Experimental Study on Workability of Self-Compaction Concrete

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Abstract- *A self-compaction concrete (SCC) is a special concrete developed to easily flow and pass through reinforcement and fill the formwork without any external force. And saves time, energy and cost of construction.*

In this study we have conducted test on workability of SCC and various components of concrete matrix such as cement, coarse aggregate, fine aggregate, water and chemical admixtures and found appropriate results of our project.

SCC is more efficient in flow ability and fills the formwork without any external forces and provides flexibility to design and cast a structure with different shapes.

This project study contributes to the comparing and understanding of properties of nominal aself-compaction concrete with various mix proportions.

We have conducted various workability tests like Flow table test, slump cone test, J-ring test, L-Box test, U-Box test, V-funnel test in our laboratory to determine the difference between the nominal and cself-compaction concrete.

Keywords- Self-constricting, Matrix, Mix proportions.

I. INTRODUCTION

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. The elimination of vibrating equipment improves the environment on and near construction and precast sites where concrete is being placed, reducing the exposure of workers to noise and vibration. SCC is still not widely used in India in spite of its many advantages including reduction in labor and fast track construction etc. This is because of lack of sufficient data and information on SCC made of materials available in the different parts of the country and hence insufficient confidence of engineers in producing this material. India has abundant supply of fly ash, with its sources well distributed across the country. SCC generally possesses a high powder content which keeps the concrete cohesive with high flow ability. This high powder content is required to maintain a sufficient yield value of the fresh mix and cement cannot be the only powder material in SCC. For achieving economy, a substantial part of this powder could also contain fly ash. SCC can accommodate more than 200 kg/m3 of fly ash which is regarded as a high-volume addition. Hence it is considered worthwhile to investigate the influence of fly ash in SCC.

History and development of SCC

In the mid-1980s, exploration begun into underwater induction technology within the UK, North America and Japan led to the improvement of concrete mixes with a high degree of washout resistance. However, the creation of durable structures from such mixes enforced adequate compaction by skilled workers. At the same time in Japan, a gradual reduction in the number of skilled workers in the construction industry was leading to a reduction in the quality of construction work, with subsequent knock-on effects on concrete durability (Okamura et al., 1998). One quick fix to overcome the durability issues in concrete structures independently of the quality of construction work was to use self-compacting concrete (SCC) (Okamura and Ouchi, 2003). Its use was early proposed by Okamura (1986) who also conducted a fundamental study on the workability of SCC. The first prototype SCC was concluded in 1988 at Tokyo University, adopting constituent materials promptly used in conventional vibrated concrete (Ozawa et al., 1989). The main reasons for the employment of SCC were to shorten the construction time, to avoid vibrating the confined zones which are a bit crucial to reach and to erase noise caused by vibration (Okamura and Ouchi, 2003). In the far two decades, self-consolidating concrete has been advanced further, applying different materials such as pulverized-fuel ash (PFA), ground granulated blast furnace slag (GGBS) and condensed silica fume (CSF). SCC has achieved wide interest especially for structures with very complicated shapes, crucial casting process and congested reinforcement.

The present study deals with the process of preparing of self-constricting concrete and it's working. Various tests are conducted on the workability of the self-constricting concrete. The grade of concrete used is M20 which was designed in accordance with IS: 10262-2009. We have chosen mix design of M20 grade, in order to find the properties and working of self-constricting concrete. Over the last decade, extensive research has been devoted to achieve self-compact ability. Three different types of mixes can be distinguished: "Powder-type" by increasing the powder content, "VMA-type" using viscosity modifying admixture (VMA) and "Combined- type" by increasing powder content and using a viscosity agent in consideration of structural conditions, constructional conditions, available material, restrictions in concrete production plant.

