%	22.1	29.3	38	0.6	1.97	3.0748

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 Robo Sand

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

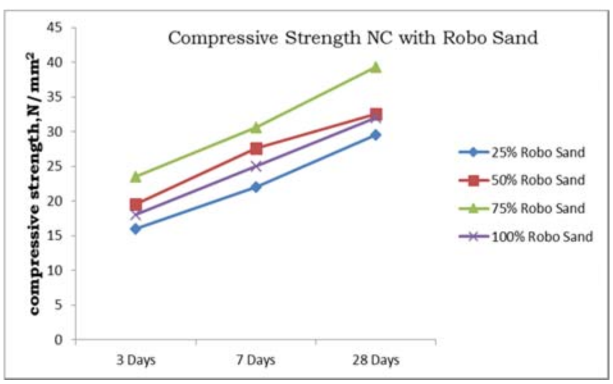

Plate 6: Compressive strength of Normal concrete with Robo Sand

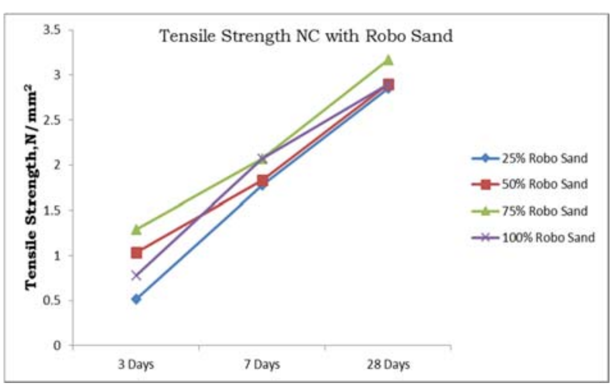

Plate 7: Tensile Strength of Normal Concrete with Robo Sand

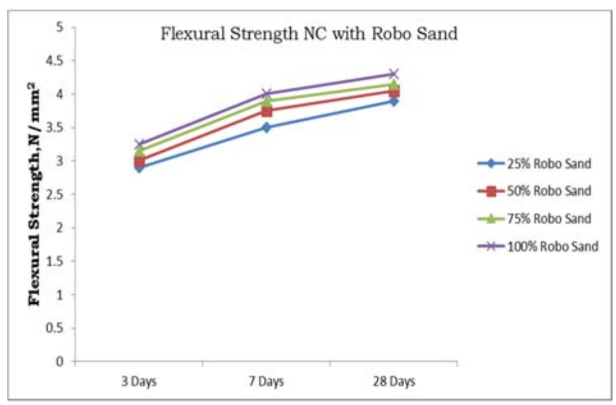

Plate 8: Flexural Strength of Normal concrete with ROBO Sand

5.4. Optimized Mix of Silica Fume

From the results obtained silica fume optimization is done. 15% of silica fume is considered as optimum mix.

5.4.1. Quantities of materials of optimized silica fume Mix

Table 5.4.1: Quantities of materials per m^3

Silica Fume Proportion	Cement (kg)	Silica fume (kg)	Water (lt)	Fine Aggregate (kg)	Coarse Aggregate (kg)
15%	340	60	180	580	1120

5.4.2. Fresh Properties

Table.5.4.2: Fresh Properties of optimized silica fume Mix

Slump	0
Compaction Factor	0.78

5.4.3. Hardened Properties

Table.5.4.3: Hardened Properties of Optimized Silica fume mix

No of days	Compressive strength (N/mm^2)	Tensile strength (N/mm^2)	Flexural strength (N/mm^2)
3 days	25.25	1.12	4
7 days	34.7	2.03	4.82
28 days	44.1	3.07	5.12

