International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-6 Issue-8, March 2017

Self-Compacting Concrete – A Review

Ma'aruf A., S.I.Abba, Nuruddeen M. M

Abstract: ***Concrete is an essential material in the building industry with world consumption estimated close to 25 billion tons every year and it is considered as the widely used material in the world. Concrete is defined in the wider perspective as " any product or mass made by the use of a cementing medium'' and the medium is the product of hydraulic cement and water reaction. The shortcoming in conventional concrete such as poor flow faculty and subsequent segregation quandaries leading to poor culminating and delayed construction time led to the development of self-flowing or self levelling concrete. Self-compacting concrete (SCC) is a development of conventional concrete, where the use of vibrators for compaction is no more required. Formulating SCCs is a compromise between adequately high fluidity to ascertain good casting and an adequate consistency to eschew phase separations quandaries (segregation or bleeding). SCC mixes must have three important properties: flow under its own weight to completely fill intricate and complex forms, under its own weight the ability to pass through and bond congested reinforcement and high segregation resistance to aggregate. A mix proportion was proposed by Okamura and Ozawa for SCC where the water/powder ration is to be adjusted and aggregate and fine aggregate contents fixed with self-compatibility achieved with the addition of plasticizer dosage. The content of the course aggregate is fixed at 50 percent of the total solid volume while the 40 percent of the mortar volume is fixed for the fine aggregate content and 0.9-1.0 water/powder ratio is assumed depending upon the properties of the powder and super plasticizer dosage. Conducting a number of trials determined water /powder ratio. Lack of established mix design procedure yet is one of the limitations of SCC.***

Keywords: Self compacting, Admixture, super plasticizer, viscosity modifying agent

I. INTRODUCTION

Self-compacting concrete is a special kind of concrete that can permeate and fill the gaps of reinforcement and the corners of molds without any desideratum of vibration and compaction during the placing process (1). The highly fluid nature of SCC makes it suitable for placing in difficult conditions and in sections with congested reinforcement. Development of self-compacted concrete is a desirable achievement in the construction company in order to resolve the issues associated with casting the concrete in place. Considering lack of uniformity and complete compaction of concrete by vibration, researchers at the University of Tokyo, Japan, started developing SSC in the late 1980's and by 1990's they have develop and start to use the SCC that does not require vibration to achieve full compaction (2).

Manuscript published on 30 March 2017.
***Correspondence Author(s)**
Ma'aruf A., Department of Civil Engineering, Kano University of Science and Technology, Wudil, Nigeria.
S.I.Abba, Department of Physical Planning Unit, North West University, Kano, Nigeria.
Nuruddeen M. M, Department of Civil Engineering, Kano University of Science and Technology, Wudil, Nigeria.

In 1996, a large consortium of European countries embark on a project aimed at developing SSC for practical applications, as these countries were interested in exploring the significance and potentials of SCC developed by Japan. The project is titled ''Rational Production and Improved Working Environment through using self-compacting concrete'' (3) (2). As skills of workers, the shape and amount of reinforcement bars or the arrangement of structures does not affect self-compacting concrete because of its high fluidity and resistance to segregation it can also be pumped to longer distance (4). The elimination of vibration leads to an improved concrete quality, decreased skilled labor and shortens the time needed for construction. On the other hand, vibrating the concrete creates noise that has a noxious physical impact on workers and affects the surrounding neighborhood. The self-compacting concrete is widely used in post or pretension concrete sections. It possesses the ability to moulded into any shape with the help of mould. It is used in congested areas were compaction equipment's cannot be used. Thus reducing the cost of the structure to about one tenth of the total cost of structure (4) . *Some of the advantages of Self-compacting concrete include the following*;It can be placed faster without mechanical vibration and less screeding which course reduction in placement cost ,Better and more uniform structural surface finish with little or no remedial surface work, Hard to reach areas and restricted sections can be filled easily, Creating structural and architectural shapes and surfaces finish difficult to obtained using conventional concrete,Better consolidation around reinforcement and ties the reinforcement, Better pumping ability, Eliminating variable operator related effort of consolidation by improving of uniformity in placement of concrete ,High labor saving , Cost saving by reducing the construction period, Easily placed in thin walled elements with limited access, Industrialized production of concrete, Eliminating vibrator noise, potentially increasing construction duration in urban areas, ''white finger syndrome'' a serious injury from vibration is prevented.

II. MATERIALS FOR SCC

Mixture proportion for SCC vary from those of ordinary concrete, in that the self compacting concrete has more powder content and less coarse aggregate. The ingredients of concrete can be grouped into two classes, namely active and in acting class, the active class comprises of cement and water, whereas in active includes of fine and coarse aggregate (3) (5). Generally, ordinary Portland cement (OPC) is employed in preparing SCC (5) (6) (7). "Suitability is established for mixing water and for recycled water from concrete production conforming to EN 1008'' (8).

Portable water is used generally in the production of SCC (9). To produce a homogeneous and cohesive mix, self-compacting concrete demands a large amount of powder content compared to conventional vibrated concrete. (10) reported that SCC often contains powder in the order of 450–600 kg/m3 of concrete.