Powder-Type SCC Okamura and Ozawa proposed a simple mix proportioning system for SC mix. Their main ideas were to fix the coarse aggregate content at 50% of solid volume and the fine aggregate content at 40% of mortar volume. Depending on the properties of mortar, the water to powder ratio is in the range of 0.9-1. This ratio should be carefully selected due to the high sensitivity of SCC to it. The self-compatibility is achieved by adjusting the super-plasticizer dosage and the final water to powder ratio. This independent consideration of gravel and sand, results in a relatively high content of paste. The Japanese method has been adopted and used in many European countries as a starting point for the development of SCC. Su and Miao (2003) then developed an alternative method, henceforth referred to as 'the Chinese method' which starts with packing all coarse and fine aggregates, and then filling of the aggregate voids with paste. This easier method can result in less paste and hence saving the most expensive constituents, namely cement and filler. With this method, concrete with normal strength is obtained, while in Japanese method a higher strength than actually required can be attained.

VMA-Type SCC (viscosity modifying admixture type) By adding a high dosage of VMA to the mix of SCC, plastic viscosity can be controlled and increased without adding extra powder. To achieve flow-ability using this method a higher amount of super-plasticizer or higher water-powder ratio is required compared with the powder-type method.

Combined-Type SCC This charter of mix was advanced to improve the robustness of powder-type SCC by adding a slight amount of VMA. In such mixes, the VMA content is less than that in the VMA-type SCC and the powder content and water to powder ratio are less than those in the powder-type SCC. The viscosity is provided by the VMA along with the powder. This type of SCC was reported to have high filling ability, high segregation resistance and improved robustness.

Materials

Cement Cement is such a material that has cohesive and adhesive properties in the presence of water such cement is called hydraulic cement. These consist preliminary of silicates and aluminates of lime obtained from limestone and clay. In this experiment 53 grade ordinary Portland cement (OPC) with brand name Jaypee cement was used for all SCC mixes. The cement used was fresh and without any lumps, the testing of cement was done as per IS: 8112-1989.

Fine aggregates the sand used in this present study is collected from the bed of river Tungabhadra the sand passing through 4.75 mm size sieve is used in the preparation of concrete mix. The sand confirms to grading Zone II as per IS: 383- 1970 (Reaffirmed 1997). The properties of sand such as fineness modulus and specific gravity were determined as per IS: 2386-1963. The specific gravity of fine aggregate is found to be 2.64 and having fineness modulus 2.62. The water absorption is 1.5%. The bulk density of fine aggregate in compact state 1768 kg/m3.

Coarse aggregatethe coarse aggregate used in this present study is 12mm (40%) & 16mm (60%) down size graded confirm to IS 383-1970 (Reaffirmed 1997) locally available crushed stone obtained from local quarries. The physical properties have been determined. The specific gravity of coarse aggregate is found to be 2.65. The water absorption is 0.3%. The bulk density of coarse aggregate in compact state is 1584kg/m3.

Water The water used in the mixing of concrete was potable water and its free from organic content, turbidity and salts confirms to IS 456-2000 was used for mixing and for curing throughout the experiment program.

Super plasticizeras the locally available PCE based super plasticizers proved to be very effective in SCC; this study is carried out using such type of super plasticizers. CONPLAST SP430 Commercially available poly- carboxylic ether based super plasticizer it is an admixture of a new generation based on modified polycarboxylic ether. Conplast SP430 is a super plasticizer manufactured by Dom Constructive Solutions, was used in this experimentation. Its use enhances the workability of the mix and strength aspect, helps in producing a better compaction and finishing. It also permits reduction in water content.

Conplast SP430

High performance super plasticising admixture

Description

Conplast SP430 is a chloride free, superplasticising admixture based on selected sulphurated naphthalene polymers. It is supplied as a brown solution which instantly disperses in water. Conplast SP430 disperses the fine particles in the concrete mix, enabling the water content of the concrete to perform more effectively. The very high levels of water reduction possible allow major increases in strength to be obtained.

Typical dosage of Conplast SP430

The optimum dosage of Conplast SP430 to meet specific requirements should always be determined by trials using the materials and conditions that will be experienced in use. This allows the optimization of admixture dosage and mix design and provides a complete assessment of the concrete mix. Starting points for such trials, based on the primary use of the product, are to use a dosage within the normal typical ranges. For high strength, water reduced concrete the normal dosage range is from 0.70 to 2.00 liters/100 kg of cementitious material, including PFA, GGBFS and micro silica. For high workability concrete the normal dosage range is from 0.70 to 1.30 liters/100 kg of cementitious material. Where a combination of performance is required, such as some increase in workability combined with reduced water content, then the whole range of dosages from 0.70 to 2.00 liters/100 kg of cementitious material can be considered.

