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AN EXPERIMENTAL STUDY ON STRENGTH CHARACTERISTICS OF SELF COMPACTING FIBER REINFORCED CONCRETE

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ABSTRACT

Self-compacting Concrete (SCC) is an innovative concrete that does not require vibration for placing and compaction. It is able to flow under its own weight, completely, filling formwork and achieving full compaction, even in the presence of congested reinforcement. Self-Compacting Concrete (SCC) has been described as the most revolutionary development in concrete construction for several decades The scope of this work was limited to the development of a suitable mix design to satisfy the requirements of SCC in the plastic state using local aggregates and to determine and compare the strength of a normal SCC mix design along with the varying percentage of cement w.r.t normal SCC mix and replacing the same with fly ash. The general objective of this study is to conduct an exploratory work towards the development of the selected SCC mix. Aim of this study is to find strength characteristics of the SCC with steel fiber in 10%,20% and 30% i.e., compressive strength and split tensile strength values and also workability of Self compacting concrete.

I. INTRODUCTION

1.1 GENERAL

Self-compacting Concrete (SCC) is an innovative concrete that does not require vibration for placing and compaction. It is able to flow under its own weight, completely, filling formwork and achieving full compaction, even in the presence of congested reinforcement. The hardened concrete is dense, homogeneous and has the same engineering properties and durability as traditional vibrated concrete.

Concrete that requires little vibration or compaction has been used in Europe since the early 1970s but Self-compacting concrete was not developed until the late 1980s in Japan. In Europe it was probably first used in civil works for transportation networks in Sweden in the mid-1990s. The European countries funded a multi-national company, industry lead project SCC 1997-2000 and since then SCC has found increasing use in all European countries.

Self-compacting concrete offers a rapid rate of concrete placement, with faster construction times and ease of flow around congested reinforcement. The fluidity and segregation resistance of SCC ensures a high level of homogeneity, minimal concrete voids and uniform concrete strength, providing the potential for a superior level of finish and durability to the structure. SSC is often produced with low water-cement ratio providing potential for high early strength, earlier remolding and faster use of elements and structures.

The elimination of vibrating equipment improves the environment on and near construction and pre cast sites where concrete is being place, reducing the exposure of workers to noise and vibration. The improved construction practice and performance, combined with the health and safety benefits, make SCC a very attractive solution for both pre-cast concrete and civil engineering construction.

In 2002 EFNARC published their "Specification & Guidelines for Self-compacting Concrete", which at that time provided state of the art information for producers and users. since then much additional technical information on SSC has been published but European design, product and construction standards do not yet specifically refer to SCC and for site applications this has limited its wider acceptance, especially by specifies and purchasers.

Self-Compacting Concrete (SCC) has been described as the most revolutionary development in concrete construction for several decades. Originally developed to offset a growing shortage of skilled labor, it has proved beneficial economically because of a number of factors including

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

Originally developed in Japan SCC technology was made possible by much earlier development of upper plasticizers for concrete. SCC has now been taken up with enthusiasm across Europe for both site and precast concrete work. Practical application has been accompanied by much research into the physical and mechanical characteristics of SCC and the wide range of knowledge generated has been shifted and combined in this guideline documents.

History of SCC

Self-compacting concrete (SCC) represents one of the most significant advances in concrete technologies for decades. Inadequate homogeneity of the cast concrete due to poor compaction or segregation may drastically lower the performance of mature concrete in-situ. SCC has been developed to ensure adequate compaction and facilitate placement of concrete in structures with congested reinforcement and in restricted areas.

SCC was developed first in Japan in 1980s to be mainly used for highly congested reinforced structures in seismic regions. As the durability of concrete structures became an important issue in Japan, an adequate compaction by skilled labors was required to obtain durable concrete structures. This requirement led to the development of SCC and its development was first reported in 1989.

