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A Study on Self-Compacting Concrete Using Portland Slag Cement with Foundry Sand and Crusher Dust as Fine Aggregate

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Abstract— Concrete plays a vital role as a construction material in the world. Studies have been carried out to investigate the possibility of utilizing a broad range of materials as partial replacement for cement and aggregate in the production of concrete. Also the construction industry is now slowly becoming aware of the environmental issues and other sustainable development issues for cement and concrete industries. It is looking for the ways and means to develop building products, which will increase the life span and quality. In this regard the merits of using ground granulated blast furnace which is a by-product of certain industries and also by using different fine aggregates like sea sand, foundry sand and crusher dust have been well recognized by the construction industry. This thesis presents an experimental investigation on strength aspects like compressive, split tensile and flexural strength of Self Compacting Concrete (SSC) containing two different industrial wastes as fine aggregate i.e. Foundry sand and Crusher dust. Both of them are used as fine aggregates in varying proportions, taking foundry sand as the fine aggregate and replacing it with Crusher dust as percentages of 0%, 25%, 50%, 75%, 100%. For this green SCC, all SCC tests are performed as per EFNARC guidelines i.e. slump flow, L-box, V funnel and T50 tests are carried out. The methodology adopted is that the fine aggregates are replaced with the industrial wastes, foundry sand and crusher dust and the performance of SCC is measured. The influence of these materials as fine aggregate is tested for workability and compressive strength, split tensile strength and flexural strength of self-compacting are investigated.

Key words: Fine Aggregate, Crusher Dust

I. INTRODUCTION

Concrete is a versatile engineering material used in most of the civil engineering structures. Its popularity as a basic building material in construction is because of its economy, good durability, ease with which it can be manufactured, the ability to mould it into any shape and size and its high compressive strength. Concrete is a composite material composed mainly of water, aggregates and cement. Often, additives and reinforcements are included in the mixture to achieve the desired physical properties of the finished material. The development of specifying a concrete according to its performance rather than the constituents and ingredients has opened innumerable opportunities for producers of concrete and the users to design concrete to suit their specific requirements. One of the most outstanding advances in the concrete technology over the last decade is Self Compacting Concrete (SCC).

Self Compacting Concrete is a highly flowable, stable concrete which flows readily into places around congested reinforcement, filling formwork without any consolidation and significant segregation. The hardened concrete is dense, homogeneous and has the same engineering properties and durability as that of traditional vibrated concrete. The use of SCC eliminates the need for compaction thereby saves time, reduces labour costs and conserves energy. Furthermore, the use of SCC enhances surface finish characteristics. Self Compacting Concrete (SCC) is one of the major branches of High Performance Concrete (HPC) which is a boon to the fast growing precast industry. Self compacting concrete requires high flowability through a superplasticizer, and too remain cohesive during handling operations special attention is needed in terms of the sand and paste content apart from a viscosity-modifying admixture to enhance stability. Self compacting concrete (SCC) can be classified as an advanced construction invention. The SCC as the name suggests, does not require to be vibrated to achieve full compaction. This offers the following benefits and advantages over conventional concrete: Improved quality of concrete and reduction of onsite repairs, faster construction times, lower overall costs, facilitation of introduction of automation into concrete construction, improvement of health and safety is also achieved through elimination of handling of vibrators and substantial reduction of environmental noise loading on and around a site. One of the disadvantages of SCC is its cost, associated with the use of chemical admixtures and use of high volume of Portland Slag Cement. One alternative to reduce the cost of SCC is the use of additions. Due to the better engineering and performance properties, additions such as Silica Fume(SF), Fly Ash(FA) and Ground Granulated Blast-Furnace Slag (GGBFS) are normally included in the production of high-strength and high-performance concrete.

