Properties of Self Compacting Concrete and its applications

By: Diyar Abubakir Karim

ABSTRACT

SCC is a high-performance concrete. Its workability, strength and durability are higher comparing to normal concrete. The purpose of this concrete concept is to decrease the risk due to the human factor, to enable the economic efficiency, more freedom to designers and constructors and more human work.

This report presents a study on the fresh and mechanical properties of self-compacting concrete, its types, constituents and applications in the construction industry. The first section of the report discusses about the various types of SCC that are used in the industry. The following section highlights the fresh properties and mechanical properties of the SCC.

The next section follows with a detailed review of the constituents of the SCC to achieve the above discussed properties. The next section discusses the applications of SCC in various fields of the construction industry.

In the end we can conclude that SCC can be used for casting heavily reinforced sections, places where there can be no access to vibrators for compaction and in complex shapes of formwork which may otherwise be impossible to cast, giving a far superior surface than conventional concrete. However, the relatively high cost of material used in such concrete continues to hinder its widespread use in various segments of the construction industry, including commercial construction,

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

1.1. General

Concrete is one of the most consumed materials in the world. The number of researches conducted on concrete increase with each passing day and the concrete types with higher workability, resistance and durability are tried to be manufactured. Self-compacting concrete (SCC) is a concrete type created as a result of these works. SCC was developed firstly for making permanent reinforced concrete constructions in Japan in 1988. Produced under favor of the new generation super additive agents, SCC prevents decomposition and increases durability by decreasing water permeability also at low water/cementitious material ration [1].

SCC is a high-performance concrete. Its workability, strength and durability are higher comparing to normal concrete. The purpose of this concrete concept is to decrease the risk due to the human factor, to enable the economic efficiency, more freedom to designers and constructors and more human work. [2]

It is a kind of concrete that can flow through and fill gaps of reinforcement and corners of molds without any need for vibrations and compacting during the pouring process. Realization of self-compacting as the key feature of fresh concrete enabled at the same time application of technologically higher quality material with improvement of economic building conditions. [3]

1.2. Aims and Objectives

This report presents a study on the fresh and mechanical properties of self-compacting concrete, its types, constituents and applications in the construction industry.

2. Types of SCC

Powder type: SCC proportioned to provide the required self-compatibility not by using a viscosity agent but primarily by reducing the water-powder ratio (in effect increasing the powder content) to impart adequate segregation resistance and using an air-entraining and high range water reducing admixture to impart high deformability.

Viscosity agent type: SCC proportioned to provide the required self-compatibility by the use of a viscosity agent to impart segregation resistance and air entraining and high range water reducing admixture to impart high deformability.

Combination type: SCC proportioned to provide the required self-compatibility primarily by reducing the water-powder ratio (in effect increasing the powder content) to impart adequate segregation resistance and using an air entraining and high range water reducing admixture to impart high deformability.

A viscosity agent is also added to reduce the quality fluctuation of fresh concrete, so as to facilitate the quality control of concrete. A suitable type should be selected from these types in consideration of the type of structure, structural condition, types of material available, and limitations at concrete production plants. [4]

3. FRESH PROPERTIES OF SCC

Self-compacting concrete (SCC) was developed in the middle of the 1980's in Japan. SCC flows alone under its dead weight up to levelling, airs out and consolidates itself thereby without any entry of additional compaction energy and without a nameable segregation. SCC owns over three key characteristics.

1. Filling Ability: Ability of to fill a formwork completely under its own weight.

2. Passing Ability: Ability to overcome obstacles under its own weight without hindrance. Obstacles are e.g. reinforcement and small openings etc.

3. Segregation resistance: Homogeneous composition of concrete during and after the process of transport and placing.

These characteristics were made possible by the development of highly effective water reducing agents (superplasticizers), those usually based on polycarboxylate ethers. Because of its special fluidity, SCC requires modified fresh concrete testing methods compared with conventional concrete. [4] Table 1 shows the SCC properties and the corresponding proposed test procedures

Table 1 SCC properties and the corresponding proposed test procedures [4]

Property tested	Test procedure
Filling ability	Slump flow - measuring the diameter of spread as well as T_{50}, the time to a spread of 500 mm.
Passing ability	Slump flow with J-ring – measuring the diameter of spread, and the blocking step, the height difference between the center of the concrete and just outside the J-ring.
Resistance to segregation	Slump flow with J-ring as above. The test is performed on the top and bottom part of concrete in a bucket. The relative difference in blocking step between the two measurements is termed the segregation indicator – the higher the value the greater the risk of segregation..

3.1.Slump Flow Test

This is a test method for evaluating the followability of SCC, where the slump flow of SCC with coarse aggregates having the maximum size of less than 40 mm is measured (Fig. 1). The basic equipment is the same as for the conventional slump test. However, the concrete placed into the mold is not rodded. When the slump cone has been lifted and the sample has collapsed, the diameter of the spread is measured rather than the vertical distance of the collapse. [5]

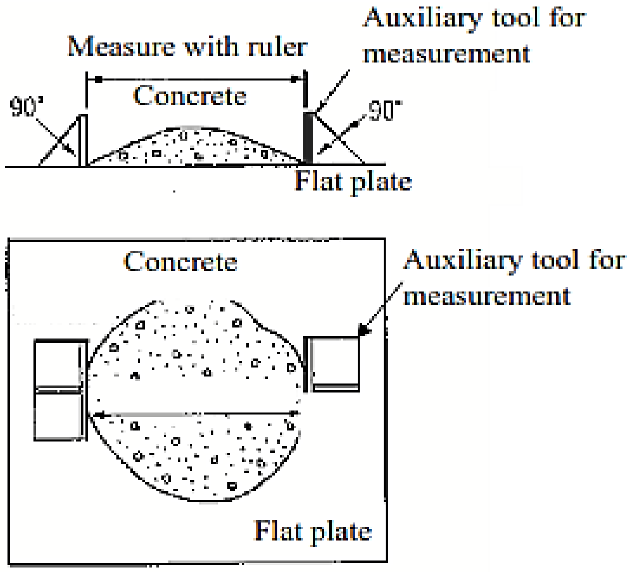

Figure 1 Slump flow test [5]