SCC can be described as a high performance material which flows under its own weight without requiring vibrators to achieve consolidation by complete filling of formworks even when access is hindered by narrow gaps between reinforcement bars. SCC can also be used in situations where it is difficult or impossible to use mechanical compaction for fresh concrete, such as under water concreting, cast in-situ pile foundation, machine bases and columns or walls with congested reinforcement.

The high flow ability of SCC makes it possible to fill the formwork without vibration, since its inception, it has been widely used in large construction in japan. Recently this concrete has gained wide use in many countries for different applications and structural configurations.

It can also be regarded as "the most revolutionary development in concrete construction for several decades". Originally developed to offset a shortage of skilled labor, it is now taken up with enthusiasm across European countries for both sites and precast concrete work. It has proved beneficial economically because of a number of factors as noted above in introduction.

Scope of study

The scope of this work was limited to the development of a suitable mix design to satisfy the requirements of SCC in the plastic state using local aggregates and to determine and compare the strength of a normal SCC mix design along with the varying percentage of cement w.r.t normal SCC mix and replacing the same with fly ash.

The general objective of this study is to conduct an exploratory work towards the development of the selected SCC mix. The specific objectives were as follows

To design a suitable SCC mix utilizing local aggregates.

To assess and compare the strength development of NC, NSCC, SCC 10, SCC 20 and SCC 30 replaced (cement replaced by fly ash).

To adopt the suitable and economical mix design based on compressive strength parameter.

Work plan

The research work was conducted in the following three phases,

The first phase included a comprehensive literature survey and collection along with material collection.

The second phase involved the fabrication, upgrading and calibration of the equipment and molds. The equipment for V funnel, J- ring and slump flow tests were fabricated and conducted to evaluate the self-compact ability of freshly prepared SCC. And the molds for preparing cubes for compressive strength test were provided by our college.

In third phase, the mix design of suitable SCC was carried out to in an explanatory manner. A series of trials were conducted to develop a suitable mix design to satisfy the requirements of SCC using local aggregates. Fourtrials mixes were prepared by water content. Out of the four trial mixes, a suitable mix design was adopted with self-compact ability and compressive strength as the criteria.

Terms and definitions

For the purposes of this report publication, the following definitions apply

Addition - Finely divided inorganic material used in the concrete in order to improve certain properties or to achieve special properties. This report refers to two types of inorganic additions defines in en 206-1 as: nearly inert additions (type i); pozzolanic or latent hydraulic additions (type ii)

Admixtures - Materials added during the mixing process of the concrete in small quantities related to the mass of cement binder to modify the properties of fresh or hardened concrete.

Binders - The combination of cement and type ii addition

Filling ability - The ability of the fresh concrete to flow into and fill all spaces within the formwork

Flow ability - The flow of fresh concrete when unconfined by formwork or reinforcement.

Fluidity - The ease of flow of fresh concrete.

Mortar - The fraction of concrete comprising of paste plus those aggregates less than 4 mm.

Paste - The fraction of the concrete comprising powder, water and air along with admixtures if applicable.

Passing ability - The ability of the fresh concrete to flow through tight openings such as spaces between the steel reinforcing bars without segregation and blocking.

Powder (fines) - Materials of particle size smaller than 0.125 mm.

Note: It includes this size fraction in cement, additions and aggregates.

Self-compacting concrete (SCC) - Concrete that is able to flow and consolidate under its own weight, completely fill the formwork even in the presence of dense reinforcement, whilst maintaining homogeneity and without the need for any additional compaction.

Segregation resistance - The ability of the concrete to remain homogeneous in composition while in its fresh state.

Viscosity - The resistance to flow of material once flow has started.

Viscosity modifying admixtures (VMA) - Admixtures added to fresh concrete to increase cohesion and segregation resistance.

