Durability Study on Self Compacting Concrete

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***Abstract*— Self Compacting Concrete is generally defined as the "Concrete, which does not need Compaction." It means SCC gets compacted without external efforts like vibration, tamping etc. The mixture therefore is required to have the ability of flowing, filling voids and being stable. Due to these characteristics, SCC is ideally suited for concreting structures, which have heavily congested reinforcement or difficult access conditions. The use of SCC in actual construction is still less in India. Lack of awareness, Technical data could be cited as the main reasons. Considerable research is carried out in India towards the technology development so that SCC could soon find a place in the Indian Construction Industry. The ingredients used for SCC are 53 grade ordinary Portland cement, river sand, coarse aggregate, super plasticizer, class-F fly ash from thermal power plant, viscosity modifying agent. Cement is replaced by fly ash at 10%, 20%, 30% and 40% levels by weight of cement.**

In the present experimental investigation the main concentration is focused on durability properties of self compacting concrete mixes. The number of trail mixtures are used and tests such as Slump Flow, V-Funnel, L-box etc. Then investigations are carried out for Percentage loss in compressive strength, Percentage loss of weights, Durability factors for the specimens immersed in H2So4, HC1 and Na2So4 Solutions for 28 days and Permeability aspect. The super plasticizer mix ratios are 1%, 1.5%, 2% and 2.5% like that VMA also mix at 1%, 1.5%, 2% and 2.5%. For each mix 9 numbers of cube and 18 numbers of cylinder are cast. The cube used to find the compressive strength and the cylinder used to find compressive strength and tensile strength. Chemical attack by strength deterioration factor test Acid resistance test, Alkaline resistance test, Sulphate resistance test to Comparative study on conventional with self-compacting concrete.

I. INTRODUCTION

Concrete is the most versatile construction material because it can be designed to withstand the harshest environments while taking on the most inspirational forms. Engineers are continually pushing the limits to improve its performance with the help of innovative chemical admixtures and supplementary cementitious materials. 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 1980's in Japan. In Europe it was probably first used in civil works for transportation networks in Sweden in the midl990's. The multi-national, 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. SCC is often produced with low water-cement ratio providing the potential for high early strength, earlier demoulding and faster use of elements and structures. 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. The improved construction practice and performance, combined with the health and safety benefits, make SCC a very attractive solution for both precast concrete and civil engineering construction.

II. SPECIFICATIONS OF INGREDIENTS

Generally a good quality of cement like 53 grade cement is preferred but it may vary according to the grade of SCC needed. The maximum size of the aggregates depends on the particular application and is usually limited to 12 mm. the particles smaller than 0.125 mm contribute to the powder content. The moisture content in the aggregates should also be closely monitored and must be taken into account. Suitability is established for mixing water and for recycled water from concrete production conforming that the minerals and other elements do not effect the properties of concrete

Admixtures used shall comply with EN 934-2:2000 (including annex A), where appropriate super plasticizer is an essential component of SCC to provide the necessary workability. Other types may be incorporated as necessary, such as Viscosity Modifying Agents (VMA) for stability, air entraining admixtures, retarders for control of setting etc. Super plasticizer like Glenium b 232, Structro 100 is found to be more effective. Fly ash is a fine inorganic material with pozzolanic properties, which can be added to SCC to improve its properties and also as a substitute of cement to certain extent. In addition to all the above ingredients, some other pigments and admixtures shall also be used according to the working conditions and requirements.

III. ADVANTAGES OF USING SCC

SCC has got many advantages over normal concrete. It can even be cheaper than normal concrete if fly ash is locally available and a suitable viscosity modifying agents is used.

Advantages of SCC over NC are as follows:

Faster construction.

By using SCC, the production of concrete can be more industrialized. The evolving ready mix concrete is easily possible by using the property pump ability.

Reduction in site man power.

The man power used for the vibration and for compaction of concrete is saved.

Better surface finishes.

The Self Compacting Concrete has a high percentage of fines, and the property of fallibility enables the concrete to give a better surface finish.

Easier placing.

The SCC unlike the normal conventional concrete can be placed easily. The SCC can also be poured inside the reinforcement.

Reduced noise levels in work site.

The noise produced by the compactors and vibrators is avoided. This enables better communication in the work site.

Safer working environment.

As there is less man power required in the site, the problems resulting from congestion etc.., are reduced, this results in a safer working environment.

Economical construction.

In SCC the cementitious materials like fly ash can be used, which is a waste product in thermal power plant. Fly ash costs very less compared to other building materials, ultimately resulting in economical construction.

Improved filling capacity through highly congested reinforcement.

The SCC has a higher filling and flowing ability when compared to the conventional concrete thereby it enables to fill through the congested reinforcement. This eliminates the difficulty of vibrating through the congested reinforcement.

Time of construction is minimized.

