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Characteristic Studies on Self-compacting Concrete using Nano Silica with Copper Slag

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Abstract

The paper examines the possibility of using copper slag as partial replacement of sand and Nano Silica as partial replacement of cement and super plasticizer and Viscosity Modifying Agent are used in self compacting concrete, in order to overcome problems associated with cast-in-place concrete. Self compacting concrete does not require skilled labours. The percentage of copper slag to be added is 10 %, 20 %, 30 % of total weight of sand. The percentage of Nano Silica to be added is 2 %, 4 %, 6 %, and 8 % of total weight of cement. According to ACI: 211.4 R code of practice, control specimen is casted for M_{40}. Finally the workability and strength characteristics of concrete have been compared with conventional concrete.

Keywords: *copper slag, nano silica, self-compacting concrete*

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INTRODUCTION

Development of self-compacting concrete (SCC) is a desirable achievement in the construction industry in order to overcome problems associated with cast-in-place concrete. Self compacting concrete is not affected by the skills of workers, the shape and amount of reinforcing bars or the arrangement of a structure and, due to its high-fluidity and resistance to segregation it can be pumped longer distances. The concept of self-compacting concrete was proposed in 1986 by Professor Hajime Okamura, but the prototype was first developed in 1988 in Japan, by Professor Ozawa at the University of Tokyo. Self-compacting concrete was developed at that time to improve the durability of concrete structures. Since then, various investigations have been carried out and SCC has been used in practical structures in Japan, mainly by large construction companies. Investigations for establishing a rational mix-design Method and self-compact ability testing methods have been carried out from the viewpoint of making it a standard concrete. Fine aggregate is an essential component of concrete. The most commonly used fine aggregate is natural river sand. The global consumption of natural river sand is very high due to the extensive use of concrete. In particular, the demand of natural river sand is quite high in developed countries owning to infrastructural growth. The non-availability of sufficient quantity of ordinary river sand for making cement concrete is affecting the growth of construction industry in many parts of the country. Recently, Tamilnadu government has imposed restrictions on sand removal from the river beds due to unsafe impacts threatening many parts of the state. On the other hand, the copper slag was generated by the industry has accumulated over years. Only insignificant quantities have been utilized and the rest has been dumped unscrupulously resulting in environment problem. In the present work, it is aimed at developing a new building material from the copper slag, an industrial waste as a replacement material of fine aggregate in concrete. By doing so, the objective of reduction of cost of construction can be met and it will help to overcome the problem associated with its disposal including the environmental problems of the region [1–6].

ADVANTAGES OF THE SELF-COMPACTING CONCRETE

- It reduces the cost of labours needed for curing and compacting the concrete

- It holds well in the place of large buildings and in complicated areas where curing and compaction process is difficult and costly.
- Marked improvement in durability on account of better compaction.
- Extremely suitable for slim and complicated moulds.
- Covers the reinforcement area effectively.
- Construction process is very faster.

INGREDIENTS USED

Cement : Ordinary Portland cement 53 grade (OPC)
Fine aggregate : Natural river sand
Coarse aggregate : Maximum stone size of 10 mm – 12.5 mm is used
Water : Ordinary potable water
Mineral admixtures : Nano silica
Self-compacting admixtures : Super plasticizer (SP CONPLAST 430, 1 %), VMA (0.8 %)

MATERIAL PROPERTIES

Shown in (Tables 1–5).

Table 1: *Test Results for Fine Aggregate.*

S NO	SAND TYPE	NAME OF THE TEST	ZONE III
1.	River Sand	Specific gravity	2.74
2.		Fineness modulus	2.62

Table 2: *Test Results for Coarse Aggregate.*

S.NO	NAME OF THE TEST	RESULT OBTAINED
1.	Specific gravity	2.71
2.	Impact strength	9.415 %
3.	Crushing strength	22.57 %

Table 3: *Test Results for Copper Slag.*

S.NO	NAME OF THE TEST	RESULT OBTAINED
1.	Specific gravity	3.83
2.	Hardness	6 to 7 Mohr's Scale
3.	Bulk density	1.87 (Kg/l)
4.	Granulated	Black in color

Table 4: *Trial – I Material Quantity.*

AS PER EUROPIAN STANDARD	
Cement	398 kg/m^3
Fine aggregate	1000 kg/m^3
Coarse aggregate	1108.13 kg/m^3
Water	139 ml
Super plasticizer	4.68 lit/m^3
Viscosity Modifying Agent	3.64 lit/m^3

Table 5: *Trials – II Material Quantity.*

AS PER ACI: 211.4R	
Cement	504.21 kg/m^3
Fine aggregate	683.24 kg/m^3
Coarse aggregate	1108.13 kg/m^3
Water	146.61 ml
Super plasticizer	3.79 lit/m3
Viscosity Modifying Agent	3.35 lit/m3

Note: The maximum result should be obtain in the 2nd trial, so it will taken as a final mix proportion

WORKABILITY

The workability test results are shown in Table 6.