II. LITERATURE REVIEW

2.1 General

SCC can be defined as the concrete that is able to flow in the interior of the formwork, passing through the reinforcement and filling it in a natural manner, consolidating under the action of its own weight. The filling ability, passing ability and stability can be considered as the main properties of fresh SCC. These functional requirements are not common to conventional concrete and therefore are handled through special tests. These tests need to be carefully controlled to ensure that the ability of SCC to be placed without difficulty remains acceptable. The flow developed techniques that are still evolving.

2.2 A simple mix design method for self-compacting concrete by N Su et al

This paper of Nan Su proposes a new mix design method for self-compacting concrete. First the amount of aggregates required is determined and the paste of binders is then filled into the voids aggregates to ensure that the concrete thus obtained has flow ability, self-compact ability and other desired SCC properties. The amount of aggregates, binders and mixing water, as well as type and dosage of super plasticizer to be used are the major factors influencing the properties of SCC. Slump flow, V-funnel and compressive strength tests were carried out to examine the performance of SCC, and the results indicate that the proposed method could produce successfully SCC of high quality. Compared to the method developed by Japanese Ready Mixed Concrete Association, this method is simpler, easier for implementation and less time consuming, requires a smaller amount of binders and saves cost.

The research work conducted by N Su et al concluded that

1. The aggregate PF determines the aggregate content and influences the strength, flow ability and self-compacting ability.
2. SCC designed and produced with the proposed mix design method contains more sand but less coarse aggregates, thus the passing ability through gaps of reinforcement can be enhanced.
3. In this design method, the volume of sand to mortar is in the range of 54-60%.
4. The water content of SCC prepared by the proposed method is about 170-176 kg/m3 for the medium compressive strength.
5. The amount of binders used in the proposed method can be less than that required by other mix design methods due to the increased sand content.
6. This novel mix design method is simpler, requires a smaller amount of binders and saves cost.
7. As SCC produced with this method contains less coarse aggregates, further studies are needed to evaluate its effect on the elastic modulus of concrete.
8. The optimal PF for SCC with different

requirements merits further investigations.

2.3 Simple test methods to characterize the rheology of SCC by Y.V.S.S.U.Mahesh and Manu Santhanam

SCC requires a mixture with high fluidity while avoiding segregation. In order to characterize the rheological properties of SCC, many test methods are developed such as slump flow test, V funnel test; J-ring test etc. measurements of rheological parameters are also sometimes performed using sophisticated and expensive rheometers. In this study an attempt has been to correlate multiple field test methods for flow behavior of SCC, so that these can be used interchangeably.

Based on the laboratory work, the following conclusions can be drawn.

1. The slump flow value can be used to qualitatively characterize the SCC mixture as acceptable or unacceptable.
2. Viscosity of the SCC mixture decreases with an increase in the water to powder ratio. The decrease in viscosity is indicated by the drop in T50 and V-funnel flow time.
3. Data suggests a linear relationship between the V-funnel flow time and the T50 slump flow. Thus, these two tests can be used interchangeably in the field.
4. It is crucial to complete the tests in shorter duration of time in order to get a true measure of the performance in various tests.
5. Further work is necessary to correlate the field test values with a rheometers based study of the rheological parameters for SCC.

2.4 How economic is self-compacting concrete? by B.V.B.Pai

Self-compacting concrete was developed as an answer to the problem of consolidating concrete in heavily reinforced structures. There is a feeling amongst certain engineers that SCC cost is much more than that of the corresponding normal strength or high strength concrete. The cost of ingredients of NSC/HSC and SCC differ marginally- SCC materials cost just about 10-15 percent higher. If an in depth analysis of the other components of costs like the cost of consolidation, finishing etc. is carried out. Then one would realize that SCC is certainly not a costly concrete. Further the other advantages of SCC far outweigh those of NSC/HSC. With a view to arrive at proper comparison, a mix was proportioned to make SCC have the same target strength of 40 MPa high strength concrete and relative cost analysis are tabulated in this paper.