II. NECESSITY OF THE WORK

Use of waste and by-products in concrete will lead to green environment and such concrete can be called as “Green Concrete”. There are various types of waste materials that can be considered for usage in concrete. Over 400 million tonnes of waste materials are being produced by various industries every year. Such materials can be used in the construction industry as replacements of the materials used in the manufacture of concrete thereby reducing the cost of manufacture. There is a great interest and tendency between researchers and concrete technologists to develop concretes by multi-unique characteristics, which would not be attained in traditional conventional concrete. The approach of manufacturing SCC was recently modified and developed to produce SCC with high performance and high strength characteristics. However, all previous efforts and attempts in the field of SCC were concerned with Ordinary Portland Cement (OPC) and mineral blends such as fly ash, slag and limestone powder, there is a lack of knowledge regarding the utilization of Portland Slag Cement (PSC) with mineral blends in the development of SCC. Generally, with the growth of construction activities in India there is severe cement crisis to meet the demands of the construction industry. To meet the demands now-a-days almost all the major cement manufacturers are producing blended cements consisting of Portland Pozzolana Cement (PPC) and Portland Slag Cement (PSC) where PSC has a significant presence in the Indian market as far as the production and usage is concerned. Now there is a need to design concrete to address the demands of the construction industry with different replacement of industrial wastes as fine aggregates.

III. OBJECTIVES OF THE STUDY

The specific objectives of the present investigations are as listed below:

- To conduct feasibility study of producing Self Compacting Concrete SCC of grade M30 taking foundry sand as the fine aggregate and varying replacements of it with Crusher dust.
- To evaluate the fresh concrete characteristics in terms Slump flow, V-funnel flow time, L-box blocking ratio.
- To evaluate the compressive strength of self compacting concrete cubes at 3, 7 & 28 days by varying replacements of the fine aggregate foundry sand with crusher dust as 0%, 25%, 50%, 75%, 100%.
- To evaluate the split tensile strength of self compacting concrete cylinders at 3, 7 & 28 days by varying replacements of the fine aggregate foundry sand with crusher dust as 0%, 25%, 50%, 75%, 100%.
- To evaluate the flexural strength of self compacting concrete prisms at 3, 7 & 28 days by varying replacements of the fine aggregate foundry sand with crusher dust as 0%, 25%, 50%, 75%, 100% .

IV. SCOPE OF THE STUDY

The scope of the present investigation is to study and evaluate the effect of replacement of fine aggregate with industrial wastes foundry sand and crusher dust in the self compacting concrete. The self compacting concrete is made by varying replacements of fine aggregate foundry sand with crusher dust as 0%, 25%, 50%, 75%, 100%. Fresh concrete tests such as slump flow value, V-funnel flow time, L-box blocking ratio are investigated and hard concrete tests such as compressive strength for cubes of standard size 150 mm × 150 mm × 150 mm (length x breadth x depth) were casted and tested for 3, 7 & 28 days, split tensile strength for cylinders of size 150 mm x 300 mm (diameter x height) were casted and tested for 3, 7 & 28 days and flexural strength for prisms of size 500 mm × 100 mm × 100 mm were casted and tested for 3, 7 & 28 days.

V. METHODOLOGY

Self Compacting Concrete (SCC) is an emerging technique in the field of concrete technology. SCC is an innovative idea to tackle the problem of concreting through dense reinforcement. SCC is unique because of its properties like fill ability, flowability, pumpability and make production of concrete more industrialized.

From the literature review it is found that all previous efforts and attempts in the field of SCC were concerned with Portland slag cement (PSC) and mineral blends such as fly ash, slag and limestone powder and very few of the self compacting concrete mixes with replacement of fine aggregate. The present study is the utilization of Portland slag cement with replacement of different industrial wastes like Foundry sand and Crusher dust as fine aggregates in the development of SCC. Therefore an attempt was carried out herein to investigate the effect of industrial wastes on the properties of SCC when PSC was used.

