STUDY AND ANALYSIS OF SELF-COMAPCTING CONCRETE

Project Report submitted in partial fulfilment of the requirement for the degree of

Bachelor of Technology in Civil Engineering

Under the supervision of

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CERTIFICATE

This is to certify that the work titled "Study and Comparative Analysis of Self-Compacting Concrete with Conventional Concrete" submitted by **Abhishek Mishra (111613) & Himanshu Wadhwani (111647)** in partial fulfilment for the award of degree of B.Tech. of Jaypee University of Information Technology, Waknaghat has been carried out under my supervision at JUIT,Waknaghat campus. This work has not been submitted partially or wholly to any other University or Institute for the award of this or any other dergree or diploma.

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Working on this project has been a great learning experience for us, which provided a brisk and viable experience to us. Our experience while working in this project ranges from the moment of anxiety, when we could not solve the problem for several days, to moments of ecstasy when after struggling for several days we were ultimately able to find solution to our problems. We would like to express our gratitude to all the people who helped us in our project but some omissions are inevitable.

It is said that behind the accomplishment of any effort there are some dedicated individuals who put in their best to get the job done.

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ABSTRACT

Concrete is a composite construction material made primarily with cement, water and aggregate. There are many formulations of concrete, which provide varied properties, and concrete is the most used man-made product in the world.

Concrete is widely used for making architectural structures, foundations, brick/block walls, pavements, bridges/overpasses, motorways/roads, runways, parking structures, dams, pools/reservoirs, pipes, footings for gates, fences, poles and even boats.

Famous concrete structures include the Burj Khalifa (world's tallest building), Hoover Dam, The Panama Canal and The Roman Pantheon.

Concrete technology was known by the Ancient Romans and was widely used within the Roman Empire – The Colosseum; is largely built of concrete and the concrete dome of the Pantheon is the world's largest. After the Empire passed, use of concrete became scarce until the technology was re-pioneered in the mid- 18th century. There are inorganic materials that also have pozzolanic or latent hydraulic properties. These very fine-grained materials are added to the concrete mix to improve the properties of concrete (mineral admixtures), or as a replacement of Portland cement (blended cements).

Self-compacting concrete (SCC) is a high – performance concrete that can flow under its own weight to completely fill the form work and self-consolidates without any mechanical vibration. Such concrete can accelerate the placement, reduce the labour requirements needed for consolidation, finishing and eliminate environmental pollution. The so called first generation SCC is used mainly for repair application and for casting concrete in restricted areas, including sections that present limited access to vibrate. Such value added construction material has been used in applications justifying the higher material and quality control cost when considering the simplified placement and

handling requirements of the concrete.

The successful production of self – compacting concrete (SCC) for use, is depended on arriving at an appropriate balance between the yield stress and the viscosity of the paste. Specially formulated high range water reducers are used to reduce the yield stress to point to allow the designed free flowing characteristics of the concrete. However, this alone may result in segregation if the viscosity of the paste is not sufficient to support the aggregate particles in suspension.

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CHAPTER 1

INTRODUCTION

1.1 GENERAL

Self-compacting concrete SCC is a fluid mixture, which is suitable for placing difficult conditions and also in congested reinforcement, without vibration. In principle a self-compacting or self – consolidating concrete must:

- ✓ Have a fluidity that allows self – compaction without external energy
- ✓ Remain homogeneous in a form during and after the placing process and
- ✓ Flow easily through reinforcement

Self-consolidating concrete has recently been used in the pre – cast industry and in some commercial applications, however the relatively high material cost still hinders the wide spread use of such specialty concrete in various segments of the construction industry, including commercial and residential construction.

Compared with conventional concrete of similar mechanical properties, the material cost of SCC is more due to the relatively high demand of cementation materials and chemical admixtures including high - range water reducing admixtures (HRWRA) and viscosity enhancing admixtures (VEA). Typically, the content in materials can vary between 450 and 525 kg/m^3 SCC targeted for the filling of highly restricted areas and for repair applications.

Such applications require low aggregate volume to facilitate flow among restricted spacing without blockage and ensure the filling of the formwork without consolidation. The incorporation of high volumes of finely ground powder materials is necessary to enhance cohesiveness and increase the paste volume required for successful casting of SCC.

Proper selection of finely ground materials can enhance the packing density of solid particles and enable the reduction of water or HRWRA demand required to achieve high deformability. It can also reduce viscosity for a given consistency; especially in the case of SCC made with relatively low Water – Binder ratio. Reducing the free water can decrease the VEA dosage necessary for stability. High binder content typically includes substitutions of cement with 20 to 40% fly ash or GGBS and, in some cases low contents of micro silica employed. The cost of SCC can be reduced through the selection of adequate concrete making materials and admixture constituents, including partial substitutions of cement and supplementary cementation materials by readily available fillers.

Regardless of its binder composition, SCC is characterized by its low yield value to secure high deformability, and moderate viscosity to provide uniform suspension of solid particles, both during casting and thereafter until setting. The mixture proportioning of SCC to simultaneously meet the various performance requirements at minimum cost involves the optimization of several mixture constituents that have a marked influence on performance. This process is quite complex and can be simplified by understanding the relative significance of various mixture parameters on key properties of SCC. This includes deformability, passing ability, filling capacity and segregation resistance.

As with any new technology, there was clearly a learning curve to overcome, and refinement of the materials and mix proportions used took care to finally achieve optimum performance. In Japan, self – compacting concretes are divided into three different types according to the composition of the mortar:

- ✓ Powder type
- ✓ Viscosity – modifying agent (stabilizer) type
- ✓ Combination type

For the powder type, a high proportion of fines produce the necessary mortar volume, while in the stabilizer type, fines content can be in the range admissible for vibrated concrete. The viscosity required to inhibit segregation will then be adjusted by using a stabilizer (Kosmatka et al., 2002). The combination type is created by adding a small amount of stabilizer to the powder type to balance the moisture fluctuations in the manufacturing process.

The SCC essentially eliminates the need for vibration to consolidate the concrete. This results in an increase in productivity, a reduction in noise exposure and a finished product with few if any external blemishes such as "bug holes", however, after completion of proper proportioning, mixing, placing, curing and consolidation, hardened concrete becomes a strong, durable, and practically impermeable building material that requires no maintenance.

1.2 BENEFITS AND ADVANTAGES

At present self – compacting concrete (SCC) can be classified as an advanced construction material. The ‘SCC’ as the name suggests, does not require to be vibrated to achieve full compaction. This offers benefits and advantages over conventional concrete:

- ✓ Improved quality of concrete and reduction of onsite repairs.

- ✓ Faster construction times.
- ✓ Lower overall costs.
- ✓ Facilitation of introduction of automation into concrete construction.
- ✓ Improvement of health and safety is also achieved through elimination of handling of vibrators.
- ✓ Substantial reduction of environmental noise loading on and around a site.
- ✓ Possibilities for utilization of "dusts", which are currently waste products and which are costly to dispose of.
- ✓ Better surface finishes.
- ✓ Easier placing.
- ✓ Thinner concrete sections.
- ✓ Greater Freedom in design.
- ✓ Improved durability, and reliability of concrete structures.
- ✓ Ease of placement results in cost savings through reduced equipment and labour requirement.
- ✓ SCC makes the level of durability and reliability of the structure independent from the existing on – site conditions relate to the quality of labour, casting and compacting systems available.
- ✓ The high resistance to external segregation and the mixture self – compacting ability allow the elimination of macro – defects, air bubbles, and honey combs responsible for penalizing mechanical performance and structure durability.