As the production of SCC can be industrialized, the time required for the construction is reduced.

IV. DURABILITY TESTS ON SCC

Durability

Durability of the cement concrete is defined as the ability to resist weathering action, chemical attack, abrasion or any other process of deterioration.

Acid Resistance Test

The cubes of size 150 mm*150 mm*150 mm will be caste and gets cured for 28 days. The initial weight of cubes after 28 days will be taken as (W1). After that the cubes are immersed in 5% by weight of water of diluted hydrochloric acid (HCl) with pH value of 2 for a period of 28 days.The concentration of this solution should be maintained throughout this period. After that 28 days the cubes will taken from acid water and the surfaces should be cleaned well and weight will recorded as (W2). The compression strength of the cubes should be calculated. The loss in compressive strength and the improvement of resistance of acid attack of the concrete cubes should be calculated.

Alkaline Resistance Test

The cubes of size 150 mm*150 mm*150 mm will casted and gets cured for 28 days. After that the cubes are immersed in 5% by weight of water of sodium hydroxide (NaOH) for a period of 28 days. The concentration of this solution should be maintained throughout this period. After that 28 days the cubes will taken from alkaline water and the surfaces should be cleaned well. The compression strength of the cubes can be calculated. The loss in compressive strength of the concrete cubes should be calculated.

Sulphate Resistance Test

The cubes of size 150 mm*150 mm*150 mm will casted and gets cured for 28 days. After that the cubes are immersed in 5% by weight of water of sodium sulphate (Na_2SO_4) and 5% of magnesium sulphate ($MgSO_4$)for a period of 28 days also another set of specimen will kept for alternate wet and dry tests and repeated for 56 cycles. The concentration of this solution should be maintained throughout this period. After 28 days the cubes will taken from solution also after 56 cycles of alternative wetting and drying. The surfaces should be cleaned well. The compression strength of the cubes can be calculated, the changes in strength of cubes should be found.

V. EXPERIMENTAL INVESTIGATION

STUDY ON MATERIAL

Fly ash

Fly ash is one of the residues generated in combustion, and comprises the fine particles that rise with the flue gases. Ash which does not rise is termed bottom ash. In an industrial context, fly ash usually refers to ash produced during combustion of coal. Fly ash is generally captured by electrostatic precipitators or other particle filtration equipment before the flue gases reach the chimneys of coal-fired power plants, and together with bottom ash removed from the bottom of the furnace is in this case jointly known as coal ash. Depending upon the source and makeup of the coal being burned, the components of fly ash vary considerably, but all fly ash includes substantial amounts of silicon dioxide (SiO_2) and calcium oxide (CaO), both being endemic ingredients in many coal-bearing rock strata.

Ash used as a cement replacement must meet strict construction standards, but no standard environmental regulations have been established in the United States. 75% of the ash must have a fineness of 45 µm or less, and have a carbon content, measured by the loss on ignition (LOI), of less than 4%. In the U.S., LOI needs to be under 6%. The particle size distribution of raw fly ash is very often fluctuating constantly, due to changing performance of the coal mills and the boiler performance. This makes it necessary that, if fly ash is used in an optimal way to replace cement in concrete

production, it needs to be processed using beneficiation methods like mechanical air classification. But if fly ash is used also as a filler to replace sand in concrete production, unbeneficiated fly ash with higher LOI can be also used. Especially important is the ongoing quality verification.
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Super plasticizers

Super plasticizers, also known as high range water reducers, are chemicals used as admixtures where well-dispersed particle suspension are required. These polymers are used as dispersants to avoid particle aggregation, and to improve the flow characteristics (rheology) of suspensions such as in concrete applications. Their addition to concrete or mortar allows the reduction of the water to cement ratio, not affecting the workability of the mixture, and enables the production of self-consolidating concrete and high performance concrete. This effect drastically improves the performance of the hardening fresh paste. Indeed the strength of concrete increase whenever the amount of water used for the mix decreases. However, their working mechanisms lack of a full understanding, revealing in certain cases cement-super plasticizer incompatibilities.

Viscosity Modifying Agent (VMA)

Viscosity modifying admixtures (VMAs) are water-soluble polymers that increase the viscosity of mixing water and enhance the ability of cement paste to retain its constituents in suspension. Cement paste serves as the basis for the workability properties of self compacting concrete (SCC) and these properties could be assessed by self consolidating cementitious materials (SCCM). SCCMs have to be sufficiently fluid to ensure the fluidity of the SCC itself and sufficiently viscous to support the coarse aggregates.

Water

Portable tap water available in laboratory with pH value of 7.0 ± 1 and confirming to the requirement of IS: 456-2000 was used for mixing concrete and curing the specimens as well.

