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# Use of Self Compacting Concrete for Sustainable yet Economic Development

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**ABSTRACT:** Self-compacting concrete (SCC) has many benefits in terms of production and placement of traditional concrete namely, elimination of external or internal vibration for compaction, better flowability, workability and pumpability, as well as increased bonding with congested reinforcement. Moreover, the placement of SCC is faster and requires less labour. The appearance (surface finish), mechanical performance and durability of SCC can be considerably better than traditional concrete. However, the methods of production, placement, quality control and finishing are essential for SCC. Constructability issues may arise for specifiers and contractors if related standards, guidelines or practices are not appropriately followed for production and placement. Self-compacting concrete is less tolerant to abrupt changes in aggregate moisture content, chemical admixtures and water content. The type of concrete mixer, transport time and the methods of concrete placement and finishing can affect the properties of SCC. Therefore, robust quality control measures must be in place during the production and placement of SCC. The excellent flowability of SCC compared to traditional concrete makes pumping the best method of placement. However, there is a high chance of air entrainment due to a higher flow rate, which can result in bug holes and segregation. Normally SCC has less surface imperfections compared to traditional concrete, but it would be susceptible to bug holes, honeycombing and cracking if guidelines of production and placement were not followed appropriately. This chapter explains how the admixtures, aggregate moisture content and water to solids ratio should be controlled for the reliable production of SCC. Also, the effect of concrete mixers on the properties of SCC, and the methods of quality control at batching plants and during placement are explained. Finally, transport, pumping, placement and finishing of SCC with common issues and solutions will be discussed.

**KEYWORDS:** Self Compacting Concrete, Concrete Mixture, Concrete Mix Design, Fibres

## I. INTRODUCTION

Concrete, as it is known nowadays, has been used for thousands of years. Concrete is constituted by a composite of coarse aggregate kept together by a paste of hydraulic binder, which was already used by the Romans in the construction of part of their structures, some of which survived to the present days. With the invention of normal Portland cement (NPC) in the first half of the 19th century, concrete as it is known today appeared, which became in modern times the most important construction material in the world. Nevertheless, and despite the popularity of its use, concrete is associated with several anomalies observed in infra-structures currently in use, usually linked to problems related to the mixes, to poor casting at the construction site or to inadequate or even inexistent maintenance processes, which may lead to permanent deterioration of the structures and to the consequent loss of usability conditions. The increase of worldwide social empathy towards the planet's sustainability problems has, nowadays, led to a greater concern of the environmental impact of the use of concrete in construction. This is now one of the major concerns, if not the main concern of the concrete industry. Naturally, the search for sustainability solutions is (or should be) causing significant changes to the current living standards, leading to the identification of the most "problematic" sectors. Recognising the concrete industry as one of the main consumers of natural raw materials and energy resources, therefore constituting one of the main contributors to the worsening, for example, of the planet's greenhouse effect (Meyer, 2002), comes up, as a logical consequence, the need to develop and test new solutions. Therefore, the new challenge faced by the construction industry, and already acknowledged by many, is that of providing more efficient answers in terms of development and use of new techniques and materials that can respond to a higher and tighter level of requirements in terms of environment and that may, simultaneously, achieve superior performances with lower costs. In other words, it will be necessary to produce concrete with excellent mechanical properties in parallel with high



durability levels and controlled costs. Self-compacting concrete (SCC), requiring no consolidation work at site or concrete plants, has been developed in Japan to improve the durability and uniformity of concrete in 1988 (Okamura and Ouchi, 1999). The mix composition is chosen to satisfy all performance criteria for the concrete in both the fresh and hardened states. There is no standard method for SCC mix design, and many academic institutions as well as admixture, ready-mixed, precast and contracting companies have developed their own mix proportioning methods.

One of the most important differences between SCC and conventional concrete is the incorporation of a mineral admixture. Thus, many studies on the effects of mineral admixtures on the properties of SCC have been conducted. These studies show the advantage of mineral admixture usage in SCC, such as improved workability with reduced cement content (Poppe and Shutter, 2005).