1.3 DEVELOPMENTS IN SCC

For several years beginning in 1983, the problem of the durability of concrete structures was a major topic of interest in Japan. The creation of durable concrete structures requires adequate compaction by skilled workers. The designs of modern reinforced concrete structures become more advanced, the designed shapes of structures are becoming increasingly complicated and heavy reinforcing is no longer unusual. Furthermore, the gradual reduction in the number of skilled workers in Japan's construction industry has led to a similar reduction in the quality of construction work. One solution for the achievement of durable concrete structure independent of the quality of construction work is the employment of self – compacting concrete, which can be compacted into every corner of a form work, purely by means of its own weight and without the need for vibrating compaction. Okamura proposed the necessity of this type of concrete in 1986. Studies to develop self – compacting concrete, including a fundamental study on the workability of concrete, have been carried out by "Ozawa and Maekawa" at the university of Tokyo.

The prototype of SCC was first completed in 1988 using materials already on the market. The proto type performed satisfactorily with regard to drying and hardening shrinkage, heat of hydration, denseness after hardening, and other properties. This concrete was named “High Performance Concrete" and was defined as follows at the three stages of concrete:

1. Fresh : Self-Compactable

2. Early age: Avoidance of initial defects.

3. After hardening: Protection against external factors.

"High Performance Concrete" was defined as a concrete with high durability due to a low water– cement ratio by professor Aitcin et al (Gangneetal 1989). Since then, the term high performance concrete has been used around world to refer to high durability concrete. Therefore, H.Okamura and M.Ouchi, the authors, of an invited paper on see for JACT 2003 have changed the term for the proposed concrete, for their work, to "Self – compacting High performance concrete".

1.4 MECHANICAL CHARACTERSTICS

- Characteristic compressive strength at 28 days shall be 25-60 MPa.
- Early age compressive strength shall be 5-20 MPa at 20-24 hours (Equivalent age at 20 degrees Celsius).
- "NORMAL" creep and shrinkage.

1.5 HOW DOES IT WORK?

A self-consolidating concrete must:

1) Have a fluidity that allows self – consolidation without external energy.
2) Remain homogenous in a form during and after the placing process and,
3) Flow easily through reinforcement.

To achieve these performances, Okamura redesigned the concrete mix design process. His mix design procedure focused on three different aspects:

I. Reduction of the aggregate content in order to reduce the friction, or the frequency of collisions between them increases the overall concrete fluidity.
II. Increasing the paste content to further increase fluidity.
III. Managing the paste viscosity to reduce the risk of aggregate blocking when the

concrete flows through obstacles.

In rheological terms, even though a significant amount of research tends to show that SCC's viscosity varies with the shear rate and acts as a pseudo plastic material, SCC is often described as Bingham fluid (visco- elastic) where the stress/shear rate ratio is linear and characterized by two constants – viscosity and yield stress.

Back to the performance based definition of SCC, the self –consolidation is mainly governed by yield stress, while the viscosity will affect the homogeneity and the ability to flow through reinforcement. As the SCC's viscosity can be adjusted depending on the application, the yield stress remains significantly lower than other types of concrete in order to achieve self –consolidation.

1.6 APPLICATIONS

Applications of self-compacting concrete in Japan:

Current conditions on application of self – compacting concrete in Japan.

After the development of the prototype of self – compacting concrete at the University of Tokyo, intensive research was begun in many places, especially in the research institutes of large construction companies. As a result, self – compacting concrete has been used in many practical structures. The first application of self – compacting concrete was in a building in June 1990. Self-Compacting concrete was then used in the towers of a pre stressed concrete cable – stayed bridge in 1992. Since then, the use of self-compacting concrete in actual structures has gradually increased. Currently, the main reasons for the employment of self – compacting concrete can be summarized as follows:

- **a)** To shorten construction period.
- **b)** To assure compaction in the structure: especially in confined zones where vibrating compaction is difficult.
- **c)** To eliminate noise due to vibration: especially at concrete products plants.

The production of self-compacting concrete as a percentage of Japanese ready mixed concrete, which accounts for 70% of total concrete production in Japan, is only 0.1%. The current status of self-compacting is 'special concrete 'rather than 'standard concrete'.

Other applications of self-compacting concrete are summarized below:

1) Bridge (anchorage, arch, beam, girder, tower, pier, joint between beam and girder).

2) Box culvert.

3) Building

4) Concrete filled steel column

5) Tunnel(lining, fill of survey tunnel & immersed tunnel)

6) Dam(concrete around structure)

7) Concrete products(box, culvert, wall, water tank , slab segment)

8) Diaphragm wall

9) Tank(side wall, joint between side wall and slab)

10) Fire proof

1.7 LARGE SCALE CONSTRUCTION

Self-Compacting concrete is currently being employed in various practical structures in order to shorten the construction period of large-scale constructions.

The anchorages of Akashi-Kalikyo (Akashi straits) Bridge opened in April 1998, a suspension bridge with the longest span in the world (1,991mts), is a typical example (Kashima 1999).Self-Compacting concrete was used in the construction of the two anchorages of the bridge. A new construction system that makes full use of the performance of self-compacting concrete was introduced for the purpose. The concrete was mixed at the batcher plant next to the site, and was then pumped out of the plant. It was transported 200mts through pipe to the casting site, where the pipes were arranged in rows 3 to 5mts apart. The concrete was cast from gate valves located at 5mts intervals along the pipes. These valves were automatically controlled so that the surface level of the cast concrete could be maintained. The maximum size of the coarse aggregate in the self-compacting concrete used at this site was 40mm the concrete fell as much as 3mts, but segregation did not occur, despite the size of coarse aggregate. In the final analysis the use of self-compacting concrete shortened the anchorage construction period by 20% from 2.5 to2 years.

Self-Compacting concrete was for the wall of a large LNG tank belonging to the Osaka gas company. The adoption of self-compacting concrete in this particular project had the following merits:

1. The number of lots decreased from 14 to 10 as the height of one lot of concrete was increased.
2. The number of concrete workers was reduced from 150 to 50.
3. The construction period of the structure decreased from 22to18 months.

1.8 NECESSITY FOR NEW STRUCTURAL DESIGNS AND CONSTRUCTION SYTSTEMS

Self-Compacting concrete saves the cost of vibrating compaction and ensures the compaction of the concrete in the structure. However, total construction cost cannot always be reduced, except in large – scale constructions. This is because conventional construction systems are essentially designed based on the assumption that vibrating compaction of concrete is necessary.

Self-Compacting concrete can greatly improve construction systems previously based on conventional concrete that required vibrating compaction. This sort of compaction, which can easily cause segregation, has been an obstacle to the rationalization of construction work. Once this obstacle is eliminated, concrete construction can be rationalized and a new construction system including form work, reinforcement, support and structural design, can be developed.

One example of this is the so called sandwich structure, where concrete is filled into a steel shell. Such a structure has already been completed in Kobe, and could not have been achieved without the development of self – compacting concrete (shishido et al, 1999).

CHAPTER 2

MATERIALS OF SCC

The materials used for SCC are selected from those by the conventional concrete industry. Typical materials used for SCC are coarse aggregate, fine aggregate, cement, mineral admixtures (fly ash, ground – granulated blast furnace slag), and chemical admixtures (super – plasticizer, viscosity – modifying agents). SCC can be designed and constructed using a broad range of normal concreting materials, and that this is essential for SCC to gain popularity.