The research concluded that

1. SCC is comparably superior to conventional concrete in respect of all properties.
2. It should be preferred choice when concreting conditions are difficult.
3. Cost of only the materials of SCC may appear to be slightly more about 15 percent or so.
4. On more rational basis of the total costs including the labor charges for formwork and making good finished surfaces, SCC will be more advantageous.
5. From holistic considerations, SCC will be more cost effective.

2.5 Experiments for mix proportioning of self-compacting concrete by S.Subramanian and D. Chattopadhyay

SCC is a fluid mixture, which is suitable for placing in difficult conditions and in structures with congested reinforcement without vibration. It is characterized by high powder content. The resulting concrete has an excellent surface finish. The article describes the development of the mix proportions for self-compacting concrete and also the procedure used for selecting the combination of VMA, super plasticizer and ultra-fine powders. The results of the preliminary trials with the mixture so developed are described in this report.

The conclusions drawn by this research work are

1. The trial proportion suggested by Okamura and Ozawa appears to be suitable for rounded gravel aggregate. When using crushed angular aggregate, the proportions are to be adjusted, incorporating more fines.
2. This sensitivity to changes in mixture proportions requires that a VMA be used.
3. Suitability of self-compacting concrete mixture proportion was verified through placement trials in complicated mold and in a field trial. The results were encouraging.

III. CONSTITUENT MATERIALS

General

The constituent materials for SCC are same as those used in traditional vibrated concrete conforming to EN 206-1. In most cases the requirements of ingredients are individually covered by specific European standards. However in order to be sure of uniform and consistent performance for SCC additional care has to be taken in the initial selection and also in the frequent monitoring for maintaining uniformity in mix from batch to batch.

To achieve these requirements, the control of the constituent materials needs to be increased and the variations restricted so that the daily production of SCC s within the conformity criteria without the need for testing and/or adjust every batch.

Cement

All the cements which conform to EN 197-1 can be used for the production of SCC. The correct choice of cement type is normally dictated by specific requirement of SCC and was bought near our college. The cement was of 53 grade Aditya Birla cement.

1.1 Additions

Due to the fresh property requirements of SCC, inert and pozzolanic/hydraulic additions are commonly used to improve and maintain the cohesion and segregation resistance. The addition will also regulate the cement content in order to reduce heat of hydration and thermal shrinkage.

Particle size distribution and composition of concrete constituents so increased requires monitoring of deliveries to meet the specification. SCC is often selected for its high quality finish and good appearance but his may be compromised if the source of addition does not have good color consistency.

Fly ash

The particle size distribution, shape and water absorption of mineral fillers may affect the water demand and its suitability for use in the manufacture of SCC. Calcium carbonate based mineral fillers are widely and can give excellent rheological properties and good finish. The most advantageous fraction is smaller than 0.125 mm and it is desirable for >70% to pass a 0.075 mm sieve in general. Fillers specifically ground for this application offer the advantage of improved batch to batch consistency of particle size distribution. Control over water demand and making concrete particularly suitable for SCC compared with other available materials is of prime importance.

Fly ash is an effective addition for SCC providing increased cohesion and reduced sensitivity to variation in water content. Fly ash was bought from Raichur thermal power plant conforming to EN 450-1 and EN 450-2.

Aggregates

Normal weight aggregates should conforming to EN 12620 and meet the durability requirements of EN 206-1. Lightweight aggregates should conform to EN 130551.

The moisture content, water absorption, grading and variations in fines content of all aggregates should be closely and continuously monitored and must be taken into account in order to produce SCC of constant quality. Use of washed aggregates will normally more consistent product. Changing the source of supply is likely to make a significant change to the concrete properties and should be carefully evaluated.

The shape and particle size distribution of the aggregates is very important and affects the packing and void content. Some mix design methods use void content of the aggregate in predicting the volumes of paste and mortar required. Single sized aggregates and a gap in the grading between coarse and fine aggregates are used in some design mix. The aggregates were bought from the nearby site and the coarse aggregates used was of 12.5 mm downsize.