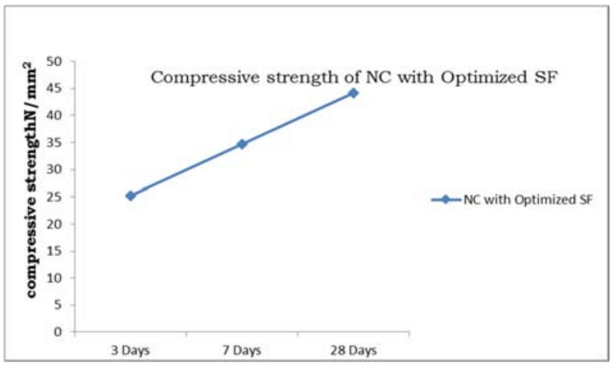

Plate 9: Compressive Strength of NC with Optimized SF

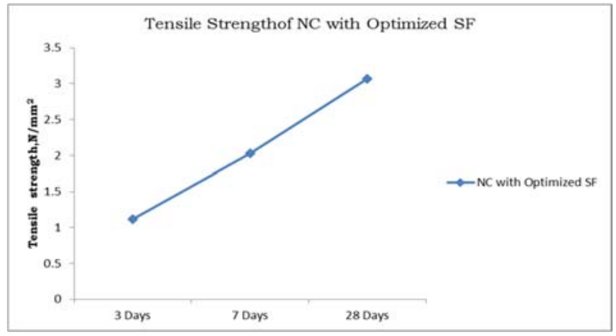

Plate 10: Tensile Strength of NC with Optimized SF

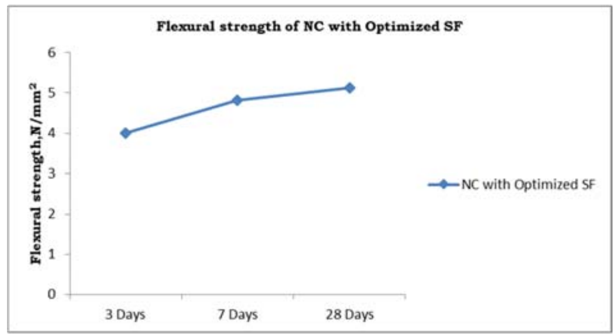

Plate 11: Flexural Strength of NC with Optimized SF

5.5. Normal concrete with optimized silica fume and robo sand

Optimized value of Silica fume is mixed with the different proportions of the Robo Sand.

5.5.1. Quantities of materials for Normal concrete with Optimized Silica fume 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 Silica fume (kg)
25%	340	180	435	145	1120	60
50%	340	180	290	290	1120	60
75%	340	180	145	435	1120	60
100%	340	180	0	580	1120	60

5.5.2. Fresh Properties

Table 7.7.2: Fresh Properties of NC with Optimized SF and Robo Sand

Robo sand proportion	Slump (mm)	Compaction factor
25%	20mm	0.869
50%	30mm	0.88
75%	50mm	0.9
100%	20mm	0.852

5.5.3. Hardened Properties

Table 5.5.3: Hardened Properties of NC with Optimized SF and Robo Sand

% of Robo Sand	Compressive Strength (N/mm^2)			Tensile Strength (N/mm^2)			Flexure Strength (N/mm^2)		
	3days	7days	28days	3days	7days	28days	3days	7days	28days
25%	23	28.9	31	1.988	2.0374	3.0748	3.89	4.01	4.53
50%	26.8	32.5	39.8	1.988	2.0374	3.14	3.29	3.89	4.86
75%	30.25	37	48.2	1.55	2.26	3.215	3.28	3.80	4.9
100%	28.3	32.1	43.4	1.64	2.17	3.21	3.16	3.79	4.14