Six different mixes (SCCN, SCC0, SCC25, SCC50, SCC75 and SCC100) were employed to examine the influence of foundry sand and crusher dust in SCC on the fresh and hardened concrete when PSC cement was used. The water binder ratio for all the mixes is kept constant at 0.45. SCCN is the basic mix in which only conventional sand is used as the fine aggregate. In mixes SCC0, SCC25, SCC50, SCC75 and SCC100 the fine aggregate foundry sand is replaced by the crusher dust as 0%, 25% 50%, 75% and 100% (by mass) respectively. The essential component of SCC is a high range water reducer (HRWRA) which is also known as superplasticizer. SCC mixtures always include a high-range water-reducing admixture (HRWRA) to ensure workability is enhanced. Several trial mixes were conducted to determine the optimum dosage of superplasticizer for each of the mixtures in order to achieve the required self compacting properties as per EFNARC standards.

Fresh concrete tests such as Slump flow value, V-funnel flow time, L-box blocking ratio are investigated and hard concrete tests such as compressive strength for cube of standard size 150 mm × 150 mm × 150 mm (length x breadth x depth), split tensile strength for cylinder of size 150 mm × 300 mm (diameter x height) and flexural strength for prism of size 500 mm × 100 mm × 100 mm (length x breadth x depth) were tested for 3, 7 & 28 days.

The workability tests on fresh concrete such as Slump flow, V-funnel, L-box are measured. As the percentage of crusher dust in fine aggregates is increasing, the slump flow value is increasing.

VI. EXPERIMENTAL INVESTIGATION

The properties and specifications of various materials used in the preparation of test specimens are as follows.

A. *Cement*

The cement used for the investigation was Ordinary Portland Slag Cement (PSC) with brand JAYPEE cement confirming to IS: 455-1989. The cement is fresh and is of uniform colour and consistency. It is free from lumps and foreign matter.

B. *Fine Aggregate*

The fine aggregate used in the present experimental programme is conventional sand confirming to zone –II as per 383: 1970. It is clean, inert and free from organic matter, silt and clay. The physical properties of sand are shown in table 1

S.No	Property	Value
1	Grading of sand as per IS-383	Zone II
2	Specific gravity	2.45

3	Bulk density (i) Loose state (ii) Compacted state	 1556 Kg/m^3 1718 Kg/m^3
4	Fineness modulus	2.44

Table 1: Physical properties of conventional sand

The fine aggregate used in the present experimental programme is foundry sand confirming to zone - III as per 383: 1970. It is clean, inert and free from organic matter, silt**.** The physical properties of the foundry sand are given in Table 2

S.No	Property	Value
1	Grading of sand as per IS-383	Zone III
2	Specific gravity	2.39
3	Bulk density (i) Loose state (ii) Compacted state	 1290 Kg/m^3 1430 Kg/m^3
4	Fineness modulus	2.01

Table 2: Physical properties of foundry sand

1) *Properties of Crusher Dust*

The fine aggregate used in the present experimental programmed is crusher dust confirming to zone - II as per 383: 1970. It is clean, inert and free from organic matter, silt and clay. The physical properties of the crusher dust are given in the Table 3

S.No	Property	Value
1	Grading of sand as per IS-383	Zone II
2	Specific gravity	2.50
3	Bulk density (i) Loose state (ii) Compacted state	 1750 Kg/m^3 1980 Kg/m^3
4	Fineness modulus	2.57

Table 3: Physical properties of crusher dust

C. Coarse Aggregate

The coarse aggregate used, was from an established quarry satisfying the requirements of IS 383: 1970. In this experimental programme aggregates of only 10 mm size are used. The parameters specific gravity, bulk density, water absorption and fineness modulus were determined. The physical properties of aggregates are given in Table 4

S.No	Property	Value
1	Specific gravity	2.76
2	Bulk density (i) Loose state (ii) Compacted state	 1527 Kg/m^3 1720 Kg/m^3
3	Fineness modulus	6.51

Table 4: Physical properties of coarse aggregate

D. Chemical Admixture

Chemical admixtures reduce the cost of construction, modify the properties of concrete and improve the quality of concrete during mixing, transportation, placing and curing.

