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Effect of Size of Aggregate

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Chapter 1

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-l l 2000[Code of Practice for Plain and Reinforced Concrete], concretes ranging 2S -55 MPa are called standard concretes while those above SS MPa can be termed as high strength concrete. Concretes above 120/ l 50 MPa are called ultra high strength concrete. High strength concrete bas numerous applications world wide in tall buildings, bridges with long span and buildings in aggressive environments. Building elements made of high strength concrete are usually densely reinforced. This congestion of reinforcement leads to serious problems while concreting. Densely reinforced concrete problems can be solved by using concrete that can be easily placed and spread in between the congested reinforced concrete elements. A highly homogeneous, well spread and dense concrete can be ensured using such a type of concrete.

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/rnm2. 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 I 980'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. This requirement led to the development ofSCC. The development ofSCC was first reported in 1989. SCC is a new kind of High Performance Concrete (HPC) which has an excellent defonnability and segregation resistance. By name it can be defined as a concrete, which can flow through and fill the gaps of reinforcement and comers of the moulds without any need for external vibration. SCC compacts itself due to its self weight and de-aerates almost completely while flowing in the fonnwork. SCC can also be used in situations where it is difficult or impossible to use mechanical compaction for fresh concrete

as underwater concreting, cast in-situ pile foundations, machine bases and columns or walls with congested reinforcement. The high flowability of SCC makes it possible to fill the formwork without vibration. Since its inception, it has been widely used in large construction works or projects in Japan. Recently, this concrete has gained wide use for different applications andstructural configurations across the world. High strength concrete can be produced with nonnal concrete. But these concretes cannot flow freely by themselves, to pack every comer of mouldsand all gaps of reinforcement. High strength concrete based elements require thorough compaction and vibration in the construction process. SCC has more favourable characteristics such as high fluidity, good segregation resistance and distinctive self-compacting ability with out any need for external or internal vibration during the placing process. It can be compacted into every comer of formwork purely by means of i~ o"s'jbwcight without any segregation. Hence, it reduces the risk of honey cotftt/irttof concrete. Development of SCC is a very desirable achievement in the construction industry for overcoming the problems asswith cast-in place concrete. It is not affected by the skill of workers, shape and amount of reinforcing bar arrangement of a structure. Due to its high fluidity and resisting power to segregation, it can be pumped over longer distances. It extends the possibility of use of various by products in its manufacturing. The use of SCC not only shortens the construction period but also ensures quality and durability of concrete. It replaces manual compaction of fresh concrete with a modern semi-automatic placing technology. Some of the advantages of Self Compacting Concrete are as follows:

I. Less noise from vibrators and reduced danger from Hand Ann Vibration Syndrome (HA VS).

2. Safe working environment.

3. Speed of placement, resulting in increased production efficiency.

4. Ease of placement, requiring fewer workers for a particular pour.

S. Better assurances of adequate uniform consolidation.

6. Reduced wear and tear on fonm from vibrator.

7. Reduced wear on mixers due to reduced shearing action.

8. Improved surface quality and fewer bug holes, requiring fewer patching.

9. Improved durability.

I 0. Increased bond strength.

11. Reduced energy consumption from vibration equipment.

12. Best suited where reinforcement congestion is a problem. The functional requirements of a fresh SCC are different from those of a vibrated fresh Normal Concrete (NC). Filling of formwork with a liquid.

