Performance And Strength Evaluation For M70 Grade of SCC With Partial Replacemnt of Flyash And Various Sizes of Aggregates

Satti Rama Veera Manikanta Reddy[1], Sri. Md. Nazeer Ahamed[2]
[1, 2] Department of Civil Engineering
[1, 2] KITS Divili

Abstract- *Concrete is a versatile widely used construction material. Concrete occupies unique position among the modern construction materials, Concrete is a material used in building construction, consisting of a hard, chemically inert particulate substance, known as an aggregate (usually made for different types of sand and gravel), that is bond by cement and water. Researchers have been trying to improve its quality and enhance its performance. Recent changes in construction industry demand improved durability of structures. There is a methodological shift in the concrete design from a strength based concept to a performance based design. Self - compacting concrete (SCC) is a high - performance concrete that can flow under its own weight to completely fill the form work and self-consolidates without any mechanical vibration. Such concrete an accelerate the placement, reduce the labour requirements needed for consolidation, finishing and eliminate environmental pollution. The so called first generation SCC is used mainly for repair application and for casting concrete in restricted areas, including sections that present limited access to vibrate. The guiding principle behind self-compaction is that "the sedimentation velocity of a particle is inversely proportional to the viscosity of the floating medium in which the particle exists". The other features of mix proportion of SCC include low water to cementitious material ratio, high volume of powder, high paste to aggregate ratio and less amount of coarse aggregate. One of the popularly employed techniques to produce Self Compacting Concrete is to use fine materials like Fly Ash, GGBFS etc., in concrete, besides cement, the idea being to increase powder content or fines in concrete.The original contribution in the field of SCC is attributed to the pioneering work of Nan Su et al; who have developed a simple mix design methodology for Self Compacting Concrete. In this method, the amount of aggregate required is determined first, based on Packing Factor (PF).This will ensure that the concrete obtained has good flowability, self-compacting ability and other desired SCC properties. The European Federation of Producers and Applicators of Specialist Products for Structures (EFNARC) [2005] have also laid down certain guidelines for fresh properties of SCC*

I. INTRODUCTION

The versatility and the application of concrete in the construction industry need not be emphasized. Research on normal and high strength concrete has been on the agenda for more than two decades. As per IS: 456-2000 [Code of Practice for Plain and Reinforced Concrete], concretes ranging 25 - 55 MPa are called standard concretes while those above 55 MPa can be termed as high strength concrete. Concretes above 120/150 MPa are called ultra-high strength concrete. High strength concrete has numerous applications worldwide in tall buildings, bridges with long span and buildings in aggressive environments. Self compacting concrete (SCC) is a concrete, which flows and compacts only under gravity. It fills the mould completely without any defects. Usually self-compacting concretes have compressive strengths in the range of 60-100 N/mm2. However, lower grades can also be obtained and used depending on the requirement. SCC was originally developed at the University of Tokyo in Japan with the help of leading concrete contractors during 1980's to be mainly used for highly congested reinforced structures in seismic regions. As durability of concrete structures was an important issue in Japan, an adequate compaction by skilled labors was required to obtain durable concrete structures.

II. LITERATURE REVIEW

A detailed review of literature on the performance of different types of concrete specimens that were exposed to higher temperature is reported in this chapter. Shape of specimen, size of specimen, magnitude of temperature load applied on the specimen, duration of heating, time temperature curve, rate of heating, rate of cooling, time taken for hot test after curing period, time taken for load test after heating, stressed/unstressed test on hot members, type of cooling adopted on heated specimens etc. are the parameters that influence the test results. To completely understand the behavior of concrete under elevated temperature, it is necessary to consider all the key factors involved while designing the experimental setup. However it is difficult to carry out experimental investigations considering all the parameters that influence the performance of concrete exposed to elevated temperatures. Hence different researchers considered different sets of parameters. This chapter summarizes the salient features of the experimental and analytical investigations reported in the literature. The analysis of the data indicates that the behaviors of Normal Compacting Concrete and Self Compacting Concrete are different. The effects of elevated temperatures on the properties of concrete such as compressive strength, tensile strength, flexural strength and spalling reported in the literature are summarized.