Moreover, SCC incorporates a high range of water reducers (HRWR, Superplasticizers) in larger amount and frequently a viscosity modifying agent (VMA) in small doses. The question that dominates the selection of materials for SCC include: (i) limits on the amount of marginally unsuitable aggregates, that is those differed from real shapes and sizes, (ii) choice of HRWR, (iii) choice of VMA, and (iv) interaction and compatibility between cement, HRWR, and VMA.VMA. The major work in producing SCC involves designing of appropriate mix proportion and evaluating properties of the obtained concrete.

In practice fresh state of SCC shows high fluidity, self-compacting ability and segregation resistance all of which are influencing the reduction of risk of honeycombing of concrete (11). Dependability and durability of reinforced concrete structures can greatly be increased with the above good properties of SCC produced. The constituent materials, used for the production of Self-Compacting Concrete (SCC) shall generally comply with the requirements of EN 206 (12) .

Formulating SCCs is a compromise between adequately high fluidity to ascertain good casting and an adequate consistency to eschew phase separations quandaries (segregation or bleeding). SCC mixes must have three important properties: flow under its own weight to completely fill intricate and complex forms, under its own weight the ability to pass through and bond congested reinforcement and high segregation resistance to aggregate (13) . A mix proportion was proposed by Okamura and Ozawa for SCC where the water/powder ration is to be adjusted and aggregate and fine aggregate contents fixed with self-compatibility achieved with the addition of plasticizer dosage (14). The content of the course aggregate is fixed at 50 percent of the total solid volume while the 40 percent of the mortar volume is fixed for the fine aggregate content and 0.9-1.0 water/powder ratio is assumed depending upon the properties of the powder and super plasticizer dosage. Conducting a number of trials determined water /powder ratio. Lack of established mix design procedure yet is one of the limitations of SCC.

Admixtures : SCC incorporates chemical admixtures - in particular, a high range water, reducing admixture (HRWRA) and sometimes, viscosity-modifying agent (VMA). The HRWRA assist in achieving good flow at low water contents and VMA reduces bleeding and enhances the stability of the concrete mixture. An effective VMA can also reduces the powder requirement and still offer the required stability. Moreover, SCC almost always includes a mineral admixture, to enhance the deformability and stability of concrete. Issues linked with the use of chemical admixtures are discussed in this section.

Coarse aggregates and Fine aggregate: Aggregates shall conform to EN 12620. The maximum size of the aggregates depends on the particular application and is usually limited to 20 mm (8). Particles smaller than 0,125 mm contribute to the powder content. As far as mechanical properties are concerned, the course and fine aggregate used for the development of self-compacting concrete and conventional concrete are the same (9). However, shape and overall particle size distribution of coarse and fine aggregate must be given a serious consideration as the mobility and stability of the mix relay on this parameters. Coarse aggregate of nominal size of 19mm of crushed limestone with natural local sand as fine aggregate was used in concrete mixture (15).

Mixing Water: Water is essential for all socioeconomic development and for maintaining healthy ecosystems (16). Suitability is established for mixing water and for recycled water from concrete production conforming to EN 1008 (8).

Superplasticizer Suitable for Self-compacting Concrete: Superplasticizers tend to slow down the cement hydration (17). They gave room for improvement of admixtures in self-compacting concrete. To achieve this purpose, characterization of materials is unavoidable. The requirements for superplasticizer in self-compacting concrete may be summarized as follows: High dispersion effect for low water/powder (cement) ratio; less than 100% approx. By volume**,** keeping up the dispersing effect for at least two hours after mixing and reduce the sensitivity of temperature changes. **High range water reducers:** Due to its theological requirements, filler insertion (both reactive and inert) are normally used in SCC to enhance and maintain the workability, as well as to regulate the cement content and to reduce the heat of hydration. A number of investigation have been carryout on the utilisation of various types of HRWRAs with or without viscosity modifying agents in self-compacting concrete (18), (19). These studies seem to indicate those that HRWRAs that work on the concept of ‘steric hindrance’ needed a lower dosage compared to those based on ‘electrostatic repulsion’. Stated in other words, acrylic copolymers (AC) and polycarboxylate ethers (PCE) are funtional at lower dosages compared to sulfonated condensates of melamine (SMF) or naphthalene (SNF) formaldehyde (20). **Viscosity modifying agents:** The conventional method of improving the stability of flowing SCC is to increase the fines and reduce the aggregate contents by using a large amount of filler, reactive or inert. But the reduction in aggregate content result in using high volumes of cement which result in turn leads to a higher rise in temperature and an increase in cost. An alternative approach consists of incorporating viscosity-modifying admixture to enhance stability (21). Chemical admixtures are, however, expensive, and their use may increase the materials cost. Saving in labor cost might offset the increased cost, yet, while using mineral admixtures such as fly ash, blast furnace slag, or limestone filler could increase the slump of the concrete mixture without increasing its cost (15). Current works indicate that SCC produced with less powder content and VMA had similar fresh concrete properties as SCC with high powder contents produced without VMA (22).