Chapter-2

Objectives and scope of the work

Despite its advantages and versatile nature, SCC has not gained much popularity in India,though it has been widely promoted in the Middle East for the last two decades. Awarenessiof SCC has spread across the world, prompted by concerns with poor consolidation and durability in case of conventionally vibrated normal concrete. All the researchers have developed SCC taking the CA/FA ratio and also considered the limited content of coarse aggregate and more content of fines. But, there are very limited investigations reported considering the size effect of coarse aggregate content in the development of SCC. Keeping this in view, the present experimental investigation is taken up to study the effect of size of coarse aggregate in the development of M70 grade of Self Compacting Concrete. Powder content is the main aspect of a SCC mix design. In the present work, flyash is maximized in the SCC mixes as a filler material. Keeping in view the idea explained above, a detailed and a systematic experimental program is laid down as explained in the next paragraphs. The main objective of the present investigation is: To study of effect of the size of aggregate on the strength and flow of M70 grade of Self compacting concrete by using Nansu mix design procedure. With the above objectives in mind the experimental program is categorized as detailed below. Casting of 27 standard cubes, 27 standard cylinders and 27 standard prisms, covering M70 grade of concrete, three aggregate sizes, three periods of curing and three specimens of each type. In this study, high strength (M70) of SCC with three different maximum size of aggregate (20, 12.5, 10 mm) were designedbased on Nan Su method, to determine the effective maximum size of aggregate. The grade of concrete and age of curing were the parameters in the study. A detailed experimental program was planned to achieve the objective of the study is explained in Chapter-3.

Chapter-3

Experimental Program

3.0 General

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 detenniniog the properties of SCC in fresh state. The experimental program consisted of casting and testing specimens for arriving at the maximum size of aggregate. M70 grade of concrete is considered in this study. In the first stage the effective maximum size of aggregate for M70 grade of concrete was arrived. Nan Su method of mix design [200 l] 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. A total of 27 cubes of standard size 150 mm x 150 mm x 150 mm, 2 7 prisms of standard size 100 mm x I 00 mm x 500 mm and 27 cylinders of 150 mm diameter and 300 mm height were cast for determining the compressive strength, flexural strength and split tensile strength respectively. The parameters of the study thus included size of aggregate and age of curing for satisfying the fresh properties of SCC as per EFNARC specifications [2005] based on a number of trials. The present investigation is mainly directed towards developing a mix with good SCC, with different sizes of coarse aggregate and for M70 grade of concrete. The details of fresh properties and hardened properties ofSCC with different sizes of coarse aggregate and different are discussed in detail in

Chapter-4.

The details of the materials, mix proportioning, specimen preparation and test methodology are briefly presented in this chapter.

3.1 Materials

The materia.ls 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 beenused in the study. It was procured from a single source and stored as per IS: 4032 -1977. Care has been taken to ensure that the cement of same company and same grade is used throughout the investigation. The cement thus procured was tested for physical Properties in accordance with the IS: 12269 -1987.

Table 3.1. Physical properties of ordinary Portland cement

S.No. Property. Time Method. Time Result. IS Standard

1. Normal Vicat Apparatus. 30%. ----

Consistency. (IS 4031. Part-4)

2. Specific Gravity. Sp. Gr bottle3.09. ------

(IS 4031. Part- 4)

3 Initial Setting. 96 minutes. Not less than 30 min.

Time

Vicat Apparatus

Final Setting. (IS 4031 Part -4). 207 minutes. . Not less than 10 hour.

Time

4. Fineness. Sieve test on sieve. 1.3%. 10%

3.1.2 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 bulkdensity 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 coarse aggregate chosen for SCC was typically round in shape, well graded and smaller in maximum size than that used for conventional concrete. The size of coarse aggregate used in self compacting concrete was between 10mm 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 lO 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 indexand fineness modulus are shown in Table 3.2.

Table 3.2 Physical properties of fine aggregate and coarse aggregate.

S.No Property Method. Fine Aggregate. coarseAggregate

1.Specific GravityPycnometer 2.41 2.63

(IS:2386 Part 3-1986)

2. Bulk Density

Loose IS 2386 Part- 3 19861548kg/m³. 1451kg/m³

Compacted. 16801kg/m³. 1602kg/m³

3. Bulking. IS 2386 Part -3 1986. 6%wc. -----

4. Flankines. IS.2386 Part –2.1963----8.08%

Index

5. Elongation. IS 2386 Part-2 1963. ------. 0%

Index

6. Fineness. Sieve Analysis. 3.62. 6.02

Modulus. IS 2386 Part – 2 1963

3.1.4 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.

3.1.5Fly Ash

Fly ash 1s 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 precl itated 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 pm to more than 100 qm with the typical particle size measuring less than 20 pm. 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 coiitainlng silica, alumina, imn, 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 fiyash for use as pozzolana and admixture]. It was tested in accordance with IS: 1727 —1967 [Methods of test for pozzolana materials]. A typical oxide composition of Indian fly ash is shown in Table 3.3. The chemical composition and physical characteristics of flyash used in the present investigation were given in Tables 3.4 and Table 3.5.

