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A Study on Compressive Strength of Self-Compacting Concrete Using Portland Slag Cement with Partial Replacement of Fine Aggregate by Foundry Sand

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ABSTRACT: Concrete plays a vital role as a construction material in the world. In the present scenario, waste materials from various industries are added to the mix. Over 400 million tons of waste materials are being produced by various industries every year. Metal industries use large amounts of sand as part of the metal casting process. Foundries successfully recycle and reuse the sand many times in a foundry. When the sand can no longer be reused in the foundry, it is removed from the foundry and is termed as Foundry sand. Foundry sand production is nearly 6 to 10 million tons annualy. There is a possibility of substituting natural fine aggregate withwaste foundry sand which offers technical, economic and environmental advantages which are of great use in the construction sector. 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.

KEYWORDS: SCC,Foundry sand,slump flow value, L-box blocking ratio, V funnel flow time, T_{50} s.

I. INTRODUCTION

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. Concrete technology has made tremendous strides in the past decade. 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. 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. The hardened concrete is dense, homogeneous and has the same engineering properties and durability as that of traditional vibrated concrete.

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. Self compacting concrete (SCC) can be classified as an advanced construction invention. 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)

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and Ground Granulated Blast-Furnace Slag (GGBFS) are normally included in the production of high-strength and high-performance concrete. The use of one of these additions could increase the fluidity of the concrete and may reduce the requirement of super plasticizer necessary to obtain a similar slump flow compared with the same concrete containing cement only. In addition, the incorporation of these fine materials can enhance the grain size distribution in the particle packing, thus ensuring greater cohesiveness.

Slag is an addition that has a chemical composition very close to that of cement and is relatively constant. In the world there are about 250 million tonnes of slag per year, from which about 90 million tonnes are used in the production of concrete as additions. Besides, slag has other advantages such as lower heat of hydration, higher sulphate and acid resistance, better workability, lower permeability and higher corrosion resistance.

II. NECESSITY OF THE WORK

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, 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. 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 using these blended cements to address the demands of the construction industry with different replacement of industrial wastes as fine aggregates. The need to develop cost effective and energy efficient building materials is self evident in the present phase of increasingly scarce and expensive traditional building materials. Therefore, evaluating selected industrial wastes for civil engineering construction is encouraged by many countries. Using industrial wastes helps in conserving natural resources, brings about a pollution free environment as well as reduces cost of construction.

III. METHODOLOGY

Self-Compacting Concrete (SCC) is the current research area today. Many intrinsic properties of the concrete are yet to be understood clearly. The differences between High Performance Concrete (HPC) and Self Compacting Concrete (SCC) are essentially in the use of special admixture. Due to the use of chemical and mineral admixtures, a detailed study is more essential in SCC compared to conventional concrete.

All previous efforts and attempts done in the field of SCC were concerned with Ordinary Portland cement (OSC) 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(PSC) with replacement of industrial waste like Foundry sand 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.

Five different mixes (SCC0, SCC25, SCC50, SCC75 and SCC100) were employed to examine the influence of foundry sand 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. SCC0 is the basic mix in which only conventional sand is used as the fine aggregate. In mixes SCC25, SCC50, SCC75 and SCC100 the fine aggregate is replaced by the foundry sand as 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.

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 150mm × 150mm × 150mm (length x breadth x depth)were tested for 3, 7 & 28 days.

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IV. EXPERIMENTAL INVESTIGATION

MATERIALS USED:

1. *CEMENT*: The cement used for the investigation was Portland Slag Cement (PSC) with brand JAYPEE cement confirming to IS: 455-1989. The cement is fresh and is of uniform colour and consistency.

Table 1: Physical properties of PSC

S.No	Properties	Test Values	Standard Values (IS : 455-1989)
1	Specific gravity	2.94	2.90-3.15
2	Initial setting time (min)	190	>30
3	Final setting time (min)	235	<600
4	Fineness of cement (by sieving)	2.5	<10

Tests are done on Portland Slag Cement (PSC) to find various properties like specific gravity, initial setting and final setting time and fineness of cement and the above table shows the comparison between the standard values and test values which are done on Portland Slag Cement (PSC).

2. *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.