1) *Polycarboxylate ether-based superplasticizers*

Commercially available poly carboxylate ether (PCE) based superplasticizer (SP) Master Glenium SKY 8630 was used in all the self-compacting concrete mixtures. It is an F-type high-range water reducer, in conformity with ASTM:C 494, IS 9103:1999 & IS 2645:2003. The physical properties of the chemical admixture are given in the Table 5

S.No.	Properties	Test Values
1	Aspect	Light brown liquid
2	Relative Density	0.08+/- 0.01 at 25^{0}c
3	Ph	≥6
4	Chloride ion Content	<0.2%

Table 5: Physical properties of the chemical admixture

E. Water

The water used for cement mixing was potable water collected from the laboratory taps conforming to IS 456-2000. Water from the same source was used for curing the specimens.

VII. EXPERIMENTAL SET UP

A. Mixture Proportions

Six trial mixes were conducted to determine the optimum dosage of superplasticizer for each of the mixtures in order to achieve the required self compacting properties as per EFNARC standards. Finally one of them was selected and followed throughout this study. Six different mixes (SCCN, SCC0, SCC25, SCC50, SCC75 and SCC100) were employed to study the influence of varying replacement fine aggregate foundry sand with crusher dust in SCC on the fresh, mechanical and durability properties were observed when PSC cement was used. The water-binder ratio for all the mixes was kept constant at 0.45. In mixes SCC0, SCC25, SCC50, SCC75, SCC100 the figure beside SCC represents the percentage of crusher dust in the fine aggregate quantity while the remaining is foundry sand. The essential component of SCC is high range water reducing admixture (HRWRA) which is also known as superplasticizer. SCC mixtures always include a high - range water-reducing admixture (HRWRA) to ensure concrete is able to flow under its own mass. The dosage of superplasticizer for each mix was carefully selected as over dosage may induce bleeding and strength retardation. As far as the aggregates grading is concerned, in the present investigation only 10 mm were used as coarse aggregates.

B. Mixing and Casting Details

All the materials were mixed using pan mixer with a maximum capacity of 80 litres. The materials were fed into the mixer in the order of coarse aggregates, PSC and sand. The materials were mixed dry for 1.5 min. Subsequently three-quarters of the water is added, followed by the superplasticizer and the remaining water, while mixing continued for a further 6 min in order to obtain a homogenous mixture. Upon discharging from the mixer, the self compactibility tests were conducted on the fresh concrete for each mixture. Then the fresh concrete was placed into the steel cube moulds and allowed to compact without any vibration. Finally, surface finishing was done carefully to obtain a uniform smooth surface.

C. Specimens and Curing

The specimen cubes of standard size 150 mm x 150 mm x 150 mm (length x breadth x depth) were casted for compressive strength and tested for 3, 7 & 28 days.

The specimen prisms of standards size 500 mm x 100 mm x 100 mm (length x breadth x depth) were casted for flexural strength and tested for 3, 7 & 28 days.

The specimen cylinders of standards size 150 mm x 300 mm (diameter x height) were casted for split tensile strength and tested for 3, 7 & 28 days.

The following specimens were casted for hardened concrete tests:

Number of cubes for compressive strength = 54 samples
Number of prisms for flexural strength = 54 samples
Number of cylinders for split tensile strength = 54 samples
Total numbers of samples casted = 162 samples

After casting, all the specimens were covered with plastic sheets and left at room temperature for 24hrs. The specimens of concrete mix in which the fine aggregates are replaced with major proportion of foundry sand are demoulded after 24hrs where as the ones with crusher dust are demoulded after 36hrs of casting as they consumed more time to set. The specimens were then cured in water at approximately 27^{0}C until testing was carried out at 3, 7 & 28days.