Table 3.3. Typical oxide composition of Indian Fly Ash.

S No	Characteristics.	Percentage
1.	Silica, Si02.	49-67
2.	Alumina Al2O3	16-28
3.	Iron oxide Fe203	4-10
4.	Lime Ca 0.	0.7-3.6
5.	Magnesia Mg 0.	0.3-2.6

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6. Sulphar Trioxide SO3. 0.1-2.1

Table 3.4. Chemical Requirement of Fly Ash

S.No.	Characteristics..	Requirements(% by weight).	Fly Ash used (% by weight)
1.	Silicon dioxide + Aluminum oxide + Iron oxide	70 (minimum).	94.46
2.	Silicon dioxide.	35 (minimum).	62.94
3.	Magnesium oxide.	5 (maximum).	0.60
4.	Total sulphur as Sulphur. Trioxide	2.75 (maximum).	0.23
5.	Available allcalies as Sodium oxide	1.5 (maximum).	0.05
6.	Loss on ignition.	12 (maximum).	0.30
7.	Chlorides.	-------.	0.009

Table 3.5 Physicalrequirements of FlyAsh

SNo	Characteristics	Requirements for grade of flyash (IS:3812-1981)		Experimental Results
		Grade-I.	Grade-2	
1	Fineness by Blain's Apparatus inm² /kg	320.	250.	335
2.	Lime reactivity (MPa)	4.0	3.0	9.8
3.	Compressive strength at 28. DaysasPercentage ofstrength. of correspondigplain cement mortar cubes	Not less than 80%.		86%

4.. Soundness by Autoclave expansion. -------------. Nil

3.1.6 Super Plasticizer

High range water reducing admixture called as super plasticizers are used for improving the flow or worhability for lower water-cement mtios 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 3.6. Details of super Plasticizer

S.No	Property.	Result
1.	Form or stats	Liquid (sulphonated naphthalene based formaldehyde
2.	Colour.	Brown
3.	Specific. Gravity.	1.220 to 1.225 at 30 C
4.	Chloride content.	Nill to IS:456
5.	Air Entrainment.	Approx 1% additional air is entrained
6.	Compatibility.	Can be used with all types of cement except high alumina cement conplast SP430 is compatible with other type of fosroc mixture when added seperately 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 upto 20% Generally there i improvement in strength upto 20% depending upon W/C ratio and other mix parameters

10. Durability. Reductionin w/c enables increase in density and impermeability thus enhancing durability of concrete.

11. Dosage. The rate of the addition is generally in the range of 0.5 – 2.0 litres/ kg cement

3.1.7 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 constriction chemicals.

3.2 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: 3.8 Mix Proportion and Quantities of M70 grade of SCC.

Due to the high powder content, SCC shows more plastic shrinkage or creep than ordinary concrete mixes. These aspects should therefore be considered during designing and specifylng the SCC.

By definition of SCC, it is clear that the fresh concrete has to fulfill various properties. The SCC must be adequately free flowing so that the coarse aggregate particles can float in mortar but the air can still rise and escape adequately. Sedimentation of the coarse aggregate particles and upward movement of fine mortar, paste or water before the concrete sets must be avoided. Otherwise, the SCC components will be resulting inhomogeneous compositions that can adversely affect their durability and fitness for use. The paste volume and grading curve must be chosen so that the concrete completely fills the form work and is not held back in front of the gaps between the reinforcement. Suitable test methods by which the corresponding requirements can be verified were developed to ensure that the SCC meets these requirements.

Many different test methods have been developed in an attempt to characterize the properties of SCC. So far, no single method or combination of methods has achieved universal approval and most of them have their adherents. Similarly, no single method has been found which characterizes all the relevant workability aspects. Each mix design should be tested by more than one test method for different workability parameters. The requisite test methods are described in Table 3.9.