Table 2: Physical properties of conventional sand

S.No	Property	Value
1	Grading of sand	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

Tests are done on conventional sand to find various properties like specific gravity, bulk density and fineness modulus and the values are tabulated in Table 2.

3. *FOUNDRY SAND*: The fine aggregate used in the present experimental programme is foundrysand confirming to zone - III as per 383: 1970.

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Table 3: Physical properties of Foundry sand

S.No	Property	Value
1	Grading of sand	Zone III
2	Specific gravity	2.39
3	Bulk density (i) Loose state (ii) Compacted state	 1.29 gm/cc 1.43 gm/cc
4	Fineness modulus	2.01

Tests are done on foundry sand to find various properties like specific gravity, bulk density, fineness modulus and zone category and the values are tabulated in Table 3.

4. *COARSE AGGREGATE*: Thecoarse aggregate used, was from an established quarry satisfying the requirements of IS 383: 1970. In this experimental programme aggregates of only 10mm size are used.

Table 4: Physical properties of coarse aggregate

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

The coarse aggregate used in this research is of 10mm size and various tests like specific gravity, bulk density and fineness modulus are performed on the aggregate and values are tabulated in Table 4.

5. *CHEMICAL ADMIXTURE*: Poly carboxylate ether(PCE)-based superplasticizer (SP) Master Glenium SKY 8630 was used in 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.

Table 5: Physical properties of chemical admixture

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%

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Superplasticizer (SP) Master Glenium SKY 8630 is used as a chemical admixture and its properties like colour, relative density, Ph and chloride ion content are tabulated in Table 5.

V. MIXING AND CASTING DETAILS

Five different mixes (SCC0, SCC25, SCC50, SCC75 and SCC100) were employed to study the influence of varying replacement fine aggregate with foundry sand in SCC. 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 foundry sand in the fine aggregate quantity. 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.

All the materials were mixed using pan mixer with a maximum capacity of 80litres. The materials were fed into the mixer in the order of coarse aggregates, PSC and sand. The materials were mixed dry for 1.5min. 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.Number of cubes casted for compressive strength =45 samples

VI. SPECIMENS AND CURING

The specimen cubes of standard size 150mm X 150mm X 150mm (length X breadth X height) were casted for compressive strength and tested for 3, 7 & 28days.After casting, all the specimens were covered with plastic sheets and left at room temperature for 24hrs. The specimens were then cured in water at approximately 27^0C until testing was carried out at 3, 7 & 28days.

VII.TESTING OF SPECIMENS

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.

VIII. RESULTS AND DISCUSSIONS

The results based on experimental work are presented in tables and discussed. The results obtained from experimental work including sieve analysis and compressive strength.

Table 6: Details of mix proportions in Kg/m^3

Constituent	SCC 0	SCC25	SCC50	SCC75	SCC100
PSC	450	450	450	450	450
Water	202.5	202.5	202.5	202.5	202.5
Water/Binder Ratio	0.45	0.45	0.45	0.45	0.45
Conventional Sand	836.5	627.35	418.23	209.11	0
Foundry Sand	0	204	408	612	816
10 mm	770.1	770.1	770.1	770.1	770.1
Chemical Admixture	4.05	4.05	4.05	4.05	4.05

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0.9%					
Slump Value in mm	640	600	400	320	300
Density of Concrete	2259.1	2253.9	2248.8	2243.7	2238.6

Percentage of the slump flow is given by $\frac{SLUMP\ FLOW\ VALUE - SLUMP\ CONE\ DIAMETER}{SLUMP\ CONE\ DIAMATER}\ X\ 100$

where slump cone diameter = 200mm

Table 7:Fresh Properties Of The Self-Compacting Concrete

Mix Notation	T 50 (S)	Slump Flow (mm) >550 Mm	Percentage of Flow (%)	V-Funnel Flow Time (S)	L-Box Blocking Ratio
SCC0	6	640	220	34	0.83
SCC25	7	600	200	38	0.80
SCC50	13	400	100	54	0.57
SCC75	18	320	60	61	0.46
SCC100	20	300	50	64	0.40

The above table shows the slump flow with respect to percentage of foundry sand. From the results it can be seen that as the percentage of foundry sand increases the slump flow decreases. Out of the five mixtures only two mixtures have exhibited slump flow values above i.e 640 and 600 mm showing the capability of concrete to deform under its own weight. Slump flow of 650 ± 50 mm is required for SCC only two concretes developed here have satisfied the requirements. From the above statements it is observed that the slump flow value of SCC is decreasing with increase in percentage of foundry sand.