3.2.J Ring Test

The J-Ring consists of a ring of reinforcing bar, each reinforcing is 100 mm long. The diameter of this ring is 300mm. The spacing of the bars is adjustable, although 3 times the aggregate maximum size is recommended. For fiber reinforced concrete the bars should be placed 1 to 3 times the maximum fiber length. The J-ring test aims to investigate both the filling ability and the passing ability of SCC. It can be used to investigate the resistance of SCC to segregation by comparing test results from two different portions of sample. The J-ring test measures three parameters: flow spread, flow time T50J (optional) and blocking step. The J-ring flow spread indicates the restricted deformability of SCC due to blocking effect of reinforcement bars and the flow time T50J indicates the rate of deformation within a defined flow distance. The blocking step quantifies the effect of blocking.

The J- ring test was used to assess the passing ability of SCC. The J-ring is a rectangular section (30 mm by 25 mm) open steel ring with 300 mm in diameter, 100 mm in height, and had a gap of 35 mm between deformed bars. The ring was positioned around the base of the slump cone. The test was conducted in the same fashion of the slump flow test.

The difference between the slump flow and J-Ring flow provides an indication of the passing ability of the concrete. Both tests are based on the cone in the same orientation. Both flow diameters with and without the J-Ring are reported to the nearest 10 mm as well as for the difference between them. [6]

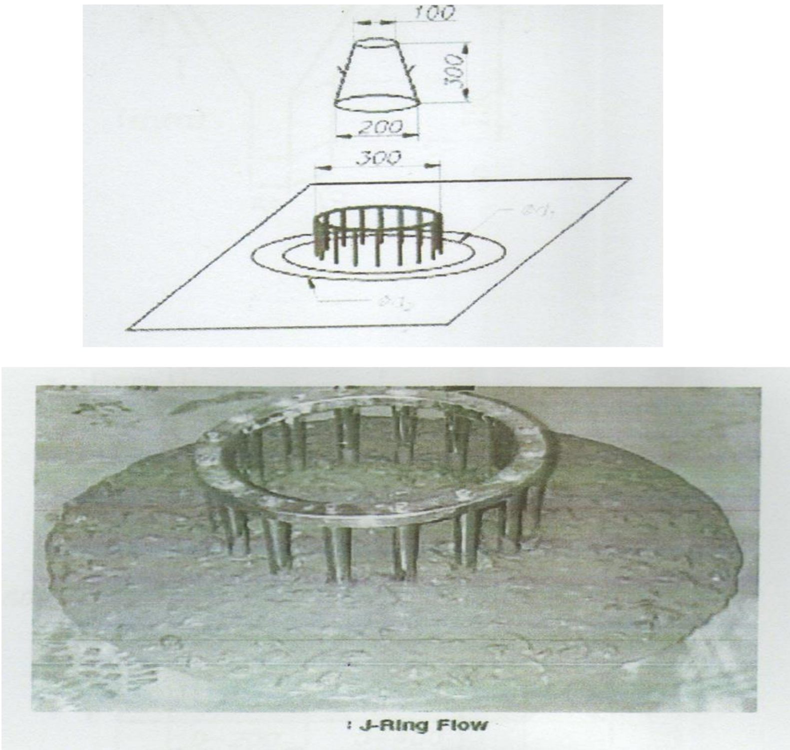

Figure 2 J-Ring Test [6]

3.3.Funnel Test

A test method for evaluating the material segregation resistance of SCC, using a funnel as shown in Fig. 2, where the efflux time of SCC with coarse aggregates having the maximum size of less than 25 mm is measured.

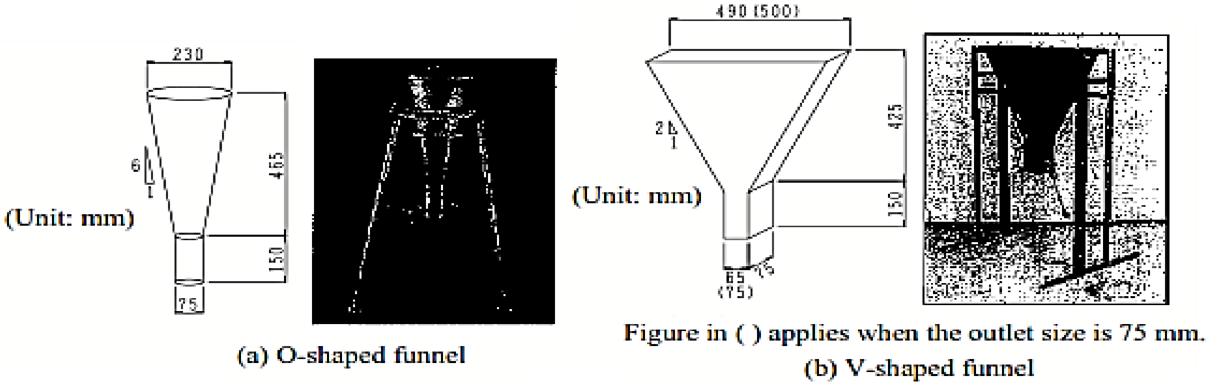

Figure 3 Shape, dimension and overview of funnel [5]

3.4.U-Type and Box-Type Tests

These are methods for testing followability of SCC through an obstacle with coarse aggregates having the maximum size of less than 25 mm (Fig. 3). Time and height to be filled in the chamber B and amount of aggregate passed through the obstacle are measured for self-compatibility.