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S.No. Method. Property

1. Slump flow test. Filling Ability

2. T50 cm flow test. Filling Ability

3. V-funnel test Filling ability

4 V-Funnel at Ts minutes Segregation resistance

s L-Box test. Passing ability

6 U-Box test Passing ability

7 Fill box apparatus test Passing ability

8 J-Ring Passing ability

9 Orimet test Filling ability

10 OTM screen stability test. Segregation resistance

For the initial mix design of SCC all three workability parameters need to be assessed to ensure that alJ aspects a.J1e fulfilled. A full-scale test should be done to verify the self-compacting characteristics of the chosen design for a particular application. For site quality control, two test methods are generally sufficient to monitor production quality. Typical combinations are Slump-flow and V-funnel or Slump-flow and J-ring.

3.4.2 Workability criteria for the fresh SCC

Filling ability, passing ability and segregation resistance are the requirements for judging the workability criteria of fresh SCC. These requirements are to be fulfilled at the time of placing of concrete. Typical acceptance criteria for Self- compacting Concrete with a maximum aggregate size up to 20 mm are shown in

3.4.3 Test Methods

lt was observed that none of the test methods (or SCC has yet been standardized, and neither the tests described are yet perfected or definitive. A brief description of the tests has been presented below. They are mainly ad-hoc methods, which have been devised specifically for SCC.

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Slump Flow Test measures the spread or dow of concrete sample, once the cone is lifted ather than the traditional slump (drop in height) of the concrete sample. The T50 test is also determined during the Slump Flow Test. It is simply the amount of time that the concrete takes to flow to a diameter of 50 centimeters. The slump flow test procedure a.Slump flow apparatus The mould used is in the shape of a truncated cone with internal dimensions 200mm diameter at the base, l00mm diameter at the top and a height of 300mm. The base plate is of a stiff non- absorbing material of at least 700mm square, marked with center location for the slump cone, and further concentric circle of 500mm diameter. The other apparatus required are trowel, scoop, ruler, and a stop match.

b Procedure About 6 liter of concrete is needed to perform the test. The base plate and the inside of the slump cone were moistened. The base plate wan placed on level stable ground and the slump cone was placed centrally on the base plate and hold down firmly. The concrete was filled into the cone with the scoop without camping. The excess material on the top of slump cone was removed and leveled with a trowel.

The surplus concrete around the base of the cone was removed. The slump cone was raised vertically upwards allowing the concrete to flow out freely. The time taken for concrete to reach the 500 mm spread circle was recorded by using the stopwatch. This is the T50 time. After the flow of concrete was stopped, the final diameter of concrete in two perpendicular directions was measured. The average of the two measured diameters is called as slump flow in mm.

3.4.3.2 L - Box test

This test, based on a Japanese design for underwater concrete, has been described by Petersson, 1999. This test assesses the flow o£ concrete, and also the extent to which it is subjected to blocking by reinforcement. The apparatus is shown in Fig.3.2. The apparatus consists or « rectangular-section box in the shape of an 'L', with a vertical and horizontal section, separated by a moveable gate, in front of which, vertical lengths of reinforcement bars are fitted. The vertical section is filled with concrete, and then the gate is lifted to let the concrete flow into the horizontal section. When the flow has stopped, the height of the concrete at the end of the horizontal section is expressed as a proportion of that remaining in the vertical section called as H2/H 1 ratio or blocking ratio. lt indicates the slope of the concrete when the concrete is at rest. This is an indication of passing ability, or the degree to which the passage of concrete through the bars is restricted.

The horizontal section of the box can be marked at 200mm and 400mm from the gate and the time taken to reach these points measured. These are known as the T20 and T40 times and are indicators of the filling ability.

a. Procedure

About 14 liters of concrete is needed to perform the test. The apparatus was placed on the level ground. It was ensured that the sliding gate can open and close freely. The inside surfaces of the apparatus were moistened and surplus water was removed. The vertical section of the apparatus was filled with the concrete sample.