III. METHODOLOGY

Wide spread applications of SCC have been restricted due to lack of standard mix design procedure and testing methods.It is pertinent to mention that only features of SCC have been included in Indian Standard Code of practice for plain and reinforced concrete (fourth revision), [2000]. Slump flow test, L-box test, V-funnel test, U-box test, Orimet test & GTM Screen test are recommended by EFNARC [European Federation of Producers and Applicators of Specialist Products for Structures, May 2005] for determining the properties of SCC in fresh state. The experimental program consisted of casting and testing specimens for arriving at the maximum size of aggregate.In the first stage the effective maximum size of aggregate for M70 grade of concrete was arrived. Nan Su method of mix design [2001] was adopted to arrive at the suitable mix proportions. The mix proportion for M70 grade was arrived, taking the different sizes of aggregate into consideration. The effective size of aggregate was arrived for M70 grade of concrete, based on the mechanical properties and fresh properties of SCC.

MATERIALS USED AND THEIR PROPERTIES

MATERIALS

The materials used in the experimental investigation are locally available cement, sand, coarse aggregate, mineral and chemical admixtures. The chemicals used in the present investigation are of commercial grade. 3.1.1 Cement Ordinary Portland cement of 53 grade [IS: 12269-1987, Specifications for 53 Grade Ordinary Portland cement] has been used in the study. It was procured from a single source and stored as per IS: 4032 - 1977.

Table 1. Physical properties of Ordinary Portland Cement

S. No	Property	Test Method	Test Results	IS Standard
1.	Normal Consistency	Vicat Apparatus (IS:4031 Part-4)	30%	
2.	Specific Gravity	Sp. Gr Bottle (IS:4031 Part-4)	3.09	
3.	Initial Setting Time	Vicat Apparatus (IS:4031 Part-4)	96 minutes	Not less than 30 minutes
	Final Setting Time		207 Minutes	Not less than 10 hours
4.	Fineness	Sieve test on sieve no.9 (IS: 4031 Part -1)	1.3%	10%
5.	Soundness	Le-Chatlier method (IS: 4031 Part-3)	2mm	Not more than 10mm

FINE AGGREGATES

The fine aggregate used was locally available river sand without any organic impurities and conforming to IS: 383 - 1970 [Methods of physical tests for hydraulic cement]. The fine aggregate was tested for its physical requirements such as gradation, fineness modulus, specific gravity and bulk density in accordance with IS: 2386 - 1963 [Methods of test for aggregate for concrete] and is shown in Table 3.2. The sand was surface dried before use.

COARSE AGGREGATE

The size of coarse aggregate used in self compacting concrete was between10mm to 16mm. The rounded and smaller aggregate particles provide better flowability and deformability of concrete and also prevent segregation. Graded aggregate is also important particularly to cast concrete in highly congested reinforcement or formwork having small dimensions. Crushed granite metal of sizes 16 mm to 10 mm graded obtained from the locally available quarries was used in the present investigation. These were tested as per IS 383-1970 [Methods of physical tests for hydraulic cement]. The physical properties like specific gravity, bulk density, flakiness index, and elongation index and fineness modulus are shown in Table 3.2.

WATER

Water used for mixing and curing was potable water, which was free from any amounts of oils, acids, alkalis, sugar, salts and organic materials or other substances that may be deleterious to concrete or steel confirming to IS : 3025 - 1964 part22, part 23 and IS : 456 - 2000 [Code of practice for plain and reinforced concrete]. The pH value should not be less than 6. The solids present were within the permissible limits as per clause 5.4 of IS: 456 - 2000.

FLY ASH

Fly ash is one of the most extensively used supplementary cementitious materials in the construction field resembling Portland cement. It is an inorganic, noncombustible, finely divided residue collected or precipitated from the exhaust gases of any industrial furnace. Most of the fly ash particles are solid spheres and some particles, called cenospheres, are hollow and some are the plerospheres, which are spheres containing smaller spheres inside.The particle sizes in fly ash vary from less than 1 μm to more than 100 μm with the typical particle size measuring less than 20 μm.Their surface area is typically 300 to 500 m2/kg, although some fly ashes can have surface areas as low as 200 m2/kg and as high as 700 m2/kg. Flyash is primarily silicate glass containing silica, alumina, iron, and calcium. The relative density or specific gravity of flyash generally ranges between 1.9 and 2.8 and the color is generally grey. Flyash used in this investigation was procured from Kakatiya Thermal Power Project, Andhra Pradesh, India.It confirms with grade I of IS: 3812 -1981 [Specifications for flyash for use as pozzolana and admixture]. It was tested in accordance with IS: 1727 -1967 [Methods of test for pozzolana materials].