Since cement is the most expensive component of concrete, reducing cement content is an economical solution. Additionally, the mineral admixtures can improve particle packing and decrease the permeability of concrete. Therefore, the durability of concrete is also increased. Industrial by-products or waste materials such as limestone powder, fly ash and granulated blast furnace slag are generally used as mineral admixtures in SCC. Thereby, the workability of SCC is improved and the used amount of by-products or waste materials can be increased. Besides the economical benefits, such uses of by-products or waste materials in concrete reduce environmental pollution. Fly ash is an industrial by-product, generated from the combustion of coal in the thermal power plants. The increasing scarcity of raw materials and the urgent need to protect the environment against pollution has accentuated the significance of developing new building materials based on industrial waste generated from coal fired thermal power stations creating unmanageable disposal problems due to their potential to pollute the environment.

The main advantages of application of self-compacting concrete on site are as follows:

- No vibration of fresh concrete is necessary during placement into forms.
- Placement of concrete is easier.
- Faster and more efficient placement of fresh concrete is achieved. Total concreting time is reduced.
- Noise level on construction site is reduced. Thus the number of working hours on the construction site can be increased and the night shift in urban zones is enabled.
- Energy consumption is reduced.
- Required number of workers on construction site is reduced. ↴ Safer and healthier working environment is obtained.

## II. RELATED WORK

**Liana Iureş and Corneliu Bob, 2010** presented a paper on the characteristics of the self-compacting concretes, their advantages and disadvantages when they are used in buildings. Due to its properties and composition, the self-compacting concrete is described here as being one of the future friendly environmental materials for buildings. Tests concerning to obtaining a self-compacting concrete, together with the specific fresh concrete properties tests, are described.

**Dhiyaneshwaran, S. ,2013** investigated the study of workability and durability characteristics of SelfCompacting Concrete (SCC) with Viscosity Modifying Admixture (VMA), and containing Class F fly ash. In this investigation, SCC was made by usual ingredients such as cement, fine aggregate, coarse aggregate, water and mineral admixture fly ash at various replacement levels (10%, 20%, 30%, 40% and 50%).

**Arivalagan S, 2013** conducted an experimental program aimed at producing and evaluating SCC made with high volumes of fly ash. The study focused on comparison of fresh properties of SCC containing varying amounts of fly ash with that containing commercially available admixture. Test results proved the feasibility to develop low-cost SCC using Class F fly ash.

**Tarun R. Naik, 2014** presented a paper on development, properties, and advantages and disadvantages of using high-strength self-consolidating concrete in the construction industry. It also presents results of a study recently completed for manufacturing economical high-strength self-consolidating concrete containing high-volumes of fly ash.

In this study, Portland cement was replaced by Class C fly ash in the range of 35 to 55% by the mass of cement. The results of fresh and hardened properties of concrete show that the use of high-volumes of Class C fly ash in self-consolidating concrete drastically reduces the requirements for superplasticizer (HRWRA) and viscosity modifying agent (VMA) compared with the normal dosage for such admixtures in self-consolidating concrete.



Miao Liu, 2016 investigated the influence of fly ash and ground glass on the mortar fraction of the SCC and then using these results to produce concrete mixes with the target fresh properties. Hardened concrete of these mixes were measured and the relationships between these investigated. The results showed that for constant filling ability of the SCC, replacement of cement with fly ash or ground glass requires an increase in water/powder ratio and a reduction in superplasticizer dosage. Both additions degraded the passing ability, consistence retention and hardened properties but not to a prohibitive extent. SCC with up 80% cement replaced by fly ash or glass volume ratio of 6.4% is possible and the material properties of SCC are similar to those of normally vibrated concrete (NVC).

