Studies on the comparative strength of self-compacting concrete (SCC) by preventing steel fibers from entering the mixture

Dulam.Chiranjeevi[1]|V.Bhavani[2]|B.Navya sri[3]|C.Ashok[4]

1Associate Professor, CIVIL department, Brilliant Grammar School Educational Society's Group of Institutions-Integrated Campus, Hyderabad, TS.

2 Assistant Professor, CIVIL department, Brilliant Grammar School Educational Society's Group of Institutions-Integrated Campus, Hyderabad, TS.

3&4 UG SCHOLARS, CIVIL department, Brilliant Grammar School Educational Society's Group of Institutions, Hyderabad-Integrated Campus, TS.

ABSTRACT:

A flowing concrete mixture that may solidify under its own weight is known as self-compaction concrete (SCC). Concrete placement issues in crowded reinforced areas can be reduced or even eliminated with SCC technology. This project calls for the development of SCC through the use of mineral and chemical admixtures. A rational method of mix design is to be adopted using EFNARC (European federation of national associations representing for concrete) guidelines. SCC is to be created utilizing chemical and mineral admixtures once the proportions of an M40 grade mix are first determined using IS 10262:2009. Later SCC is altered by changing the aforesaid mix's steel fiber volume percentages. The experimental approach outlined in the EFNARC recommendations must be used to investigate the fresh state qualities of SCC flowbility, fill-ability, and pass-ability. The stress-strain behavior and compressive and tensile strength testing of SCC with and without the addition of steel fibers for 14, 28, and 60 days, using varying volume fractions of steel fibers (1%, 2%, 3%, and 4%).

1.0 INTRODUCTION:

GENERAL

The world is currently seeing the creation of extremely complex and demanding civil engineering facilities. Concrete is frequently the most crucial and Widely used material is called upon to feature very high strength and sufficient workability qualities. In the field of concrete technology, efforts are being made to create concrete with unique properties. By adding different admixtures to concrete up to specific ratios, researchers worldwide are trying to create high-performance concrete. Self Compacting Concrete (SCC) is one of the most notable developments in concrete technology during the past ten years. The qualities in the fresh state are the primary features of SCC. The ability of the mix to flow under its own weight without vibrating, to flow through highly crowded reinforcement under its own weight, and to maintain homogeneity without segregation are the main goals of the mix design. Because of its unique qualities, SCC has the potential to greatly enhance the caliber of concrete structures and create new concrete application opportunities.

HISTORY OF SCC

Self-compacting concrete was first developed in 1986 in Japan to achieve durable concrete structures. For several years, the problem of the durability of concrete structures is a major topic of interest for construction Engineers. Sufficient compaction is needed for conventional concrete and that causes segregation. With plain concrete, it is difficult to ensure uniform material quality in heavily reinforced zone where steel is not correctly surrounded by concrete and which finally leads to durability problems.

MECHANISM FOR ACHIEVING SELF COMPACTABILITY

The method for achieving self-compactability involves not only high deformability of paste or mortar, but also resistance to segregation between coarse aggregate and zone of reinforcing bars. Okamura and Ozawa have employed the following methods to achieve self compactability.

- Limited coarse aggregate content
- Low water-powder ratio
- Use of super plasticizer

The frequency of collision and contact between aggregate particles can increase as the relative distance between the particles decrease and then internal stress near obstacles. Research has found that the energy required for flowing is consumed by the increased internal stress, resulting in blockage of aggregate particles. Limiting the coarse aggregate content, whose energy consumption is particularly intense, to a level lower than normal is effective in avoiding this kind of blockage.