NOTE - Aggregate particles smaller than 0.125 mm is deemed to contribute to the powder content of the SCC.

Coarse aggregates

Coarse aggregates conforming to EN 12620 are appropriate for the production of SCC. Lightweight aggregates has been successfully used for SCC but note that aggregates may migrate to the surface if paste viscosity is low and this may not be detected by sieve segregation resistance test.

The reinforcement spacing is the main factor in determining maximum size of aggregates. Aggregate blocking must be avoided as SCC flows through reinforcement and V funnel test indicates the passing ability of SCC mix. The maximum size of aggregate should be limited to 12 to 20 mm although larger sizes are being used. The particle size distribution and shape of coarse aggregate directly influence the flow and passing ability of SCC and its paste demand. Aggregates being more spherical lesser will be the blocking and greater will be the flow because of reduced internal friction.

Fine aggregates/sand

The influence of fine aggregates on the fresh properties of SCC is of prime importance than that of the coarse aggregates. Particle size fraction of less than 0.125 mm should be included in the fines of cement paste and should be accounted for calculating water powder ratio.

The high volume of paste in SCC mixes results in reduction of internal friction between sand and particles along with good grain size distribution. Many SCC mix design methods use blended sand to match an optimized aggregate grading curve and this can also help to reduce the paste content where as some producers prefers gap graded sand.

Admixtures

Super plasticizers or high range water reducing admixtures conform to EN 934-2 table 3.1 and 3.2are essential component of SCC. Viscosity modifying admixtures (VMA) may also be used to reduce segregation and sensitivity of the mix due to variations in other constituents, especially to moisture content. Other admixtures including air entraining, accelerating and retarding may be used in the same way as in conventional ones but proper advice should be taken from the admixture manufacturer on use and the optimum time for addition and they should conform to EN 934-2.

Choice of admixtures for optimum performance may be influenced by physical and chemical properties of the binder/addition. Factors such as fineness, carbon content, alkali and C_3A may have an effect. It is therefore recommended that compact ability is carefully checked if a change in supply of any of these constituents is to be made.

Admixtures will normally be very consistent from batch to batch but moving to another source or to another type from the same manufacturer is likely to have a significant effect on SCC performance and should be carefully checked before any change is made. The admixture samples were provided by BASF India Pvt Ltd.

Mixing water

Water conforming to EN 1008 should be used in SCC mixes. Where recycled water recovered from processes in the concrete industry is used the content and in particular any variation in content of suspended particles should b taken into account as this may affect batch to batch uniformity of the mix. Locally available water is used for preparing the concrete mix.

IV. MATERIAL TESTING

General

This chapter deals with the details of material testing carried out including various physical properties of constituent materials. All the test methods were conducted as recommended by IS standards.

Cement

Specific gravity test

Aim: To determine the specific gravity of cement for SCC using specific gravity bottle.

Apparatus: Weighing the balance of accuracy (0.001gm), Specific gravity bottle, Kerosene.

Test procedure

1. Weigh the empty specific gravity bottle W_1 g.
2. Fill the bottle with distilled water of the bottle W_2 g.
3. Empty the bottle dry and fill it completely kerosene weigh the bottle W_3 g.
4. Empty the bottle up to some level and fill the bottle with cement weigh of W_4 g.
5. The remaining portion of the bottle is filled with kerosene weigh it W_5 g after expelling the air.

Table 1 – Tabulation of specific gravity test of cement

Sl no	Description	Trial - 1	Trial - 2	Trial - 3
1	Weight of empty specific gravity bottle W_1 g	61	62	61
2	Weight of specific gravity bottle + distilled water W_2 g	161	162	161
3	Weight of specific gravity bottle + kerosene W_3 g	141	142	141
4	Weight of cement taken for test W_4 g	14	14	14
5	Weight of specific gravity bottle + cement + kerosene W_5 g	151	152	151
6	Specific gravity of cement S =	2.80	2.77	2.80

Result: The specific gravity of cement is found to be 2.79

Normal consistency test

Aim: To determine the standard consistency or normal consistency of cement.