Mix design Conplast SP430

Where the primary intention is to improve strengths, initial trials should be made with normal concrete mix designs. The addition of the admixture will allow the removal of water from the mix whilst maintaining the workability at the levels obtained before the use of the admixture. After initial trials, minor modifications to the overall mix design may be made to optimise performance. Where the primary intention is to provide high workability concrete, the starting mix design should be one suitable for use as a pump mix. Advice on mix design for flowing concrete is available from the Fosroc Customer Service Department. In correctly designed flowing concrete, the improved dispersion of the cement particles and the more efficient use of mixing water will improve mix cohesion. The 13 slight air entrainment obtained with Conplast SP430 will also help to minimise bleed and segregation. After initial trials, minor modifications to the mix design may be made to optimize performance.

Compatibility Conplast SP430

Conplast SP430 is compatible with other Fosroc admixtures used in the same concrete mix. All admixtures should be added to the concrete separately and must not be mixed together prior to addition. The resultant proper- ties of concrete containing more than one admixture should be assessed by the trial mix procedure recommended on this data sheet to ensure that effects such as unwanted retardation do not occur. Conplast SP430 is suitable for use with all types of ordinary Portland cements and cement replacement materials such as PFA, GGBFS and silica fume.

Uses of conplast SP430

- To provide excellent acceleration of strength gain at early ages and major increases in strength at all ages by significantly reducing water demand in a concrete mix.
- Particularly suitable for precast concrete and other high early strength requirements.
- To significantly improve the workability of site mixed and precast concrete without increasing water demand.
- To provide improved durability by increasing ultimate strengths and reducing concrete permeability
- In screeds it reduces the water content required to give suitable workability for placing and compaction.

Advantages of conplast SP430

- Major increases in strength at early ages without increased cement contents are of particular benefit in precast concrete, allowing earlier stripping times.
- Makes possible major reductions in water: cement ratio which allow the production of high strength concrete without excessive cement contents
- Use in production of flowing concrete permits easier construction with quicker placing and compaction and reduced labor costs without increasing water content.
- Increased workability levels are maintained for longer than with ordinary sulphurated melamine admixtures.
- Improved cohesion and particle dispersion minimises segregation and bleeding and improves pump ability
- Chloride free, safe for use in prestressed and rein- forced concrete.
- In screed material, the lower water content leads to quicker drying times

Mix Proportions of SCC

Mixture ID	Cement (kg/m3)	Sand (kg/m3)	C.A (kg/m3)	Water	w/p	SP (kg/m3)	SP (%)
CM	550	910	590	252	0.45	9.0	1.64
SCC1	465	910	590	228	0.41	10.73	1.95
SCC2	415	910	590	233.3	0.42	9.91	1.80
SCC3	355	910	590	242	0.44	9.91	1.80

Where,
CM = Control Blend,
W/p = Water/ Powder (concrete + SCM)
SCC1 = Compacting toward oneself Cement with 15 % FA as concrete substitution.
SCC2 = Compacting toward oneself Cement with 25 % FA as concrete substitution.
SCC3 = Compacting toward oneself Cement with 35 % FA as concrete substitution.
CA = Coarse totals SP = Super plasticizer

Fresh properties of self-constricting concrete

The fresh concrete is an assembly of solid particles which behaves like other granular materials. The paste is then added in quantities, which are adequate to fill the voids between the aggregate particles.

The assumption is made that fresh concrete is a homogeneous material of uniform composition. The three key properties of SCC of its fresh state are to be achieved are given below.

1. Filling ability
2. Passing ability
3. Segregation resistance.

Following properties are tested in the laboratory

Filling ability

It is the potential of concrete to flow under its own weight both vertically downwards and horizontally, without honeycombing around any shape. Filling ability refers to the ability of SCC mix to deform and undergo changes in shape with completely filling all areas and corners of the formwork horizontally and vertically while maintaining its homogeneity. The deformability of SCC is characterized by the concrete’s fluidity and cohesion, and mainly assessed using the slump flow test.

