International Journal of Civil and Structural Engineering– IJCSE
Volume 1 : Issue 3 [ISSN 2372 – 3971]
Publication Date : 30 September, 2014

SCC Mix Design using User Interface Software

A reliable method of SCC mix design for Indian construction conditions

[Richa Bhardwaj and Anshuman Dogra]

Abstract*—Self-compacting concrete (SCC) is a flowing concrete mixture that is able to consolidate under its own weight. Such concrete can be used for casting heavily reinforced sections at 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. Various approaches for designing the mix composition of SCC have been published worldwide, however each has its own suitability and limitations. Earlier methods e.g. Ojawa, LCPC, Hwang etc. are more or less specific to certain conditions and materials. In this study, a new generalized method for Mix Design Of SCC, suitable for Indian construction conditions, is proposed and a QT Creator Based Software is developed on the basis of generalized formulated equations. QT Creator is a cross-platform C++ integrated development environment, which is used to make a user interface software for SCC mix design. The proposed method is applicable to wider range of SCC applications in Indian construction conditions and is verified by comparing with real time SCC mix designs used in various construction projects in India.

***Keywords*— Self Compacting Concrete (SCC), Ojawa, LCPC, Hwang, QT Creator, C++ based user interface etc.**

I. Introduction

Self-compacting concrete (SCC) is a flowing concrete mixture that does not require vibrators for its compaction. It can consolidate under its own weight, completely filling formwork and achieving full compaction. The hardened concrete is dense, homogeneous and has the same engineering properties and durability as traditional vibrated concrete. Self-compacting concrete offers a rapid rate of concrete placement, with faster construction times and ease of flow around congested reinforcement. The fluidity and segregation resistance of SCC ensures a high level of homogeneity, minimal concrete voids and uniform concrete strength, providing the potential for a superior level of finish and durability to the structure. SCC is often produced with low water-cement ratio providing the potential for high early strength, earlier demoulding and faster use of elements and structures. The elimination of vibrating equipment improves the environment on and near construction and precast sites where concrete is being placed, reducing the exposure of workers to noise and vibration. The improved construction practice and performance, combined with the health and safety benefits, makes SCC a very attractive solution for both precast concrete and civil engineering construction.

Richa Bhardwaj
National Institute Of Technology, Hamirpur
India

Anshuman Dogra
Birla Institute Of Technology, Mesra, Ranchi
India

However, there are no standard methods for SCC mix design. Because of different conceptions and a wide range of possible constituent materials, many methods have been proposed and developed. These include ‘‘Standardized mix design method of SCC’’ proposed by the JRMCA, a simplified version of Okamura’s method. On the other hand, the Laboratory Central Des Ponts et Chausses (LCPC), the Swedish Cement and Concrete Research Institute (CBI), research groups in both Mainland China and Taiwan all have proposed different mix design methods of SCC. Our aim here is to find a generalised method of SCC mix design to satisfy Indian conditions and to develop a software program based on generalised formula which gives accurate and quick results.

Development of SCC mix design comprises of three stages:

1. Formulations of generalized equations on the basis of packing factor theory.
2. Verification of proposed method for various construction projects in India.
3. Development of a software program for SCC mix proportion design.

II. Development of SCC Mix Design

The principal consideration of the proposed method is to fill the paste of binders into voids of the aggregate framework piled loosely. Usually, the volume ratio of aggregates is about 52–58%. In other words, the voids in the loose aggregates are about 42–48% according to ASTM C29. The strength of SCC is provided by the aggregate binding by the paste at hardened state, while the workability of SCC is provided by the binding paste in fresh state. Therefore, the contents of coarse and fine aggregates, binders, mixing water and SP will be the main factors influencing the properties of SCC. The proposed mix design can be summarized in steps shown below:

A. *Calculation of Coarse and fine aggregates*

The packing factor (PF) of aggregate is defined as the ratio of mass of aggregate of tightly packed state in SCC to that of loosely packed state. Clearly, PF affects the content of aggregates in SCC. A higher PF value would imply a greater amount of coarse and fine aggregates used thus decreasing the content of binders in SCC. Consequently, its flowability, self-compacting ability and compressive strength will be reduced. On the other hand, a low PF value would mean increased dry shrinkage of concrete. As a result, more binders are required, thus, raising the cost of materials.

$$W_c = P.F \times \rho_{cl} \times \left(1 - \frac{s}{a}\right) \quad (1)$$

$$W_f = PF \times \rho_{fl} \times \frac{s}{a} \quad (2)$$

Where W_c = Coarse aggregate content (Kg/m^3),
W_f = Fine aggregate content (Kg/m^3),

PF = Packing Factor

ρ_{cl} = Loose bulk density of coarse aggregate (Kg/m^3),
ρ_{fl} = Loose bulk density of fine aggregate (Kg/m^3),

s/a = Volume ratio of fine aggregate to total aggregate (50% - 57%)

B. Calculation of Cement content

To secure good flowability and segregation resistance, the content of binders (powder) should not be too low. Too much cement used will increase the drying shrinkage of SCC. Therefore Cement content to be used is:

$$C = \frac{f'_{cd}}{f'_c} \quad (3)$$

C = Cement content (Kg/m^3)

f'_{cd} = Designed compressive strength (MPa),
f'_c = Compressive Strength per kg of cement (MPa/kg)

C. Calculation of mixing water content

The relationship between compressive strength and water/cement ratio of SCC is similar to that of normal concrete. The content of mixing water required by cement can then be obtained using:

$$W_{wc} = \left(\frac{W}{C}\right) C \quad (4)$$

W_{wc} = mixing water content required by cement (kg/m^3)
W/C= Water cement ratio by weight.