D. *Testing Of the Specimens*

1) *Fresh Concrete Tests*

For determining the self-compactibility properties (slump flow, T_{50} time, V-funnel flow time, L-box blocking ratio) tests were performed on all the mixtures.

The order of testing was:

1) Slump flow test and measurement of T_{50} time
2) V-funnel flow test
3) L-box blocking test

These tests were performed in accordance with EFNARC standards.

2) *Hardened Tests*

The compressive strength was obtained, at a loading rate of 140 Kg/cm^2/min at the age of 3, 7 & 28 days on 3000KN Compression testing machine. The average compressive strength of three specimens was considered at each age. The split tensile strength was also tested on the same machine at the age of 3, 7 & 28 days. The flexural strength was tested on the Universal Testing Machine at the age 3, 7 & 28 days. All these three tests were performed according to the Bureau of Indian Standards 516:1959.

VIII. RESULTS AND DISCUSSION

The results based on experimental work are presented in the tables and discussed. The results obtained from experimental work including sieve analysis, compressive strength, split tensile strength and flexural strength are tabulated.

Constituent	SCCN	SCC0	SCC25	SCC50	SCC75	SCC100
PSC	450	450	450	450	450	450
Water	202.5	202.5	202.5	202.5	202.5	202.5
Water/Binder Ratio	0.45	0.45	0.45	0.45	0.45	0.45
Conventional Sand	836.5	0	0	0	0	0
Foundry Sand	0	816	612	408	204	0
Crusher Dust	0	0	213.4	426.8	640.1	853.5
10mm	770.1	770.1	770.1	770.1	770.1	770.1
Chemical Admixture 0.9%	4.05	4.05	4.05	4.05	4.05	4.05
Slump Value in mm	640	300	320	480	630	680
Density of Concrete (Kg/m^3)	2259.1	2238.6	2248.0	2257.4	2266.7	2276.1

Table 6: Details of mix proportions in Kg/m3

Percentage of the slump flow is given by

$$\frac{SLUMP\ FLOW\ VALUE - SLUMP\ CONE\ DIAMETER}{SLUMP\ CONE\ DIAMATER}\ X\ 100$$

Where slump cone diameter = 200 mm

Mix Notation	T 50 (s)	Slump Flow (mm) >550mm	Percentage of Slump Flow (%)	V-funnel Flow Time (s)	L-box Blocking Ratio
SCCN	6	640	220	36	0.83
SCC0	20	300	50	64	0.40
SCC25	18	320	60	61	0.46
SCC50	11	480	140	46	0.64
SCC75	6	630	215	34	0.81
SCC100	5	680	240	28	0.88

Table 7: Fresh properties of the self-compacting concrete

Fig. 1: Workability of SCC

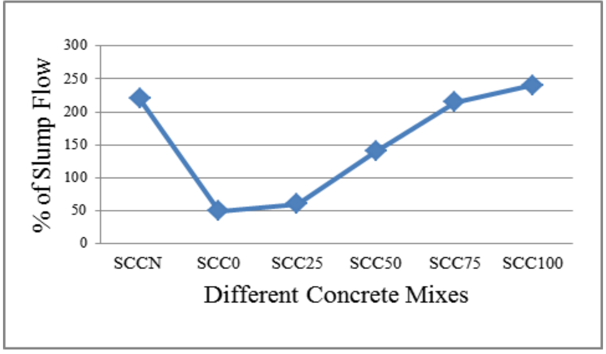

Fig. 2: Percentage of slump flow value Vs Concrete mixes

Fig. 3: Slump flow value

Fig. 4: V-funnel

Fig. 5: L-box test

The above Table 6 shows the constituents of different SCC mixes and as the replacement of fine aggregate differs, the quantities of conventional sand, foundry sand and crusher dust differs as shown in the table. Table 7 shows the slump flow value with respect to percentage of crusher dust as fine aggregate. From the results it can be seen that as the percentage of crusher dust increases the slump flow value increases from 300 mm to 680 mm. Out of the six mixtures only three mixtures SCCN, SCC75, SCC100 have exhibited slump flow values between 630 to 680 mm showing the capability of concrete to deform under its own weight. Slump flow of 600 ± 50 mm is required for SCC and only these three concretes developed here have satisfied the requirements. From the above statements it is observed that the slump flow value of SCC is increasing with the increase in percentage of crusher dust.