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

VMAs have been in use for a long time (23). (24) reported obtaining 0.3% as the optimum dosage of VMA suitable for adjusting admixture content. They were mainly used for underwater concreting in the past, but are now also used in self-compacting concrete. Most VMAs have polysaccharides, as acting ingredient; however, some starches could also be appropriate for control of viscosity in SCC (25), (26). (27) studied the properties of super flowing concrete containing fly ash and reported that the replacement of cement by 30% (40% for only one mixture) fly ash resulted in excellent workability and flowability.

Other researchers (28) evaluated the influence of supplementary cementitious materials on workability and concluded that the replacement of cement by 30% of fly ash can significantly improve rheological properties. But most of the authors believe that, the percentage replacement of cement with fly ash, in the various published studies, did not exceed 30% (except the one 40% mixture by (27) by weight of the total cementitious materials. **Admixture compatibility:** A large amount of superplasticisers, typically SNF-based, is added to SCC to make it flowable at a fair water contents. There occur the problem of incompatibility between cement and HRWRA, which is generally felt acutely for mixtures having low water content. (29) have studied the behaivoir between SNF and cement. In concretes having low water content and high superplasticizer dosage, gypsum (present in cement) may precipitate out, causing a premature stiffening of the paste and consequent loss of slump (30). **Mineral fillers**: Water absorption, shape and particle size of mineral fillers can affect the demand of water/sensitivity and therefore suitable for use in the manufacture of self-compacting concrete (31). Minerals widely used are calcium based and can give excellent rheological properties and a good finish. Some of the mineral fillers include fly ash, silica fumes, ground blast furnace slag, etc. **Fly Ash:** Fly ash provide increase cohesion and reduced sensitivity to changes in water content. Incorporating high-volume class f fly ash in the design of self-compacting concrete is possible (15). **Silica Fume**: Its good cohesion and improved resistance to segregation can be obtained from self-compacting concrete with addition of silica fume due to its high level of fineness and practically spherical shape. **Ground blast furnace slag**: Ground granulated blast furnace slag (ggbs) provides reactive fines with a low heat of hydration. Reduced robustness with the problem of consistence control my result using high proportion of ggbs, while setting slower setting can increase the risk of segregation.

III. DEVELOPING SCC MIXES

To design a proper SCC mixture is not a simple task. Various investigations have to be carried out in order to obtain rational design methods. The mix of SCC must meet three key properties (32) thus: Ability to flow into and completely intricate and complex forms under its own weight, Ability to pass through and bond to congested reinforcement under its own weigh and High resistance to aggregate segregation.

The SCC mixes are designed and tested to meet the demand of the projects. Several different approaches have been used to develop SCC. Okamura and Ozawa (33) have proposed a simple mixture proportioning system. In this method, the coarse and fine aggregate content is kept constant,so that self-compatibility can be achieved by adjusting water/cement ratio and superplasticizer dosage only.

- The coarse aggregate content in concrete is fixed at 50% of the solid volume
- The fine aggregate amount is fixed at 40% of the mortar volume.
- The water-powder ratio in volume is assumed as 0.9 to 1.0, depending on the properties of the powder.
- The superplasticizer dosage and the final water-powder ratio are determined so as to ensure self-compactability.

For conventional concrete, strength requirement is the viewpoint in fixing water cement ratio, while for self-compacting concrete, self-compactabiliy determine the ratio of water-powder because self-compactability is very sensitive to his ration (34). In most cases, the required strength does not govern the water-cement ratio due the water-powder ratio is small enough for obtaining the desired strength for ordinary structures unless most of the powder materials in use is not reactive. Another method to achieve self-consolidating property is to incorporate a viscosity modifying admixture (VMA) to enhance stability (19) (35). Another rational method of mix design is based on the material artribute for various grades of SCC by including high volume fly ash as mineral admixture (36).

3.1. Mechanism for achieving self-compactability

The method for achieving self-computability involves resistance to segregation in between course aggregate and mortar when the concrete flows through the confined zones of reinforcement members and the high deformability of paste or mortar. (37) have employed the following method to achieve self-compactability as in figure 1, (19995).

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

International Journal of Innovative Technology and Exploring Engineering
IJITEE
www.ijitee.org
Exploring Innovation