ADVANTAGES OF SCC

Self-compacting concrete originally developed to offset growing shortage of skilled labour, it has improved beneficial economically because of number of factors including

- Faster construction
- Reduction in site man power
- Better surface finishes
- Easier placing
- Improved durability and reliability of concrete structures
- Greater freedom in design
- Thinner concrete sections
- Reduced noise levels, absence of vibration
- Safer working environment

2.0LITERATURE REVIEW

Present-day Self Compacting Concrete is an advanced construction material. As the name suggests, it does not require to be vibrated to achieve full compaction. These offer many benefits and advantages over conventional concrete. These include an improved quality of concrete and reduction of on-sight repairs, faster construction times, lower overall costs, facilitation of introduction of automation into concrete construction. An important improvement of health and safety is also achieved through elimination of handling of vibrators and a substantial reduction of environmental noise loading on and around a site. The composition of SCC mixes includes substantial proportions of fine grained inorganic materials and this gives possibilities for utilization of mineral admixtures, which are currently waste products with no practical applications and are costly to dispose off (St John 1998).

Hajime Okamura[1] (1997)

He discussed the selection of new type of concrete, which can be compacted into every corner of formwork purely by means of its own weight, was proposed by Okamura (1997). In 1986, he started a research project on the flowing ability and workability of this special type of concrete, later called Self Compacted Concrete. The Self Compact ability of this concrete can be largely affected by the characteristics of materials and the mix proportions. In this study, Okamura (1997) has fixed the coarse aggregate content to 50% of the solid volume and fine aggregate content to 40% of the mortar volume; so that self compact ability could be achieved easily by adjusting the water to cement ratio and super-plasticizer dosage only.

Subramanian and Chattopadhyay[2] (2002)

Subramanian and Chattopadhyay are research and development engineers. The research concentrated on several trials carried out to arrive at an approximate mix proportion of Self Compacting Concrete, which would give the procedure for the selection of a Viscosity modifying agent, a compactable super plasticizer and the determination of their dosages. In order to show the necessity of using a viscosity modifying agent along with a super plasticizer to reduce the segregation and bleeding, the mixture proportion developed by the two researchers was used to cast a few trial specimens.

1. The volume of sand in a mortar was fixed at 40%. The water content varies from 210-230 liters along with the use of super plasticizer.
2. A combination corresponding to 0.1% by weight of water of welangam and 0.53% acrylic co-polymer type super plasticizer.
3. A micro silica dosage of about 3% can reduce the dosage of VMA from 0.1% to 0.15%.

Dehn et al[3] (2000)

They have focused their research work on a time development of SCC compressive and splitting tensile strength and bond behaviour between the reinforcing bars and the SCC compared to normal concrete. In order to ensure a good production of SCC, a mix design should be performed, so that the predefined properties of the fresh and hardened concrete would be reached for sure. All the components should be co-ordinate so that the bleeding and segregation would be prevented. Because of these aspects, their mix design was based on the experience from Japan, Netherlands, France and Sweden. Due to the fact that the load bearing capacity of a reinforced concrete structure is considerably influenced by the bond behaviour between the reinforcing bars and the concrete, the following items were taken into account

- ❖ Anchorage of the Reinforcing bars
- ❖ Crack width control
- ❖ Lapped Reinforcing bars.

Kazumasa Ozawa[4] (1989)

After Okamura began his research in 1986, other researchers in Japan have started to investigate Self Compacting Concrete, looking to improve its characteristics. One of those was Ozawa (1989). He has succeeded in developing Self Compacting concrete for the first time. By using different types of super plasticizers, he studied the workability of concrete and developed a concrete which was very workable. It was suitable for rapid placement and had a very good permeability. Other experiments carried out by Ozawa (1989) focussed on the influence of mineral admixtures, like fly ash and blast furnace slag, on the flowing ability and segregation resistance of Self compacting Concrete. After trying different proportions of admixtures, he concluded that 10-20% of fly ash, 25-45% of slag cement, by mass, showed the best flowing ability and strength characteristics.

Khayat et al[5] (1997)

The objective of Khayat et al. (1997) research was to evaluate the uniformity of in situ mechanical properties of Self Consolidating Concrete used to cast experimental wall elements. The Self compacting concrete mixtures incorporated various combinations of cementitious materials and chemical admixtures. The water cementitious materials ratios ranged from 0.37 to 0.42. Khayat et al. found out that all cores from both types of concrete exhibited little variation in compressive strength and modulus of elasticity in relation to the height of the wall indicating a high degree of strength uniformity. However compressive strength and modulus of elasticity were greater for SCC samples than those obtained from the medium fluidity conventional concrete.