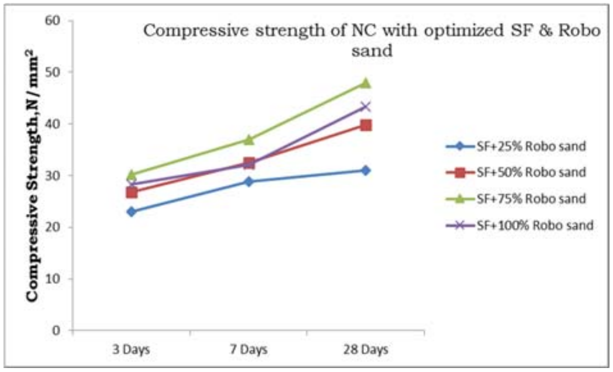

Plate 12: Compressive Strength of NC with Optimized SF& Robo sand

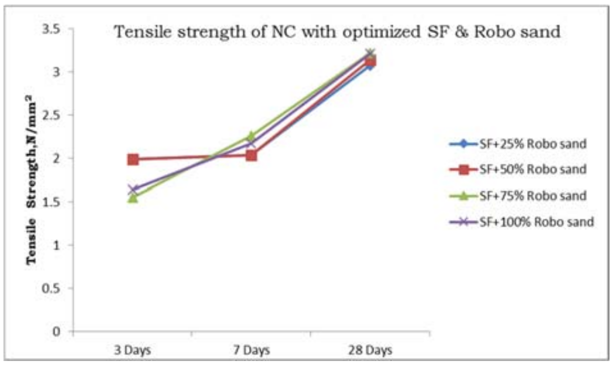

Plate 13: Tensile Strength of NC with Optimized SF & Robo Sand

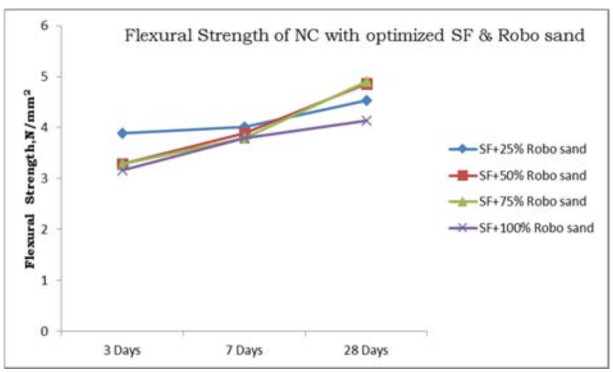

Plate 14: Flexural Strength of NC with Optimized SF & Robo Sand

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%

5.6.5. Weight loss and compressive strength loss for normal concrete with 15% silica fume

Acid%	%Wt and %CS loss	DAYS		
		7	14	28
2%Hcl	%Wt loss	0%	0.35%	0.76%
	%CS loss	10.65%	14.50%	20.86%

5.6.6. Weight loss and compressive strength loss for NC with 15% silica fume and 75% Robo sand

Acid%	%Wt and %CS loss	DAYS		
		7	14	28
2%Hcl	%Wt loss	0%	0%	.18%
	%CS loss	5.34%	8.5%	12.1%

6. Comparative Study

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

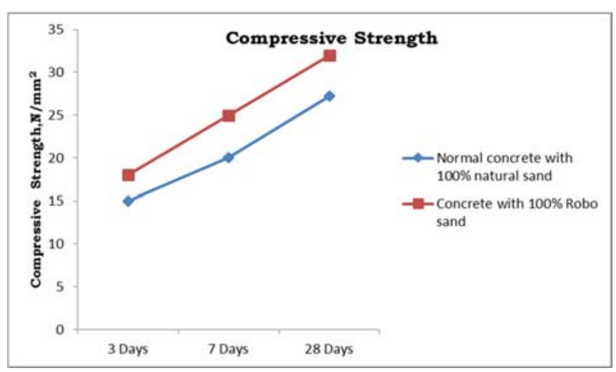

Plate 15: Compressive strength of NC with normal sand and Robo sand

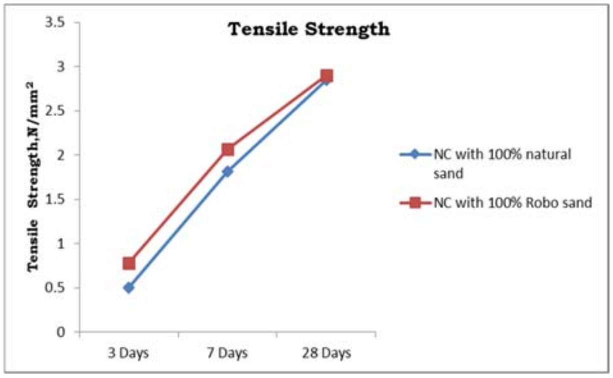

Plate 16: Tensile Strength of NC with normal sand and Robo sand

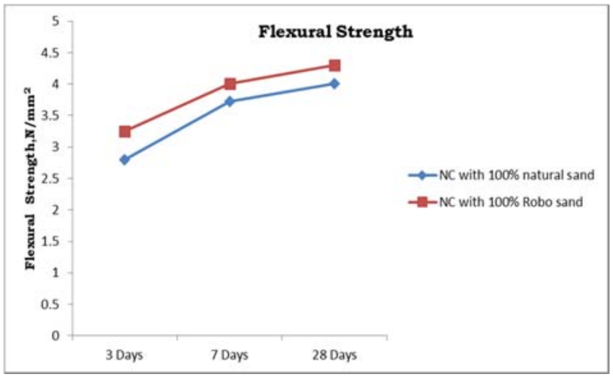

Plate 17: Flexural Strength of NC with natural sand and Robo Sand

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

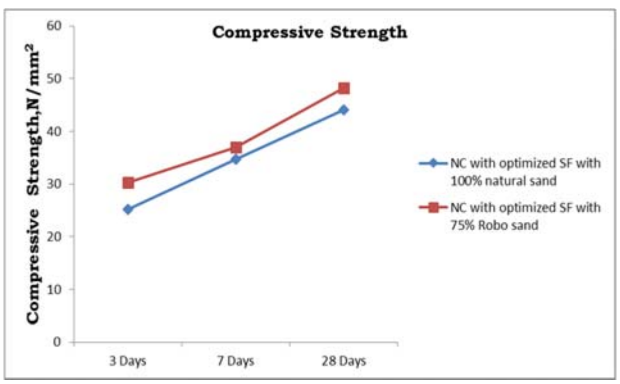

Plate 18: Compressive Strength of NC with Optimized SF with natural sand and Robo sand