The sliding gate of the vertical section was lifted and concrete has allowed flowirig out into the horizontal section. The time taken for concrete to reach the 200 and 400 mm marks in the horizontal section was measured simultaneously by using the stopwatch. The dlstances HI and H2 were measured when the concrete stops flowing and the blocking ratio H2/Hl is calculated. The maximum time required for performing this L - box test is 5 minutes. 3.4.3.3. V — funnel test and V — funnel test at T5 minutes This test was developed in Japsn and used by Ozawa et al, [I 989]. The equipment consists of a V-shaped funnel, shown in Fig.3.3. The V-funnel test is used to determine the filling ability of the concrete with a maximum aggregate size of 20mm. The funnel was filled with about 12 liter of concrete and the time taken for it to flow through the apparatus measured. Afier this the funnel was refilled concrete and left for 5 minutes to settle. If the concrete shows segregation then the flow time increases significantly.

a. Procedure for flow time

About 12 liters of concrete was needed to perform this test. The V-funnel apparatus was placed on the firm ground. The inside surfaces of the V — funnel wasmoistened and tht surplus water in funnel was dmined through trap door by opening it. Before starting the test, the trap door was closed and a bucket was placed underneath . The V — funnel apparatus was completely filled with concrete without any compaction. The top surface was leveled with the trowel. The trap door was opened and concrete was allowed to flow out under gravity. By using the stopwatch, the time taken for the complete discharge of concrete from the funnel was measured. The whole test has to be performed within 5 minutes.

b. Procedure for flow time at T5 minutes

After measuring the flow time, the trap door of the V-funnel was closed and a bucket was placed underneath. Again the concrete was filled into the apparatus completely without any compaction. The top surface was leveled with the trowel.

The trap door was opened after 5 minutes and the concrete was allowed to flow out under gravity. The time for the complete discharge of concrete from the funnel was recovered. funnel test apparatus (SCC mixes}

3.4.3.4 I - Ring test

The I — Ring test 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 x 25mm) open steel ring, drilled vertically with holes to accept threaded sections of reinforcement bar. These sections of bar can be of different diameters and spaced at different intervals in accordance with normal reinforcement considerations. The diameter of the ring of vertical bars is 300mm, and the height 100 mm.

The I — Ring can be used in conjunction with the Slump flow test. These combinations judge the flowing ability and the passing ability of the concrete. The slump flow spread was measured to assess flow characteristics. The J — Ring bars can be set at any spacing to impose a more or less severe test of the passing ability of the concrete. After the test, the difference in height between the concrete inside and that just outside the I — Ring is measured. This is an indication of passing ability, or the degree to which the passage of concrete through the bars is restricted.

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Equipment

The mould used is in the shape of a truncated cone with the internal dimensions 200mm diameter at the base, l0Omm diameter at the top and a height of 300mm. The base plate is of a stiff non- absorbing material, at least 700mm square, marked with center location for the slump cone, and further concentric circle of 500mm diameter. A rectangular section (30mm x 25mm) open steel ring, drilled vertically with holes is called as I - ring. The holes can be screwed threaded sections of reinforcement bar. The other apparatus required are trowel, scoop, ruler, and a stop watch.

Procedure

About 6 liters of concrete is needed to perform this test. Moisten the base plate and inside of slump cone, place the base-plate on level stable ground. The slump cone was placed on the level ground and the J — ring was placed centrally inside the slump cone and was held down firmly. The concrete was filled into the cone with the scoop without any compaction. The top surface of the cone was leveled with the trowel. The surplus concrete amund the base of the cone was removed.

The slump cone is mised vertically upwards to allow the concrete to flow out freely through the rings. The difference in height between the concrete just inside the bars and that junt outside the bars was measured. The avemge of the difference in height at four locations (in min) was measured.

Chapter — 4

Conclusions

Based on the systematic and detailed experimental study conducted on SCC mixes with an aim to develop performance mixes, the followirig are the conclusions arrived.

1. mixes designed using the lower size of aggregate yielded better fresh properties than higher size of aggregates.

2.As the strength of concrete increases, the effective size of aggregate has decreased.

Significant contribution of the Project:

The present investigation has brought out explicitly the effect of size of aggregate on the compressive strength and other mechanical properties of self compacting concrete.

Scope of the future work:

1.The simplified mix design methodology was presented may be extended to the more number of concrete strength ranges.

2.The investigations may be conducted with different mineral admixtures like Rice Husk Ash and GGBS apart from fly ash.