### III. METHODOLOGY

#### 1) MIX DESIGN FOR M30 GRADE CONCRETE

**Total volume(V) = Cement (c) + fine aggregate (fa) + coarse aggregate (ca)+ Water (w) Trial mix:**

- Taking (aggregate/cement) ratio = 4.5
- $V = (w + c/s_c + (1/p) * (fa/S_{fa})) * 1/1000$
- $S_c = \text{sp. Gravity of cement} = 3.14$
- $W = \text{max. mass of water per meter cube} = 186$
- $P = c/a \text{ ratio} = 1/4.5$
- Assuming water cement ratio = 0.4
- Taking 80% of  $w = 186 * 0.8 = 148.8 \text{ kg/m}^3$
- Therefore, quantity of cement required =  $148.8/0.4 = 372 \text{ kg/m}^3$
- Quantity of aggregate required =  $4.5 * 372 = 1674 \text{ kg/m}^3$
- Total volume =  $a + c + w = 2194.8$  **Final mix:**
- Taking  $a/c = 4$
- Taking 90% of  $w = 186 * 0.9 = 167.4 \text{ kg/m}^3$
- Taking  $w/c = 0.4$
- Therefore, quantity of cement required =  $167.4/0.4 = 418 \text{ kg/m}^3$
- Quantity of aggregate required =  $418 * 4 = 1672 \text{ kg/m}^3$
- Taking fine aggregate 35 % Of total aggregate =  $627 \text{ kg/m}^3$
- Therefore, coarse aggregate =  $1045 \text{ kg/m}^3$
- Therefore, mix proportion = 418: 627: 1045
- Final mix proportion = 1(c): 1.5(fa): 2.5(ca) **Quantity of materials required for 9 cubes:**
- $= 0.15 * 0.15 * 0.15 * 9 + 10\% \text{ of } (0.15 * 0.15 * 0.15 * 9)$
- $= 0.03341 \text{ m}^3$
- $\frac{1.5 * 1500 * 0.03341}{1 + 1.5 + 2.5} = 15.035 \text{ kg}$
- Fine aggregate =  $15.035 * 1.5 = 22.55 \text{ kg}$
- Coarse aggregate =  $15.035 * 2.5 = 37.58 \text{ kg}$
- Water = 6.014 kg
- Plasticiser (Aura mix 300) = 0.2% of cement = 31 gm

#### 2) CEMENT

Cement has different properties and characteristics which depend upon their chemical compositions. By changing in fineness of grinding, oxide compositions cement has exhibit different properties and different kind of cement. The use of additives, changing chemical composition, and use of different raw materials have resulted in the availability of many types of cements.



### 3) AGGREGATES

Aggregates are the important constituents in concrete. They give body to the concrete, reduce shrinkage and effect economy. The fact that the aggregates occupy 70-80 present of volume of concrete, it has some impact on various characteristics and properties of concrete.

### 4) MINERAL FILLER

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

### 5) FLY ASH

Fly ash has been shown to be an effective addition for SCC providing increased cohesion and sensitivity to changes in water content. In India, in particular fly-ash is amply available and can be a sustainable alternative. Fraction of fly ash below 45  $\mu\text{m}$  are useful as pozzolanic, however, particles finer than 5  $\mu\text{m}$  are highly useful. Fly ash must confirm to the relevant IS standard (IS: 3812 –2007).

### 6) MICRO SILICA/SILICA FUME

The high level of fineness and practically spherical shape of silica fume results in good cohesion and improved resistance to segregation. However, silica fume is also very effective in reducing or eliminating bleed and this can give rise to problems of rapid surface crusting.

### 7) GROUND GRANULATED BLAST FURNACE SLAG

Ground granulated blast furnace slag (GGBS) provides reactive fines with a low heat of hydration. GGBS is already present in some cement but is also available as an addition and may be added at the mixer.

### 8) FINE AGGREGATE / SAND

The influence of fine aggregates on the fresh properties of the SCC is significantly greater than that of coarse aggregate. Particles size fractions of less than 0.075 mm should be included in the fines content of the paste and should also be taken into account in calculating the water powder ratio.

The high volume of paste in SCC mixes helps to reduce the internal friction between the sand particles but a good grain size distribution is still very important. Many SCC mix design methods use blended sands to match an optimised aggregate grading curve and this can also help to reduce the paste content.