2.1 MATERIALS

2.1.1 AGGREGATES

The coarse aggregate chosen for SCC is typically round in shape, is well graded, and smaller in maximum size than that used for conventional concrete typical conventional concrete could have a maximum aggregate size of 40 mm or more. In general, a rounded aggregate and smaller aggregate particles aid in the flow ability and deformability of the concrete as well as aiding in the prevention of segregation and deformability of the concrete as well as aiding in the prevention of segregation. Gradation is an important factor in choosing a coarse aggregate, especially in typical uses of SCC where reinforcement may be highly congested or the formwork has small dimensions. Gap – graded coarse aggregate promotes segregation to a greater degree than well-graded coarse aggregate. As with conventional concrete construction, the maximum size of the coarse aggregate for SCC depends upon the type of construction. Typically, the maximum size of coarse aggregate used in SCC ranges from approximately 10 mm to 20 mm.

Generally aggregates occupy 70% to 80% of the volume of concrete and have an natural rock (crushed stone, or natural gravels) and sands, although synthetic materials such as slag and expanded clay or shale are used to some extent, mostly in lightweight concretes (Miness et al.,2003). In addition to their use as economical filler, aggregates generally provide concrete with better dimensional stability and wear resistance. Although aggregate strength can play sometimes an important role, for example in high – strength concretes, for most applications the strength of concrete and mix design are essentially independent of the composition of aggregates.

However, in other instances, a certain kind of rock maybe required to attain certain concrete properties, e.g., high density or low coefficient of thermal expansion (Neville, 1993).

In order to obtain a good concrete quality, aggregates should be hard and strong, free of undesirable impurities, and chemically stable (Garberand Hoel, 1998). Soft and porous rock can limit strength and wear resistance, and sometimes it may also break down during mixing and adversely affect workability by increasing the amount of fines. Rocks that tend to fracture easily along specific planes can also limit strength and wear resistance (Neville, 1993). Aggregates should also be free of impurities like silt, clay, dirt or organic matter. If these materials coat, the surfaces of the aggregate, they will isolate the aggregate particles from the surrounding concrete, causing reduction in strength. Silt, clay and other fine materials will increase the water requirements of the concrete, and the organic matter interfere with the cement hydration.

All normal concreting sands are suitable for SCC. Both crushed and rounded sands can be used. Siliceous or calcareous sands can be used. The amount of fines less than 0.125 mm is to be considered as powder and is very important for the rheology of the SCC. A minimum amount of fines (arising from the binders and the sand) must be achieved to avoid segregation.

2.1.2 CEMENT

The most common cement currently used in construction is Type IIII Portland cement. This cement conforms to the strength requirement of a Type I and the C_3A content restriction of a Type II. This type of cement is typically used in construction and is readily available from a variety of sources. The Blaine fineness is used to quantify the surface area of cement. The surface area provides a direct indication of the cement fineness. The typical fineness of cement ranges from 350 to 500m^2/kg for Type I and Type III cements, respectively.

2.1.3 FLY ASH

Fly ash (or) pulverized fly ash is a residue from the combustion of pulverized coal collected by mechanical separators, from the fuel gases of thermal plants. The composition varies with type of fuel burnt, load on the boiler and type of separation. The fly ash consists of spherical glassy particles ranging from 1 to 150 micron in diameter and also passes through a 45-micron sieve. The constituents of fly ash are mentioned below:

Silicon dioxide	----- SiO_2	--- 30 – 60 %
Aluminium oxide	-----Al_2O_3	--- 15 - 30%
Unburnt fuel	----- (carbon)	--- up to 30%
Calcium oxide	-----CaO	--- 1 – 7%
Magnesium oxide	-----MgO	---small amounts
Sulphur trioxide	-----SO_3	---small amounts

Fly ash is one of the most extensively used by-product materials in the construction field resembling Portland cement (Pfeifer, 1969). It is an inorganic non-combustible, finely divided residue collected or precipitated from the exhaust gases of any industrial furnace.

Many class ‘e’ ashes when exposed to water will hydrate and harden in less than 45 minutes. In concrete, class Fly ash is often used at dosages of 15% to 25% by mass of cementitious material and class ‘e’ fly ash is used at dosages of 15% to 40% (Halstead, 1986). Dosage varies with the reactivity of the ash and the desired effects on the concrete (Mindess et al., 2003). Because of their spherical morphology, when using fly ash admixtures as replacement for cement, workability and long-term strengths are achieved in concretes. In such cases, they act like small balls to reduce inter particle friction. Fly ashes are also used in concrete mixes in order to reduce the heat of hydration, permeability, and bleeding. The durability is improved by providing a better sulphate resistance, control of the alkali-silica reduction, decreased chloride diffusion and reduction in calcium hydroxide (which is the most of the hydration products) and changes in pore structure. However, there are some disadvantages related to the use of fly ash regarding the reduced air entraining ability and early strength due to the influence of residual carbon from the ash (Gebler and Klieger, 1986).

2.1.4 GROUND GRANULATED BLAST FURNACE SLAG

Ground granulated blast-furnace slag is a non-metallic product consisting essentially of silicates and aluminates of calcium and other bases. The molten slag is rapidly chilled by quenching in water to form glassy sand like material. The granulated material when further ground to less than45 micron will have specific surface about 400 to 600m^2/kg. The chemical composition of blast furnace slag is similar to that of cement clinker:

Cao - 30 – 45%

SiO_2 - 17 – 38%

Al_2O_3 -15 – 25%

Fe_2O_3 - 0.5 – 2.0%

MgO- 4 – 17%

MnO_2- 1 – 5%

Glass- 85 – 98%

Specific Gravity- 2.9

The performance of slag largely depends on the chemical composition, glass content and fineness of grinding. The quality of slag is governed by IS-12089 of 1987.

2.1.5 MICRO SILICA

Silica fume also referred to as micro silica or condensed silica fume, is another material that is used as an artificial pozzolonic admixture. It is a product resulting from reduction of high purity quartz with coal in an electric and furnace in the manufacture of silicon or ferrosilicon alloy. Silica fume rises as oxidized vapours. It cools, condenses and is collected in cloth bags. It is further processed to remove impurities and to control particle size, condensed silica fume is essentially silicon dioxide (more than 90%) in non-crystalline form. since it an airborne material like fly ash, it has spherical shape. It is extremely fine with particle size less than I micron and with an average diameter of about 0.1 micron, about 100 times smaller than average cement particles. Silica fume has specific surface area of about 20,000m^2/kg, as against 230 to 300 m^2/kg that of cement.

2.1.6 SUPERPLASTICIZER

Super plasticizer is essential for the creation of SCC. The job of SP is to impart a high degree of flow ability and deformability, however the high dosages generally associate with see can lead to a high degree of segregation. Super plasticizer is a chemical compound used to increase the workability without adding more water i.e. spreads the given water in the concrete throughout the concrete mix resulting to form a uniform mix. Super plasticizer improves better surface expose of aggregates to the cement gel. Super plasticizer acts as a lubricant among the materials. Generally in order to increase the workability the water content is to be increased provided a corresponding quantity of cement is also added to keep the water cement ratio constant, so that the strength remains the same.

Super plasticizers (high-range water-reducers) are low molecular-water-soluble polymers designed to achieve high amounts of water reduction (12.30%) in concrete mixture in order to attain a desired slump (Gagne et al., 2000). These admixtures are used frequently to produce high- strength concrete (>50 Mpa), since workable mixes with water-cement ratios well below
0.40 are possible (Whiting, 1979). They also can be used with water reduction to produce concretes with very high slumps, in the range of 150 to 250 mm (6 to 10 inches). At these high slumps, concrete flows like a liquid and can fill forms efficiently, requiring very little vibration. These highly workable mixtures are called flowing concretes and require slumps to be in excess of 190mm (8.5 inches).