3.0 GENERAL REQUIREMENTS OF MIX DESIGN

MIX PROPORTIONING

In designing the mix it is most useful to consider the relative proportions for the key components by volume rather than by mass..

- Water/Powder ratio by volume of 0.80 to 1.10
- Total powder content -160 to 240 liters (400-600kg) per cubic meter.
- Coarse aggregate content normally 28 to 35 percent by volume of the mix
- Water: cement ratio is selected based on requirements in EN 206.Typically water content does not exceed 200 liter/m^3.
- The sand content balances the volume of the other constituents

Generally, it is advisable to design conservatively to ensure that the concrete is capable of maintaining its specified fresh properties despite anticipated variations in raw material quality. Some variation in aggregate moisture content should also be expected and allowed for at mix design stage .Normally ,viscosity –modifying admixtures are a useful tool for compensating for the fluctuations due to any variations of the sand grading and the moisture content of the aggregates.

In the event that satisfactory performance cannot be obtained, then consideration should be given to fundamental redesign of the mix. Depending on the apparent problem, the following courses of action might be appropriate.

- Using additional or different types of filler,(if available);
- Modifying the proportions of the sand or the coarse aggregate;
- Using a viscosity modifying agent, if not already included in the mix;
- Adjusting the degree of the super plasticizer and/or the viscosity modifying agent;
- Using alternative types of super plasticizer (and/or VMA), more compatible with local materials:
- Adjusting the dosage of admixture to modify the water content, and hence the water/powder ratio.

PRODUCTION AND PLACING

The production of self-compacting concrete needs to be carried out in plants where the equipment, operation and materials are suitably controlled. Production should therefore be carried out at ISO 9000 accredited plants or plants with quality systems that conforms to ISO 9000 or similar. It is recommended that production staff involved in the production of self-compacting concrete have been trained and also have experience in self-compacting concrete.

PRODUCTION:

If possible, aggregates should be covered to minimize the fluctuation of surface moisture content. It is also necessary to have good storage capacity for aggregates and additions (if used)

Mixing

Time of addition of admixture is important, and procedures should be agreed with the supplier after plant trails. If the consistence has to be adjusted after initial mixing, then it should generally be done with the admixtures. If the requirements of EN 206 for the water/cement ratio can be maintained, the water content can be varied to make the necessary modification.

Production control

Aggregates

During production of SCC, tests of aggregate grading and moisture content should be carried out more frequently than usual, since SCC is more sensitive than normal concrete to variations.

Mixing process

At the start of contract and in the absence of previous experience with the particular mix design, additional resources may be needed for supervision of all aspects of initial production of SCC.

Delivery and transportation

Depending on the size of the concrete structure to be produced in SCC, production capacity journey time and placing capability need to be balanced. Unexpected production stops can result in consistence variations that adversely affect the end result.

SCC should be designed so that workability is maintained to meet the requirements of the contract.

4.0REQUIREMENTSFOR CONSTITUTENT MATERIALS

Cement

All typical of cements conforming to EN 197 are suitable, selection of the type of cement will depend on the overall requirements for the concrete, such as strength, durability etc.

C_3A content higher than 10% may cause problems of poor workability retention.

The typical content of cement is 350-450kg/m^3.

More than 500 kg/m^3 cement can be dangerous and increase the shrinkage.

Less than 350 kg/m^3 may only be suitable with the inclusion of other fine filler, such as fly ash, pozzolana, etc.

Sand

All normal concreting sands are suitable for SCC. Both crushed and rounded sands can be used. Siliceous or calcareous can be used.

The amount of fines less than 0.125mm is to be considered as powder and is very important for the rheology of the SCC. A minimum amount of fines (arising from the binders and the sand) must be achieved to avoid segregation.

Coarse Aggregates

All types of aggregates are suitable. The normal maximum size is generally 16 – 20mm; however particle sizes up to 40mm or more have been used in SCC. Consistency of grading is of vital importance.