Table 2.

Table: 3.2 Physical properties of Coarse and Fine aggregate.

S.No	Property	Method	Fine Aggregates	Coarse Aggregates
1.	Specific Gravity	Pycnometer IS:2386 Part3-1986	2.41	2.63
2.	Bulk Density Loose Compacted	IS:2386 Part 3-1986	1548 kg/m^3 1680 kg/m^3	1451kg/m^3 1602kg/m^3
3.	Bulking	IS:2386 Part 3-1986	6% w c	---
4.	Flakiness Index	(IS:2386 Part 2-1963)	---	8.08%
5.	Elongation Index	(IS:2386 Part 2-1963)	---	0%
6.	Fineness Modulus	Sieve Analysis (IS:2386 Part 2-1963)	3.62	6.04

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Table 3.

Table: 3.3 Typical Oxide Composition of Indian fly ash

S.NO	Characteristics	Percentage
1.	Silica, SiO_2	49-67
2.	Alumina Al_2O_3	16-28
3.	Iron oxide Fe_2O_3	4-10
4.	Lime CaO	0.7-3.6
5.	Magnesia Mg O	0.3-2.6
6.	Sulphar Trioxide SO_3	0.1-2.1
7.	Loss on Ignition	0.4-1.9
8.	Surface area m^2/kg	230-600

Table 4.

Table: 3.4 Chemical requirements of fly ash.

S.No	Characteristics	Requirements (% by weight)	Fly Ash used (% by weight)
1.	Silicon dioxide (SiO_2) plus aluminum oxide(Al_2O_3) plus iron oxide (Fe_2O_3)	70 (minimum)	94.46
2.	Silicon dioxide (SiO_2)	35 (minimum)	62.94
3.	Magnesium Oxide (MgO)	5 (max.)	0.60
4.	Total sulphur as sulphur trioxide(SO_3)	2.75 (max.)	0.23
5.	Available alkalies as sodium oxide(Na_2O)	1.5 (max.)	0.05
6.	Loss on ignition	12 (max.)	0.30
7.	Chlorides		0.009

Table 5.

Table: 3.5 Physical requirements of fly ash

S.No	Characteristics	Requirements for grade of flyash (IS:3812-1981)		Experimental Results
		Grade - I	Grade - II	
1.	Fineness by Blain's apparatus in m2/kg	320	250	335
2.	Lime reactivity (MPa)	4.0	3.0	9.8
3.	Compressive strength at 28 days as percentage of strength of corresponding plain cement mortar cubes	Not less than 80%		86%
4.	Soundness by Autoclave expansion	---		Nil

LABORATORY EXPERIMENTATION:-

SUPER PLASTICIZER

High range water reducing admixture called as super plasticizers are used for improving the flow or workability for lower water-cement ratios without sacrifice in the compressive strength. These admixtures when they disperse in cement agglomerates significantly decrease the viscosity of the paste by forming a thin film around the cement particles. In the present work, water-reducing admixture Glenium conforming to IS 9103: 1999 [Specification for admixtures for concrete], ASTM C - 494 [Standard Specification for Chemical Admixtures for Concrete] types F, G and BS 5075 part.3 [British Standards Institution] was used. The details of the super plasticizer used are given in Table 3.6.

Table 6.

Table: 3.6 Details of Super Plasticizer

S.No	Property	Result
1.	Form or state	Liquid (sulphonated naphthalene based formaldehyde)
2.	Colour	Brown
3.	Specific gravity	1.220 to 1.225 at 30°C
4.	Chloride content	Nil to IS:456
5.	Air entrainment	Approx. 1% additional air is entrained.
6.	Compatibility	Can be used with all types of cements except high alumina cement. Conplast SP430 is compatible with other types of Fosroc admixtures when added separately to the mix.
7.	Workability	Can be used to produce flowing concrete that requires no compaction.
8.	Cohesion	Cohesion is improved due to dispersion of cement particles thus minimising segregation and improving surface finish.
9.	Compressive strength	Early strength is increased up to 20%. Generally, there is improvement in strength up to 20% depending upon W/C ratio and other mix parameters.
10.	Durability	Reduction in w/c ratio enables increase in density and impermeability thus enhancing durability of concrete.
11.	Dosage	The rate of addition is generally in the range of 0.5 - 2.0 litres /100 kg cement.