Passing ability

This is the potential of the concrete to flow freely without getting blocked through dense reinforcement. Passing ability refers to the ability of SCC mix to pass through congested reinforcement without blocking, whilst maintaining good suspension of coarse particles in the matrix, thus avoiding arching near obstacles and blockage during flow. The J-ring and L-box tests are the most common methods used to assess this property. The probability of blocking increases when the volume fraction of large aggregates and/or fibers increases. The size of aggregates, their shapes and their volume fraction influence the passing ability of SCC, moreover, the presence of fibers especially long and hooked or crimped ends make self-compacting fiber reinforced concrete (SCFRC)more difficult to pass through reinforcement.

Resistance to segregation

This is the potential of SCC to resist separation of aggregate from the paste to maintain a homogenous mix during and after placement. Segregation Resistance (Homogeneity/Cohesiveness) Segregation resistance refers to the ability to retain the coarse components of the mix and the fibers in suspension in order to maintain a homogeneous material. Stability is largely dependent on the cohesiveness and the viscosity of the concrete mixture which can be increased by reducing the free water content and increasing the amount of fines.

II. LITERATURE REVIEW

Self-Compacting Concrete

M.C. Nataraja, Anvit Gadkar and Giridhar Jogin (2018) et al. Developed a simple procedure to produce self-compacting concrete based on the requirement of strength by slight modification to IS 10262:2009. Considered the limits prescribed by EFNARC and investigated on 25 mix proportions to obtain the relationship between compressive strength and water cementitious ratio of SCC. For this method, compressive strength ranges from 20MPa to 60MPa were considered by using poly corboxilic ether based high water reducing agent. It was observed that w/c from 0.47 to 0.37 was sufficient to obtain the strength values between 25 to 60MPa. Fresh properties and strength results occurred by this procedure were in good agreement.

Athiyamaan. V & G. Mohan Ganesh (2018) et al. Studied about SCC mix design using nan-su method and trail mixes were carried out by using Design of Experiments method (DOE). In trail mixes central composite design was farmed with variables; cement, superplasticizer, w/c, Fine aggregate and coarse aggregate. 33 trail runs were investigated and M16 numbered mix gave optimum results. And also noted that by decreasing coarse aggregate from 750Kg/m3 to 710 kg/m3 increase the rheological properties but signs against the strength, increasing of fine aggregate will results of maximum packing factor.

Workability test on SCC

Daniel C, Joel Shelton J, Vincent Sam Jebadurai S, Arun Raj E (2016) et al. Studied on high strength self-compacting concrete by using copper slag in place of river sand at an interval of 10% from 0% to 100% with water cement ratio at 0.4 and super plasticizer was maintained at 0.6%. Wet concrete properties like passing ability, flow ability and filling ability was tested by using L-box, U-box, V-funnel, slump flow test. Mechanical properties like flexural strength, split tensile strength, compressive strength was also known at 7 days and 28 days. By the increase of copper slag, workability improves and at 40% replacement shows the optimum values in both fresh and hardened properties.

M. Fadee, R. Mirhosseini, R. Tabatabaei & M.J. Fadaee (2015) et al. Investigated about usage of copper slag as cementitious material in self-compacting concrete (SCC); physical and chemical analyses were performed. Cement was replaced with copper slag at 20%, 25%, 30%, 35% and 40%, and tests were conducted to know the variation of fresh and mechanical properties with and without copper slag. V-funnel and J-Ring tests on wet concrete, compressive strength at 7, 14, 28- and 42-days age on hardened concrete were conducted. In the results, it shows that copper with 40% gives better passing ability and filling ability than without copper slag. Copper slag with 20% gives 85 percentage of compressive strength without slag, by this it was recommended to use at 20%.

Admixtures in SCC

C. Sashidhar, B. Radhamma, J. Gurujawahar, C. Yedukondalu (2018) et al. Studied about self-compacting geopolymer concrete with 50:50 proportions using class F fly ash and GGBS with artificial sand as fine aggregate. EFNARC guidelines are considered for trail mixes to get optimum proportions and 8M, 10M, 12M NaoH issued in the experiment. Various fresh properties like segregation resistance, passing ability and filling ability were examined by using test methods; L-box, T500 slump flow, v-funnel and slump flow. It was observed that by increasing the NaOH morality the fresh properties are decreased and no adverse effect has been marked when self-compacting geopolymer concrete mixes prepared with artificial sand.