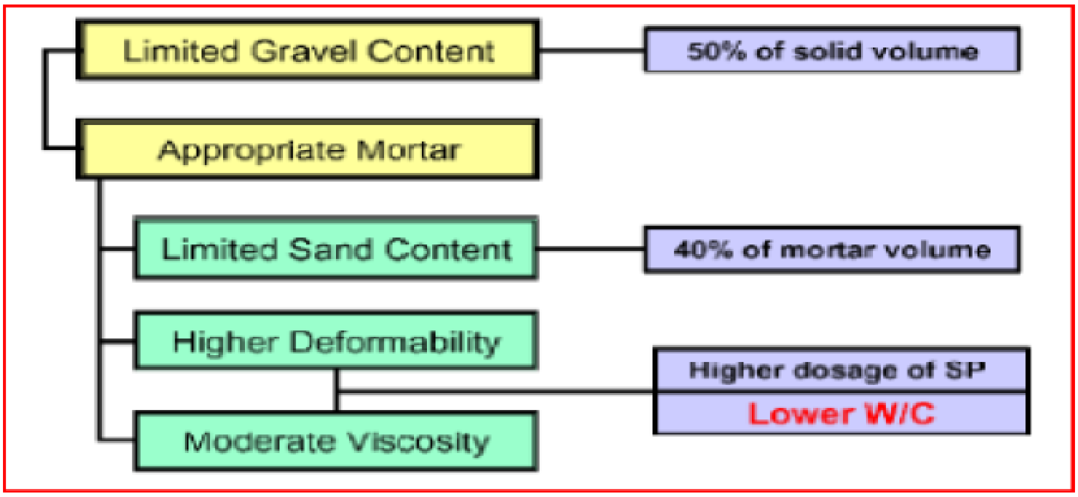

Figure 1 (34) Method for Achieving Self Compactability

Limited aggregate content , Low water-powder ratio and Use of superplasticizer . As the relative distance between the particles decreases, the frequency of collision and contact between aggregate particles decreases and the internal stress can increase when concrete is deformed particularly near obstacles (34). Research has found that the energy required for flowing is consumed by the increase internal stress, resulting in blockage of aggregate particles. This kind of blockage can be avoided to a lower level than normal by limiting the coarse aggregate content, whose energy consumption is particularly intense. When concrete flows through obstacles highly viscous paste is required to avoid blockage of coarse aggregate Figure 4. A deformed concrete with high paste viscosity, prevent localize increases in internal stresses due to the approach of coarse aggregate particles. Achievement of high deformability is by employment of superplasticizer, keeping water powder ratio to very low value.

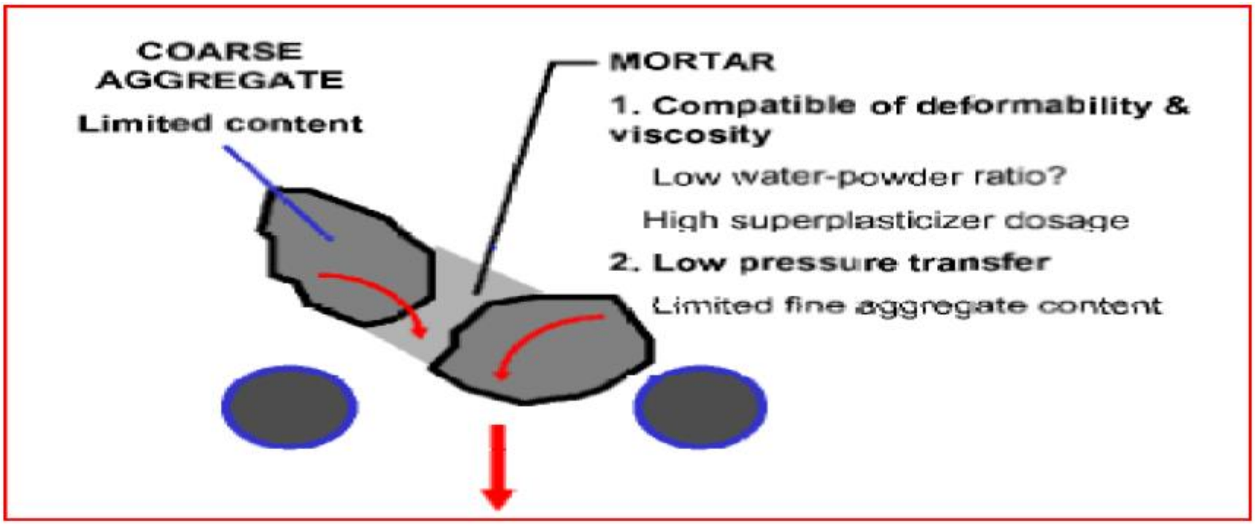

Figure 2 (34) Mechanism for Achieving Self-Compactability

Acceptance Test: As Self-Compactability of concrete is determined by the degree of compaction in a structure and poor Self-compactability cannot be compensated by construction work, the whole amount of concrete must be checked before casting (34). However, a conventional testing method for self-compactability require sampling and this may be extremely laborious if the self-compactability acceptance test is to be carried out for the whole amount of concrete. (38) develop a suitable acceptance test method for self-compactability as follows:

- The testing apparatus installed between the agitator truck and the pump at the job sit. The whole amount of concrete is poured into the apparatus.
- If the concrete flows through the apparatus, the concrete is considered as self-comtactable for the structure. If the concrete is stopped by the apparatus, the concrete is considered as having insufficient self-campactability and the mix proportion has to be adjusted.

Osaka Gas LNG tank site used the apparatus successfully and saved a considerable amount of acceptance test work (figure) 6 (39) .

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

Figure. 3 (34) Automatic Acceptance Test at Job Site

3.2. Method of Test of Fresh Self-Compacting Concrete

Many different test methods have been developed in attempts to characterize the properties of SCC. So far no single method or combination of methods has achieved global approval and most of them have their followers. Similarly, no single method has been found which characterizes all the relevant workability aspects so each mix design should be crosscheck and tested by more than one test method so as to get different workability parameters (8).

