ORIGINAL RESEARCH PAPER

Engineering

LITERATURE REVIEW ON SELF-COMPACTING CONCRETE

KEY WORDS: self compacting concrete; slump flow test; V-funnel test; L-box test; Segregation resistance test.

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ABSTRACT

The paper presents review of the characteristics of the self-compacting concretes(SSC). SSC is a concept in which ingredients of the concrete mix are designed so that the concrete compacts by itself by its own weight to all corners of formwork, to obtain durable, strong, high strength and impervious concrete. Due to its properties and composition, the self-compacting concrete is described here as being one of the future friendly environmental material for buildings. Tests concerning to obtaining a self compacting concrete, together with the specific fresh concrete properties tests, are described and conclusions are drawn.

I. INTRODUCTION:

Self-compacting concrete (SCC) is an innovative concrete that does not require vibration for placing and compaction. The invention of SCC is considered one of the most important developments in the construction industry. SCC is produced with low water-cement ratio providing the potential for high early strength, earlier demoulding and faster use of elements and structures. It is able to flow under its own weight due to its highly fluid nature and achieving a full compaction even in a formwork with complicated shapes and dense reinforcement. The elimination of vibration improves the productivity, shortens construction time, increases the safety of working environment and reduces the labour and equipment cost. The improved construction practice and performance, combined with the health and safety benefits, make SCC a very attractive solution for both precast concrete and civil engineering construction.

II. LITERATURE REVIEW:

Hajime Okamura[1] and Masahiro Ouchi[2], Self-compacting concrete was first developed in 1988 to achieve durable concrete structures. Since then, various investigations have been carried out and this type of concrete has been used in practical structures in Japan, mainly by large construction companies. They had made investigations for establishing a rational mix-design method and self compactability testing methods have been carried out from the viewpoint of making self- compacting concrete a standard concrete.

Aurelia Bradu, et al they had investigated the higher powder content, limited volume and nominal maximum size of coarse aggregate, larger quantity of superplasticisers represent design requirements in achieving the self compatibility. The changes of the concrete composition lead to a different properties in hardened state.

Konstantinos G. Trezos, et al this proposed paper examines water permeability of SCC as an important step towards the definition of concrete durability. Three SCC mixtures and two NC mixtures have been produced and concrete specimens have been cured in two different ways (air curing, underwater curing). Water permeability has been evaluated by conducting permeability tests at various ages (7, 14, 28 and 56 days), evaluating the water flux into the concrete surface.

Liana Iureş and Corneliu Bob, they had presented 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 enviromental material for buildings. Tests concerning to obtaining a selfcompacting concrete, together with the specific fresh concrete properties tests, are described.

Campion and Philippe reviewed the application of SSC for bridge repair at Rempenbruke and repair of 9.4 km long tunnel at the mainhearts square in Zurich.

Andreas Leemann et al (2007) carried out a study on the effect of viscosity modifying agent (VMA) on mortar and concrete used to obtain the flow properties and the rheology is studied. Mainly VMA is used in the SCC to obtain the free flow without any segregation. Inorganic VMA micro silica (MS) and nano silica slurry (NA) and organic VMA high molecular ethylenoxide derivate (EO), Natural Polysaccharide (PS), starch derivate (ST) are used. These are combined with Super plasticizer (SP) for varying water binder ratios (w/b) are tested. While addition of VMA and SP shows the marginal difference in flow properties and rheology. The organic VMA MS and NS and the organic VMA to show a bigger gradient and VMA PS (0.4% and 0.8%) and ST a smaller gradient than the mix without VMA. PS causes the strongest increase of yield stress and MS the lowest. Combination of VMA and SP shows the improvement in compressive strength at the age of 28 days. Variation of w/b, the addition of SP and VMA all change flow properties and rheological properties in a different way. The in organic VMA cause an acceleration of hydration and higher compressive strength[5].

III. DEVELOPMENT OF SELF COMPACTING CONCRETE:

Concrete that requires little vibration or compaction has been used in Europe since the early 1970s but self-compacting concrete was not developed until the late 1980's in Japan. The prototype of self-compacting concrete was first completed in 1988 using materials already on the market. The prototype performed satisfactorily with regard to drying and hardening shrinkage, heat of hydration, denseness after hardening, and other properties. This concrete was named "High Performance Concrete" and was defined as follows at the three stages of concrete:

(1) Fresh: self-compactable
(2) Early age: avoidance of initial defects
(3) After hardening: protection against external factors

During the 1990s, the use of the new type of concrete has been expanded over Europe and America, and in the last fifteen years SCC is also being used in construction retrofit.