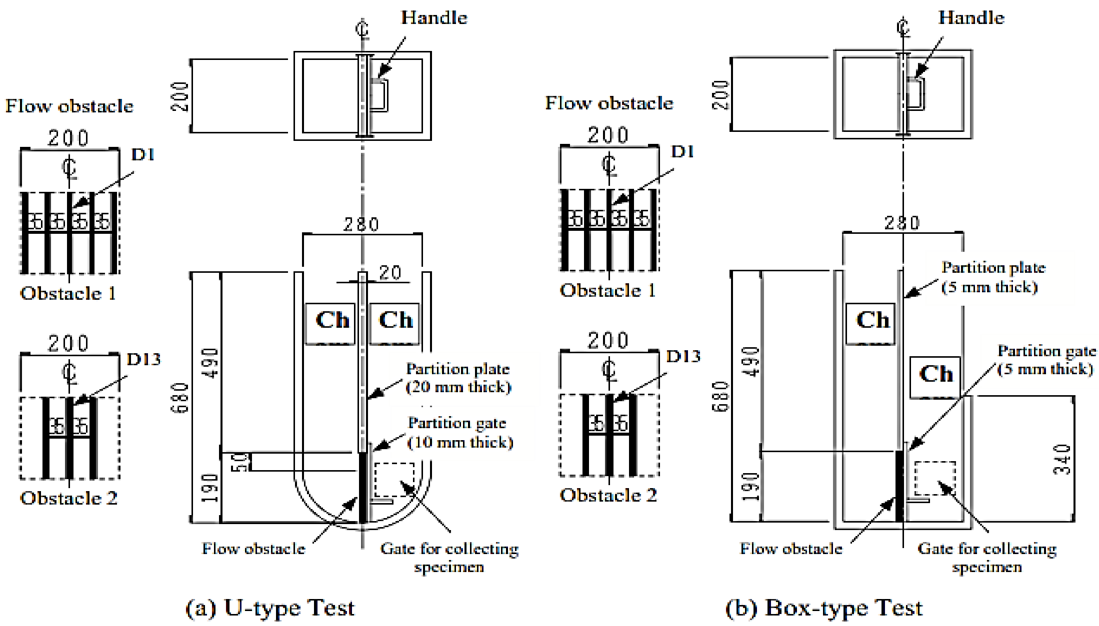

Figure 4 Shape of Filling Unit and Flow Obstacle [5]

3.5. Recommended specifications for SCC are the following:

- A good SCC shall normally reach a slump flow value exceeding 60cm without segregation.
- SSCC shall remain flowable and self-compacting for at least 90 minutes.
- SSCC shall be able to withstand a slope of 3 % in case of free horizontal Surface
- SSCC shall be pumpable for at least 90 minutes and through pipes with a length of at least 100 m. [7]

4. PROPERTIES OF HARDENED SCC: STRUCTURAL PROPERTIES

The basic ingredients used in SCC mixes are practically the same as those used in the conventional HPC (High Performance Concrete) vibrated concrete, except they are mixed in different proportions and the addition of special admixtures to meet the project specifications for SCC.

The hardened properties are expected to be similar to those obtainable with HPC concrete. Laboratory and field tests have demonstrated that the SCC hardened properties are indeed similar to those of HPC. Table 3 shows some of the structural properties of SCC.

Table 2 Structural Properties of SCC [7]

Items	SCC
Water-binder ratio (%)	25 to 40
Air content (%)	4.5-6.0
Compressive strength (age: 28 days) (MPa)	40 to 80
Compressive strength (age: 91 days) (MPa)	55 to 100
Splitting tensile strength (age:28 days) (MPa)	2.4 to 4.8
Elastic modulus (GPa)	30 to 36
Shrinkage strain (x 10^{-6})	600 to 800

4.1.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. There is little difficulty in producing self-compacting concrete with characteristic cube strengths up to 60MPa. In-situ strengths were derived from core samples taken along the whole length of the full-size elements. [8]

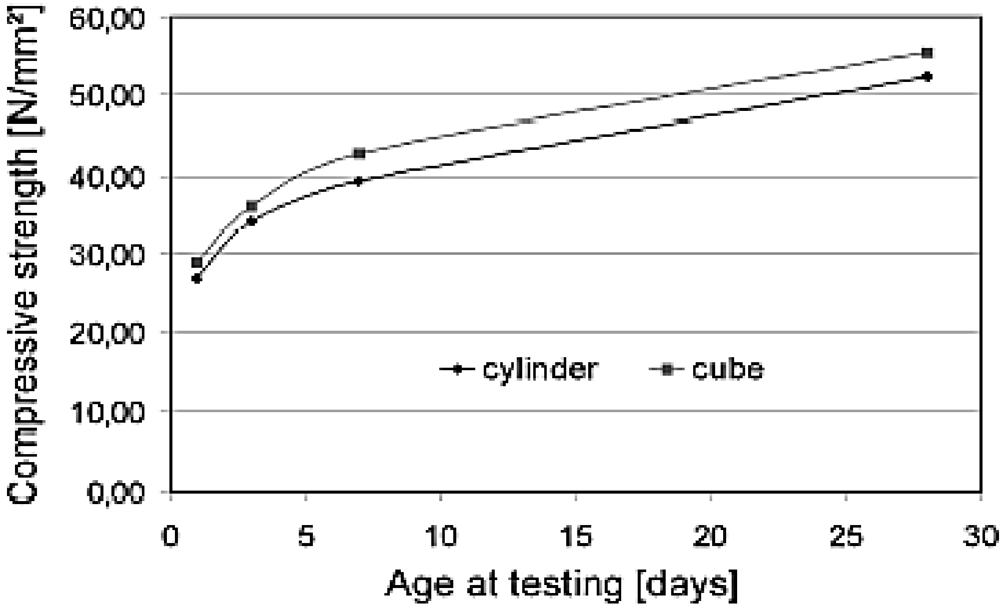

Figure 5 Time development of the cube and the cylinder compressive strength [7]