3.2.1. Measurement of SCC Flow Properties in Fresh State

***Filling Ability Tests*:**

Slump flow test: This is used to measure the free horizontal flow (under the influence of gravity alone) of SCC on plain surface without any obstruction. The concrete poured in slump cone without external compaction and the cone get lifted, then the average diameter of the flown concrete measured to check the filling ability of that concrete. The time T_{50cm} is the secondary indication of the flow. The time taken in second is measured instantly as the cone is lifted for the time when horizontal flow reach 500mm (40). The slump flow is used to find the filling ability of the SCC. The higher the slump flow value the greater its ability to fill formwork under its own weight. A value of at least 650mm is required for SCC (32).

Segregation Resistance Test:

V- Funnel test and V-Funnel test at $T_{5minutes}$: The V-funnel test is used to find the segregation resistance of SCC. The SCC sample is poured into the V-funnel apparatus, then it is allowed flow by its own weight. The emptying time of V-funnel is noted. The test measure the ease of flow of the concrete, the shorter flow times indicate greater flow ability. After 5 minutes setting segregation of concrete will show a less continuous flow with an increase in flow time. The device is used to measure the filling ability of self-compacting concrete. It consist of a transparent rectangular box with a number of obstacles through which the concrete is left to follow. The apparatus paced on a firm level support having a height of 1m. At the top side the funnel is placed through which the concrete is let to follow till it cover the most of the obstacles the rear end of the box.

L Box Test: Box test: This test the passing ability of the fresh concrete In this, the vertical section of the apparatus is filled with fresh concrete the gate is lifted to allow the concrete in the horizontal section, the propotion of the height of the concrete at the end of the horizontal section to the height of the remaining vertical section should be greater than 0.8 (8) (40). The L-box ratio is calculated as H_2/H_1, the ratio of H_2/H_1 is higher than 0.8, self-compacting concrete has good passing ability.

3.2.2. Physical Test:

The density of the hardened concrete is determined by measuring the weight of a cube in the air and underwater, according to standard NEN 5967

Compressive Strength: The Traditional vibrated concrete will have slightly lower strength compared with self-compacting concrete with similar water cement or cement binder ratio due to lack of vibration, giving an improved interface between the aggregate and harden paste (31).

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

Figure 3.7 (32) Compressive Test Equipment

Tensile Strength: For a particular concrete strength class and maturity, the tensile strength of self-compacting concrete may be assumed to be the same as that of normal concrete as the volume of paste (cement +fine + water) has no significant effect on tensile strength (31).

Drying Shrinkage: Loss of water from concrete to atmosphere causes drying shrinkage (8). Generally cement paste loses water though few types of aggregate also loses water. Shrinkage is the sum of the autogenous and drying shrinkage. Autogenous shrinkage results from internal consumption of water during hydration, the volume of the hydration product less than the original volume of the hydrated cement and water. Thus the reduction in volume causes tensile stress that results in autogenous shrinkage.

Deterioration Studies: Durability properties and existing environmental conditions largely determine the service life of the structure. Dead, live and special loads are designed for every show that its load-carrying capacity is not exceeded. Existing design procedures may include environmental loads that can have effects on geometrical and material properties to ensure adequacy of service life.the deterioration process of materials are initiated by environmental loads especially the corrosion of steel in concrete. Environmental loads cause reduction of the cross-section of area of reinforcement bars beside cracking and appalling of the concrete cover results in loss of the section bearing capacity. (41) when partially replacing 20% of cement with silica fume and 20% fine aggregate as quarry dust shows a very good resistance to alkaline attack and acid attack, sulfate attack and chloride attack than conventional concrete. This is due to the improvement of macro structure. Subjecting high strength, SCC to elevated temperature there was a maximum decrease in compressive strength of 24% at $400^{o/c}$ for 12 hours and a corresponding decrease in 15% of tensile strength at the same temperature and duration with 9% weight lost at the same condition (42).

IV. CONSTRUCTION ISSUES

Use of SCC has been demonstrated in a number of structures in Japan and Europe. A frequently cited case has been the construction of anchorages for the Akashi-Kaikyo bridge in Japan (43). Examples of other applications include: construction of a wall of a large liquefied natural gas tank in Japan (44), viaduct in Yokohama City (45), and a number of bridges in Sweden (46). Experience in these projects brings to light certain construction issues relating to the use of SCC. One issue is that of understanding the limit of flow distance of the concrete, in order to avoid segregation of coarse aggregate. Results from Japan indicate that for distances less than 10 m, segregation does not occur. (47) proposed the use of automatic gate valves for discharging the concrete at many different points, at intervals of 6-20 m. Another issue is that of the lateral pressure of the SCC on the formwork, due to the highly fluid nature of SCC (48). Higher rates of casting with SCC could compound the problem of excess formwork pressure. Prima facie, it may appear that more robust formwork and falsework will be required. However, available results indicate that SCC exerts about the same pressure as conventional concrete. This can be attributed perhaps to the inherent thixotropy of SCC, or in other words to, the significant buildup of viscosity following a period of rest. Research from Sweden has shown61 that the use of SCC actually resulted in pressures less than the design values for conventional concrete, and only slightly more than the conventionally-vibrated concrete. For example, at the same casting rate of 1.5 m/hour for a 3 m high wall, the forming pressure developed at the base was 25 kPa for normally-vibrated concrete and 29 kPa for SCC, while the calculated design value was more than 40 kPa. Difference in form pressures of the two concretes was not significant, given the vast differences in mixture design and compaction. In the same study, form pressure was found to be proportional to the casting rate.