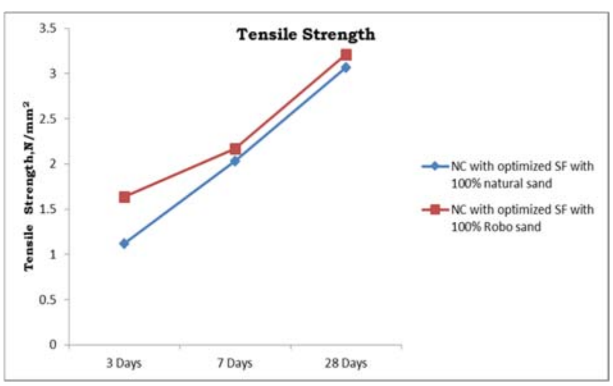

Plate 19: Tensile Strength of NC with Optimized SF with natural sand and Robo sand

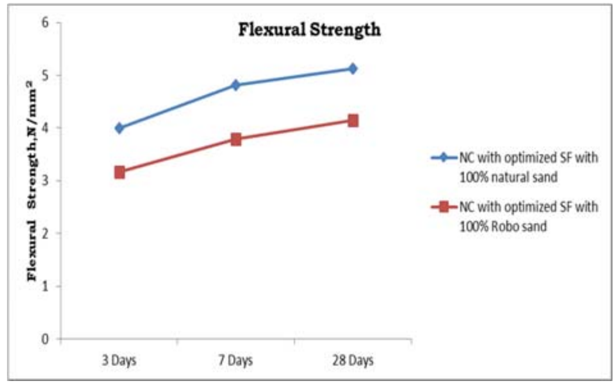

Plate 20: Flexural Strength of NC with Optimized SF with natural sand and Robo sand

7. Discussions

7.1. Silica Fume

1. From the fresh properties of normal concrete with silica fume, it is observed that replacement of cement with 15%silica fume decreases the workability.
2. Replacement of cement with 15% silica fume to normal concrete has increased the compressive strength values by 32.8% at 3 days, 41.6% at 7 days, 24.5% at 28 days. Similarly the tensile strength also 10.24% at 7 days, 6.83% at 28 days.
3. This shows that the tensile and compressive strengths increases by replacement of cement with silica fume up to certain percentage and beyond this percentage if silica fume is increased there is reduction in strength due to lack of workability.
4. Similarly there is an improvement in flexural strength also.

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 Silica Fume and Robosand

1. With Robo sand there is slight improvement in workability by 10-20mm slump as compared with the mix of normal concrete with silica fume as shown in the Table.5.5.2.
2. With the robo sand in normal concrete with silica fume mix there is an increase of Compressive strength of 8.33%-19.6% at 3 days, 3.92%-6.86% at 7days, 3.33%-9.29% at 28 days for various percentages of Robo sand as shown in the Table 5.5.3.
3. Similarly there is also an improvement in tensile strength.
4. Similarly there is also an improvement in flexural strength.

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

7.6. Compressive strength loss and weight loss for normal concrete with 15% silica fume

1. The strength loss for 7days,14days and 28days are 10.65%,14.5% and 20.86% respectively
2. The weight loss for 7days,14days and 28days are 0%,0.35% and 0.76% respectively

7.7. Compressive strength loss and weight loss for normal concrete with 15% silica fume and 75%robo sand

1. The strength loss for 7days, 14days and 28days are 5.39%, 8.5% and 12.12% respectively
2. The weight loss for 7days, 14days and 28days are 0%,0% and 0.18% respectively

8. Conclusions

The following conclusion can be drawn from this work.

1. The Optimum percentage replacement level of Silica fume in ordinary Portland cement based on the concrete maximum compressive strength and water/cement ratio of 0.45 was 15%.
2. The addition of silica fume provides high compressive strength development, comparative normal concrete. The 28 days strength increase in the 15% silica fume specimen was higher by 28.6%.
3. The admixture concrete has shown decrease in workability with silica fume.
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 Silica fume.
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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