Table 6: Workability Test Result.

Trials	L-Box (h2/h1) mm	V-Funnel (Sec)	Slump flow mm	U-Box (h2 - h1) mm
1	0.85	9	680	18
2	0.90	8	710	20
3	0.9	10	700	20

Specimens Casting and Testing

The cubes of size 150 mm, cylinder of size 150 mm diameter and 300 mm height and prism of size 150 mm length, 50 mm depth, 50 mm breadth of both conventional and self-compacting concrete were cast as shown in Figures (1–2). The strength related tests were carried out for hardened conventional concrete and self-compacted concrete at the age of 7 days and 28 days to ascertain the strength related properties such as compressive strength, split tensile strength and flexural strength.

Fig 1: Casting of Specimens.

Fig 2: Testing of Specimens.

RESULTS AND DISCUSSION

The compressive strength of cube, split tensile strength of cylinder and flexural strength of prism are given below in (Tables 7–12) and (Figures 3–11).

Table 7: Compressive Strength of Conventional Cubes.

Compressive strength(N/mm^2)			
Conventional	3 days	7 days	28 days
	17.21	28.39	48.625

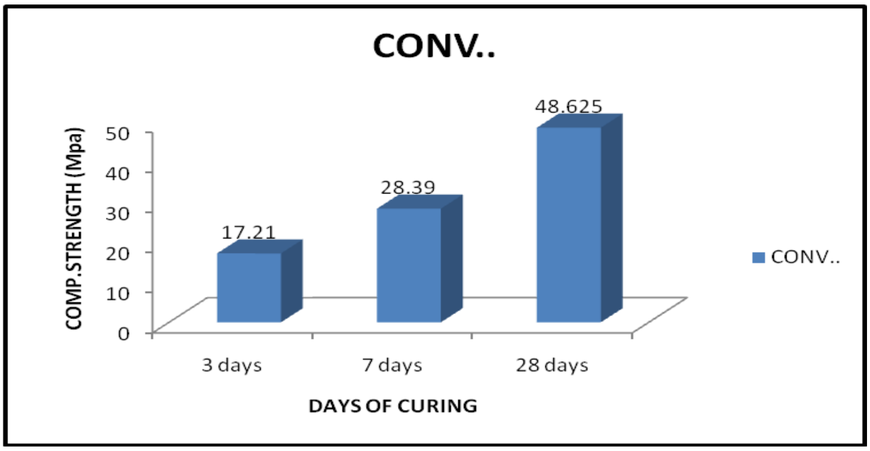

Fig. 3: *Comp. Strength of Conventional Cubes.*

Table 8: *Split Tensile Strength of Conventional Cylinder.*

Split tensile strength(N/mm^2		
	7 days	28 days
Conventional	1.39	4.58

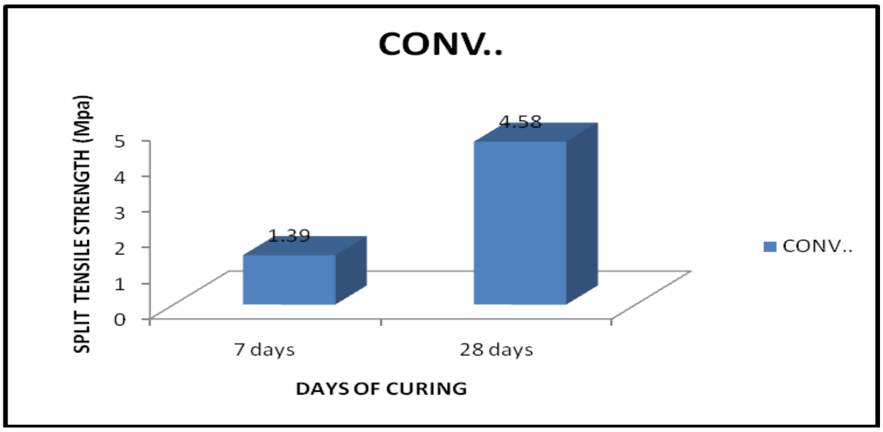

Fig. 4: *Split Tensile Strength of Conv. Cylinder.*

Table 9: *Flexural Strength of Conventional Prism.*

Flexural strength(N/mm^2)		
	7 days	28 days
Conventional	1.56	3.95

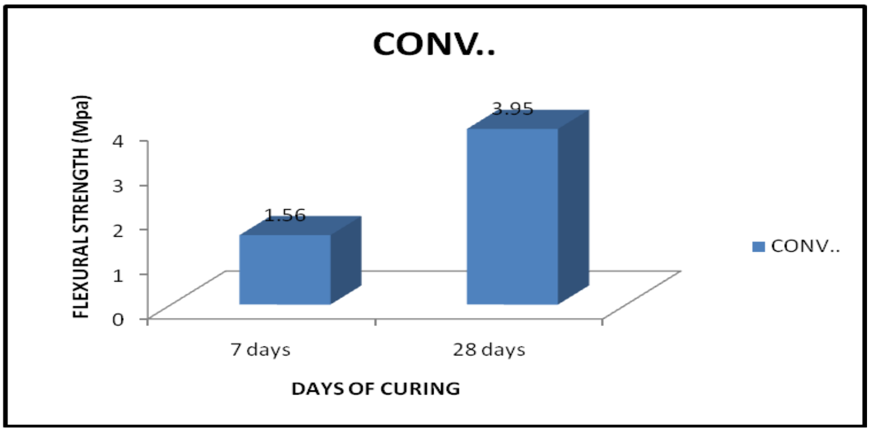

Fig. 5: *Flexural Strength of Conv. Prism.*

Table 10: *Compressive Strength of SCC Cubes.*

Compressive strength N/mm^2			
SCC	3 days	7 days	28 days
	14.43	26.46	46.136

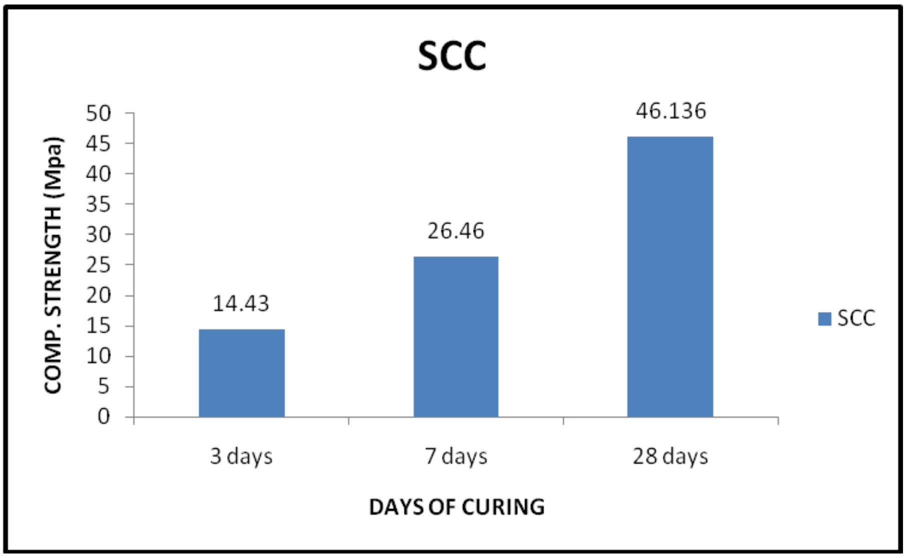

Fig.6: *Comp. Strength of SCC Cubes.*

Table 11: *Split Tensile Strength of SCC Cylinder.*