Regarding the characteristics of different types of aggregate, crushed aggregates tend to improve the strength because of the interlocking of the angular particles, while rounded aggregates improve the flow because of lower internal friction.

Gap graded aggregates are frequently better than those continuously graded, which might experience grater internal friction and give reduced flow.

Admixtures

The most important admixtures are the super plasticizers (high range water reducers), used with a water reduction greater than 20%.

The use of a Viscosity Modifying Admixture (VMA) gives more possibilities of controlling segregation when the amount of powder is limited. This admixture helps to provide very good homogeneity and reduces the tendency to segregation.

REQUIREMENTS FOR SCC

SCC differs from conventional concrete in that its fresh properties are vital in determining whether or not it can be placed satisfactorily. The various aspects of workability which control its filling ability, its passing ability and its segregation resistance all need to be carefully controlled to ensure that its ability to be placed remains acceptable.

Open time

The time during which the SCC maintains its desired rheological properties is very important to obtain good results in the concrete placing. This time can be adjusted by choosing the right type of super plasticizers or the combined use of retarding admixtures. Different admixtures have different effects on open time, and they can use according to the type of cement and the timing of the transport and placing of the SCC.

TEST METHODS FOR SELF – COMPACTIBILITY OF CONCRETE

It is important to appreciate that none of the test methods for SCC has yet been standardized, and the tests described are not yet perfected or definitive. The methods presented here are descriptions rather than fully detailed procedures. They are mainly ad-hoc methods, which have been devised specifically for SCC.

One principal difficulty in devising such tests is that they have to assess three distinct, though related ,properties of fresh SCC- its filling ability(flow ability),its passing ability (free from blocking at reinforcement),and its resistance to segregation (stability).No single test so far devised can measure all three properties.

- There is no clear relation between test results and performance on site;
- There is little precise data, therefore no clear guidance on compliance limits;

SLUMP FLOW TEST

The slump flow is used to assess the horizontal free flow of SCC in the absence of obstructions. It was first developed in Japan. for use in assessment of underwater concrete. The test method is based on the test method for determining the slump. The diameter of the concrete circle is a measure for the filling ability of the concrete.

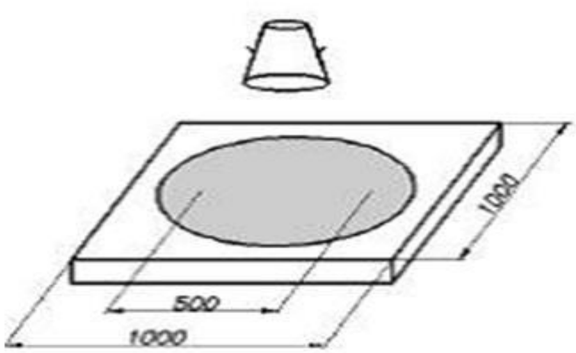


Figure shows Slump Flow Test

J - RING TEST

The principal of the J Ring test may be Japanese, but no references are known. The J Ring test itself has been developed at the University of Paisley. The test is used to determine the passing ability of the concrete. The equipment consists of a rectangular section (30mm×25mm) open steel ring, drilled vertically with holes to accept threaded sections of reinforcement bars.The J Ring can be used in conjunction of the slump flow, the Orimet test, or eventually even the V funnel. These combinations test the flowing ability and (the contribution of the J Ring) the passing ability of the concrete.

Fig: 4.2 J - ring test Apparatus

5.0EXPERIMENTAL INVESTIGATIONS OF INGREDIENTS OF SFRSCC OF M60 GRADE

The present investigations are aimed to study the workability and strength properties of a SFRSCC with the usage of super plasticizer and VMA under normal curing methods. The test method used for the evaluation of self-compact ability of fresh concrete in the present investigations is

1. Slump flow by Abrams Cone test and T_{50cm} – slump flow test.
2. L-box test
3. V- Funnel test and V Funnel test at $T_{5minutes}$.