IV. PRODUCTION AND PRODUCTION CONTROL:

The production of self-compacting concrete shall be carried out in plants where the equipment, operation and materials are properly controlled. It should therefore be carried out at plants or where the production is carried out with equipment and control systems equal or superior to plants. The production control at plants should as a **role** be performed by an engineer experienced in producing self-compacting concrete.

V. CONSTITUENT MATERIALS:

SCC consists of similar components as conventionally vibrated

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concrete: cement, aggregates, water, mineral and chemical admixtures. The passing ability and segregation resistance of SCC is achieved by the decrease of coarse aggregate content and the growing up of the powder quantities. The superplasticisers (high range water reducers) are responsible for the high fluidity of concrete mix, while the powder and viscosity modifying agents lead to a better stability and cohesion, reducing bleeding and segregation of the mix.

Mineral admixtures are used as an extra fine material; the most used is the limestone filler that represents a chemically inert by-product of limestone crushers. The addition of limestone powder improves the particle packing by filling the small pores between cement grains and augments the water retention of fresh mixes.

VI. BATCHING:

(1) The tolerances for batching errors should be as specified in the Standard Specification. However, batching errors should be controlled with lower tolerances where required. It is recommended (and is a requirement in some EU member countries) that the producer will be accredited to ISO 9001 or equivalent. It is recommended that the maximum tolerance for batching errors of air-entraining and high-range water-reducing admixtures and superplasticizers be 2%.

(2) When additional batching equipment is to be installed, it should be confirmed beforehand that the batching errors of the equipment are in the specified range.

(3) Where such chemical admixtures as thickeners are manually charged into the mixer or aggregate batching tank, a system whereby charging control is ensured should be adopted.

(4) The capacity of batching equipment should be confirmed beforehand, since insufficient capacities can limit the batch size.

VII. MIXING AND MIX DESIGN:

The method for achieving self-compatibility involves not only high deformability of paste or mortar, but also resistance to segregation between coarse aggregate and mortar when the concrete flows through the confined zone of reinforcing bars. The mix design process is graphically presented in Fig.1.

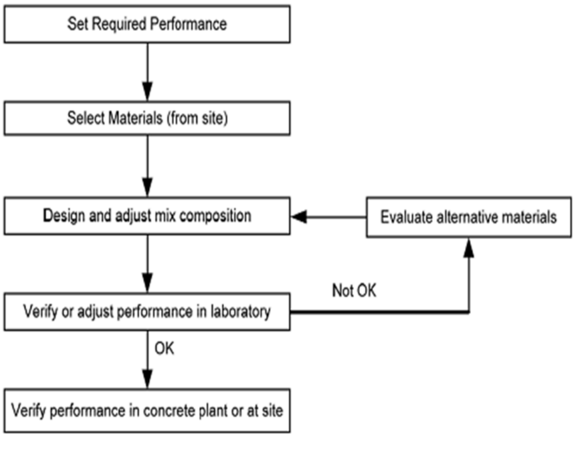

Fig.1 Mix Design Procedure of Self-Compacting Concrete.

The time necessary to achieve complete mixing of SCC may be longer than for normal concrete due to reduced frictional forces and to fully activate the superplasticiser. It is important that preliminary trials are carried out to ascertain the efficiency of individual mixers and the optimum sequence for addition of constituents. The volume of concrete for preliminary full-scale trials should not be less than half the capacity of the mixer. The mixing succession and duration are very important in the production of SCC, due to their influence on the properties of fresh concrete. Self-compacting concrete can be produced with any efficient concrete mixer including paddle mixers, free fall mixers and truck mixers but force action mixers are generally preferred. The aggregates, cement and powder were efficiently mixed dry until attain a uniform distribution, sequential, water was added into the mixer and continued to blend and finally the superplasticisers with the remaining water was introduced and mixed to obtain an homogeneous mix. The method for achieving self-compactability involves not only high deformability of paste or mortar, but also resistance to segregation between coarse aggregate and mortar when the concrete flows through the confined zone of reinforcing bars. The mix proportioning of self-compacting concrete is shown and compared with those of normal concrete in Fig.2.