Split tensile strength N/mm^2		
SCC	7 days	28 days
	7.72	10.15

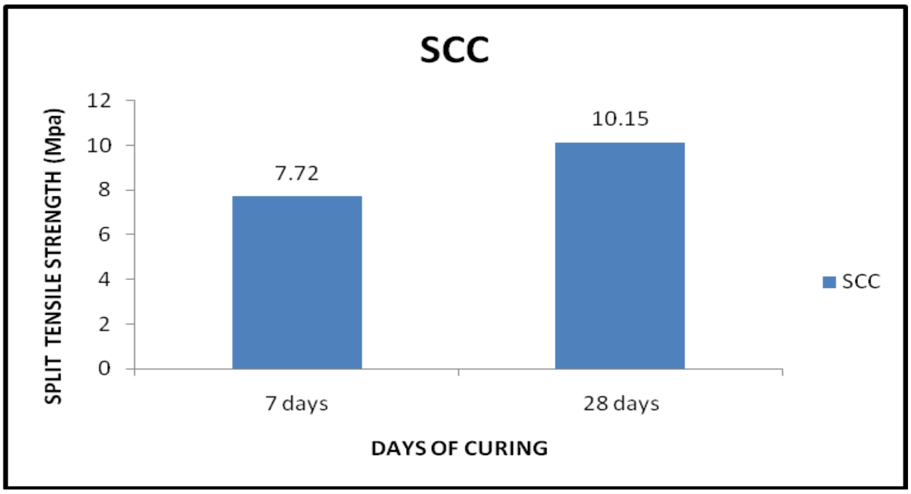

Fig. 7: *Split Tensile Strength of SCC Cylinder.*

Table 12: *Flexural Strength of SCC Prism.*

Flexural strength N/mm^2		
SCC	7 days	28 days
	4.52	6.98

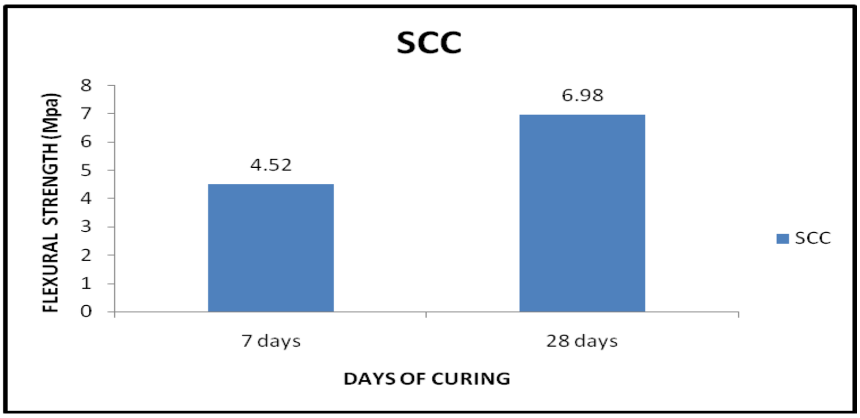

Fig. 8: *Flexural Strength of SCC Prism.*

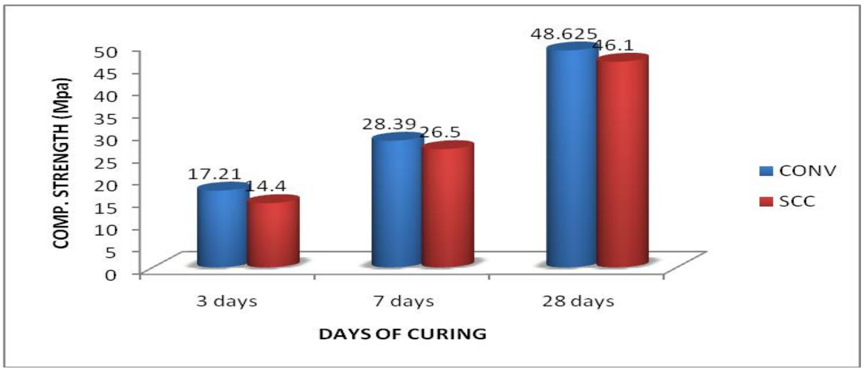

Fig. 9: *Comparison chart for NC and SCC Cubes.*

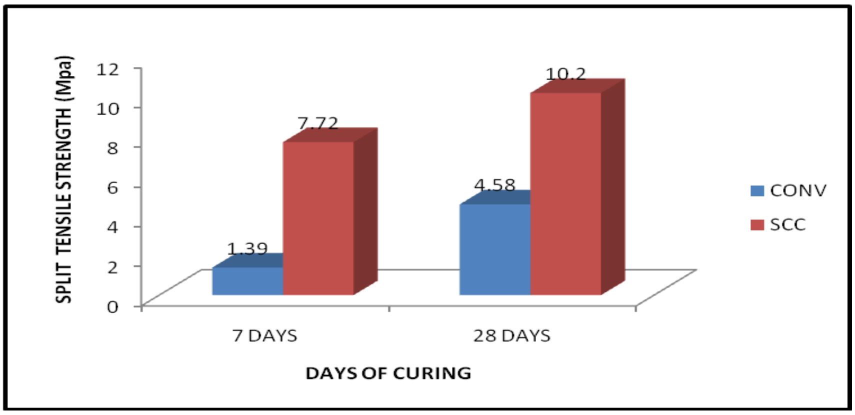

Fig. 10: *Comparison chart for NC and SCC Cylinder.*

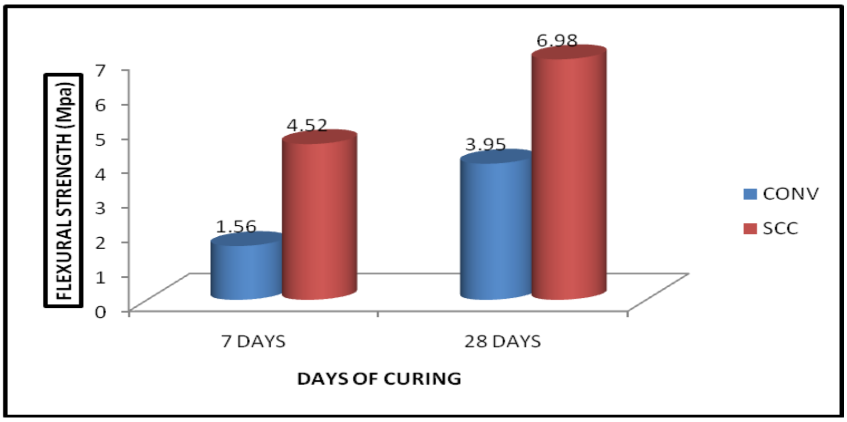

Fig. 11: *Comparison Chart for NC and SCC Prism.*

NANOSILICA REPLACEMENT

The percentage of Nano Silica to be replaced is 2 %, 4 %, 6 %, and 8 % of total weight of cement. According to ACI: 211.4R code of practice, control specimen is casted for M_{40}.