Apparatus: Vicat apparatus, plunger and mold, gauges, trowel, measuring jar, weighing balance and stop watch.

Test procedure

1. Weigh about 400gm of cement and place in the dish.
2. Add 25% of water by weight of cement and is uniformly mixed to form a paste.
3. Fill the cement paste Vicat mold.
4. After completely filling the mold, shake the mold to expel air.
5. A standard plunger of 10mm diameter, 50mm long attached and brought down to touch the surface of plate in the test block and reading

should be set to 40mm because the height of the mold is 40 mm.

6. Quickly allowing it to sink into the paste by its own weight and take the reading when penetration stops.

7. Procedure should be repeated by increasing the % of water till the penetration of the plunger 5 to 7 mm from bottom. The water content at which the plunger shows the reading of 5 to 7 is the normal consistency of the cement.

Table 2 – Tabulation of normal consistency test of cement

- Mass of cement taken = 400 g

Description	Trial - 1	Trial - 2	Trial - 3	Trial - 4	Trial - 5
Percentage water	24	25	26	27	28
Initial reading, mm	0	0	0	0	0
Final reading, mm	14	12	10	9	7
Height not penetrated, mm	14	12	10	9	7

Result: The normal consistency of cement is found to be 28 percent

Initial and Final setting time test

Aim: To determine the initial and final setting time of cement.

Apparatus: Vicat apparatus, needle and mold, gauges, trowel, measuring jar, weighing balance and stop watch.

Procedure

Initial setting time: All steps remain the same as that of normal consistency test. The two changes would be the use of needle instead of plunger and the cement paste is made by adding certain quantity of water i.e. 85% of the normal consistency of cement found out earlier. The initial setting time is recorded till the needle shows the reading of 5 to 7mm. The time after which the needle shows 5 to 7 mm is the initial setting time of the cement and is generally found to be greater than 30 minutes.

Table 3 – Tabulation of initial setting time test of cement

- Mass of cement taken = 400 g
- Mass of water taken = 0.85 x P x mass of cement taken = 0.85 x 0.28 x 400 = 95.2 g

Description	1	2	3	4	5	6	7	8
Time in minutes	0	5	10	15	20	25	30	34
Initial Reading, mm	0	0	0	0	0	0	0	0
Final Reading, mm	0	14	13	12	10	8	8	6
Height not penetrated, mm	0	14	13	12	10	8	8	6

Result: The Initial setting time of cement is found to be 34 minutes.

Final setting time: All arrangements and procedure remains the same as that of initial setting time test. The final setting time is recorded till the needle fails to pierce through the paste more than 0.5 mm. The time at which the needle fails to pierce through paste is the final setting time of cement and is generally found to be less than 600 minutes.

Tabulation

- Mass of cement taken = 400 g
- Mass of water taken = 0.85 x P x mass of cement taken = 0.85 x 0.28 x 400 = 95.2 g

Result: The final setting time is found to be 520 minutes.

Fine aggregates

Sieve Analysis test

Aim: To determine the particle size distribution of fine aggregate by sieving.

Apparatus: Weighing balance, thermostatically controlled oven, sieve shaker, wire brush, sieve size 4.75 mm, 2.36 mm, 1.18 mm, 600 µ, 300 µ, 150 µ and pan.

Test procedure

1. Write down the weight of each sieve as well as the bottom pan to be used in the analysis.
2. Record the weight of the given dry soil sample.
3. Make sure that all the sieves are clean, and assemble them in the ascending order of sieve numbers (4.75 mm sieve at top and 0.15 mm sieve at bottom). Place the pan below 0.15 mm sieve. Carefully pour the soil sample into the top sieve and place the cap over it.
4. Place the sieve stack in the mechanical shaker and shake for 10 minutes.
5. Remove the stack from the shaker and carefully weigh and record the weight of each sieve with its retained soil. In addition, remember to weigh and record the weight of the

bottom pan with its retained fine soil. And the fineness modulus of given soil sample is calculated.