Self- compacting concrete test methods have two main purposes:

Cement

Cement in general can be defined as a material which possesses very good adhesive and cohesive properties, which make it possible to bond with other materials to form compact mass. It is most important constitute of concrete; it forms the binding medium for the discrete ingredients.

Oxide	%content
CaO	60-67
SiO_2	17-25
Al2O3	3.0-8.0
Fe_2O_3	0.5-6.0
MgO	0.1-4.0
Alkali's	0.4-1.3
SO_3	1.3-3.0

Table: 5.1 Chemical Composition Limits of O.P.C.

6.0 MIX DESIGN

Mix design is defined as the process of selecting suitable ingredients of concrete and determining their relative proportions with the object of producing concrete of certain minimum strength and durability as economical as possible.

Design parameters for M_{40} Grade

Characteristic compressive strength

a) Required in the field at 28 days : 40Mpa
b) Maximum size of aggregate : 10mm(rounded)
c) Degree of workability : 0.80 CF
d) Degree of quality control : Good
e) Type of exposure : Wild
f) Compressive strength of cement : 54.00 N/mm^2 at 28 days

Specific gravity of fine aggregate : 2.59

Specific gravity of coarse aggregate : 2.50

Fineness modules of fine aggregate : 2.94

7.0 EXPERIMENTAL RESULTS AND GRAPHS

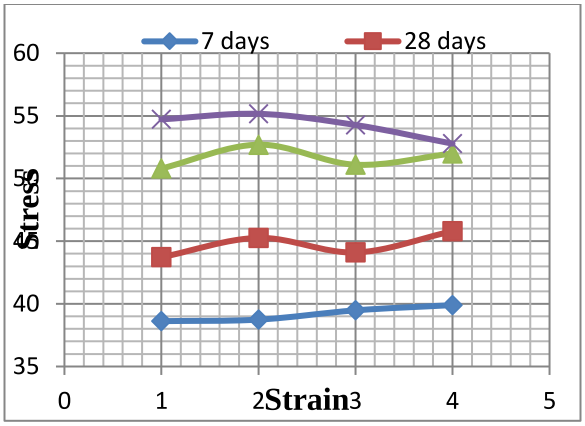
7.1 Workability Parameters for M_{40} grade Steel Fibered Self Compacting Concrete

Sl. No.	Test Method	Unit	Typical range of Values	
			Minimum	Maximum
1	Slump flow	mm	670	800
2	V-funnel	sec	2	5
3	L- box	mm	8	10
4	U-box	mm	14	20
5	J- ring	mm	6	8

Table: 7.1 Workability Parameters for M_{40} Grade SCC

Fig: 7.2 Compressive Testing of SCC Cube Using Digital Compression Testing Machine

The cubes of size 150 mm × 150 mm specimens are casted for testing them after 7, 28, 60 & 90 days. The load is applied and the respective results are tabulated below. Each of 4 specimens is tested for those above mentioned periods and the average of those test results is calculated



***Graph: 7.1* 1% of Steel Fibers used in Cube Specimen**

CONCLUSION

• To provide stability and fluidity to the concrete mix, SCC mix needs a high range of superplasticizer and VMA, a high powder content, and a lower amount of coarse aggregate.

• The stress-strain curves are plotted in this work by increasing the volume percentage of steel fibers.

• Fly ash's high powder content is preserved while coarse particles are reduced by the use of mineral admixtures like micro silica.

• A comparison is made between the strength studies pertaining to split tensile strength and compressive strength.

REFERENCES

[1]Okamura.H, Self Compacting high performance concrete international Vol. 19, no 7, pp50-54, July 1997.

[2]S.Subramanian, D. Chattopadhy, “Experiments for mix proportions of Self Compacting concrete”, The Indian concrete journal, January 2002, ppl13-20.

[3] Dehn et al, “ Time development of the material properties and the bond behavior of SCC, 2000

[4] Kazumasa Ozawa “Effects of paste content on flow characteristics of SCC containing local natural pozzolan”, Vol.7, 2013

[5] Kamal H. Khayat “Relationship between Rheology and Flowable Concrete Workability”, 2009 SP 23, 1982