The following (Tables 13–14) and Figure 12 shows the test results of workability of various percentage of Nanosilica replaced with cement.

Table 13: *Workability Test Results for Various % of Nano Silica.*

Mineral Admixtures	% Of Nano Silica Replaced	L-Box (h2/h1) mm	V-Funnel (Sec)	Slump flow mm	U-Box (h2 - h1) mm
Nano silica	2	0.88	10	692	17
	4	0.90	8	710	20
	6	0.92	10	700	19
	8	0.86	12	680	19

Table 14: *Nano Silica Replacement Results.*

% of Nano Silica Replaced (By weight of cement)	Avg. Compressive Strength (N/mm^2)		Avg. Split Tensile Strength(N/mm^2)	Avg. Flexural Strength (N/mm^2)
	7 Days	28Days	28 Days	28 Days
2	26.73	43.11	3.20	5.25
4	29.08	48.00	4.39	5.5
6	36.73	53.86	4.45	5.63
8	29.61	51.37	4.14	5.19

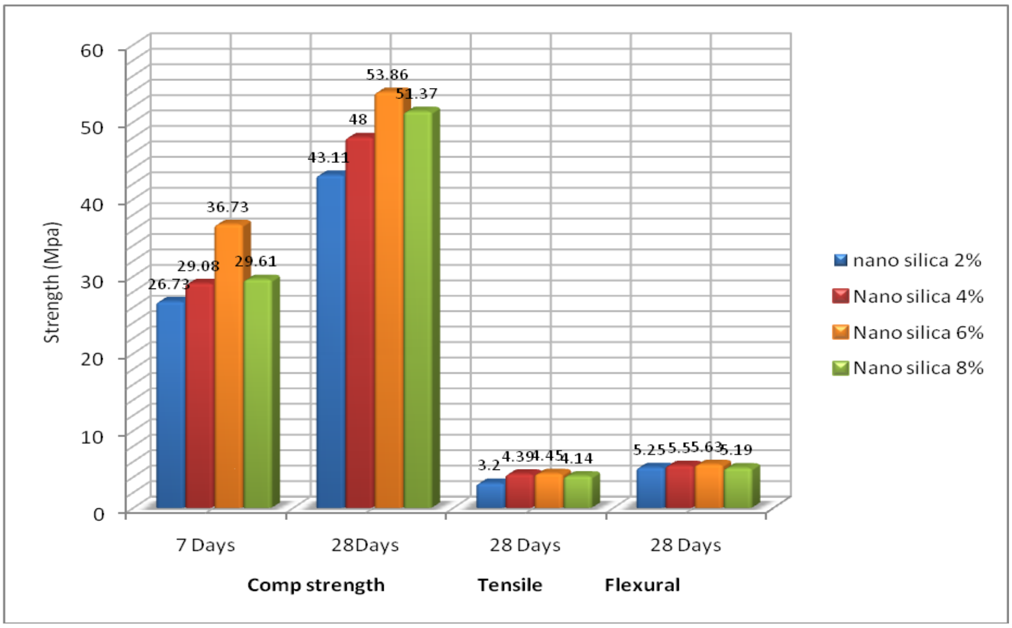

Fig. 12: *Nano Silica Replacement Chart.*

- The test results show clearly 6 % of Nano Silica replacement has given maximum results (53.86 Map), so that is the optimum percentage for replacement.