4.2.Tensile Strength

Tensile strengths are based on the indirect splitting test on cylinders. For SCC, the tensile strengths and the ratios of tensile and compressive strengths are in the same order of magnitude as the conventional vibrated concrete as shown in Fig. 6.

4.3.Bond Strength

Pull-out tests have been performed to determine the strength of the bond between concrete and reinforcement of different diameters. In general, the SCC bond strengths expressed in terms of the compressive strengths are higher than those of conventional concrete.

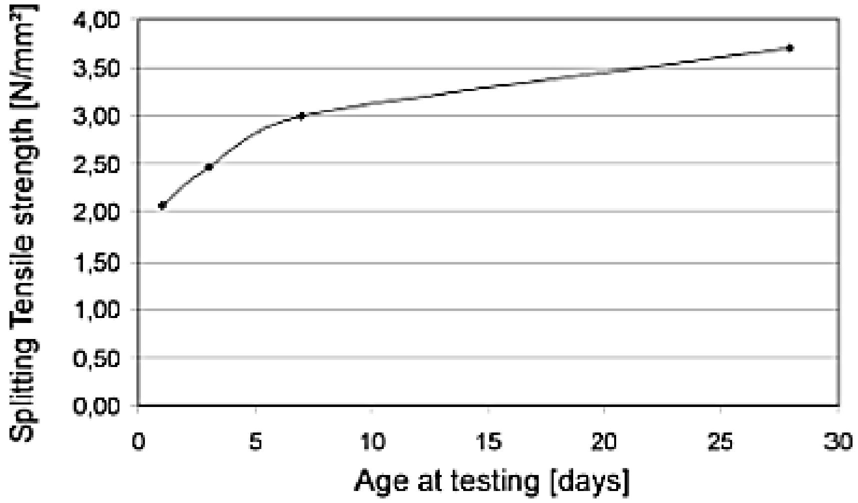

Figure 6 Time development of the splitting tensile strength [7]

4.4.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/(fc) 0.5 has been widely reported, and all values of this ratio were close to the one recommended by ACI for structural calculations for normal weight traditional vibrated concrete.

Table 3 the relation between comp. Strength and modulus of elasticity [7]

cube compressive strength	[N/mm²]	56,17	55,25	54,81	**55,41**
modulus of elasticity	[N/mm²]	29190	29754	31217	**30100**

4.5. Freeze/thaw resistance

This property was assessed by loss of ultrasonic pulse velocity (UPV) after daily cycles of 18 hours at -30°C, and 6 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 mixes). The lower strength SCC mix (housing) has performed less well than the reference in this freeze/thaw regime.

4.6.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. When the stiffness, the shrinkage or the creep is critical in the project it is necessary to test these properties.

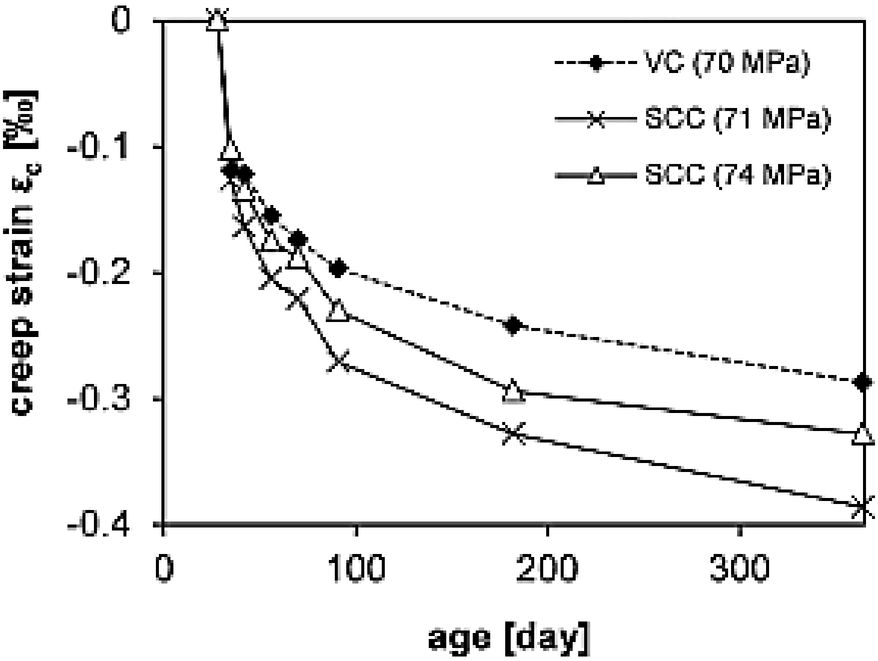

Figure 7 Creep strain of VC and SCC produced with OPC vs Time [5]