### 9) ADMIXTURES

SCC invariably incorporates chemical admixtures - in particular, a high range water reducing admixture (HRWRA) and sometimes, viscosity-modifying agent (VMA). The HRWRA helps in achieving excellent flow at low water contents and VMA reduces bleeding and improves the stability of the concrete mixture. An effective VMA can also bring down the powder requirement and still give the required stability.

### 10) AIR ENTRAINING ADMIXTURES

Air entraining admixtures may be used in the production of SCC to improve freeze thaw durability. They are also used to improve the finishing of flat slabs and air entrainment is particularly useful in stabilising low powder content and/or lower strength SCC.



## 11) FIBERS

Both metallic and polymeric fibers can be used in the production of SCC, but they may reduce flowability and passing ability. Trials are therefore needed to establish the optimum type, length and quantity of fibers, as well as the dose of superplasticizer, to give all the required properties to both the fresh and hardened concrete.

Polymer fibers can be used to improve the stability of SCC, as they help prevent settlement and cracking due to plastic shrinkage of the concrete. Steel or long polymer structural fibers are used to modify the ductility/toughness of the hardened concrete. Their length and quantity is selected depending on the maximum size of aggregate and on structural requirements.

## IV. EXPERIMENTAL RESULTS

### 1 Slump Flow Test

The Slump-flow test is the simplest and most widely adopted test method for evaluating the filling/flow ability/quality of self-compacting concrete in the laboratory and at construction sites (ASTM C 1611). Basically, the slump flow test is used to assess the horizontal free flow of SCC in the absence of obstructions. On lifting up the slump cone filled with concrete the concrete flows. The average diameter of the concrete circle is a measurement for the flow ability of the concrete. In this study, thereby the diameter of the concrete flowing out of the slump cone was measured by calculating the average of two perpendicularly measured diameters to determine the slump flow of SCC.

### 2 T50 Test

The time T50 cm is a secondary indication of flow ability of concrete. Basically, this test is a part of slump flow test. It measures the time taken by the concrete in seconds - from the instant the cone is lifted to the instant when horizontal flow reaches to the diameter of 500mm (Sonebiet al, 2001).

### 3 V- Funnel Test

The flow ability of the fresh concrete can also be tested with the V-funnel test, where the flow time is measured. This test apparatus consists of a funnel with a rectangular cross section ( top dimension is 495 mm by 75 mm and the bottom opening is 75 mm by 75 mm) and the total height is 572 mm with a 150 mm long straight section. In this study the funnel was filled with about 12 liter of fresh concrete and the time taken to flow through the apparatus was measured as illustrated in Figure 3. Shorter flow time indicates greater flow ability. In addition, T5min was also measured with V-funnel, which indicates the tendency for segregation. If the concrete shows segregation, the flow time will increase significantly. In this method, however, the funnel was refilled with concrete and left for 5 minutes to settle. Thus, the tendency of concrete for segregation was observed.

### 4 L -Box Test

The passing ability of SCC through narrow spaces, even with congested area of reinforcement, can be assessed by the L-box test (Bhuva et al., 2011). The vertical section of the apparatus in was filled up with 14 litre fresh concrete and after one minute, the concrete was let to pass through the reinforcement towards the horizontal section. When the concrete was in stable condition, the height of concrete at the end of the horizontal section Roy, Mohammed, Mansur, Hasan & Ullah ICPACE 2019(H2) and height of the vestige of concrete in the vertical section (H1) were measured individually to calculate the blocking ratio H2/H1, in order to observe the passing ability of fresh SCC.



**5 Density Test**

The unit weight estimated in this study is freshly mixed SCC unit weight, which was calculated following the ASTM specification (ASTM C138 / C138M - 17a) right after the samples being casted. The following formula in the equation (1) was used to calculate the unit weight of fresh SCC.

$$D = (M_c - M_m) / V_m \quad (1)$$

Where, ‘D’ is the density/unit weight of concrete (Kg/m<sup>3</sup>), ‘M<sub>c</sub>’ is the mass of mold filled with concrete (Kg), ‘M<sub>m</sub>’ is the Mass of mold (Kg) and ‘V<sub>m</sub>’ is the volume of mold (m<sup>3</sup>).