6. Plot a particle distribution graph with cumulative percentage passing on Y-axis and sieve sizes in X-axis.

V. EXPERIMENTAL INVESTIGATIONS

General

This chapter deals with the details of tests that are conducted to check the requirements of SCC along with the compressive strength test in hardened state along with graphical analysis of increase in strength with increase in age of concrete. All the tests are conducted as per European and Indian standards. The main purpose for selecting these tests is due to easy fabrication and their relation to key properties of self- compacting concrete along with good repeatability and reproducibility. The equipment of J-ring and V funnel tests were locally fabricated to standard dimensions.

Slump flow test

Introduction

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.

Assessment of test

This is a simple, rapid test procedure. It can be used on site, though the size of the base plate is somewhat unwieldy and level ground is essential. It is the most commonly used test, and gives a good assessment of filling ability. It gives no indication of the ability of the concrete to pass between reinforcement without blocking, but may give some indication of resistance to segregation. It can be argued that the completely free flow, unrestrained by any boundaries, is not representative of what happens in practice in concrete construction, but the test can be profitably be used to assess the consistency of supply of ready-mixed concrete to a site from load to load.

Equipment

• The apparatus is shown in image 1 (appendix) mold in the shape of a truncated cone with the internal dimensions 200 mm diameter at the base, 100 mm diameter at the top and a height of 300 mm, conforming to EN 12350-2 base plate of a stiff non absorbing material, at least 700mm square, marked with a circle marking the central location for the slump cone, and a further concentric circle of 500mm diameter
• trowel
• scoop
• ruler
• stopwatch (optional)

Procedure

1. About 6 liters of concrete is needed to perform the test, sampled normally.
2. Moisten the base plate and inside of slump cone,
3. Place base plate on level stable ground and the slump cone centrally on the base plate and hold down firmly.
4. Fill the cone with the scoop. Do not tamp, simply strike off the concrete level with the top of the cone with the trowel. (In case of normal concrete, it is filled in four layers and each layer being tamped by 25 times).
5. Remove any surplus concrete from around the base of the cone.
6. Raise the cone vertically and allow the concrete to flow out freely.
7. Measure the final diameter of the concrete in two perpendicular directions.
8. Calculate the average of the two measured diameters is the slump flow in mm. In case of normal concrete the slump height is calculated in mm.

Table 4 - Tabulation of Slump test

Concrete mix	Slump type	Slump value(mm)	Expected slump value (mm)
NC	Height	90	75 - 100
NSCC	Diameter	652	650 - 800
SCC 10	Diameter	657	650 - 800
SCC 20	Diameter	659	650 - 800
SCC 30	Diameter	662	650 - 800

Result: The values hence obtained with the tests are found to be satisfactory.

Comments on result

The slump value obtained for NSCC, SCC 10, SCC 20 and SCC 30 are higher and has greater flow in comparison with NC and can be used in congested reinforced areas with much ease. Higher the slump flow (SF) value, the greater its ability to fill formwork under its own weight. A value of at least 650 mm is required for SCC as per guidelines of EFNARC.

All SCC mixes with replacements shows good flow property, but SCC 30 has greater flow in comparison with other mixes. This mix can be adopted in field if it satisfies other SCC properties and strength parameter.

J Ring test

Introduction

The principle of the J-Ring test may be Japanese. 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 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, 3x the maximum aggregate size might be appropriate. The diameter of the ring of vertical bars is 300mm, and the height 100 mm.

The J-Ring can be used in conjunction with the Slump flow, the Orimet test, or eventually even the V funnel. The flowing ability or passing ability of SCC is tested by J ring test. The J-Ring bars can principally 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 J-Ring is measured. This is an indication of passing ability, or the degree to which the passage of concrete through the bars is restricted.