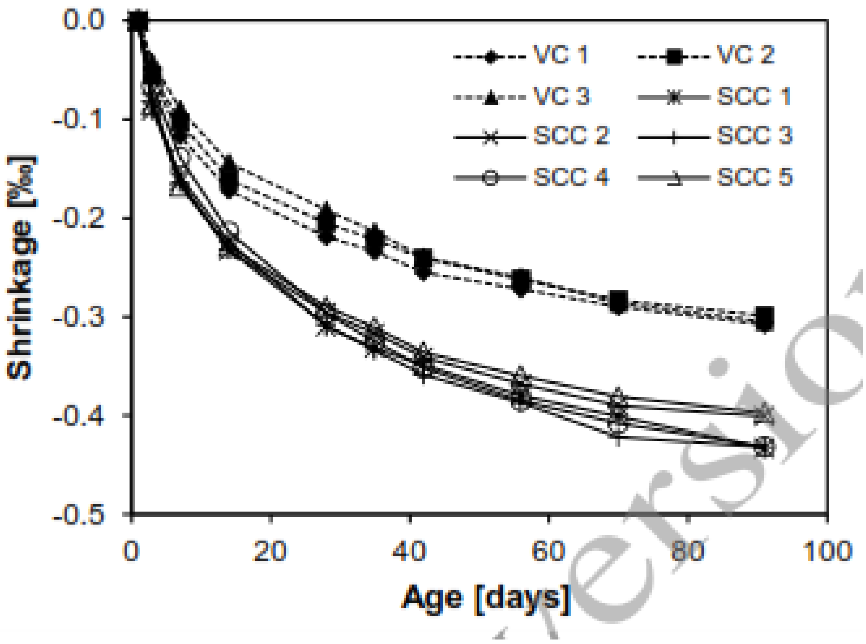

Figure 8 Total shrinkage VC and SCC [5]

5. CONSTITUENT MATERIALS OF SCC

For SCC, control of the constituent materials needs to be increased and the tolerance variations restricted.

Powder: is the blended mix of cement and filler particles smaller than 0.125mm. The addition of filler in an appropriate quantity enhances both workability and durability without sacrificing early strength.

Cement: All cements can be used for SCC but should not contain C_3A higher than 10% to avoid the problems of poor workability retention. The selection of cement type depends on the overall requirements for concrete, such as strength and durability.

Filler: Fly ash, blast furnace slag, ground glass, silica fume are commonly used fillers for producing SCC. Limestone powder can increase the fluidity without increase in cost.

Mineral Fillers: The distribution of particle size, shape and water absorption of mineral fillers may affect the water demand/ sensitivity and therefore suitability for use in SCC. Calcium carbonate based mineral fillers are widely used and can give excellent rheological properties and good finish.

The most advantageous fraction is that smaller than 0.125 mm and in general it is desirable for more than 70% to pass on 0.063mm sieve.

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

Table 4 Types of additions to SCC [9]

TYPE I	Inert or semi-inert	• Mineral filler (limestone, dolomite etc) • Pigments
TYPE II	Pozzolanic	• Fly ash conforming to EN 450 • Silica fume conforming to EN 13263
	Hydraulic	• Ground granulated blast furnace slag (If not combined in an EN 197-1 cement, national standards may apply until the new EN 15167 standard is published)

Coarse Aggregate (CA): Normal and lightweight coarse aggregates were successfully used for SCC. If the paste viscosity is low the lightweight aggregate may migrate to the surface. If the coarse aggregate in the mixture exceeds a certain limit blockage would occur independently of the mortar viscosity. To increase the passing ability reducing the volume of coarse aggregate is more effective than decreasing sand/paste ratio. Maximum aggregate size is determined based on spacing between reinforcement. In general aggregate of maximum size between 12 to 20mm is used. Particle size distribution and shape of CA directly influence the flow and passing ability. Rounded shape is better to prevent blocking and facilitate the flow.

Fine Aggregate (FA): The influence of FA on fresh properties of SCC is greater than that of CA. Particle fractions less than 0.125mm should be include the fines content of the paste and should be taken into account in calculating the water/powder ratio. If the volume of paste in SCC is high the internal friction between sand particles is reduced. Using blended sand is better to reduce the paste content.

Admixtures: High range water reducers are necessary for SCC. Polycarboxylic acid- based materials were used. Other types such as viscosity modifying admixture (VMA), air entraining admixture (AEA) to improve freeze-thaw resistance, retarders for control setting were used. Viscosity modifying admixture (VMA) is useful for enhancing the rheological properties and consistency of SCC. It also used to reduce segregation and sensitivity of the mix due to variations in other constituents especially to moisture content. Other admixtures including air entraining, accelerating and retarding may be used in the same way as normal concrete but advice should be sought from the manufacturer on use and the optimum time for addition.

Super plasticizer: Should have:

- **H**igh dispersing effect for low w/p ratio (less than 1 by volume). Maintenance of the dispersing effect for at least two hours after mixing.

- Less sensitivity to temperature changes.

Fly ash: providing increased cohesion and decreased sensitivity to changes in water content. High level of fly ash may produce a paste fraction which is so cohesive that it can be resistant to flow.

Silica fume: high level of fineness and practically spherical shape of silica fume results in good cohesion and improve resistance to segregation. However silica fume also can eliminate bleeding and can give rise to problems of rapid surface crusting, can result surface defects, difficulty in finishing the top surface.

Ground granulated blast furnace slag: a high proportion of this GGBS may affect stability of SCC resulting in reduced robustness with problems of consistence control, while the risk of segregation is increased by affecting slower setting.

Typical Ranges of the Constituent Materials for SCC

* Water content is 170 to 176 kg/m^3. Should not exceed 200 kg/m^3.