**6 Compressive and Tensile Strengths Test**

Both compressive strength and tensile strength tests were carried out upon the specific SCC specimens as per ASTM C39 and ASTM C496 respectively using universal testing machine in concrete laboratory.

**Results and Discussion**

The overall fresh properties of SCC investigated in this study have been summarized in Table 4. The various tests namely Slump flow, T50, V-funnel and L-Box were conducted on five different mixture batches in order to observe these fresh properties of SCC as per ASTM guidelines.

Case ID	V Funnel Test, time (sec)	Slump Flow (mm)	L-Box Test Blocking ratio(H2/H1)	T50 Test Time (sec)
Case1-WC35	1. 15	2. 427.5	3. 0.67	4. 7
Case2-WC40	11	575	0.85	5
Case3-WC42	10	618	0.92	3.5
Case4-WC45	6	647	0.95	3
Case5-WC50	4	712	0.98	2

The compressive strength test is one of the most significant parameters of self-compacting concrete as it is important for structural and functional role of SCC. This can be affected by various interdependent factors such as water cement ratio, compressive strength of cement, properties of aggregates, it can be its shape, grading, strength, stiffness, and most importantly its size. Other factors may include curing period, testing parameters, specimen and test age.

There is decrease in the amount of compressive strength can be observed with increase in the amount of fly ash and it increases with increase in the amount of silica fume. Though the strength decreases with loft in the fly ash and increased by the silica fumes, the use of it is encouraged due to its ability to tackle the hazards affecting the environment.

It was observed that both the compressive strength and the tensile strengths increased with the decrease of water-cement ratio and it was observed that the compressive strength was 1 time that of tensile strength. Thus, it may be noticed that the designed values were not to be observed and results were not up to the mark. This could take place due to increase in water content or chemical admixture.



Slump flow and v funnel test resulted in consistency of self-compacting concrete by its own weight without any external vibrations or compaction. In l box test, even in congested reinforcement without any further segregation SCC gained satisfactory passing ability and filling ability Savings in labor cost can compensate the cost of cement, super plasticizer and mineral admixture and it could also increase its fluidity of SCC without extra expense. SCC improves the current precast concrete and civil engineering construction with practices and performance related too health and safety. It can be observed that water cement has significant effect on the fresh and harden properties of SCC. The SCC can be readily used in construction if available at local level instead of days old use of orthodox cement to ultimately contribute to the sustainable development of any country and can be a revelation in the society.

#### V. CONCLUSION

The use of SCC adds value in various ways, namely because of the decrease of the time associated with the casting task due to the decrease of the amount of work needed and of the need for compacting devices, as well as due to new construction systems. One should also mention the added ease with which concrete is cast in densely reinforced structures and areas of difficult access, the noise reduction on the work site and, consequently, on the surrounding environment, as well as the decrease of injuries associated with the compacting process by vibration and the significant improvement of the final quality of the concrete finishing surfaces. The use of SCC can also give an important contribute to achieve a more sustainable development, namely through the incorporation of significant quantities of sub-products from other industries (such as mineral additions), the possibility of incorporating recycled materials in its composition in substitution of natural aggregate and the potential increase of the structures durability that will lead to longer life cycles with a consequent decrease of the structures global costs and of the material associated with demolitions. Regarding its composition and when compared with conventional concrete (CC), SCC contains higher quantities of ultra fine materials (cement and mineral additives) as well as of superplasticizer and sometimes of viscosity modifying agents. On the other hand, SCC contains significantly lower quantities of coarse aggregate. The use of superplasticizers is needed as a way to increase fluidity while the ultra-fine material, as well as the viscosity moulders, contribute to maintaining the viscosity needed for a correct self-compacting without the occurrence of segregation, bleeding or particles flocculation. On the other hand, the lower quantities of coarse aggregate contribute to reducing the blocking phenomena allowing SCC to fulfil the moulds and to move through densely reinforced zones. Due to the differences in composition (and material consumption), SCC emerges as a material with properties, in both fresh and hardened states, very distinct from those of CC, namely at the level of materials consumption and durability.

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