VI. TESTS ON FRESH CONCRETE

Slump flow test and T50cm test:

The slump flow test aims at investigating the filling ability of SCC. It measures two parameters, flow spread and flow time T50 (optional). The former indicates the free, unrestricted deformability and the latter indicates the rate of deformation within a defined flow distance.

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.

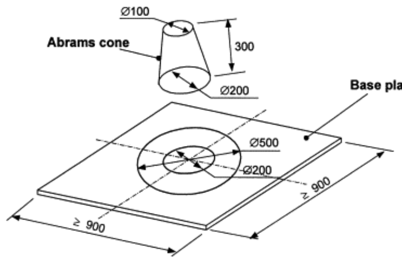


Fig. 1 Slump flow test Apparatus

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. 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, stop watch. 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 T_{50} 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).

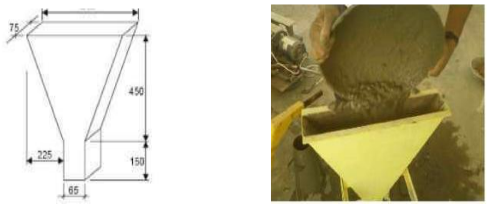
The higher the slump flow (SF) value, the greater its ability to fill formwork under its own weight. A value of at least 650mm is required for SCC. There is no generally accepted advice on what are reasonable tolerances about a specified value, though ± 50mm, as with the related flow table test, might be appropriate.

V- funnel test and V funnel test at T_5 minutes:

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.

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.



(a) (b)
Fig. 2 V-Funnel test Apparatus

V-funnel, Bucket, Trowel, Scoop, Stop Watch. 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.

L box Test:

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 ($H2/H_1$ in 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.

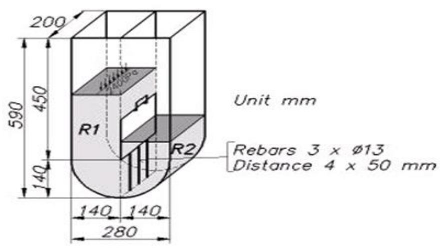
This is a widely used test, suitable for laboratory, and perhaps site use. It assesses filling and passing ability of SCC, and serious lack of stability (segregation) can be detected visually. Segregation may also be detected by subsequently sawing and inspecting sections of the concrete in the horizontal 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.

(a) (b)
Fig. 3 L–Box test Apparatus

L box , Trowel ,Scoop, Stop Watch. 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 waterfall 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 "H_1" and "H2" are measured. Calculate H2/H1, the blocking ratio. The whole test has to be performed within 5 minutes. If the concrete flows as freely as water, at rest it will be horizontal, so H2/H1 = 1. Therefore the nearer this test value, the 'blocking ratio', is to unity, the better the flow of the concrete. The EU research team suggested a minimum acceptable value of 0.8. T20 and T40 times can give some indication of ease of flow, but no suitable values have been generally agreed. Obvious blocking of coarse aggregate behind the reinforcing bars can be detected visually.

U – Box Test:

U - box test is used to measure the filling ability(flow ability) and segregation properties of the SCC. In this test, the degree of compatibility can be indicated by the height that the concrete reaches the other part of box after flowing through an obstacle. The test measures filling and segregation properties of Self Compacting Concrete. U - Box, as shown in Fig 4, made of steel, with a flat, horizontal top and placed on Vertical supports, and with a momentary releasable, watertight sliding gate. The apparatus consists of vessel that is divided by a middle wall into two compartments as shown by R1 and R2 in fig. An opening with a sliding gate is fitted between the two compartments. Reinforcement bars with normal diameter of 12mm are installed at the gate with centre to centre distance of 50mm. this creates a clear spacing of 35mm between the bars. The U - box is mounted vertically and the central door is closed The fresh concrete is filled in the left compartment of U - box.



S.No	Trail Mix	Compressive Strength (N/mm2)	
		7 Days	28 Days
1	SCC 1	27.51	47.56
2.	SCC 2	28.22	48.14
3.	SCC 3	30.45	48.64
4.	SCC 4	27.87	49.71
5.	SCC 5	27.77	50.94
6.	SCC 6	29.02	48.69
7.	SCC 7	30.59	47.63
8.	SCC 8	29.23	45.69

Fig. 4 U – box test

The gate is opened. The concrete will now flow out from one compartment to another. The difference in height between the concrete surfaces on either compartment is measured. This difference in height indicates the self leveling ability and passing ability of self compacting concrete. If the concrete flows as freely as water, at rest it will be horizontal, so H1-H2 = 0. Therefore the nearer this test value, the 'filling height', is to zero, the better the flow and passing ability of the concrete.

VII. TESTS ON HARDENED CONCRETE

Compression test:

The cube specimen is of the size 15 x 15 x 15 cm. If the largest nominal size of the aggregate does not exceed 20 mm. Cylindrical test specimens have a length equal to twice the diameter. They are 15 cm in diameter and 30 cm long. Smaller test specimens may be used but a ratio of the diameter of the specimen to maximum size of aggregate, not less than 3 to 1 is maintained.