Assessment of test

These combinations of tests are considered to have great potential, though there is no general view on exactly how results should be interpreted. There are a number of options – for instance it may be instructive to compare the slump-flow/J-Ring spread with the unrestricted slump-flow: to what extent is it reduced? Like the slump-flow test, these combinations have the disadvantage of being unconfined, and therefore do not reflect the way concrete is placed and moves in practice.

Equipment

• Mold without foot pieces, in the shape of a truncated cone with the internal dimensions 200 mm diameter at the base, 100 mm diameter at the top and a height of 300 mm.

• Base plate of a stiff non-absorbing material, at least 700mm square, marked with a circle showing the central location for the slump cone, and a further concentric circle of 500mmdiameter.

• Trowel

• Scoop

• Ruler

• J-Ring a rectangular section (30mm x 25mm) open steel ring, drilled vertically with holes. In the holes can be screwed threaded sections of reinforcement bar (length 100mm, diameter 10mm, spacing 48 +/- 2mm)

Procedure

1. About 6 liters of concrete is needed to perform the test, sampled normally.
2. Moisten the base plate and inside of slump cone,
3. Place base-plate on level stable ground.
4. Place the J-Ring centrally on the base-plate and the slump-cone centrally inside it and hold down firmly.
5. Fill the cone with the scoop. Do not tamp, simply strike off the concrete level with the top

of the cone with the trowel.
6. Remove any surplus concrete from around the base of the cone.
7. Raise the cone vertically and allow the concrete to flow out freely.
8. Measure the final diameter of the concrete in two perpendicular directions.
9. Calculate the average of the two measured diameters. (In mm).
10. Measure the difference in height between the concrete just inside the bars and that just outside the bars.
11. Calculate the average of the difference in height at four locations (in mm).
12. Note any border of mortar or cement paste without coarse aggregate at the edge of the pool of concrete.

VI. CONCLUSIONS

The following conclusions can be made by this report;

• Flow ability property of all SCC mixes gave better results in slump tests among the mixes SCC 30 gave better slump value of 662 mm in comparison with other mixes.

• Passing ability property of all SCC mixes by J-ring test gave good results among the mixes NSCC, SCC 20 and SCC 30 gave good result with the value of 3 mm in comparison with SCC 10.

• Passing ability property of all SCC mixes by V funnel test gave good results among the mixes NSCC gave good result with the value of 10 sec in comparison with other SCC mixes.

• Segregation resistance property of all SCC mixes gave good results in V funnel test at T5 minutes among the mixes NSCC gave better value of + 1 sec in comparison with other mixes.

• As per the results of compressive strength tests, NSCC and SCC 10 showed better results in comparison with NC and other SCC mixes with the values of 42.53 and
40.76 N/mm2.

• As per the results of split tensile strength tests, NSCC and SCC 10 showed better results in comparison with NC and other SCC mixes with the values of 5.10 N/mm2 and 5.21 N/mm2

• The mix design of NSCC and SCC 10 obtained can be adopted in the field as it satisfies the properties of SCC in fresh state and strength parameter as well.

• With the economy point of view SCC 10 can be adopted in conjunction with NSCC because of which the cost can be reduced to 7 – 8 percent from 15 – 16 percent.

Future scope of study

As Self-compacting concrete is a recent development that shows potential for future applications. It meets the demands placed by the requirements of speed and quality in concrete construction. Further investigations are required in the follwing points;

• Use of basic rheological measurements to establish empirical or arbitrary test parameters;

• Determination of yield stress and plastic viscosity for different placing conditions;

• Establishing the role of fines, super plasticizers, and VMA in SCC, with respect to compatibility between these systems;

• Development of criteria for using marginally unsuitable aggregates (in respect of shape and grading) as well as alternative aggregates (such as manufactured sand) in SCC;

• Preparation of a set of design tables for mixture proportioning of SCC on the lines of ACI Committee 211.

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