Figures 1 and 3 show the workability of Self compacting concrete and the slump flow value respectively. Figure 2 is a graph drawn between percentage of slump flow value and different concrete mixes. The percentage of slump flow is the percentage amount of increase in the diameter of the slump with respect to the slump cone diameter. Figures 4 and 5 show the physical tests on the Self compacting concrete, i.e. the V-funnel test and the L-box test respectively.

The time taken during T_{50} for crusher dust i.e 5 sec and less than that of the foundry sand with 20 sec and conventional concrete with 6 sec. The V-funnel flow also exhibited a similar behavior. V-funnel measurements of two mixtures SCC0 and SCC25 have been very high. However, all other four concrete mixtures filled the moulds with its own weight without the need for vibration. Many researchers have used both T50 and V-funnel times as indicators of viscosity of highly flowable concrete mixes. To improve this flowability, the dosage of superplasticizer have to be increased within the specified limits (mentioned by the supplier).

Experimental measurements related with L-box ratio indicate the filling and passing ability of each mixture. L-box test is more sensitive to blocking. The determined L-box ratio of the six mixes with respect to varying replacement of the fine aggregate foundry sand with crusher dust are presented in. It can be seen that the concrete mix with conventional sand as fine aggregate and the mixes with crusher dust percentage as 75% and 100% of the fine aggregate exhibited values greater than 0.8 whereas remaining all the mixes exhibited values less than 0.8.

Mix Notation	Compressive Strength in MPa		
	3rd day	7th day	28th day
SCCN	20.89	27.33	38.10
SCC0	18.00	25.55	38.89
SCC25	19.33	28.00	37.78
SCC50	21.77	29.77	38.89
SCC75	24.88	34.44	42.89
SCC100	27.77	34.66	45.78

Table 8: Compressive strengths of different mixes at different ages of concrete

Fig. 6: Testing of cubes in Compression testing machine

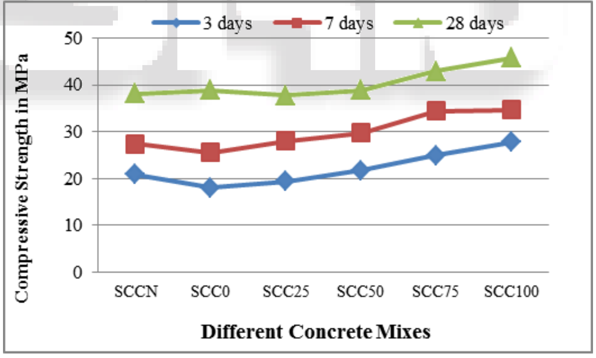

Fig. 7: Cube compressive strength Vs different concrete mixes

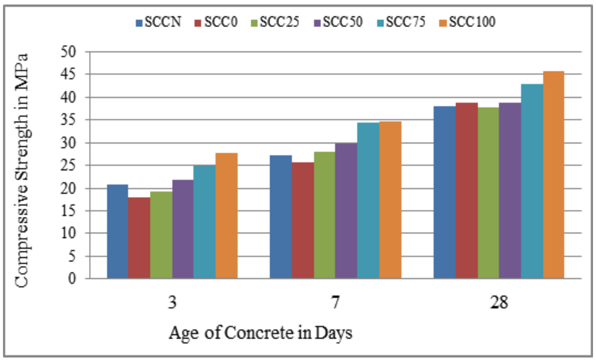

Fig. 8: Cube compressive strength of different mixes at different ages

From the above Table 8 and Figures 7 and 8, it is clear that with the increase in percentage of crusher dust as fine aggregate, the compressive strengths have been increasing. It is observed that the SCC with crusher dust as 100% replacement of the fine aggregate has shown better performance. Figure 6 shows the testing of a cube specimen in the Compression testing machine.