V. CONCLUSIONS

The review shows that the application of self-compacting cannot be overemphasized, especially in the areas of post and pretension concrete structures as it possess the ability to be moulded into any shape even in congested areas were compacting equipment are difficult to be used.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

Thus reducing the cost of the structure. Numerous others advantages of self-compacting concrete include uniform surface finish, better consolidation around the reinforcement, better pumping ability and much more.

REFERENCE

1. Self-Compacting Concrete: Theoretical and experimental study. Brouwers, H.J.H. and Radix, H.J. 2005, ELSEVIER, pp. 2116–2136.
2. Ouchi, Masahiro, Nakamura, Sada-aki and Hallberg, Thomas Osterberg and Sven-Erik. APPLICATIONS OF SELF-COMPACTING CONCRETE IN JAPAN, EUROPE AND THE UNITED STATES. ISHPC . 2013, pp. 1-20.
3. RELIABILITY BASED DESIGN OF REINFORCED CONCRETETWO-WAY SOLID SLABS USING EURO CODE 2. Abubakar, I. and Ma'aruf, A. 4, NSUKKA : Ngerian Journal of Technology (NIJOTECH), 2014, Vol. 33. 1115-8443.
4. Self Compacted Concrete. Garg, Er. Neeraj Kumar. 2016, International Journal of Recent Research Aspects, pp. 116-117.
5. ASSESSMENT OF SELF COMPACTING CONCRETE IMMERSED IN ACIDIC SOLUTIONS WITH PARTIAL REPLACEMENT OF CEMENT WITH MINERAL ADMIXTURE. Gautham, K. Santosh and S.Uttamraj. I, 2015, International Journal of Research and Innovation in Civil and Construction Engineering (IJRICCE), Vol. II, pp. 194-200.
6. Evaluation of strength at early ages of self-compacting concrete with high volume fly ash. Sukumar, Binu, Nagamani, K. and Raghavan, R. Srinivasa. 2008, Costruction and building materials, Vol. 22, pp. 1394-1401.
7. Experimental Investigation of the Effect of Manufactured Sand and Lightweight Sand on the Properties of Fresh and Hardened Self-Compacting Lightweight Concretes. Zhu, Yiyun, Cui, Hongzhi and Tang, and Waiching. 735, s.l. : MDPI, 2016, MDPI, Vol. 9, pp. 1-17.
8. EFNARC. Specification and Guidelines for self-compacting concrete. Farnham : EFNARC, Association, 2002.
9. A Silent Concrete in Scenic Valley. Bapat, S. G., Kulkarni, S. B. and Bandekar, K.S. 1, 2004, An International Journal of Nuclear Power, Vol. 18, pp. 43-51.
10. Experimental study for obtaining self-compacting concrete. V, Jagadish and RV, Sudharshan MS : Ranganath. 77, 2003, Indian concrete Journal, Vol. 8, pp. 1261-6.
11. A simple mix design method for self-compacting concrete. Su, Nan, Hsu, Kung-Chung and Chai, His-Wen. 2001, Cement and Concrete Research, Vol. 31, pp. 1799–1807.
12. Specification and Guidelines for Self Compacting Concrete. Poulson, Brian. Norfolk : EFNARC, 2002. ENARC.
13. APPLICATIONS OF SELF-COMPACTING CONCRETE IN JAPAN, EUROPE AND THE UNITED STATE. Ouchi, et al. Washington, D.C. : s.n., 2003. ISHPC.
14. Self-Compacting Concrete - Procedure for Mix Design. AGGARWAL, Paratibha, et al. 12, 2008, Leonardo Electronic Journal of Practices and Technologies, pp. 15-24.
15. Self Compacting Concrete Incorporating high volume of class F Fly Ash : Preliminary result. Bouzouba, N. and Lachemib, and M. 2001, Cement and Concrete Research, Vol. 3, pp. 413-420.
16. Assessment of Water Quality Changes at Two Location of Yamuna River Using the National Sanitation Foundation of Water Quality (NSFWQI). Abba, S.I., Said, Y.S. and Bashir3, A. 8, INDIA : Journal of Civil Engineering and Environmental Technology Krishi Sanskriti Publications, 2015, Vol. 2. 2349-8404; Online ISSN: 2349-879X;.
17. Influence of Mineral additions and chemical admixture on setting and volumetric autogenous shrinkage of SCC equivalent mortar. G, Heirman, L, Vandewalle and D, Van Gemert. Grand, Belgium : s.n., 2007. Proceeding of the 5th RILEM symposium on SCC.
18. Effect of Welan Gum- High ang Range Water Reducer of Cement Grout. Khayat, K. H. and Yahia, A. 1997, ACI Journal, Vol. 94, pp. 365-372.
19. High strength self-compacting concrete, original solutions associating Organic and Inorganic admixtures. Sari, M, E, Prat and JF, Labastire. 29, 1999, Cement and Concrete Research, Vol. 6, pp. 813-818.
20. Performance of Self-consolidating Concrete Made with Various Admixtur Combinations. Hwang, S. D., et al. 2003. Proceeding of the 3rd International RILEM Symposium on Self-compacting concrete.