* Cement content is 350 to 450 kg/m^3.

* Total powder content (cement + filler): 400 to 600 kg/m^3 .

* Super-plasticizer: 1.8% of the total powder content.

* Water/powder ratio is 0.8 to 1.1 (by volume). A w/p ratio is in the range of 0.3 to 0.38 (by mass) for tropical and Middle East conditions.

* Coarse aggregate content: 28 to 35% by volume of the mix, or 700 to 900 kg/m^3.

* Sand content: balances the volume of other constituents, should be greater than 50% of the total aggregate content. Sand ratio is an important parameter in SCC and the rheological properties increase with an increase in sand. [9]

6. APPLICATIONS OF SELF COMPACTING CONCRETE

SCC has many advantages compared with normal concrete, including:

1. SCC characterized by high resistance to segregation that can be cast without vibration, and accordingly saves labor and consolidation noise.
2. SCC results in durable concrete structures.
3. SCC has a rapid rate of concrete placement, with faster construction times.
4. SCC can easily flow around congested steel reinforcement.
5. SCC has a high level of homogeneity, minimal voids and uniform concrete strength.
6. SCC has a superior level of finish and durability to the structure.
7. SCC often produced with low water/cement ratio providing for high early strength, earlier demolding and faster use of elements and structures. [3]

Due to its various advantages of Self-Compacting Concrete, SCC have been successfully used in some large projects in many countries in the past decades. In fact (in fact,) SCC has transformed the way that concrete construction is performed through the world.

6.1.Bridge Girders Project and High Strength SCC:

Because of the favorable properties that SCC exhibits, the Federal Highway Administration and the precast concrete industry have been promoting the research and development of SCC for structural applications in bridges. If SCC is properly specified and used, it has the potential to yield more economical and higher quality pre-stressed concrete products than conventional concrete. To take advantage of this new technology, there was a need to study production feasibility and structural performance of pre-stressed SCC bridge girders made with aggregates. Proportioning, behavior, and properties of SCC are highly dependent on the coarse aggregates physical properties.

Self-compacting concrete was then used in the towers of a pre-stressed concrete cable-stayed Shin-Kiba Ohashi bridge in 1991. Lightweight self-compacting concrete was used in the main girder of a cable-stayed bridge in 1992. Since then, the use of self-compacting concrete in actual structures has gradually increased. Self-compacting concrete has been successfully used in France, Denmark, the Netherlands, Germany, USA and UK, apart from Japan.

A typical application example of Self-compacting concrete is the two anchorages of Akashi-Kaikyo (Straits) Bridge opened in April 1998, a suspension bridge with the longest span in the world (1,991 meters). The volume of the cast concrete in the two anchorages amounted to 290,000 m3. A new construction system, which makes full use of the performance of self-compacting concrete, was introduced for this.

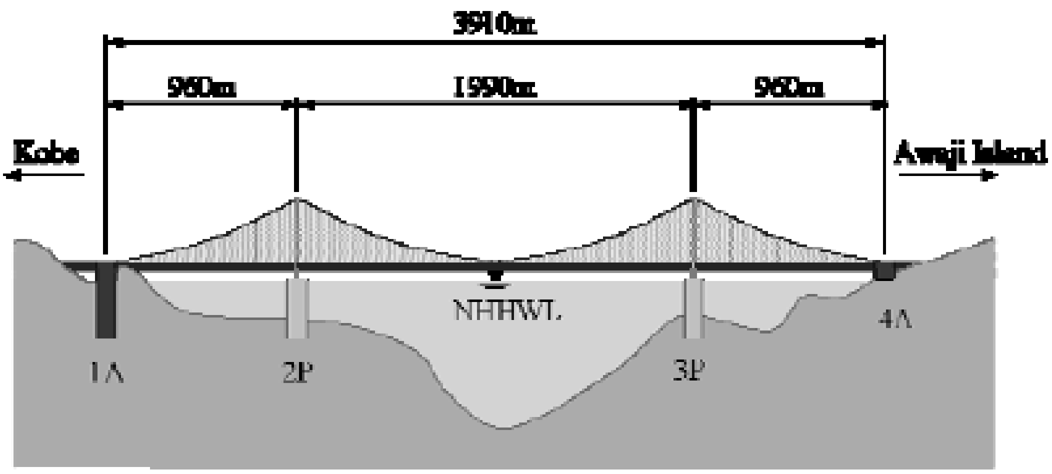

Figure 9 Used for anchorages at Akashi Kaikyo Bridge [10]

The concrete was mixed at the batcher plant beside the site, and was the pumped out of the plant. It was transported 200 meters through pipes to the casting site, where the pipes were arranged in rows 3 to 5 meters apart. The concrete was cast from gate valves located at 5 meter intervals along the pipes. These valves were automatically controlled so that a surface level of the cast concrete could be maintained. In the final analysis, the use of self-compacting concrete shortened the anchorage construction period by 20%, from 2.5 to 2 years.

6.2. SCC application for Tanks

Self-compacting concrete was used for the wall of a large LPG tank belonging to the Osaka Gas Company, whose concrete casting was completed in June 1998. The volume of the self-compacting concrete used in the tank amounted to 12,000 m3. The adoption of self-compacting concrete means that

(1) The number of lots decreases from 14 to 10, as the height of one lot of concrete casting was increased.

(2) The number of concrete workers was reduced from 150 to 50.