Fig. 5 Compression Test Setup

Compression test develops a rather more complex system of stresses. Due to compression load, the cube or cylinder undergoes lateral expansion owing to the Poisson's ratio effect. The steel platens do not undergo lateral expansion to the some extent that of concrete, with the result that steel restrains the expansion tendency of concrete in the lateral direction. It has been found that the lateral strain in the steel platens is only 0.4 of the lateral strain in the concrete. When the friction is eliminated by applying grease, graphite or paraffin wax to the bearing surfaces the specimen exhibits a larger expansion and eventually splits along its full length. The compression test specimens were tested on a compression testing machine of capacity 2000 kN.Load is applied gradually as the rate of 14 N/mm2/min or 320 kN/min.

Table. 1 Compressive Strength of Cubes

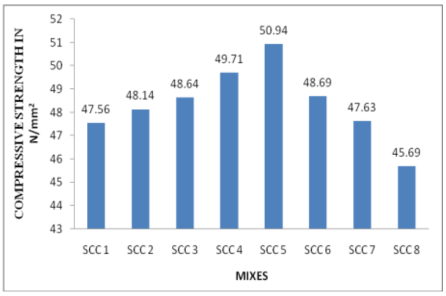


Fig. 6 Cube compressive strength at 28 days

Split tensile test:

Tensile strengths are based on the indirect splitting test on cylinders. This is also sometimes referred as, "Brazilian Test". This test was developed in Brazil in 1943. At about the same time this was also independently developed in Japan. The test is carried out by placing a cylindrical specimen horizontally between the loading specimen of a compression testing machine and the load is applied until failure of the cylinder, along the vertical diameter. The tensile strength is one of the basic and important properties of the concrete. The concrete is not usually expected to resist, the direct tension because of its low tensile and brittle in nature. However the determination of tensile strength of concrete is necessary to determine the load at which the concrete members crack.

Fig. 7 Split Tensile Test on Cylinder Specimen

Table. 2. Split-Tensile strength at 7 days and 28 days

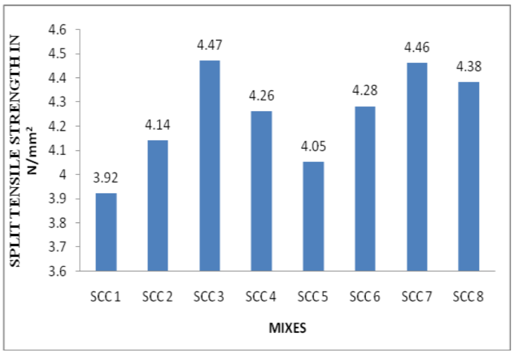


Fig. 8 Split tensile strength at 28 days

S.No	Trail Mix	Split Tensile Strength (N/mm^2)	
		7 Days	28 Days
1	SCC 1	2.80	3.92
2	SCC 2	2.82	4.14
3	SCC 3	3.10	4.47
4	SCC 4	2.72	4.26
5	SCC 5	2.80	4.05
6	SCC 6	2.78	4.28
7	SCC 7	3.15	4.46
8	SCC 8	2.86	4.38

Cylinder compressive strength test:

The cylinder are cast and tested in the same position the standard size of cylinder is 15 cm diameter and 30 cm height in actual structures in the field the casting and loading is similar to that of the cylinder and not like the cube therefore the use of cylinder is more popular particularly in the research laboratories.

Cylinder compressive strength = Ultimate load / Area of cylinder.

Fig. 9 Cylinder compressive test

Table. 3 Cylinder compressive strength at 7days and 28days.

S.No	**Trail Mix**	**Compressive Strength (N/mm^2)**	
		7 Days	**28 Days**
1	SCC 1	23.68	38.52
2.	SCC 2	25.12	40.23
3.	SCC 3	28.62	43.25
4.	SCC 4	24.35	41.26
5.	SCC 5	24.57	39.23
6.	SCC 6	25.82	40.81
7.	SCC 7	29.55	43.49
8.	SCC 8	25.89	45.85

VIII. CONCLUSION

Basic tests for cement, coarse aggregate and fine aggregate were conducted and results were tabulated. The experimental stages of investigation can be carried out in phase II of this project work The various basic tests were carried out for cement, sand, coarse aggregate and were tabulated. The fresh concrete tests like L box, V funnel, U tube and slump flow tests were conducted. The acquired mix design is used for casting cylinder and cube with replacement of cement with use of fly ash about 10%, 20%, 30% and 40% respectively. Test results for 7 days, 14 days and 28 days stress-strain relations of M40 grade of self compacting concrete were shown in graph. From the above stress-strain values find out the modulus of elasticity of self compacting concrete for various proportions.

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