21. Use of Viscosiy-Modifying Admixture to Enhance Stability ofFluid Concrete. Khayat, K. H. and Guizani, Z. 4, 1997, ACI Material Journal, Vol. 94, pp. 332-341.
22. Development of Cost-Effective Self-Compating Concrete Incorporating Fly-Ash, Slag Cement or Viscosity-Modifying Admixture. Lachemi, M., et al. 5, 2003, ACI Material Journal, Vol. 100.
23. Viscosity-Enhancing Admixture for Cement-Based Materials; An Overview. Khayat, K. H. 1998, Cement and Concrete Composite, Vol. 20, pp. 171-188.
24. INFLUENCE OF VISCOSCITY MODIFYING ADMIXTURES ON FRESH AND HARDENED PROPERTIES OF SELF COMPACTING CONCRETE WITH VARYING DOSAGE OF FLYASH. Shraddha, rao, M.V.Seshagiri and Mythili, K. I, 20115, International Journal of Research and Innovation in Civil and Construction Engineering (IJRICCE, Vol. II, pp. 123-131.
25. Self-Leveling Concrete -Design and Properties. Abbroise, J., Rols, S. and Pera, J. 1999, Concrete Science and Enfgineering, Vol. 1, pp. 140-147.
26. Evaluation of Hydoxy Prophyl Starch as a Viscosity Modifying Agent for Self-Compacting Concrete. Rajayogan, V., Santhanam, M. and Sarma, B. S. 2003. Proceeding of the 3rd International RILEM Symposium on Self-Compacting Concrete.
27. Experimental Research on the Material Properties of Super Flowing concrete. Kim, J.K., et al. 1996, Production Methods and Workability of Concrete, E & FN Spon,, pp. 271-284.
28. Application of Super workable concrete to Reinforced concerete structures with difficult construction condition. Miura, N., et al. Proceeding of ACI SP.
29. Chemical Admixture-Cement Interaction: Phenomenology and Physio-Chemical Conceptes. Jolicoeur, C. and Simard, M. A. 23, 1998, Cement and Concrete Composites, Vol. 20, pp. 87-101.
30. NEVILLE, A. M. and BROOKS, J. J. CONCRETE TECHNOLOGY. London : Pearson Edducation Limited, 2010.
31. Bibm, et al. “The European Guidelines for Self Compacting Concrete, specafication, production and use. W. Bennenk : The “TESTING-SCC” project, 2005.
32. EXPERIMENTAL INVESTIGATION OF SELF COMPACTING CONCRETE BY VARYING PERCENTAGE OF FINE AGGREGATE TO TOTAL AGGREGATE RATIO FOR DIFFERENT GRADES OF CONCRETE. J.P.Alankruta1, S.Uttamraj2,. I, 2015, International Journal of Research and Innovation in Civil and Construction Engineering (IJRICCE, Vol. II, pp. 184-193.
33. Self-compacting concrete. Development, present and future use. H, Okamura and M, Ouchi. RILEM : Rilem publications, 1999. First internation Rilem syposium on self-compacting concrete. pp. 3-14.
34. Self compacting concrete. Okamura, Hajime and Ouchi, Masahiro. 1, 2003, Journal of Advance Concrete Technology, Vol. 1, pp. 5-15.
35. Use of viscosity modifying admextures to enhance stability of fluid concrete. KH, Kayat and Z, Gaizani. 94, 1997, ACI Mater J, Vol. 4, pp. 332-40.
36. Rational mix design method for self-compacting concrete. Binu, Sukumar, K, Nagamani and M, Indumathi. Tamil Nadu, India : s.n., 2006. Proceedings of national comference on concrete technology for the future (NCCTF).
37. Mix design of self-compacting concrete. H, Okaruma and H, Ozawa. 1995, Concrete library of JSCE, Vol. 25, pp. 107-120.
38. State-of-the-art report on self-compactability evaluation. M., Ouchi. 19999. Proceeding on the International Workshop on Self-Compacting Concrete.
39. Construction of prestressed concrete outer tank for NLG storage using high-strength self-compacting concrete. H., Kimatura, et al. 1999. proceeding of the International Workshop on Self-Compacting Concrete.
40. Self-Compacting property of Highly-Flowable concrete. S, Nagataki and H, Fujiwara. Malhotra, : s.n., 1995. Second Comference on advances in Concrete Technology.
41. Duravility Properties of High Strength Self-Compacting Concrete Using Silica Fuse and Quarry Dust. K, Karthick M : Nirmalkumar. 4, 2016, Internation Journal of Scientific Engineering and Applied Scieces (IJSEAS) , Vol. 2, pp. 389-395.
42. A STUDY ON HIGHSTRENGTH SELF COMPACTING CONCRETE ON EXPOSURE TO VARIOUS TEMPERATURES. Sweth, A. and Mythili, K. I, 2014, INTERNATIONAL JOURNAL OF RESEARCH AND INOVATION IN CIVIL AND CONSTRUCTION ENGINEERING (IJRICCE), Vol. I, pp. 58-69.
43. Tanaka, K., Sato, K. and Watanabe, s. Development and Utilization of High Performance Concrete for the Construction of Akashi Kaikyo Bridge. Detroit : ACI SP, 1993.