K Ganesh Babu and B Chandrasekhar (2018) worked on high performance self-compacting concrete with fly ash of 25%, 35%, 50% and 70% as a cementitious content. Various water powder ratios were used ranging from 0.25-0.72. It was observed that fly ash-based SCC ranging from 25-110 Mpa could be produced by replacing 70-25% of cement, charge passing through the specimen is also decreased by increasing the fly ash content. Durability tests like acid attack, corrosion tests show better results by increasing fly ash percentage.

III. RESULTS AND DISCUSSIONS

Tests on Cement

Cement is an important constituent in concrete. which binds the matrix of the concrete together. So as to determine the various properties of cement different tests are conducted in the concrete technology laboratory of St. Martins engineering college. Following test are conducted on cement

1. Standard Consistency
2. Initial & Final Setting Time
3. Fineness of Cement
4. Specific gravity of Cement
5. Soundness of Cement
6. Marsh cone test
7. Compression strength of Cement

Standard procedure of the above test are given in detail with results in next part of document

Test results on cement

S.No	Test	Result
1	Fineness of cement	6%
2	Standard consistency of cement	36%
3	Initial setting time of cement	40min
	final setting time of cement	10 hrs 20 min.
4	Soundness of cement	SOUND
5	Specific gravity of cement	3.92
6	Marsh cone test	7sec at 300ml chemical dosage

Marsh cone test

The Marsh cone test is a workability test used for specification and quality control of cement pastes. Marsh cone test standard varies from one country to another, but its principle is usually the same. Thetime needed for a certain amount of material to flow out of the cone is recorded. This measured flow time is linked with the fluidity of the tested material. The longer the flow time, the lower is the fluidity.

The Marsh cone test is a simple approach to get some data about cement pastes behavior. It is used in cement-based materials mix design in order to define the saturation point, i.e. the dosage beyond which the flow time does not decrease appreciably. The cone is filled with the fluid material while the nozzle is kept closed. When the cone is filled with measured quantity of fluid, the nozzle is opened and the fluid is allowed to flow freely. The time needed for measured quantity of material to flow out is recorded as Marsh cone time.

The saturation point is defined as the chemical admixture dosage beyond which the flow time dose not decrease appreciably. The dose at which the Marsh cone time is lowest is called the saturation point. The dose is the optimum dose for that brand of cement and admixture (plasticizer or superplasticizer) for that w/c ratio.

Procedure to determine the flowability of cement by Marsh cone test

- Observations for 0 minutes, 15 minutes and 60 minutes retention period are taken.
- For first test, water cement ratio is kept as 0.55 and Conplast SP430 admixture dose of 0.2% is administered. Temperature is noted down.
- Mix the measured quantity of Jaypee Cement, water and Conplast SP430 admixture thoroughly in a mechanical mixer for two minutes.
- While mixing, first put the water in mixing bowl and then add 2 Kg of cement to this water. Stirrer for 1 minute and then add Conplast SP430 admixture dose and stirring operation is continued for next one minutes. Thus slurry is formed.
- Pour one-liter slurry into marsh cone duly closing the aperture with a finger.
- Start the stop watch and simultaneously remove the finger. Note the time taken for emptying the Marsh Cone. This time is called the "Marsh Cone Time".
- Repeat the test for 15 minutes and 60 minutes retention period for same mix and duly noting Marsh Cone time. The mixture of cement and admixture should be kept stirred throughout the test.
- Repeat the test for different plasticizer dosage i.e. 0.2% to 2.0% (AS per IS 456: 2000).
- A typical graph of Marsh Cone Time in Seconds Vs Admixture/Cement dosage in percentage is drawn and optimum dose is ascertained. This point is known as "Saturation Point"
- For Jaypee Cement and Conplast SP430 admixture, different w/c ratio i.e. 0.25, 0.30, 0.35, 0.40, 0.45, 0.50, 0.55 the whole procedure is repeated and for each combination of cement, water and plasticizer, saturation point is obtained.
- Repeat step 2 to 9 for the Jaypee Cement and Conplast SP430 admixture.