Water-reducing admixtures are negatively charge organic molecules that adsorb primarily at the solid-water interface, whereas solid particles carry residual charges on their surfaces, which may be positive, negative, or both (Russell, 1983). In cement paste, opposing charges on adjacent particles of cement can exert considerable electrostatic attractions, causing the particles to flocculate. A considerable amount of water is tied up in these agglomerates and adsorbed on the solid surfaces, leaving less water available to reduce the viscosity of the paste and hence that of the concrete. Molecules of the water reducing admixtures interact to neutralize these surface charges and because all surfaces to carry uniform charges of like sign (Mindess et al., 2003) Particles now repel each other, rather than attract, and remain fully dispersed in the paste, thus most of the water is available to reduce the viscosity of the paste and of the concrete. Because super plasticizers have air-determining properties, an air-entraining agent must be added to the concrete to get a stable air void system before a super plasticizer is added (Gagne et al., 1996).

Some high range water reducing admixtures can retard final set by one to four hours and if prolonged setting times are not convenient, the admixture can be combined with an accelerating admixture to counteract the retarding tendencies or even to provide some acceleration of setting. When water reducing admixtures are used in concrete mixtures, some increases in compressive strength can be anticipated and these increases can be observed in as early as one day if excessive retardation does not occur. It is generally agreed that increases in compressive strength are up to 25% greater than would be anticipated from the decrease in water content and cement dispersion (Ozyilirim, 2003). The reduction of the water cement ratio and the creation of a more uniform pore structure mean that the permeability of concrete can be reduced by the use of super plasticizers & improved durability is achieved.

2.1.7 ROLE OF SUPERPLASTICIZER

We know that the main action of SP is to fluidity the mix and improve the workability of concrete. Port land cement, being in fine state of division will have a tendency to flocculate in wet concrete. This flocculation's entraps certain amount of water used in the mix and there by all the water is not freely available to fluidity the mix. When plasticizers are used, they get absorbed on cement particles. The absorption of charged polymer on cement particle creates particle to particle repulsive forces, which overcome the attractive forces. This repulsive force is called zeta potential, which depends on the base, solid contents and quality of super plasticizer used. The overall result is that the cement particles are deflocculated and the water trapped inside the flocks gets released and now available to fluidity the mix.

CHAPTER 3

PROPERTIES OF SELF-COMPACTING CONCRETE

Requirements of constituent materials and factors influencing SCC are furnished in this part of the project report.

3.1 REQUIREMENTS FOR CONSTITUENT MATERIALS

3.1.1 CEMENT

All types of cement conforming to EN 197 are suitable. Selection of the type of cement will depend on the overall requirements for the concrete, such as strength, durability etc.; C_3A content higher than 10% may cause problems of poor workability retention. The typical content of cement is 350-450 kg/m^3.

More than 500Kglm^3 cement can be dangerous and increase the shrinkage. Less than 350 Kglm^3 may only be suitable with the inclusion of other fine filler, such as fly ash, pozzolana, etc.

3.1.2 AGGREGATES

3.1.2.1 SAND

All normal concreting sands are suitable for SCC. Either crushed or rounded sands can be used. Siliceous or calcareous sands can be used. The amount of fines less than 0.125 mm is to be considered as powder and is very important for the rheology of the SCC. A minimum amount of fines (arising from the binders and the sand) must be achieved to avoid segregation.

3.1.2.2 COARSE AGGREGATE

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

Regarding the characteristics of different types of aggregate, crushed aggregates tend to improve the strength because of the interlocking of the angular particles, whilst rounded aggregates improve the flow because of lower internal friction. Gap graded aggregates are frequently better than those continuously graded, which might experience greater internal friction and give reduced flow.

3.1.3 ADMIXTURES

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

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

3.2 PROPERTIES OF FRESH SCC

3.2.1 WORKABILITY

The level of fluidity of the SCC is governed chiefly by the dosing of the super plasticizer; however overdosing may lead to the risk of segregation and blockage. Consequently the characteristics of the fresh SCC need to be carefully control using preferably two of the different types of test.

3.2.2 SEGREGATION RESISTANCE

The level of fluidity of the SCC is governed chiefly by the dosing of the super plasticizer; however overdosing may lead to the risk of segregation and blockage. Consequently the characteristics of the fresh SCC need to be carefully control using preferably two of the different types of test.

3.2.3 OPEN TIME

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

3.3 PROPERTIES OF HARDENED SCC

3.3.1 COMPRESSIVE STRENGTH

In all SCC mixes compressive strengths of standard cube specimens were comparable to those of traditional vibrated concrete made with similar water-cement ratios – if anything strengths were higher.

In-situ strengths of SCC are similar to those of traditional vibrated concrete, indeed somewhat higher when limestone powder is used as filler, probably because of a densifying mechanism and the observed lower susceptibility to imperfect curing, both attribute to this type of filler.

The in-situ strengths of both types of civil engineering concrete, SCC and traditional vibrated concrete were closer to standard cube strengths than those of the housing mixes again; this is typical of higher strength concrete.

In vertical element, in-situ strengths of both SCC and traditional vibrated concrete are higher at the bottom than at the top, vibration of in-situ strengths, for both types of concrete is much lower in horizontal elements, in this case the beams. These observations are characteristic of traditional vibrated concrete. The in-situ strengths of elements cast and cured outdoors in winter (the beams), whether SCC or conventional, were lower than those cast indoors at the same time (the columns).

Overall, we might conclude that the fresh self-compacting properties of the concrete have little effect on the in-situ strengths.

3.3.2 TENSILE STRENGTH

Tensile strength was assessed indirectly by the splitting test on cylinders. For SCC, both the tensile strengths themselves, and the relationships between tensile and compressive strengths were of a similar order to those of traditional vibrated concrete.

3.3.3 BOND STRENGTH

The strength of the bond between concrete and reinforcement was assessed by pull-out tests, using deformed reinforcing steel of two different diameters, embedded in concrete prisms. For civil engineering and housing categories, the see bond strengths, related to the standard compressive strengths, were higher than those of the reference concrete were.

3.3.4 MODULUS OF ELASTICITY

Results available indicate that the relationships between static modulus of elasticity and compressive strengths were similar for SCC and the reference mixes. A relationship in the form of E/ (f_c) 0.5 has been widely reported, and all values of this ratio were close to the one recommended by ACT for structural calculations for normal weight traditional vibrated concrete.

3.3.5 FREEZE-THAW RESISTANCE

This property was assessed by loss of ultrasonic pulse velocity (UPV) after daily cycles of 18 years at 30^{o}C and 66 hours at room temperature. No significant loss of UPV has been observed after 150 cycles for the SCC or reference higher strength concrete (the civil engineering mixtures).

3.3.6 SHRINKAGE AND CREEP

None of the results obtained indicates that the shrinkage and the creep of the SCC mixes were significantly greater than those of traditional vibrated concrete.

3.3.7 SOME ASPECTS OF DURABILITY

Elements of all types of concrete have been left exposed for future assessment of durability but some preliminary tests have been carried out. The permeability of the concrete, a recognized indicator of likely durability, has been examined by measuring the water absorption of near surface concrete. The results suggest that in the SCC mixes, the near surface concrete was denser and more resistant to water ingress than in the reference mixes. Carbonation depths have been measured at one year. The civil mixes (both SCC and reference) show no carbonation. The evidence in hand and data from other source suggest that the durability performance of SCC is likely to be equal or better than that of traditional vibrated concrete.

3.3.8 STRUCTURAL PERFORMANCE

The structural performance of the concrete was assessed by loading the full-size reinforced columns and beams to failure.

For the columns, the actual failure load exceeded the calculated failure load for both types of concrete (SCC and traditional vibrated concrete).

For the beams the only available comparison is between see and traditional vibrated concrete in the civil engineering category. Here the behaviour of the two concretes in terms of cracking moment, crack width and load-deflection was similar.