VISCOSITY MODIFYING AGENT

These admixtures enhance the viscosity of water and eliminate the bleeding and segregation phenomena in the fresh concrete as much as possible. VMA is a neutral, biodegradable, liquid chemical additive designed to reduce the bleeding, segregation, shrinkage and cracking that occur in high water/cement ratio concrete mixes. VMA also contribute to stabilization for SCC mixes that are susceptible to segregation at high slump ranges. The VMA used in this investigation was Glenium stream-2 which is a product of BASF construction chemicals. The properties of VMA are given in Table 3.7.

Table 7.

Table: 3.7 Details of Viscosity Modifying Agent

S.No	Property	Result
1.	Aspect	Colourless free flowing liquid
2.	Relative density	1.01
3.	Ph	≥6
4.	Chloride ion content	< 0.2%
5.	Compatibility	Can be used with all types of cements
6.	Incompatible	Use with naphthalene sulphonate based superplasticiser admixtures.
7.	Mechanism of action	It consists of a mixture of water soluble copolymers which is adsorbed onto the surface of the cement granules, thereby changing the viscosity of the water and influencing the rheological properties of the mix.
8.	Dosage	50 to 500 ml/100 kg of cementitious material.

MIX PROPORTIONING

The mix proportioning was done based on the Nan Su approach [2001]. The mix proportion is given in Table 3.8, for different aggregate sizes

Table 8.

Table: 3.8 Mix Proportion and Quantities of M70 grade of SCC

Size of Graded Aggregate (mm)	Mix Proportion	w/c	Cement	Flyash	F.A	C.A	S.P	V.M.A
20	1:1.42:4.49:3.76:0.043	0.455	210	300	944	791	9.12	1.75
12.5	1:0.425:1.25:1.18:0.02	0.257	680	289.28	850.4	803.1	16.8	1.75
10	1:0.45:1.25:1.17:0.023	0.269	680	305.30	850.4	795.6	15.8	1.75

BATCHING AND MIXING OF SCC

The proportioning of the quantity of cement, cementitious material like Flyash, fine aggregate and coarse aggregate has been done by weight as per the mix design. Water, super plasticizer and VMA were measured by volume. All the measuring equipment's are maintained in a clean serviceable condition with their accuracy periodically checked.The mixing process is carried out in electrically operated concrete mixer. The materials are laid in uniform layers, one on the other in the order - coarse aggregate, fine aggregate and cementitious material. Dry mixing is done to obtain a uniform color. The fly ash is thoroughly blended with cement before mixing. Self Compacting characteristics of fresh concrete are carried out immediately after mixing of concrete using EFNARC specifications [2005]. The workability properties of Normal Concrete (NC) Viz., slump was maintained in the range of 75 - 100 mm and compaction factor was 0.9. In higher strength concretes, these are maintained by adjusting the mineral and chemical admixtures.

FRESH PROPERTIES OF SCC

Requirements of Self Compacting Concrete

SCC mixes must meet three key properties:

1. Ability to flow into and completely fill intricate and complex forms under its own weight.
2. Ability to pass through the congested reinforcement under its own weight.
3. High resistance to aggregate segregation.

IV. RESULTS AND DISCUSSIONS

GENERAL

The parameters involved in the study are the size of aggregate (10, 12.5, 20mm), age of curing (3, 7 and 28 days), grade of concrete (M70) and type of concrete (SCC). 5.1. Discussion on mix proportions adopted for SCC As described earlier, Nan Su method of mix design [2001] was adopted to design the SCC mix for M70 grade of concrete. As understood, Nan Su method is based on the basic principle that the paste of binders are filled in the voids of aggregates ensuring that the concrete obtained has flowability, self-compacting ability and other desired SCC properties.The packing factors assumed on the basis of better compatibility and strength, from a number of trials is 1.12 for M70 grade of concrete. From Nan Su method of mix design for SCC, the density, compatibility and strength are dependent on how effectively the aggregates are packed. Hence, the size of aggregate, shape and texture of aggregate also plays a deciding factor in the values of fresh and hardened properties.The mix proportion of M70 grade of concrete designed on the basis of Nan Su method is given in the Table 3.8 for different maximum sizes of aggregate Viz. 10, 12.5 and 20mm. For the mix proportions obtained, Table 4.1 shows the details of various parameters including total Aggregate - Cement ratio (A/C), water - cement ratio (w/c), Coarse Aggregate - Fine Aggregate ratio (CA/FA) and fine aggregate - total aggregate (S/a) for various aggregate sizes.