(3) The construction period of the structure decreased from 22 months to18 months. [11]

6.3.SCC for concrete products

Self-compacting concrete is often employed in concrete products to eliminate the noise of vibration. This improves the working environment at plants and makes it possible for concrete product plants to be located in the urban area. The annual production of concrete products using self-compacting concrete exceeded 200,000 tons in 1996. [11]

6.4.Tunnel Project

The challenge with Tunnel projects is how to fill the slot between the covers of the formwork with concrete and ensure complete filling and good surface finish. The previous practice was the use of normal slump concrete (150 mm) with vibration; however, large numbers of shallow trapped air pockets were found on the concrete surface after remodeling.

1. Due to inside casting and the limited access to the tunnel (only three manholes available for the whole length of the sewer line), it was very difficult to get the concrete to the form. Highly flowable concrete had to be pumped up to 600 m to the tunnel through manholes.
2. The shrinkage is to be less than 0.03%.
3. Very high flow was necessary for the narrow spaces within the formwork to create concrete with no voids, bubbles and aggregate pockets.
4. The early strength development to allow stripping of formwork by 12 – 14 hours because of a two shift/day production schedule.

To meet these stringent requirements, the SSC mix was designed with a low water/cement to reduce shrinkage as well as with a shrinkage-reducing admixture. Examples of Tunnels are shown in below: [10]

Figure 10 a) Tunnel picture in Los Angeles, USA b) View of the tunnel arch in SWEDEN [10]

6.5. Contemporary architectural buildings

Building conditions for contemporary architectural buildings set new, various requirements regarding construction methods of reinforced concrete buildings. Meeting those criteria led to development of concrete with specifically defined properties in fresh state. An idea of self-compacting concrete (SCC), a material that flows, that is placed into formwork and that is compacted under the influence of self-weight only, without vibration and additional processing emerged.

Presently it is a very eagerly used material both in construction sites and in production of pre-cast members. Practical applications extend from large infrastructure buildings (bridges, tanks, retaining walls, tunnels, etc.) onto architectural buildings also. SCC appears here as a structural material in load-bearing members but at the same times it also appears frequently as architectural concrete. Architectural concrete was defined by the American Concrete Institute as "concrete which will be permanently exposed to view and which therefore requires special care in selection of the concrete materials, forming, placing and finishing obtaining the desired architectural appearance".

Several characteristic examples are shown below:

Burj Dubai : The Burj Dubai structure represents the state-of-the-art in super high-rise buildings. Several different concrete mixes were used in this project. It was necessary to place 230000m^3 of fresh concrete. The designed concretes were obtained using Portland cement combined with silica fume, fly ash or ground slag. The structure has sufficient rigidity, toughness and high load-bearing capacity. In course of construction of the building the concrete was pumped to higher and higher heights so it was necessary to provide extraordinary flowing ability of concrete through pipes. A world record was achieved: on November 8, 2007 highest vertical concrete pumping for buildings, 601m, was performed. Thus concrete was poured usually at night to enable work at lower temperatures and higher humidity. Concrete was additionally cooled by adding a part of water in the form of ice. [3]

Figure 11 Burj Dubai and Arlanda Airport Control Tower, view [3]

Arlanda Airport Control Tower, Stockholm, Sweden : The total height of the tower is 83 m. The structure of the pillar consists of two shafts having different dimensions which is emphasised by two-colour design. There are several eccentrically placed circular floor structures at the top. Facade walls are parts of a cone. During the construction stage, the inner formwork was being climbed by a crane while the outer scaffolding and formwork were self-climbing. SCC was used in order to achieve the concreting speed of a standard floor height h=3.27m in a 4 day climbing cycle of formwork and to ensue high-quality concrete placing without vibration. The decreased noise level during concrete placing enabled concreting during the night shift. [3]

National Museum of 21st Century Arts (MAXXI) in Rome, Italy

MAXXI was designed by Zaha Hadid. The museum building covers a surface of 30,000 m^2 and building is characteristic for its winding exhibition space formed of reinforced concrete walls with glass roof. On its winding path the structure comes across large spans, irregular supports and long overhangs. In some places the walls are 14m high. Reinforced concrete wall surfaces are visible and they require a perfect surface finish. In order to meet all these high requirements the contractor for the concrete structure decided to use self- compacting concrete. The concrete was cast along the entire lengths of the walls to avoid construction joints. This amounted up to 70 meters in length and 9 m in height in some members. Concreting lasted even up to 18 hours. To avoid segregation, the height from which the fresh concrete was poured was limited to maximum 15cm. Application of powdered limestone and epoxy-resin additives provided perfectly smooth surface finish of concrete walls. [3]

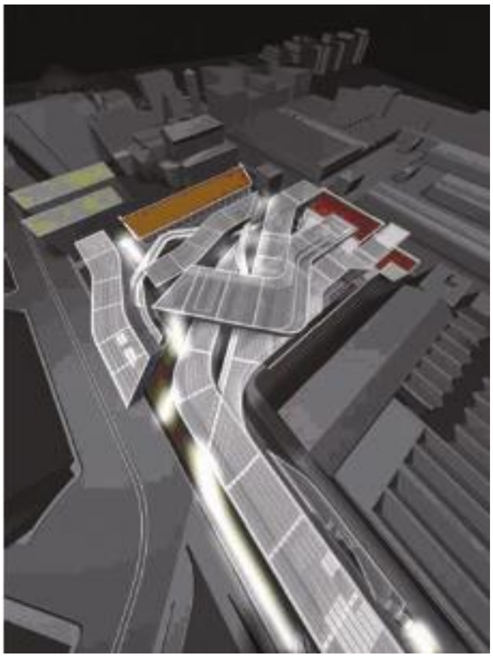

Figure 12 National Museum of 21st Century Arts in Rome Italy, model [3]