3.4 FACTORS INFLUENCING SCC

3.4.1 MORTAR

Mortar also plays a vital role as solid particle in SCC. This property is so called “pressure transferability" which can be apparent when the coarse aggregate particles approach each other and mortar is in between coarse aggregate particles. Here the mortar is subjected to normal stress. The degree of the decrease in shear deformability of mortar largely depends on the physical characteristics of the solid pattern in the mortar. It was found that the relation between the flow ability of mortar and concrete couldn’t always be same due to differences in the characteristics of the solid particles in the mortar.

3.4.2 COARSE AGGREGATE SHAPE AND GRADING

The influence of coarse aggregate on self-compaction of fresh concrete is more. Proper care should be taken while grading the coarse aggregate, whereas presence of more uneven size of aggregate may lead to the blockage of concrete due to the action of internal sources.

3.4.3 WATER POWDER RATIO AND S.P. DOSAGE

The characteristics of powder and S.P. largely affect the mortar property and so the proper water powder ratio and S.P. dosage cannot be fixed without trail mixing. Therefore once the mix proportion is decided self-compatibility has to be formulated, so that we can establish a rational method for adjusting the water to powder ratio and S.P. dosage to achieve appropriate deformability and viscosity.

3.4.4 WORKABILITY

Workability is a measure of ease by which fresh concrete can be placed and compacted. It is a complex combination of aspects of fluidity, cohesiveness, transportability, compact ability and stickiness. A good SCC shall normally reach a slump flow value exceeding 60cm without segregation. Following are the requirements for good workability in SCC:

- If required, SCC should remain flow able and self-compactable for at least 90 minutes.
- If required, SCC shall be able to with stand a slope of 3% in case of free horizontal surface.
- If required, SCC shall be pumpable for at least 90 minutes and through pipes with a length of at least 100 meters.

CHAPTER 4

MIX DESIGN PROPORTION

1. C.A. and F.A. are fixed so that self-compact ability can be achieved by adjusting water cement ratio and super plasticizer dosage only.

2. C.A. is 50% of solid volume

3. F.A. is 40% of mortar volume

4. Water cement ratio not more than 50 percent

5. Rheology approach – It involves large in expansive equipment suitable for lab which measure expansive diameter after fresh and hardened concrete.

6. Fresh approach – It involves in situ tests. The most suitable one. It is fast, reliable and flexible according to conditions.

7. High Fine Approach

8. Fill paste of binder in voids of loosely bonded aggregate. As the concrete loses heat the single bond of polymer converts to triple bond.

9. Workability of SCC is provided by binding paste at fresh state.

10. Only approach which works on chemical state rather physical state.

4.1 EFNARC PROPOSALS

An example of a procedure for efficiently designing SCC mixes is shown below. It is based on a method developed by Okamura. It is important to appreciate that this method may result in parameters which differ from those in Chapter.

The sequence is determined as:

i. Designation of desired air content (mostly 2 %)
ii. Determination of coarse aggregate volume
iii. Determination of sand content
iv. Design of paste composition
v. Determination of optimum water: powder ratio and superplasticizer dosage in mortar
vi. Finally the concrete properties are assessed by standard tests.

- Air content may generally be set at 2 per cent, or a higher value specified when freeze thaw resistant.
- Coarse aggregate volume is defined by bulk density. Generally coarse aggregate content (D> 4 mm) should be between 50 per cent and 60 per cent. When the volume of coarse aggregate in concrete exceeds a certain limit, the opportunity for collision or contact between coarse aggregate particles increases rapidly and there is an increased risk of blockage when the concrete passes through spaces between steel bars.

The optimum coarse aggregate content depends on the following parameters:

a) Maximum aggregate size. The lower the maximum aggregate size, the higher the proportion of coarse aggregate.
b) Crushed or rounded aggregates. For rounded aggregates, a higher content can be used than for crushed aggregates.

- Sand, in the context of this mix composition procedure is defined as all particles larger than 0.125 mm and smaller than 4 mm. Sand content is defined by bulk density. The optimal volume content of sand in the mortar varies between 40 – 50 % depending on paste properties. Specification & Guidelines for Self-Compacting Concrete.

- Initially the water: powder ratio for zero flow (b_p) is determined in the paste, with the chosen proportion of cement and additions. Flow cone tests with water/powder ratios by volume of e.g. 1: 1, 1:2, 1:3 and 1:4 are performed with the selected powder composition, see Figure A.1for typical results. The point of intersection with the y - axis is designated the b_p value. This b_p value is used mainly for quality control of water demand for new batches of cement and fillers.

- Tests with flow cone and V-Funnel for mortar are performed at varying water/powder ratios in the range of [0.8 – 0.9]. b_p and dosages of superplasticizer. The superplasticizer is used to balance the rheology of the paste. The volume content of sand in the mortar remains the same as determined above.

Target values are slump flow of 24 to 26 cm and V-Funnel time of 7 to 11 seconds. At target slump flow, where V-funnel time is lower than 7 seconds, then decrease the water/powder ratio. For target slump flow and V-funnel time in excess of 11 seconds, water/powder ratio should be increased. If these criteria cannot be fulfilled, then the particular combination of materials is inadequate. A trial with a different superplasticizer is the preferred alternative. Second alternative is a new additive, and as a last resort with different cement.

4.2 MIX DESIGN

1. Characteristic compressive strength required in the field at 28-days : 30Mpa
2. Maximum size of aggregate : 12.5mm (rounded)
3. Degree of workability : 0.9(compaction factor)
4. Degree of Quality Control : Good
5. Type of Exposure : Severe

4.2.1 TEST DATA ON MATERIALS

1. Specific gravity of cement : 3.01
2. Compressive strength at 7-days : Satisfies the req. of IS-269:1989(37 N\mm^2)
3. Specific gravity of C.A. : 2.625
4. Specific gravity of F.A. : 2.613
5. Water absorption for C.A. : 0.5%
6. Water absorption for F.A. : 1.0%
7. Free surface moisture for C.A. : NIL
8. Free surface moisture for F.A. : 2.0%
9. Fineness modulus of C.A. : 6.15
10. Fineness modulus of F.A. : 2.72

4.3 STEPS IN MIX PROPORTIONING

4.3.1 TRAIL MIX-1

1) Target mean strength for M30 grade concrete

$$f_{ck*} = f_{ck} + Ks$$

$$f_{ck*} = 30+1.65*6.0= 39.9 N/mm^2$$

Where,

K= probability factor for various tolerances (5%) = 1.65 from table 10.4

S = Standard deviation for different degrees of control (Good) =6.0 from table 10.6 2.

2) The water: cement ratio required for the target mean strength of 39.9 MPa is 0.38

3) Selection of water and sand content for 12.5mm maximum size aggregate and the sand confirming to ZONE –II.

- For W/C-0.6,C.F-0.8,angular,sand confirming to ZONE-II.

  a) Water content per m^3 of concrete = 208 $l\backslash m^3$

  b) Sand content as percentage of total aggregate by absolute volume = 62%

  c) C.F. = 0.9

- Corrections:

Change in Condition	Water	Sand
W/C(0.6-0.38=0.22)	0	-4.4%
C.F.=0.1	+3%	0
Rounded	-15kg	-7%
Zone-2	0	0

Table 1

The corrected water content per cubic meter of concrete:

208+ {(3/100) x208}-15 = 199.241 l/m^3

The corrected sand content as percentage of total aggregate by absolute volume:

62%- 11.4% = 50.6%

4) Water/Cement = 0.38

Water = 199.241 l\m^3

Cement = 199.24 kg\m^3

5) Determination of coarse and fine aggregate contents for the specified maximum aggregate size of 12.5 mm, the amount of entrapped air in the wet concrete is 3%, taking this in to account and applying equations:

V= [W/SW+C/SC+ fa/ (P*SFA)]*1/1000; V= [W/SW+C/SC+Ca/ ((1-p)*SCA)]*1/1000

0.97= [199.24+ (524.31/3.01) fa/ (0.506*2.613)]*1/1000

F_a=788.77kg/m^3

0.97= [199.24+ (524.31/3.01) +Ca/ ((1-0.506)*2.625)]*1/1000.