COPPER SLAG REPLACEMENT

The percentage of Copper slag was replaced 10 %, 20 %, 30 %, in the weight of sand. According to ACI: 211.4 R code of practice, control specimen is casted for M_{40}. The following (Tables 15–16) and Figure 13 shows the test results of workability of various percentage of copper slag replaced with sand.

Table 15: *Workability Test Results for Various % of Copper Slag.*

% Of Nano Silica Added	% Of Copper Slag Replaced	L-Box (h2/h1) mm	V-Funnel (Sec)	Slump flow mm	U-Box (h2 - h1) mm
6	10	0.76	12	681	19
6	20	0.81	9	694	19
6	30	0.90	11	710	16

Table 16: *Various % of Copper Slag Replacements.*

% of Nano Silica Replaced (By weight of cement)	% of copper slag Replaced (By weight of sand)	Avg. Comp Strength (N/mm^2)		Avg. Split Tensile Strength (N/mm^2)	Avg. Flexural Strength (N/mm^2)
		7 Days	28Days	28 Days	28 Days
6	10	24.08	45.78	3.30	5.25
6	20	36.53	56.53	3.67	5.40
6	30	32.49	40.08	3.58	5.54

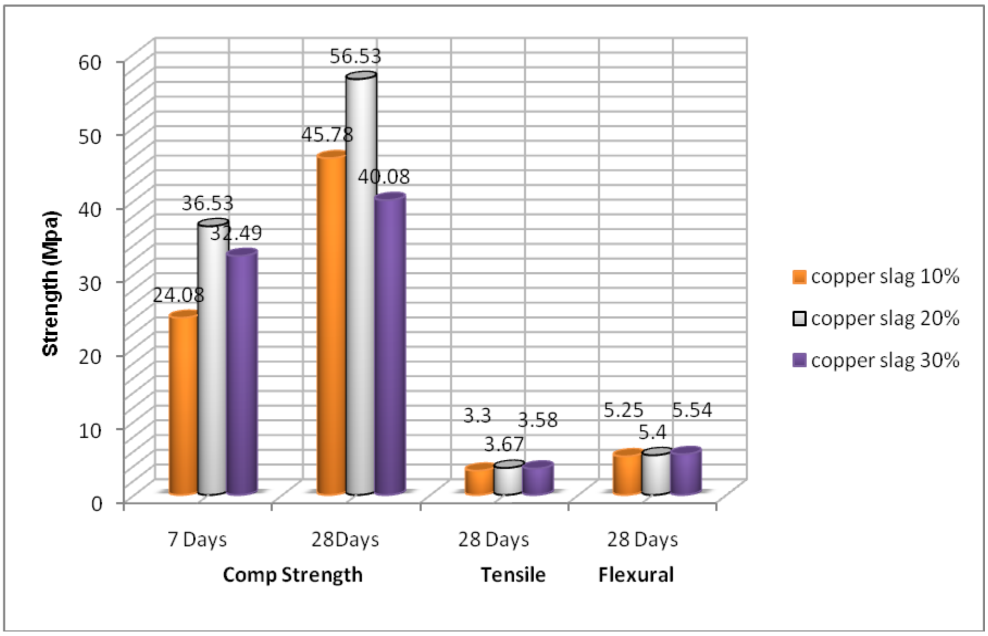

Fig. 13: *Various % of Copper Slag Replacements Chart.*

DURABILITY TESTS

1. Assurance or probability that an equipment, machine, or material will have a relatively long continuous useful life, without requiring an inordinate degree of maintenance.
2. Ability to undergo permanent deformation without cracking or fracturing.
3. Ability to exist for long without significant deterioration by resisting the effects of heavy use, drying, wetting, heating, freezing, thawing, corrosion, oxidation, volatilization, etc.

CHLORIDE ATTACK

After the completion of 28 days curing the initial weight of the specimens were noted. The specimens were immersed in chloride solution. After the specimens immersed the change in weight of specimens were taken at every 5 days interval of cyclic period up to 30 days. Finally the change in weight of specimens due to chloride attack and the strength deterioration factor also was calculated.