Mix Notation	Split Tensile Strength in MPa		
	3rd day	7th day	28th day
SCCN	2.05	2.37	3.18
SCC0	1.72	2.51	2.83
SCC25	1.98	2.58	3.04
SCC50	2.12	2.69	3.40
SCC75	2.19	2.76	3.68
SCC100	2.33	3.18	4.03

Table 9: Split tensile strengths of different mixes at different ages of concrete

Fig. 9: Testing of cylinders in Compressive testing machine

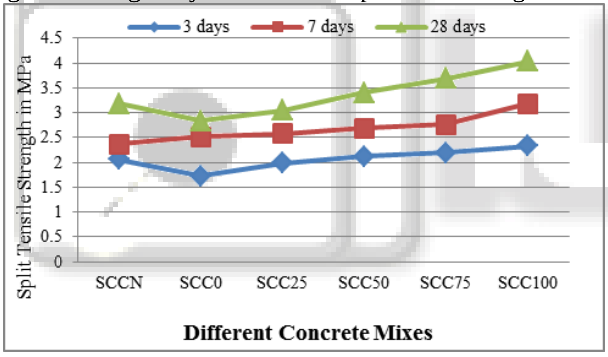

Fig. 10: Cylinder split tensile strength Vs different concrete mixes

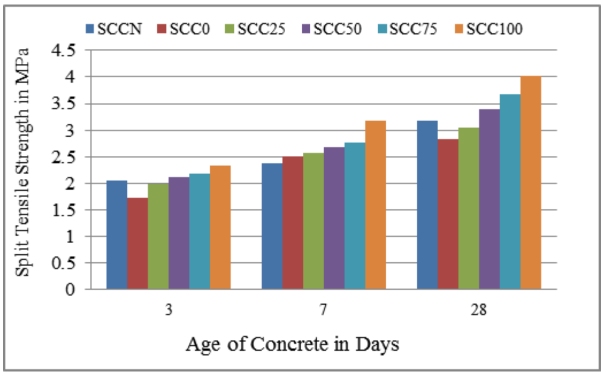

Fig. 11: Cylinder split tensile strength of different mixes at different ages

From the above Table 9 and Figures 10 and 11, it is clear that with the increase in percentage of crusher dust as fine aggregate, the split tensile strengths have been increasing. It is observed that the SCC with crusher dust as 100% replacement of the fine aggregate has shown better performance. Figure 9 shows the testing of a cylinder specimen in the Compression testing machine.

Mix Notations	Flexural Strength in MPa		
	3rd day	7th day	28th day
SCCN	3.22	4.82	6.47
SCC0	2.94	4.12	4.98
SCC25	3.57	4.28	4.98
SCC50	4.16	4.61	5.84
SCC75	4.20	4.75	6.44
SCC100	5.02	5.77	7.14