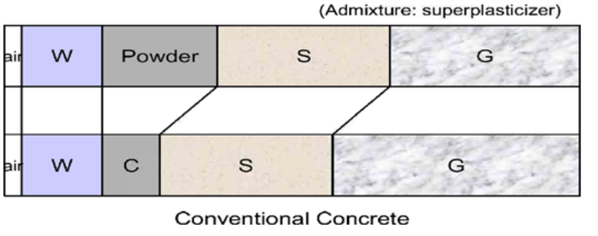

Fig.2 Mix Proportioning of Self-Compacting Concrete and Conventional Concrete.

The aggregate content is smaller than conventional concrete that requires vibrating compaction. The The degree of packing of coarse aggregate in SCC is approximately 50% to reduce the interaction between coarse aggregate particles when the concrete deforms. The degree of packing of fine aggregate in SCC mortar is approximately 60% so that shear deformability when the concrete deforms may be limited. On the other hand, the viscosity of the paste in SCC is highest than that of conventional concrete due to its lowest water-powder ratio. This characteristic is effective in inhibiting segregation.

VIII.QUALITY TESTS ON SCC:

SCC represents a mixture with high flowability and capability to fill the formwork uniformly, denser and without segregation. The mortar should have a sufficient deformatibility to ensure the self compactibility with no external mechanical compaction. A required viscosity is necessary to maintain the stability of the fresh concrete during the placement. The filling ability and stability of self-compacting concrete in the fresh state can be defined by four key characteristics. Each characteristic can be addressed by one or more test methods:

Table 1. Tests on SCC

Characteristic	Preferred test method(s)
Flowability	Slump-flow test
Viscosity (assessed by rate of flow)	T500 Slump-flow test or V-funnel test
Passing ability	L-box test
Segregation	Segregation resistance (sieve) test

The slump flow test (Fig.3) express the filling ability in the absence of obstruction, visual observations during the test can offers additional information about bleeding capacity and segregation potential.. Table 2. Shows the Slump Flow classes for SCC.

Fig.3 Slump Flow Test of SCC

Table 2. Slump Flow Classes

Class	Slump-flow in mm
SF1	550 to 650
Sf2	660 to 750
SF3	760 to 850

In order to attain a higher quality of concrete elements, it is recommended to select the slump-flow class according to the structural condition of applications, geometry of elements, degree of reinforcement.

The V-funnel test (Fig. 4) is used to evaluate the viscosity of SCC, whereby the flow time is estimated.

Fig.4 V-funnel Test of SCC

Table 3. Viscosity Classes

Class	T500, sec	V-funnel time in sec
VS1/ VF1	≤ 2	≤ 8
VS2/ VF2	> 2	9 to 25

The SCC of VS1/VF1 has sufficient ability to fill the formwork even with congested reinforcement and usually has a perfectly surface finish. The concrete of VS2/VF2 classes is characterized by a higher viscosity and improved segregation resistance, that lead to a increasing flow time and a lower formwork pressure.

The passing ability of SCC through narrow spaces, even with congested area of reinforcement, can be assessed by the L-box test (Fig. 5).

Table 4. Passing Ability Classes (L-box)

Class	Passing ability
PA1 ≥	0.80 with 2 rebars
PA2 ≥	0.80 with 3 rebars

The blocking ratio expresses the capability of fresh mix to spread among the reinforcement and fill the mould.

Table 5. Segregation Resistance Classes (Sieve Segregation)

Class	Segregation resistance
SR1	≤ 20
SR2	≤ 15

IX. CONCLUSION:

i. The elimination of vibrating equipment near construction and precast sites where concrete is being placed, reducing the exposure of workers to noise and vibration.
ii. The improved structural integrity and constructability, combined with the health and safety benefits, make SCC a very attractive solution for both precast concrete and civil engineering construction.
iii. SCC is suitable, where it is difficult to vibrate the concrete.
iv. SCC is suitable especially in highly reinforced concrete members like bridge decks or abutments, tunnel linings or tubing segments, also minimizes voids on highly reinforced areas.
v. Produces a uniform surface and allows for innovative architectural features.

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