Observation and calculations

Flowability by Marsh cone test observations

S.No	Chemical dosage	Passing in sec
1	50ml	126sec
2	100ml	87sec
3	150ml	54sec
4	200ml	36sec
5	250ml	20sec
6	300ml	7sec

Result for Marsh cone test

Max passing value is found at the chemical dosage of 300ml as 7sec

Workability test on SCC

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 (1) 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, though two people are needed if the T50 time is to be measured. 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

A mould 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 none 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

Equipment

- trowel
- scoop
- ruler
- stopwatch (optional)

Procedure for Slump flow test

About 6 liters of concrete is needed to perform the test, sampled normally. Moisten the base plate and inside of slump cone, Place base plate on level stable ground and the slump cone centrally on the base plate and hold down firmly. Fill the cone with the scoop. Do not tamp, simply strike off the concrete level with the top of the cone with the trowel. Remove any surplus concrete from around the base of the cone. Raise the cone vertically and allow the concrete to flow out freely.

Simultaneously, start the stopwatch and record the time taken for the concrete to reach the 500mm spread circle. (This is the T50 time). Measure the final diameter of the concrete in two perpendicular directions. Calculate the average of the two measured diameters. (This is the slump flow in mm).

Properties and Acceptance criteria for Slump flow

Method	Properties evaluated by the test	Acceptance criteria		
		unit	min	max
Slump flow	Filling ability, flowability, segregation and bleeding	mm	650	800

Observation and calculations

Slump flow test observations

Water cement ratio	Slump in cm
0.4	22cm
0.5	17cm
0.6	15cm

Result for Slump flow test

Slump value for the given SCC sample is found to be 22cm for W/C ratio of 0.4, 17cm for W/C ratio of 0.5 & 15cm for W/C ratio of 0.6

J Ring test

Introduction

The principle 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 x 25mm) open steel ring, drilled vertically with holes to accept threaded sections of reinforcement bar. These sec+3tions 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. These combinations test the flowing ability and (the contribution of the J-Ring) the passing ability of the concrete. The Orimet time and/or slump flow spread is measured as usual to assess flow Characteristics. 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. The Orimet option has the advantage of being a dynamic test, also reflecting placement in practice, though it suffers from requiring two operators.

Equipment

Mould, 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 500mm diameter

- 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, and spacing 48 +/- 2mm)

Procedure for J-ring test

About 6 liters of concrete is needed to perform the test, sampled normally. Moisten the base plate and inside of slump cone, Place base-plate on level stable ground. Place the J-Ring centrally on the base-plate and the slump-cone centrally inside it and hold down firmly.

Fill the cone with the scoop. Do not tamp, simply strike off the concrete level with the top of the cone with the trowel. Remove any surplus concrete from around the base of the cone.

Raise the cone vertically and allow the concrete to flow out freely. Measure the final diameter of the concrete in two perpendicular directions. Calculate the average of the two measured diameters. (in mm). Measure the difference in height between the concrete just inside the bars and that just outside the bars. Calculate the average of the difference in height at four locations (in mm). Note any border of mortar or cement paste without coarse aggregate at the edge of the pool of concrete.

Properties and Acceptance criteria for J-ring

Method	Properties evaluated by the test	Acceptance criteria		
		Unit	Min	Max
J-ring	Passing ability, flowing ability	Mm	0	10

Observation and calculations

J-ring test observations

Water cement ratio	Flowing of concrete in mm
0.4	7mm
0.5	6mm
0.6	4mm

Result for J Ring test

J-ring value for the given SCC sample is found to be 7mm for W/C ratio of 0.4, 6mm for W/C ratio of 0.5 & 4mm for W/C ratio of 0.6

V funnel test

Introduction

The test was developed in Japan and used by Ozawa et al (5). The equipment consists of a V-shaped funnel, shown in Fig. An alternative type of V-funnel, the O funnel, with a circular section is also used in Japan. The described

V-funnel test is used to determine the filling ability (flow ability) of the concrete with a maximum aggregate size of 20mm. The funnel is filled with about 12 liters of concrete and the time taken for it to flow through the apparatus measured. After this the funnel can be refilled concrete and left for 5 minutes to settle. If the concrete shows Segregation, then the flow time will increase significantly.