C_a=773.06kg/m^3.

The mix proportion then becomes:

Cement	**Sand**	**Coarse aggregate**	**Water**
524.31kg	788.77kg	773.06kg	199.24
1	1.5	1.47	0.38

Table 2

The obtained contents of cement, sand, aggregate and water per cubic meter of concrete are listed below:

Cement	**=**	**524.31 kg**
Sand	**=**	**788.77 kg**
C.A.	**=**	**773.06 kg**
Water	**=**	**199.24**

Converting into SCC Proportions:

The normal concrete mix proportions are modified as per EFNARC specifications and different trail mixes and caste. By considering the fresh properties and harden properties of the mixes we finally arrived at the SCC mixed proportions as:

Cement	**= 524.31**
F.A.	**= 788.77**
C.A.	**= 773.06**

Total aggregate (T.A) = 788.77+773.06 = 1561.83

Taking 56% of T.A as F.A

F.A= 1561.830*0.56 = 874.62 Kg/m^3

C.A =687.2kg/m^3

The modified proportion is:

Cement	**Sand**	**C.A.**	**Water**
524.31kg	87462kg	687.2kg	199.24
1	1.67	1.31	0.38

Table 3

Further in the trail mix-1 cementation material is taken as 270kg/ m^3 of cement, 148.5kg/ m^3

(55%) of fly ash, 108kg/ m^3 (40%) of GGBS and 2.7kg/ m^3 (1% addition) of micro silica is used.

The water/cementations material is 0.38

The fine aggregate/total aggregate is 62%

The contents of cement, fly ash, GGBS, micro silica, fine aggregate, coarse aggregate, water, SP 430, VMA are listed below:

Cement = 270kg/ m^3

Fly ash = 148.5kg/ m^3

GGBS = 108kg/ m^3

Micro silica = 2.7kg/ m^3

Fine aggregate = 788.77kg/ m^3

Coarse aggregate = 773.06kg/ m^3

Water = 200.98 lit/ m^3

SP 430 = 13.23 lit/ m^3

VMA = 1.85lit/ m^3

SP430 dosage = 2.5% of cementation materials

VMA = 0.35% of cementation materials

4.3.2 FINAL MIX

1) Target mean strength for M30 grade concrete :

$$\mathbf{f_{ck} = f_{ck} + Ks}$$

$$\mathbf{f_{ck} = 30+1.65*6.0 = 39.9\ N/mm^2}$$

K=probability factor for various tolerances (5%) =1.65

S=standard deviation for different degrees of control (good) =6.0

2) The water cement ratio required for the target mean strength of 39.9 Mpa is 0.38

3) Selection of water and sand content for 12.5mm maximum size aggregate and the sand confirming to ZONE-II

For W/C-0.6,C.F-0.8,angular,sand confirming to ZONE-II

- **a)** Water content per m^3 of concrete = 200 l/m^3
- **b)** Sand content as % of T.A. by absolute volume = 58%
- **c)** C.F. = 0.9 and take W/C = 0.42

- Corrections:

Change in condition	Water	Sand
W/C (0.6-0.41=0.19)	0	-3.8%
C.F + 0.1	+3%	0
Rounded	-15Kg	-7%
Zone – 2	0	0

Table 4

The corrected water content per cubic meter of concrete :

200 + ((3/100)*200) – 15 =191.00 1/m^3

The corrected sand content as percentage of total aggregate by absolute volume:

57 % - 10.8 % = 46.2 %

4) Determination of cement content:

Water/cement = 0.41

Water = 191.00 1/m3

The cement content = 191.00/0.41 = 465.85 kg/ m^3

5) Determination of coarse and fine aggregate contents for the specified maximum aggregate size of 12.5mm, the amount of entrapped air in the wet concrete is 3%, taking this into account and applying equations:

V= [W/SW+C/SC+f_a/ (p*SFA)]*1/1000; V= [W/SW+C/SC+C_a/ ((1-p)*SCA)]*1/1000

0.97= [191.00+ (465.85/3.01) +f_a/ (0.46*2.613)]*1/1000.

f_a=750.31Kg/m^3

0.97= [191.00+ (465.85/3.01) +C_a/ ((1-0.46)*2.625)]*1/1000.

C_a=884.85 Kg/m^3

The mix proportion then becomes:

Cement	**Sand**	**Coarse Aggregate**	**Water**
465.85Kg	750.31Kg	884.85Kg	191.00
1	1.61	1.90	0.41

Table 5

The obtained contents of cement sand aggregate and water per cubic meter of concrete are listed below:

Cement	=	**465.85Kg**
Sand	=	**750.31Kg**

Coarse aggregate **=** **884.85Kg**

Water **=** **191.00 Kg**

Converting into SCC proportions:

The normal concrete mix proportions are modified as per EFNARC specifications and different trail mixes and casted. By considering the fresh properties and harden properties of the mixes we finally arrived at the SCC mixed proportions as

Cement = 465.85Kg

Sand = 750.31Kg

Coarse aggregate = 884.85Kg

Total aggregate = 750.31 + 884.85 = 1635.16kg

Taking 56% of T.A as F.A

F.A = 1635.16 x 0.56 = 915.69 Kg/m^3

C.A = 719.47 Kg/m^3

The modified proportion is:

Cement	**Sand**	**Coarse Aggregate**	**Water**
465.85Kg	915.69 Kg	719.47 Kg	191.00
1	1.96	1.54	0.41

Table 6

Further in the trail mix-3 cementation material is taken as 240kg/ m^3 of cement 132 kg/ m^3

(55%) of fly ash, 96 kg/ m^3 (40%) of GGBS and 2.4 kg/ m^3 (1%) of micro silica is used

The water/cementation material is 0.41

The fine aggregate/total aggregate is 56%

The contents of cement, fly ash, GGBS, micro silica, fine aggregate, coarse aggregate, water SP 430 and VMA are listed below:

Cement	**=**	**240 Kg/ m^3**
Fly ash	**=**	**132 Kg/ m^3**
GGBS	**=**	**96 Kg/ m^3**
Micro silica	**=**	**2.4 Kg/ m^3**
Fine aggregate	**=**	**915.69 Kg/ m^3**
Coarse aggregate	**=**	**719.47 Kg/ m^3**
Water	**=**	**191.88 lit / m^3**
SP 430	**=**	**11.7 lit/ m^3**
VMA	**=**	**1.6 lit/m^3**
SP 430 dosage	**=**	**2.5% of cementation materials**
VMA	**=**	**0.35% of cementation materials.**

4.3.3 RATIO OF MIX PROPORTIONS BY WEIGHT

Mix	Grade Of Cement	Cement	F.A	C.A	Fly ash	GGBS	Micro Silica	Sp 430 Dosage	VMA Dosage
SCC	M30	1.0	3.81	3.0	0.55	0.4	0.01	0.050	0.007

Table 7

CHAPTER 5

SELF-COMPACTING CONCRETE TESTS

5.1 INTRODUCTION

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

Existing rheological test procedures have not been considered here, through the relationship between the results of these tests and the rheological characteristics of concrete is likely to figure out highly in future work, including standardization work. Many of the comments made come from the experience of the partners in the EU-funded research project on SCC. A further EU project on test methods is about too far destart. In considering these tests, there are number of points which should be taken in to account:

- One principal difficulty in devising such tests is that they have to assess three distinct, though related, properties of fresh SCC, its filling ability(flow ability),its passing ability(free from blocking at reinforcement),and its resistance to segregation(stability).No single test so far devised can measure all three properties.
- There is no clear relation between test results and performance on site.
- There is little precise data, therefore no clear guidance on compliance a limits.
- Duplicate tests are advised.
- Different test values may be appropriate for concrete being placed in vertical and horizontal elements
- The test methods and values are started for maximum aggregate size of up to 20

mm; different test values and for different equipment dimensions may be appropriate for other aggregate sizes.