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

44. Construction of Prestressed Concrete Outer Tank for LNG Storage Using High-Strength Self-Compacting Concrete. Kitamura, H., et al. Kochi, Japan : s.n., 1998. International Wokshop on Self-Compacting Concrete.
45. A Flowable Concrete in Bridge Pier Caps. Kosaka, H., et al. 2, 1996, Concrete International, Vol. 18.
46. Application of Self-Compacting Concrete for Bridge Casting . Petersson, O., Billberg, p. and Osterberg, T. Japan : s.n., 1998. Proceeding of International Wrokshop on Self-Compacting Concrete. JCE Concrete Engineering Series.
47. Placing of Highly-Flowable Concrete Using Automatic ate Valve. Arima, I., et al. 3, 1994, Concrete Journal , Vol. 32, pp. 79-85.
48. Form Pressure Generated by Self-Compacting Concrete . Billberg, P. 2003. Proceeding of he 3rd RILEM syposium on Self-Compacting Concrete .
49. Insitu Mechanical Properties of Wall Elements Casting Using Self-Compacting Concrete. KHAYAT, K. H., Manai, K. and Trudel, A. 6, 1997, ACI Materials Journal, Vol. 94, pp. 491-500.
50. Uniformity of In-situ Properties of Slf-Compacting Concrete in Full Scale Structural Element. Zhu, W., Gibbs, J. C. and Bartus, P. j. M. 2001, Cement and Concrete Coposites, Vol. 23, pp. 57-64.
51. A Comparison Between Mechanical Properties of Self-Compacting Concrete and Corresponding Properties of Normal Concrete. Persson, B. 2001, Cement and Concrete Research, Vol. 31, pp. 193-198.
52. Cracking Susceptibility Due to Volume Changes of Self-Compacting Concrete. Hammer, T. A. 2003. Proceeding of 3rd International RILEM Syposium on Self-Compacting Concrete.
53. A Study of Plastic Shrinkage of Self-Compacting Concrete. Turcry, P. and Loukili, A. 2003. Proceeding of the 3rd International RILEM Symposium onSelf-Compacting Concrete.
54. RILEM. Mechanical Properties of Self-compacting concrete. Ghent Belgium : Springer, 2014.
55. Full Scale Casting of Bridges with Self-compacting Concrete. O., P. Billberg, Petersson and Osterberg, T. 1999. RILEM Symposium on Self-Compacting Concrete.
56. Permeation properties of Self-compacting concrete. Zhu, w. and Bortos, P.J. M. 6, 2003, Cement and Concrete Research, Vol. 33, pp. 921-926.
57. Frost Resistaance, Cloride Transport and Related Microstructure of Field Self-compacting concrete. Tragarah, J., Skoglund, P. and M. 2003. Proceeding of the 3rd International RILEM Symposium on self compacting concrete.
58. Internal Frost Resistance and Salt Frost Scaling of SCC. Persson, B. 2003, Cement and Concrete Research, Vol. 33, pp. 373-379.
59. Minelli, Linda Monfardini :Fausto. Experimental Study on Full-Scale Beams Madeby Reinforced Alkali Activated ConcreteUndergoing Flexure. MDPI. August 30, 2016, pp. 1-16.
60. A conceptual approach to the mixture proportioning technique for producing self compacting concrete. Sivakumar, A., Elumalai, G. and Srinivasan, V. 3, 2011, Jornal of Civil Engineering and Construction Technology, Vol. vol. 2, pp. 65-71.
61. SELF-COMPACTING CONCRETE AND ITS APPLICATION IN CONTEMPORARY ARCHITECTURAL PRACTISE. Okrajnov-Bajić, Ruža and Vasović, Dejan. 20, 2009, SPATIUM International Review, pp. 28-34.
62. Summary of self-compacting concrete workability. Gui-xiang11, Guo and Hon-jun22, Duan. 7(part-2), July, 2015, GUO Gui-xiang Int. Journal of Engineering Research and Application , Vol. 5, pp. 138-142.

Biographies:

Engr. Ado Ma'aruf M.NSE. M.Coren, PhD. Student Civil Engineering Department Faculty of Engineering at Near East University Cyprus

Engr. S.I.Abba M.ASCE, M.Coren, M. IRED, M.IAENG. Northwest University, Kano. PhD. Student Civil Engineering Department Faculty of Engineering at Near East University Cyprus

Engr. Dr. Nuruddeen Muhammad Musa, Civil Engineering Department, Kano Univerity of Science & Technology, Wudil

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)