Assessment of test

Though the test is designed to measure flow ability, the result is affected by concrete properties other than flow. The inverted cone shape will cause any liability of the concrete to block to be reflected in the result – if, for example there is too much coarse aggregate. High flow time can also be associated with low deformability due to a high paste viscosity, and with high inter-particle friction. While the apparatus is simple, the effect of the angle of the funnel and the wall effect on the flow of concrete are not clear.

Equipment

- V-funnel
- bucket (±12 liters)
- trowel
- scoop
- stopwatch

Procedure flow time

About 12 liters of concrete is needed to perform the test, sampled normally. Set the V-funnel on firm ground. Moisten the inside surfaces of the funnel. Keep the trap door open to allow any surplus water to drain. Close the trap door and place a bucket underneath. Fill the apparatus completely with concrete without compacting or tamping; simply strike off the concrete level with the top with the trowel. Open within 10 sec after filling the trap door and allow the concrete to flow out under gravity. Start the stopwatch when the trap door is opened, and record the time for the discharge to complete (the flow time). This is taken to be when light is seen from above through the funnel. The whole test has to be performed within 5 minutes.

Properties and Acceptance criteria for V- funnel test

Method	Properties evaluated by the test	Acceptance criteria		
		Unit	min	max
V-Funnel	Filling ability, viscosity,segregation	Sec	6	12

Results for V funnel test

The time of the flow in V-funnel for SCC is found to be 8sec

L-Box test

Introduction

This test, based on a Japanese design for underwater concrete, has been described by Peterson. The test assesses the flow of the concrete, and also the extent to which it is subject to blocking by reinforcement. The apparatus is shown in figure. The apparatus consists of a 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 bar are fitted. The vertical section is filled with concrete, and then the gate 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 (H2/H1in the diagram). It indicates the slope of the concrete when at rest. This is an indication 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 times taken to reach these points measured. These are known as the T20 and T40 times and are an indication for the filling ability. The 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 bars can principally be set at any spacing to impose a more or less severe test of the passing ability of the concrete.

Assessment of test

This is a widely used test, suitable for laboratory, and perhaps site use. It assesses filling and passing ability of SCC, and serious lack of stability (segregation) can be detected visually. Segregation may also be detected by subsequently sawing and inspecting sections of the concrete in the horizontal section. Unfortunately, there is no agreement on materials, dimensions, or reinforcing bar arrangement, so it is difficult to compare test results. There is no evidence of what effect the wall of the apparatus and the consequent ‘wall effect’ might have on the concrete flow, but this arrangement does, to some extent, replicate what happens to concrete on site when it is confined within formwork. Two operators are required if times are measured, and a degree of operator error is inevitable.

Equipment

- L box of a stiff non absorbing material
- trowel
- scoop
- stopwatch

Procedure for L-box test

About 14 liters of concrete is needed to perform the test, sampled normally. Set the apparatus level on firm ground, ensure that the sliding gate can open freely and then close it. Moisten the inside surfaces of the apparatus, remove any surplus water Fill the vertical section of the apparatus with the concrete sample. Leave it to stand for 1 minute. Lift the sliding gate and allow the concrete to flow out into the horizontal section. Simultaneously, start the stopwatch and record the times taken for the concrete to reach the 200- and 400-mm marks. When the concrete stops flowing, the distances “H1” and “H2” are measured. Calculate H2/H1, the blocking ratio. The whole test has to be performed within 5 minutes.

Properties and Acceptance criteria for L-box test

Method	Properties evaluated by the test	Acceptance criteria		
		Unit	mm	Max
L-box	Passing ability,flowability,blocking effects	(h2-h1)	0.8	1.00

Result for L-box test

The time of flow of SCC in L-box is 1.7min

U-box test

Introduction

The test was developed by the Technology Research Centre of the Taisei Corporation in Japan. Sometimes the apparatus is called a “box-shaped” test. The test is used to measure the filling ability of self-compacting concrete. The apparatus consists of a vessel that is divided by a middle wall into two compartments, shown by R1 and R2 in fig. An opening with a sliding gate is fitted between the two sections. Reinforcing bars with nominal diameters of 13 mm are installed at the gate with center-to-center spacing of 50 mm. This creates a clear spacing of 35 mm between the bars. The left-hand section is filled with about 20 liters of concrete then the gate lifted and concrete flows upwards into the other section. The height of the concrete in both sections is measured.