- Similarly different test values may be appropriate for different reinforcement densities.
- In performing the tests, concrete should be sampled in accordance with EN12350-1. It is wise to mix the concrete first with a scoop, unless the procedure indicates otherwise.

5.2 SLUMP FLOW TEST

Slump flow is one of the most commonly used SCC tests at the current time. This test involves the use of slump cone used with conventional concretes as described in ASTM C-143(2002).The main difference between the slump flow test and ASTM C-143 is that the slump flow test measures the "spread" or "flow" of the concrete sample once the cone is lifted rather than the traditional "slump" (drop in height) of the concrete sample. The T_{50} test is determined during the slump flow test. It is simply the amount of time the concrete takes to flow to a diameter of 50 centimetres .Typically, slump flow values of approximately 24 to 30 inches are within the acceptable range; acceptable T_{50} times range from 2 to 5sec.

5.2.1 APPARATUS

1. Mould in the shape of a truncated cone with the internal dimensions 200mm diameter at the base,100mm diameter at the top and height of 300 mm, conforming to EN12350-2

2. Base plate of 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 500 mm diameter.

3. Trowel.

4. Scoop.

5. Ruler

6. Stopwatch.

<u>SLUMP FLOW APPARATUS</u>

<u>FIGURE 1</u>

5.2.2 <u>PROCEDURE</u>

1. Dampen slump flow table and slump cone.

2. Level the slump flow table

3. Place cone on the centre of the table that has a circle having a diameter of 50 centimetres drawn concentrically to the location for the slump cone.

4. Using funnel and with one person holding cone down(as to avoid concrete pushing itself underneath the cone),continuously fill the cone with a representative sample concrete from bucket

5. Screed and level the concrete from the top of the cone as to ensure the proper amount of concrete is within the cone.

6. Immediately remove the funnel.

7. Measure the final diameter of concrete in two perpendicular directions.

8. Record the slump flow as the average of two measurements.

5.2.3 INTERPRETATION OF RESULTS

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

In case of severe segregation most coarse aggregate will remain in the centre of the pool of concrete and mortar and cement paste at the concrete periphery. In case of minor segregation border segregation a border of mortar without coarse aggregate can occur at the edge of the pool of concrete. If none of these phenomena appear it is no assurance that segregation will not occur since this is a time related aspect that can occur after a longer period.

FIGURE 2

5.3 <u>L-BOX TEST</u>

The L-box value is the ratio of levels of concrete at each end of the box after the test is complete at each end of the box after the test is complete. The L-box consists of a "chimney "section and a "trough "section after the test is complete, the level of concrete in the chimney is recorded as H1,the level of concrete in the trough is recorded as H2.The L-box value(also referred to as the "L-box ratio", "blocking value", or "blocking ratio")is simply H2/H1. Typical acceptable values for the L-box value are in the range of 0.8 to 1.0.If the concrete was perfectly level after the test is complete, the L-box value would be equal to 1.0. Conversely, if the concrete was too stiff to flow to the end of the trough the L-box value would be equal to zero.

5.3.1 <u>APPARATUS</u>

a. L-Box of a stiff non absorbing material
b. Trowel
c. Scoop
d. Stop watch

5.3.2 <u>PROCEDURE</u>

1. Dampen all surfaces of the L-box that will be in contact with concrete.

2. Make sure that the gate is restrained as to avoid premature flow of concrete through the L-box.

3. Continuously fill the upper portion of the L-box with a representative sample concrete from a bucket.

4. Screed the concrete from the top of the box so as to ensure that proper amount of concrete is within the apparatus.

5. Promptly open/lift the gate to allow the flow of concrete through the L-box.

6. Once the concrete has ceased to flow (not more than 1 min from the lifting of the gate) measure the height of concrete at the "trough" end (H_2) and at the "chimney" end (H_1) of the L-box.

7. The L-box ratio is calculated as H_2/H_1.

L-BOX APPARATUS

FIGURE 3

5.3.3 INTERPRETATION OF RESULT

If the concrete flows as freely as water, at the rest it will be horizontal, so H_2/H_1=1. Therefore the nearer this test value, the "blocking ratio" is to unity, the better the flow of concrete. The EU research team suggested minimum acceptable values have been generally agreed. Obvious blocking of coarse aggregate behind the reinforcing bars can be visually detected.

5.4 V-FUNNEL TEST

V-funnel test is used to determine the filling ability (flow ability) of the concrete with a maximum aggregate size of 20 mm. The funnel is filled with about 12 litres of concrete and the time taken for it to flow through the apparatus is 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.

5.4.1 APPARATUS

a. V-funnel
b. Bucket
c. Trowel
d. Scoop
e. Stop watch

5.4.2 PROCEDURE

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

9. The procedure for the flow time at T_5 minutes.

10. Do not clean or moisten the inside surfaces of the funnel again.

11. Close the trap door and refill the funnel immediately after measuring the flow time.

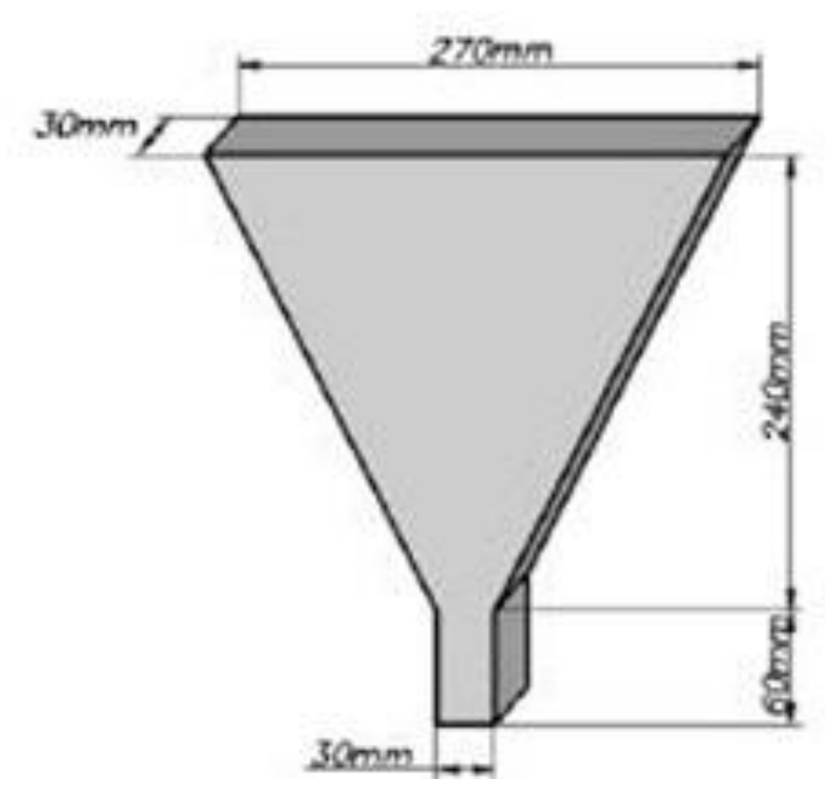
12. Place a bucket underneath.