Table 10: Flexural strengths of different mixes at different ages of concrete

Fig. 12: Testing of prisms in Universal testing machine

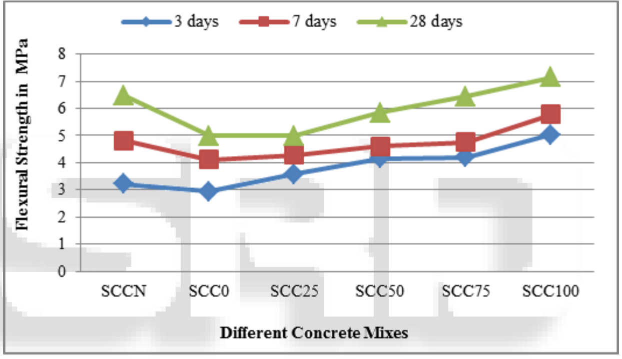

Fig. 13: Prism flexural strength Vs different concrete mixes

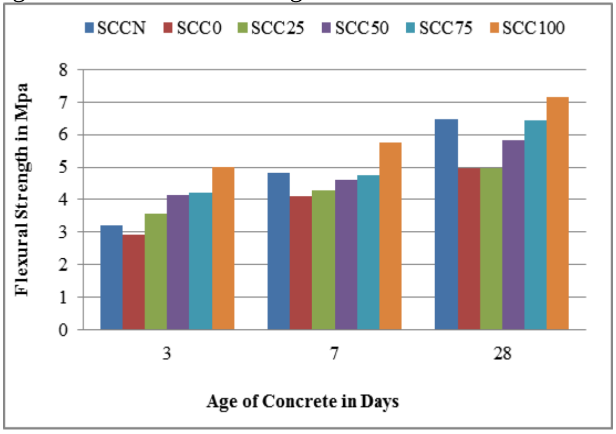

Fig. 14: Prism flexural strength of different mixes at different ages

From the above Table 10 and Figures 13 and 14, it is clear that with the increase in percentage of crusher dust as fine aggregate, the flexural strengths have been increasing. It is observed that the SCC with crusher dust as 100% replacement of the fine aggregate has shown better performance. Figure 12 shows the testing of a cube specimen in the Compression testing machine.

IX. CONCLUSIONS

The following conclusions can be drawn according to the results of this study:

1) It is observed that when crusher dust is used as the maximum percentage of fine aggregate, the characteristic strengths and the workability are improved.
2) It is observed that when foundry sand is used as the maximum percentage of fine aggregate, the characteristic strengths are attained but the workability is not satisfied.
3) The workability tests on fresh concrete such as slump flow, V-funnel, L-box are done. As the percentage replacement of crusher dust is increasing in the fine aggregate from 0% to 100%, the slump value is also increasing. When only foundry sand is used as fine aggregate, there is almost no slump flow indicating that SCC with foundry sand as fine aggregate doesn't exhibit workability with this mix design.
4) With the increasing replacement of crusher dust percentage in the fine aggregate foundry sand, V-funnel values are decreasing and L-box blocking ratio are increasing.
5) As the percentage replacements of crusher dust in the fine aggregate foundry sand are increasing, the compressive strength is increasing. When only crusher dust is used as fine aggregate, the compressive strength is maximum and is increased by 20.16%.
6) As the percentage replacements of crusher dust in the fine aggregate foundry sand are increasing, the split tensile strength is increasing. When only crusher dust is used as fine aggregate, the split tensile strength is maximum and is increased by 26.73%.
7) As the percentage replacements of crusher dust in the fine aggregate foundry sand are increasing, the flexural strength is increasing. When only crusher dust is used as fine aggregate, the flexural strength is maximum and is increased by 10.36%.
8) It is also observed that the values are increasing by the age of SCC i.e. Compressive, Split tensile and flexural strengths with increase in crusher dust.

X. RECOMMENDATIONS AND SCOPE FOR FUTURE STUDY

1) Studies on replacement of cement by pozzolanic material including replacement of fine aggregates by industrial wastes.
2) Studies on replacement of fine aggregates along with the fly ash replacement in cement.
3) Studies on creep and shrinkage properties may be carried out.
4) Studies on increasing the quantity of superplasticizer used, inorder to achieve workability properties even with the replacement of fine aggregate with foundry sand.
5) Studies on replacement of fine aggregates with a combination of industrial wastes.

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[16] IS 1026-2009 Specification for concrete mix proportioning (Guidelines).
[17] IS 5816-1999 Specification for splitting Tensile Strength of Concrete –Method of Test, First revision.