Testing and Mix Design Method of Self-Compacting Concrete

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Abstract— Self compacting concrete is a highly flowable, yet stable concrete that can spread readily into place and fill the formwork without any consolidation and without undergoing any significant separation. In general, SCC results in reduced construction times and reduced noise pollution. This paper deals with the history of SCC development and its basic principle, different testing methods to test high-flowability, resistance against segregation, and passibility. Different mix design methods using a variety of materials has been discussed in this paper, as the characteristics of materials and the mix proportion influences self-compactability to a great extent.

Keywords— Self-compacting concrete, Mix design, Superplasticizer, Water-powder ratio, Flowability.

I. INTRODUCTION

In Japan, in early eighties, premature deterioration of concrete structures were detected almost everywhere in the country. The main cause of the deterioration was recognized as inadequate compaction. In addition, the gradual reduction in the number of skilled workers in Japan’s construction industry led to a reduction in the quality of construction work. As a solution for these social and technical requirements, the concept of SCC was proposed by Prof Okamura¹ at Tokyo University in 1988. He gave the first prototype of SCC using materials already in the market. Later studies to develop SCC, including a fundamental study on the workability of concrete, were carried out by Ozawa and Maekawa². SCC has now been taken up with enthusiasm across Europe and other parts of the world, in both site and precast concrete work. Practical application has been backed up by research on its physical and mechanical characteristics of SCC. Early SCC relied on very high contents of cementitious paste, the mixes required specialized and well-controlled placing methods to avoid segregation, but the high contents of cement paste made them prone to shrinkage and high heat generation. The overall costs were very high and applications therefore remained very limited. After series of advancements it is no longer a material consisting of cement, aggregates, water and admixtures. As already mentioned it is now an engineered material with several constituents.

A. Basic Principle

The SCC is that which gets compacted due to its self-weight and is deaerated (no entrapped air) almost completely while flowing in the form work. In densely reinforced structural members, it fills completely all the voids and gaps and maintains nearly horizontal concrete level after it is placed. With regard to its composition, SCC consists of the same components as conventionally vibrated normal concrete, ie, cement, aggregates, water, additives or admixtures. However, the high dosage of super-plasticizer used for reduction of the liquid limit and for better workability, the high powder content as ‘lubricant’ for the coarse aggregates, as well as the use of viscosity-agents to increase the viscosity of the concrete have to be taken into account.

Superplasticizer enhances deformability and with the reduction of water/powder segregation resistance is increased. High deformability and high segregation resistance is obtained by limiting the amount of coarse aggregate. These two properties of mortar and concrete in turn lead to self-compactability limitation of coarse aggregate content. Figure 1 shows the basic principles for the production of SCC.

![Fig. 1.Basic principles for production of self-compacting concrete](image)

II. TESTING OF SCC

At the stage before solidification, self-compacting concrete is required to have three qualities: high-flowability, resistance against segregation and passibility, ie, ability that is necessary to pass the space between reinforcing bars. Other additional properties, such as, washout resistance and
finishability, may be significant and specified for individual projects/applications. Therefore, it is important to test whether the concrete is self-compactable or not and also to evaluate deformability or viscosity for estimating proper mix proportioning if the concrete does not have sufficient self-compactability. The existing procedures for self-compacting characteristics are those, which measure height differences at different points under free flow and also resistance against blocking. The common tests currently used, although not standardized for assessment of fresh SCC, are described here.

1. Slump Flow Test for Measuring Flowability:

The basic equipment used is the same as for the conventional Slump test (Figure 2). The test method differs from the conventional one in the way that the concrete sample placed into the mould has no reinforcement rod and when the slump cone is removed the sample collapses. The diameter of the spread of the sample is measured, ie, a horizontal distance is measured as against the vertical slump measured in the conventional test. While measuring the diameter of the spread, the time that the sample takes to reach a diameter of 500 mm (T50) is also sometimes measured. The Slump Flow test can give an indication about the filling ability of SCC and an experienced operator can also detect an extreme susceptibility of the mix to segregation. However, this information cannot be obtained from numerical results alone, a substantial previous experience in using the test and carrying out construction in SCC is essential.

2. V-funnel Test:

The V-funnel test was developed in Japan and used by Ozawa, et al. The equipment consists of a V-shaped funnel, shown in Figure 3. The funnel is filled with concrete and the time taken by it to flow through the apparatus measured. This test gives account of the filling capacity (flowability). The inverted cone shape shows any possibility of the concrete to block is reflected in the result.

3. L-box Test:

The L-box test method uses a test apparatus comprising a vertical section and a horizontal trough into which the concrete is allowed to flow on the release of a trap door from the vertical section passing through reinforcing bars placed at the intersection of the two areas of the apparatus (Figure 4). The concrete ends of the apparatus H1 and H2 measure the height of the concrete at both ends. The L-box test can give an indication as to the filling ability and passing ability.

<table>
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<tr>
<th>Sr No</th>
<th>Method</th>
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<th>Max.</th>
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<td>V-Funnel</td>
<td>Sec</td>
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<tr>
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</tr>
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</table>
III. MIX-DESIGN

The Japanese concept for design of SCC is based on a method proposed by Okamura and Ozawa. The authors have proposed a simple mix-proportioning system assuming general supply from ready-mixed concrete plants. The coarse and fine aggregate contents are fixed so that self-compactability can be achieved easily by adjusting the water to powder volume ratio and superplasticizer dosage only. The mixed design as proposed is:

- Coarse aggregate content is fixed at 50% of the solid volume;
- Fine aggregate content is fixed at 40% of the mortar volume;
- Water-powder ratio in volume is assumed as 0.9 to 1.0 depending on the properties of the powder; and
- Superplasticizer dosage and the final water-powder ratio are determined so as to ensure the self-compactability.

The value of water to powder volume ratio (Vw/Vp) is optimized by mortar flow test and Mortar Funnel Test. Takada considered the slump flow value of 650±30 mm and the V-funnel time of 11±2 s as adequate value for the workable SCC. Further to increase the viscosity and thereby reduce the deformity an organic stabilizer ‘welan gum’ was used. In organic stabilizer, there is a polymer formation of 3-dimensional framework which increases the viscosity and water adsorption.

IV. FUTURE OF SELF-COMPACTING CONCRETE

Since the development of the prototype of SCC in 1988, its use in actual structures has gradually increased worldwide. SCC addresses many environmental issues; the main ones are reduction in noise level in the factory as well as on site, reduction in personal injuries from noise and manual handling, reduction in electricity usage and reduction in the overall maintenance costs of vibration equipment. A typical application example of SCC is the two anchorages of Akashi-Kaikyo (Strait) Bridge opened in April 1998, a suspension bridge with the longest span (1991 m) in the world. The SCC provides tangible opportunities to both designer and contractor. It also has a future in the precast industry providing durable concrete at a lower cost due to lower initial investments of vibrating facilities and lower recurring costs due to faster reusage of moulds. It improves the working environment at plants and sites by eliminating noise of vibration; it is possible for concrete product plants to be located in the urban area.

V. CONCLUSION

Considering the economy and the durability of conventional concrete structures, it is observed that the quality and the density of the concrete, as well as the compaction of the concrete are main parameters that cause deterioration. For this, SCC offers new possibilities and prospects. For this, SCC offers new possibilities and prospects. It can be a boon considering improvement in concrete quality, significant advances towards automation and concrete construction processes, shortened construction time, lower construction cost and much improvement in working conditions as it reduces noise pollution.

REFERENCE