6.6. Applications of SCC in the Precast Concrete Industry

For the precast concrete industry the introduction of SCC to current production doesn't mean an important effort, since the processes at the plant can be very well controlled. The advantages of using SCC in precast concrete plants are very considerable:

a) The essential reduction of the noise level;

b) The elimination of vibration;

c) The reduction of dust in the air caused by vibration;

d) Low energy consumption;

e) The exclusion of the costly mechanical vibrators;

f) The minimisation of wear to the formwork;

g) The exclusion for the installation of vibration isolators;

h) Increased environmental safety;

i) The opportunity to produce elements with high architectural quality

For the successful production of SCC it is important that the basic constituents, like sand, gravel, fillers and superplasticizers, have a constant quality. The proper strength for demoulding SCC is attained faster than for traditionally concrete, in addition, the used formwork content elementary connections that contribute to a reduction of time for demoulding and re- installing the formwork by 50%. [13]

Figure 13 Precast elements of SCC [13]

6.7. Applications of SCC in situ concrete industry

The largest part of SCC research has analysed mechanical and rheological properties, and less on-site applications. Through literature it has been shown that there exist a lack in understanding the SCC introduction to projects, the roles of project teams and team members, proper approach to problems caused by differences between SCC and conventional concrete.

The launching of SCC for in-situ applications required a long time than in the precast concrete industry. There are a number of reasons for this:

i) The consequences of a failure are more severe than in the precast concrete industry;

ii) There is no agreement on the way in which the properties of fresh SCC at the building site has to be controlled;

iii) Difficulty to obtain robust and reliable SCC with lower concrete strength, usually used in site applications.

Slabs are casting in a distinct way than conventional concrete mixtures. It is recommended to discharge SCC at one point and let it flow into place before moving the point of placement (Fig. 12). Simultaneously, it's necessary to respect the maximum admissible horizontal spread distance. For modules, columns and thin walls SCC should be placed into the central part and then allowed to distribute over the edge and into the wall. A different method to supply is to pump them from the bottom of the formwork, for complex shapes it is desirable to pump from several locations. The use of SCC in situ applications means optimised casting process with less need of skilled workers, speedy production cycles and reduced production costs.

Figure 14 Placing slab of SCC[13]

7. CONCLUSION

Self-compacting concrete is an innovative building material, a durable concrete that fills the formwork without the need for vibrating compaction. It is more homogeneous and has less variation in production of concrete and less deviation in strength. SCC can be characterized by:

a) More sensitiveness to variations in the fresh state than conventional concrete, and requires more vigilance in production, transportation and casting process;

b) Decreased final cost of construction, due to the elimination of vibration, reduced manpower and shortened time;

c) The fluidity of SCC leads to a higher form pressure and increases the sensitivity to plastic shrinkage and early cracking;

d) Removing vibrations means less restriction to design, and improved resistance to segregation.

SCC can be used for casting heavily reinforced sections, places where there can be no access to vibrators for compaction and in complex shapes of formwork which may otherwise be impossible to cast, giving a far superior surface than conventional concrete.

However, the relatively high cost of material used in such concrete continues to hinder its widespread use in various segments of the construction industry, including commercial construction, however the productivity economics take over in achieving favourable performance benefits and works out to be economical in pre-cast industry.

8. REFERENCES

1. Karatas, M., & Gunes, A. (2015). Engineering Properties of Self-Compacting Concrete Produced by Polypropylene and Steel Fiber. Periodica Polytechnica. Civil Engineering, 59(2), 95.
2. Grdić, Z., Despotović, I., & Topličić-Ćurčić, G. (2008). Properties of self-compacting concrete with different types of additives. Facta universitatis-series: Architecture and Civil Engineering, 6(2), 173-177.
3. Okrajnov-Bajić, R., & Vasović, D. (2009). Self-compacting concrete and its application in contemporary architectural practice. Spatium, (20), 28-34.
4. VON SELBSTVERDICHTENDEM, F. R. I. S. C. H. B. E. T. O. N. E. I. G. E. N. S. C. H. A. F. T. E. N., & FRAIS, P. D. B. A. B. (2003). Fresh properties of self-compacting concrete (SCC). Otto-Graf-Journal, 14, 179.
5. Pade, C. (2006). Test methods for Self-Compacting Concrete (SCC).
6. Ouchi, M., Nakamura, S. A., Osterberg, T., Hallberg, S., & Lwin, M. (2003, October). Applications of self-compacting concrete in Japan, Europe and the United States. In 3rd International Symposium on High Performance Concrete, PCI National Bridge Conference Proceedings (pp. 19-22).
7. bu.edu.eg/.../Gamal%20Elsayed%20Abdelaziz_Self-compacting%20concrete.ppt
8. Khayat, K. H. (1999). Workability, testing, and performance of self-consolidating concrete. Materials Journal, 96(3), 346-353.
9. Malherbe, J. S. (2015). Self-compacting concrete versus normal compacting concrete: a techno-economic analysis(Doctoral dissertation, Stellenbosch: Stellenbosch University).
10. Bakhtiarian, A. H., Shokri, M., & Sabour, M. R. Application of Self-Compacting Concrete, Worldwide Experiences.
11. http://civil-resources.blogspot.com/2010/06/self-compacting-concrete.html
12. Wehbe, N., Sigl, A., & Boushek, A. (2011). Application of self-consolidating concrete in bridge structures (No. MPC Report No. 11-194).
13. Cazacu, N., Bradu, A., & Florea, N. (2016). Self-Compacting Concrete in Building Industry. Buletinul Institutului Politehnic din lasi. Sectia Constructii, Arhitectura, 62(1), 85.