Note: An alternative design of box to this, but built on the same principle is recommended by the Japan Society of Civil Engineers.

Assessment of test

This is a simple test to conduct, but the equipment may be difficult to construct. It provides a good direct assessment of filling ability – this is literally what the concrete has to do – modify by an unmeasured requirement for passing ability. The 35mm gap between the sections of reinforcement may be considered too close. The question remains open of what filling height less than 30 cm. is still acceptable.

Equipment

- U box of a stiff non absorbing material
- trowel
- scoop
- stopwatch

Procedure for U-box test

About 20 liter of concrete is needed to perform the test, sampled normally. Set the apparatus level on firm ground, ensure that the sliding gate can open freely and then close it. Moisten the inside surfaces of the apparatus, remove any surplus water Fill the one compartment of the apparatus with the concrete sample. Leave it to stand for 1 minute. Lift the sliding gate and allow the concrete to flow out into the other compartment. After the concrete has come to rest, measure the height of the concrete in the compartment that has been filled, in two places and calculate the mean (H1). Measure also the height in the other compartment (H2) Calculate H1 - H2, the filling height. The whole test has to be performed within 5 minutes.

Properties and Acceptance criteria for U-box test

Method	Properties evaluated by the test	Acceptance criteria		
		Unit	min	Max
U-box	Passing ability, filling ability & blocking effects	(h2-h1)	0	30

Result for U-box test

The passing value of SCC in U-box test is found to be 26cm.

Flow table test

Introduction

This test is performed to determine the consistency of concrete where the nominal maximum size of aggregate does not exceed 38 mm using flow table apparatus.

Apparatus

- Flow table
- Trowel
- Scale

Procedure

- Before commencing test, the table top and inside of the mould is to be wetted and cleaned of all gritty material and the excess water is to be removed with a rubber squeezer.
- The mould is to be firmly held on the centre of the table and filled with concrete in two layers, each approximately one-half the volume of the mould and rodded with 25 strokes with a tamping rod, in a uniform manner over the cross section of the mould.
- After the top layer has been rodded, the surface of the concrete is to be struck off with a trowel so that the mould is exactly filled.
- The mould is then removed from the concrete by a steady upward pull.
- The table is then raised and dropped from a height of 12.5 mm, 15 times in about 15 seconds.
- The diameter of the spread concrete is the average of six symmetrically distributed caliper measurements read to the nearest 5 mm.

Properties and Acceptance criteria for Flow table test

S.No	Method	Properties evaluated by the test	Acceptance criteria		
			Units	Min	Max
1	Flow table	Flowability, consistency & segregation	%	0	150

Observation and calculations

Flow table test observations

Chemical dosage	% flowability
100ml	52%
200ml	86%
300ml	102%

Result for Flow table test

The flow table value of SCC is found to be max at 300ml chemical dosage as 102%

IV. CONCLUSION

Self-Compacting Concrete is considered to be the most promising building material for the expected revolutionary changes on the job site as well as on the desk of designers and civil engineers. Finally, since the degree of compaction of the Self Compacting Concrete used in a structure depends directly upon the quality of the concrete itself, with no possibility of skilled workers compensating for poor ability, it is vital that we have a manufacturing system capable of producing self-compacting concrete of the required quality. We can hope and trust that self-compacting concrete will one day become so widely used that will be seen as the "standard concrete" rather than as a "special concrete". When that happens, we will have succeeded in creating durable and reliable concrete structures requiring very little maintenance work.

Pro's of using SCC

SCC is more durable and stronger than nominal concrete
SCC more time efficient than nominal concrete
SCC provides more flexibility to design and casting of structures
SCC requires on vibration for compaction
Utilization of SCC saves time and time of construction of structure
Gives good surface finishing and appearance to structure

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