The time taken during T_{50} for foundry sand is with 20 sec and conventional sand is 6 sec. The V-funnel flow also exhibited a similar behaviour. V-funnel measurements of two mixtures SCC75 and SCC100 have been very high. However, all other three concrete mixtures filled the moulds with its own weight without the need for vibration. To improve this flowability, the dosage of superplasticizer have to be increased within the specified limits (mentioned by the supplier).

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Fig 1. **Testing of cubes in Compression testing machine**

The cubes are tested in the Compression Testing Machine to determine their compressive strength at 3, 7 and 28days for various mix designs with varying replacement of conventional sand with foundry sand i.e, SCC0, SCC25, SCC50, SCC75 and SCC100.

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 five mixes with respect to varying replacement of the fine aggregate with foundry sand are presented in. It can be seen that the concrete mix with foundry sand percentage as 0% and 25% exhibited values greater than 0.8 whereas remaining all the mixes exhibited values less than 0.8.

Table 8:Compressive Strength of Different Mixes at Different Ages of Concrete

Mix Notation	Compressive strength (MPa)		
	3rd day	7th day	28th day
SCC0	20.89	27.33	38.1
SCC25	18.22	28.66	40.29
SCC50	16.44	25.11	36.45
SCC75	15.55	22.22	34.33
SCC100	18	25.55	38.89

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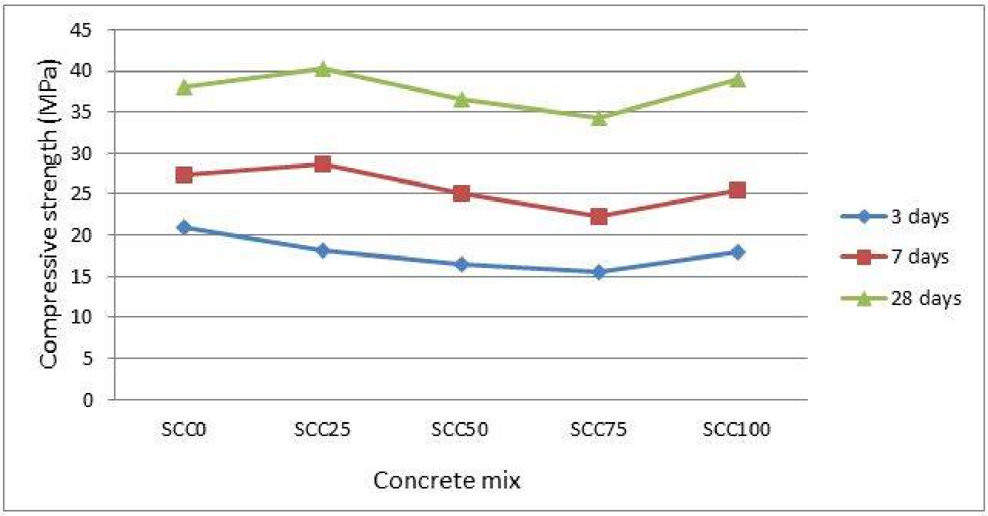

Fig 2. **Compressive strength Vs Concrete mix**

From the above table and graphs, it is clear that with the increase in percentage of foundry sand as fine aggregate, the compressive strength have been increasing from 0% to 25% and it is steadily decreasing for 50% and 75% and again increasing for 100% foundry sand. It is observed that the SCC with foundry sand as 25% replacement of the fine aggregate has shown better performance.

IX. CONCLUSION

1. It is observed that when conventional sand is used as fine aggregate, the characteristic strength and workability are achieved. With the increase in percentage of foundry sand the characteristic strengths are achieved but workability is decreased.

2. When 25% conventional sand is replaced by foundry sand, the compressive strength is maximum and increased by 5.75%.

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