(A) STRENGTH DETERIORATION FACTOR (SDF)

Strength deterioration factor was defined as the ratio of change in compressive strength to initial compressive strength. The deterioration of casted specimens was investigated by measuring the strength deterioration factor expressed in percentage and it was calculated by using the equation and shown in (Tables 17–20) and (Figures 14–17).

$$SDF = \frac{\text{Initial compressive strength-Final compressive strength}}{\text{Initial compressive strength}}$$

Table 17: Comparison of Initial & Final Compressive Strength under CHLORIDE Attack at 2% Nano Silica.

Type of attack	Days	compressive strength (N/mm^2)		% of Deterioration
		Initial	Final	
chloride	28	43.11	39.48	0.08%

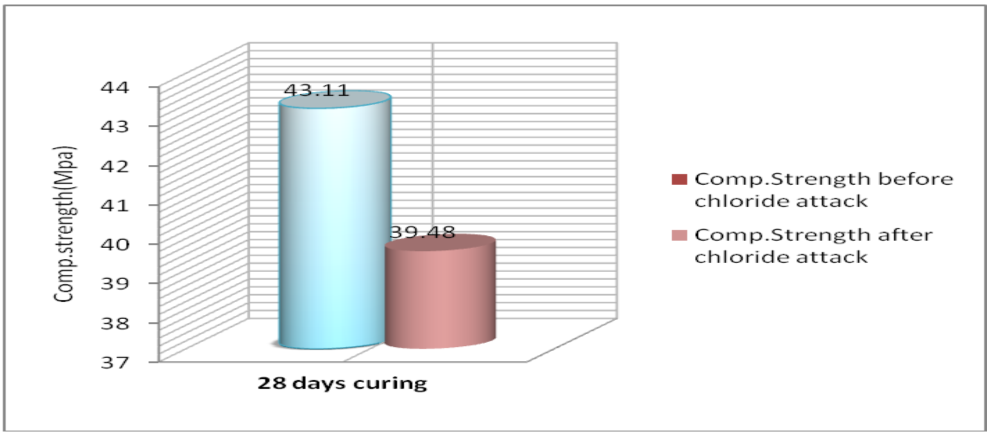

Fig. 14: Comparison of Initial and Final Compressive Strength under Chloride Attack.

Table 18: Comparison of Initial & Final Compressive Strength under Chloride Attack at 4% Nano Silica.

Type of attack	Days	compressive strength (N/mm^2)		% of Deterioration
		Initial	Final	
chloride	28	48.00	42.11	0.14%

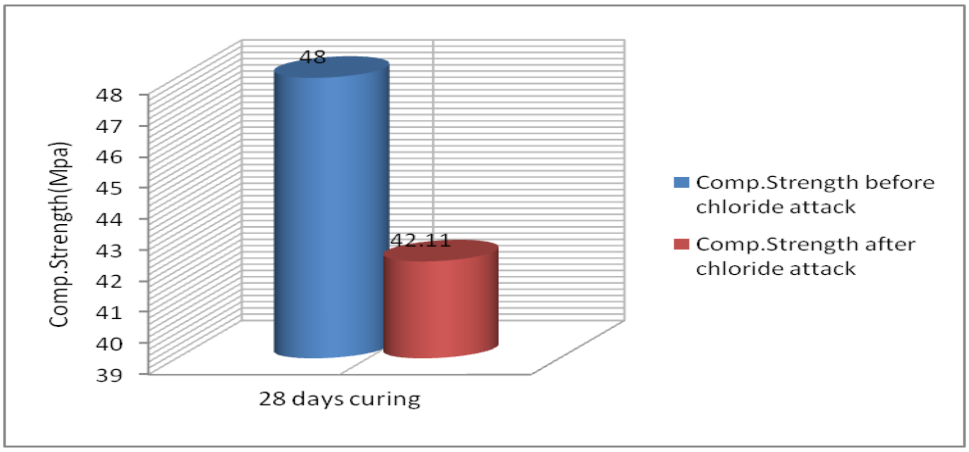

Fig. 15: Comparison of Initial and Final Compressive Strength under Chloride Attack.