Effect of size of aggregate on fresh properties of SCC

The details of the fresh properties are shown in Tables 4.2, M70 grade of concrete. Based on the fresh properties of SCC for different sizes of aggregates, it can be noted that M70 grade of concrete with all the different maximum sizes satisfied the required EFNARC specifications [2005]. The fresh properties have improved with the increase in powder content. Also the lower size of aggregate yielded better results in M70 grade of concrete.

Compressive strength

Grade of concrete, maximum size of aggregate and age of curing are the variables of investigation. The details of the compressive strengths of M70 grades are shown in Tables 4.3. From the results it was noted that, as the grade of concrete increased the effective maximum size of the aggregate has deceased. In the above cases, the cement content was 680 kg/m3 for M70 grades. The three effective sizes for the above three mixes have been arrived and the same was adopted in the further study.

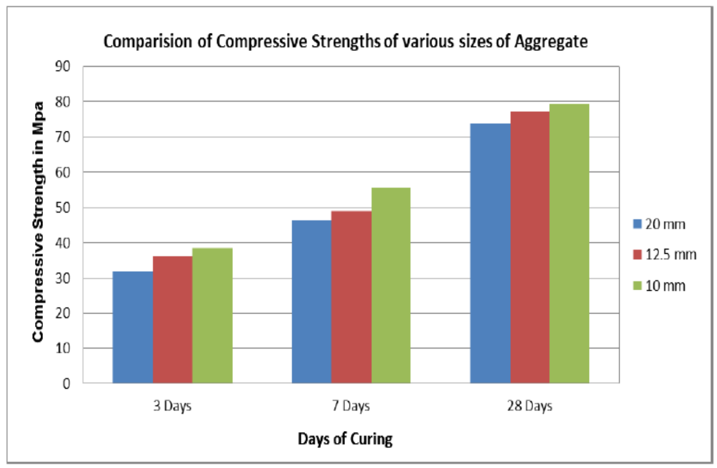

Figure 1. Bar Diagram of Compressive Strength with various sizes of Aggregates

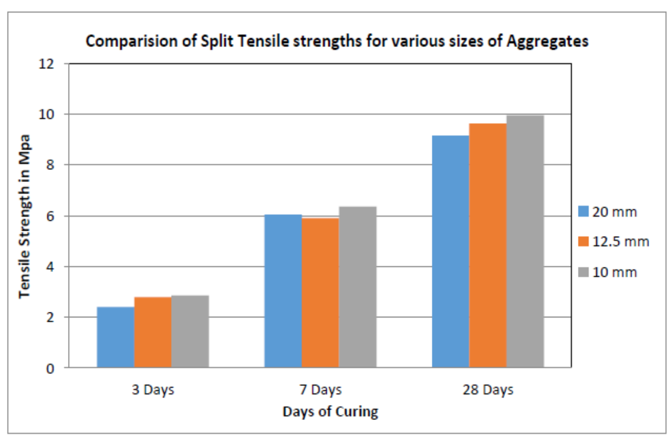

Fig 4.11: Bar Diagram of Split Tensile Strength with various sizes of Aggregates

Figure 2.

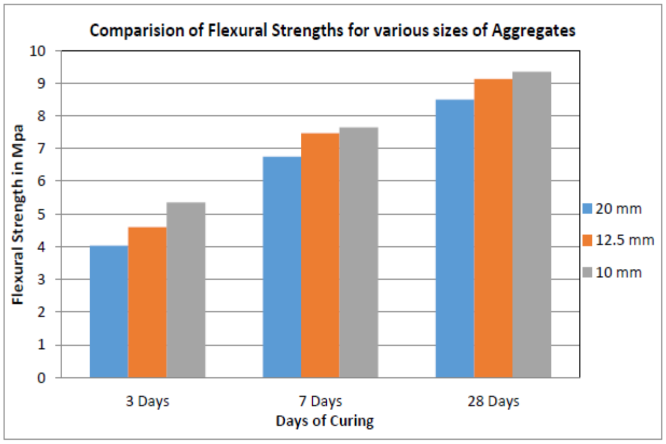

Fig 4.12: Bar Diagram of Flexural Strength with various sizes of Aggregates

Figure 3.

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