13. Fill the apparatus completely with concrete without compacting or tapping.

14. Level the top with a trowel.

15. Open the trap door 5 minutes after the second fill of the funnel and allow the concrete to flow out under gravity.

16. Simultaneously start the stopwatch when the trap door is opened and record the time for the discharge to complete (the flow time at T_5 min). This is taken to be when light is seen from above through the funnel.



SCHEMATIC DIAGRAM OF V-FUNNEL

FIGURE 4

5.4.3 INTERPRETATION OF RESULT

This test measures the ease of flow of the concrete; shorter flow time indicates greater flow ability. For SCC a flow time of 10 seconds is considered appropriate. The inverted cone shape restricts flow, and prolonged flow times may give some indication of the susceptibility of the mix to blocking.

After 5 minutes of settling, segregation of concrete will show a less continuous flow with an increase in flow time.

5.5 COMPRESSIVE STRENGTH TEST

Compressive strength of concrete is defined as the load, which causes the failure of a standard specimen (Ex 100 mm cube according to ISI) divided by the area of cross-section in uniaxial compression under a given rate of loading. The test of compressive strength should be made on 150mm size cubes.

In the compressive test the cubes while cleaned to wipe off the surface water, is placed with the cast faces in contact with the planks of testing machine, i.e. , the position of the cube when tested is at right angles to that as cast. The test was conducted at 7, 14 and 28 days conforming to IS: 516-1959. The ages shall be calculated from the time of addition of water of the dry ingredients. The load application on the cube should be done at a constant rate of stress equal to 0.2 to 0.4 MPa per second as specified in BIS 1881: Part 116:1983. The strain rate must be progressively increased as failure is approached because of the non-linear relation between the stress and strain of concrete. The compressive strength is reported to the nearest 0.5 MPa.

COMPRESSIVE STRENGTH TESTING

FIGURE 5

FIGURE 6

5.6 SPLIT TENSILE STRENGTH TEST

A concrete cylinder of size 150mm diax200mm height is subjected to the action of the compressive force along two opposite edges, by applying the force in this manner .The cylinder is subjected to compression near the loaded region and the length of the cylinder is subjected to uniform tensile stress.

$$T = {}^{2P}/_{\pi l d}$$

Where:

♦ T = splitting tensile strength, kPa

♦ P = maximum applied load indicated by the testing machine, kN

♦ l = length, m

♦ d = diameter, m

FIGURE 7 **FIGURE 8**

SPLIT TENSILE STRENGTH TEST

5.7 PREPARATION OF SCC SPECIMENS

1) PROPORTIONING

The quantity of cement, fine and coarse aggregates, fly ash, water and S.P. for each batch of proportion is prepared as mentioned in the mix design of SCC.

2) MIXING OF CONCRETE

Mixing of concrete was carried out by machine. Machine mixing is not only efficient but also economical. Before the materials are loaded in to drum about 25 percent of the total quantity of water required for mixing is poured in to the mixer drum and to prevent any sticking of cement on the bodies or at the bottom of the drum.

Then discharging all the materials i.e. coarse aggregate and cement in to the drum. Immediately after discharging the dry material in to the drum the remaining 75 percent of water is added to the drum .The time is counted from the moment all the materials are placed particularly the complete quantity of water is fed in to the drum.

3) MOULDS

The concrete is casted in to cube moulds of size l00mmxl00mm,beam moulds of size l00xl00x500mm and cylindrical moulds of 200 mm height xl50 mm dia. The moulds used for the purpose are fabricated with steel seat. It is easy for assembling and removal of the mould specimen without damage. Moulds are provided with base plates, having smooth to support. The mould is filled without leakage .In assembling the moulds for use joints between the section of the mould are applied with a thin coat mould oil and similar coating of mould oil is applied between the contact faces of mould and the base plate to ensure that no water escape during filling .The interior surfaces of the assembled mould shall be thinly coated with mould oil to prevent adhesion of concrete.

CUBE MOULD **CYLINDRICAL MOULD**

FIGURE 9

4) PLACING OF MIX IN MOULDS

After mixing the proportions in the mixing machine, it is taken out into the bucket. The concrete is placed in to the moulds (cubes, beams & cylinders), which are already oiled simply by means of hands only without using any compacting devises.

5) CURING

After 24 hours the specimens were removed from the moulds and immediately submerged in clean fresh water and kept there until taken out just prior to testing.

CHAPTER 6

THE CONCRETE WHICH STICKS & FIX

These days the SCC has found the new dimension in the grouting technology. As we know the gouts only have cement, water and fine sand which results in low compressive strength. Introducing very fine gravels talc powder, bentonite, welan gums, accelerators like calcium chloride rheobuild and rheomac will result in the grout which behaves like SCC but have the mobility much greater than it; also it will result in less bleeding and greater resistance to pressured filtration. This new concept will remove the necessity of low pressure grouting such as consolidation grouting and the grout will easily penetrate cracks in the rock strata. For tunnels it will result in more adhesion with rocks maintaining cohesion with less particle segregation. This concrete also has higher shear strength which is necessary for Head-race tunnels, audits and surge-shafts. Right now there is no IS code which provides specifications for high mobility grouts. Also the behaviour of fluids that are Newtonian and Binghamian fluids and also their rheology is not discussed anywhere in IS codes, so the scientific work on this application totally comes from research papers by M. Chuaqui, D.A. Bruce and the scientific paper of cement based grout for the use of gravel in packing models by Mohammed Hatem Mohammed, Roland Pusch, Naadheer-Al- Ansari and Sven Knutsson. This scientific paper is the junction between the SCC and the High Mobility Grouts which not only fills the gaps between the rock strata but also has the application of high normal stress and shear stress and also uses PALYGORSKITE morphology which believes in the Eigen packing and results in the grout with high compression strength.

CHAPTER 7

CONCLUSIONS

Based on the investigation conducted for the study of behaviour of self-compacting concrete the following conclusions are arrived:

1. As no specific mix design procedures for SCC are available, mix design can be done with conventional BIS method and suitable adjustments can be done as per the guidelines provided by different agencies.
2. Trail mixes have to be made for maintaining flow ability, self-compatibility and obstruction clearance.

FOR FINAL MIX:

Compressive strength of hardened concrete after 3 days = 19.8 N/mm^2

Compressive strength of hardened concrete after 7 days = 23.94 N/mm^2

Compressive strength of hardened concrete after 28 days=38.91 N/mm^2

Tensile strength of hardened concrete after 28 days = 3.47N/mm^2

SLUMP FLOW VALUES:

Serial No.	**T_{50} (in seconds)**	**Flow Value (mm)**
1.	5	632

2.	3.5	705
3.	4.5	664

Table 8

L-BOX VALUES:

Serial No.	L-Box Value
1.	**0.79**
2.	**0.80**
3.	**0.82**

Table 9

SCOPE FOR FURTHER WORK

Since a rational mix design method and an appropriate acceptance testing method at the job site have both largely been established for self-compacting concrete, the main obstacles for the wide use of self-compacting concrete can be considered to have been solved. The next task is to promote the rapid diffusion of the techniques for the production of self-compacting concrete and its use in construction. Rational training and qualification systems for engineers should also be established. In addition, new structural design and construction systems making full use of the self-compacting concrete should be introduced.

When self-compacting concrete becomes so widely used that it is seen as the "Standard concrete" rather than a "Special concrete", we will have succeeded in creating durable and reliable concrete structures that require very little maintenance work.

Now for making a High Strength Concrete of 80 to 100 MPa which also has the properties of SCC so that works like concreting of tunnel, consolidation grouting, curtain grouting, nuclear power plant concreting can be carried out easily eluding out the glitches of Conventional Concrete.

APPENDIX

SLUMP FLOW TEST IN PROGRESS

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