Table 19: *Comparison of Initial & Final Compressive Strength under CHLORIDE Attack at 6% Nano Silica.*

Type of attack	Days	compressive strength (N/mm^2)		% of Deterioration
		Initial	Final	
Chloride	28	53.86	51.89	0.03%

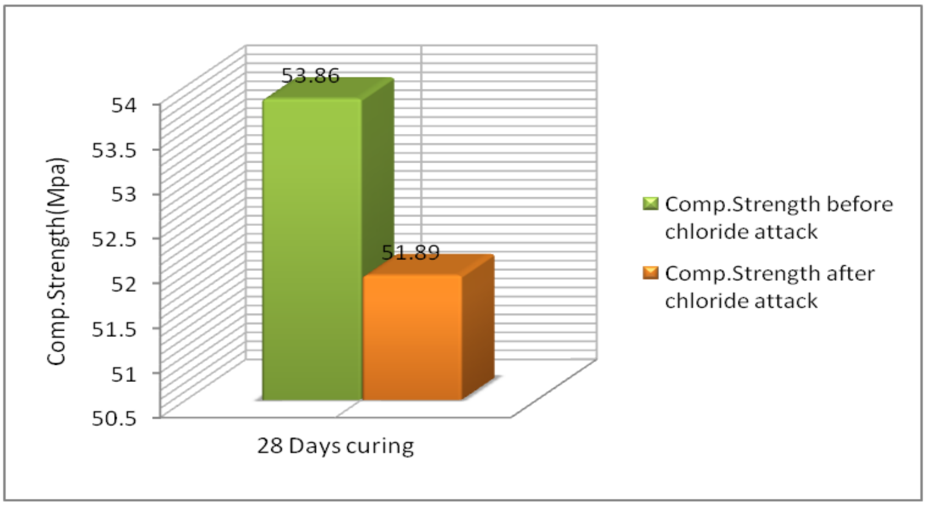

Fig. 16: *Comparison of Initial and Final Compressive Strength under CHLORIDE Attack.*

Table 20: *Comparison of Initial & Final Compressive Strength under CHLORIDE Attack at 8% Nano Silica.*

Type of attack	Days	compressive strength (N/mm^2)		% of Deterioration
		Initial	Final	
Chloride	28	51.37	48.54	0.05%

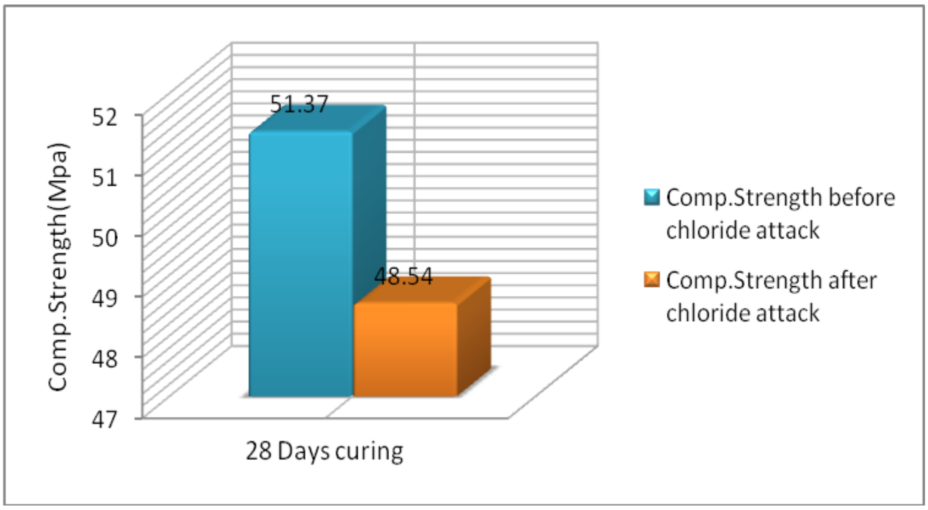

Fig.17: *Comparison of Initial & Final compressive Strength under Chloride Attack.*

CONCLUSION

After testing, the following results should be made.

- The strength of the conventional concrete has attained the target strength in 7 days and 28 days.
- The self compacting concrete has obtained the grade of strength, but it does not meet the target strength.
- The test results show clearly 6 % of Nano Silica replacement has given better results,

so that is the optimum percentage for replacement as cement.

- The test results show clearly 20 % of Copper Slag replacement has given better results, so that is the optimum percentage for replacement as sand.

REFERENCES

1. H. Mazaheripour, Ghanbarpour S., et al. *Construction and Building Materials* 2011; 25: 351–358p.
2. Gaston Espinoza-Hijazin, Mauricio Lopez. *Construction and Building Materials*. 2011; 25: 1236–1242p.
3. Fathollah Sajedi, Hashim Abdul Razak. *Construction and Building Materials* 2011; 25: 2036–2045p.
4. Luc Courard,Frederic Michel,Julie Pierard *Construction and Building Materials*. 2011; 25: 1356–136p.
5. C.Parra,M.Valcuende..Gomez .*Construction and Building Materials*. 2011; 25: 20p.
6. Ming-fang Ba, Chun-xiang Qian, *Construction and Building Materials*. 2011; 25:123–128p.