D. Calculation of Binder contents

Large amounts of powdered materials are added to SCC to increase flowability and to facilitate self-compacting. However, an excess amount of cement added will greatly increase the cost of materials and dry shrinkage. Moreover, its slump loss would become greater, and its compressive strength will be higher than that required in the design. In view of this, the proposed mix design method utilizes the appropriate cement content and W/C to meet the required strength. To obtain the required properties such as segregation resistance, binders like Fly ash and GGBS etc. are used to increase the content of binders.

$$V_{pf} = 1 - \frac{W_c}{1000 \times G_{ca}} - \frac{W_f}{1000 \times G_{fa}} - \frac{C}{1000 \times G_c} - \frac{W_{wc}}{1000 \times G_w} - V_a \quad (5)$$

$$V_{pf} = \left(1 + \frac{W}{A}\right) \times A\% \times \frac{W_{pm}}{1000 \times G_A} + \left(1 + \frac{W}{B}\right) \times B\% \times \frac{W_{pm}}{1000 \times G_B} \quad (6)$$

$$W_a = A\% \text{ x } W_{pm} \quad (7)$$

$$W_b = B\% \text{ x } W_{pm} \quad (8)$$

$$W_{wa} = (W/A)\ W_a \quad (9)$$

$$W_{wb} = (W/B)\ W_b \quad (10)$$

$$W_{wb} = (W/B)\ W_h \quad (11)$$

V_{pf}= Volume of fly ash paste
G_{ca}= Specific gravity of coarse aggregate
G_{fa}= Specific gravity of fine aggregate
G_c= Specific gravity of cement
G_w = Specific gravity of water
V_a = Air content %
W_{pm}= Total amount of pozzolonic material in SCC
W_a= Amount of A binder content
W_b= Amount of B binder content
W_{wa}= Amount of mixing water content required by A binder
W_{wb}= Amount of mixing water content required by B binder

E. Calculation of mixing water content needed in SCC

The mixing water content required by SCC is that the total amount of water needed for cement, A binder, B binder in mixing. Therefore it can be calculated as follows:

$$W_w = W_{wc} + W_{wa} + W_{wb} \quad (12)$$

F. Calculation of SP dosage

Adding an adequate dosage of SP can improve the flowability, self-compacting ability and segregation resistance of fresh SCC for meeting the design requirements. Water content of the SP can be regarded as part of the mixing water. If dosage of SP used is equal to n% of the amount of binders and its solid content of SP is m% then dosage can be obtained as follows:

Dosage of SP used :

$$W_{sp} = n\%(C + W_a + W_b) \quad (13)$$

Water content in SP:

$$W_{wsp} = (1\text{-}m\%)\, W_{sp} \quad (14)$$

III. Verification of SCC Mix Design

In this step, proposed method is used to find SCC mix design for various construction projects in India which have used SCC. Values obtained from proposed method are compared with SCC mix design used in these projects and results came out to be comparable.

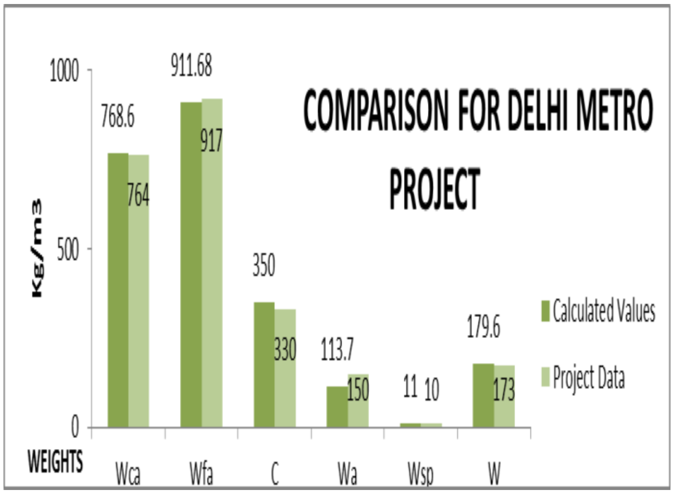

Fig. 1 Graph for comparison for Delhi metro project

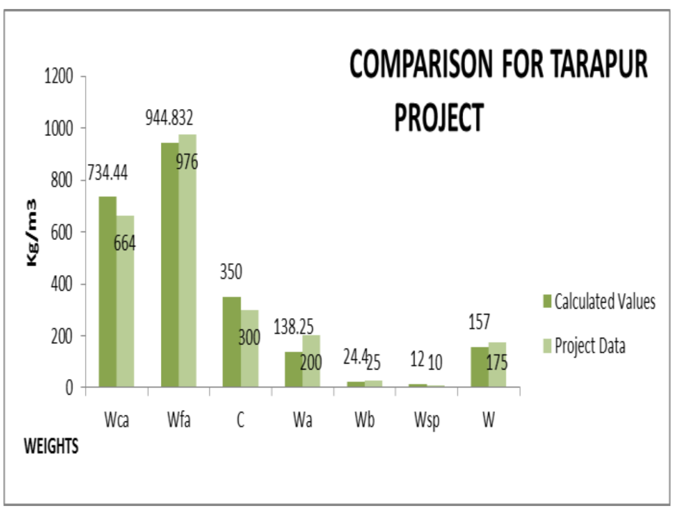

Fig. 2 Graph for comparison for Tarapur project

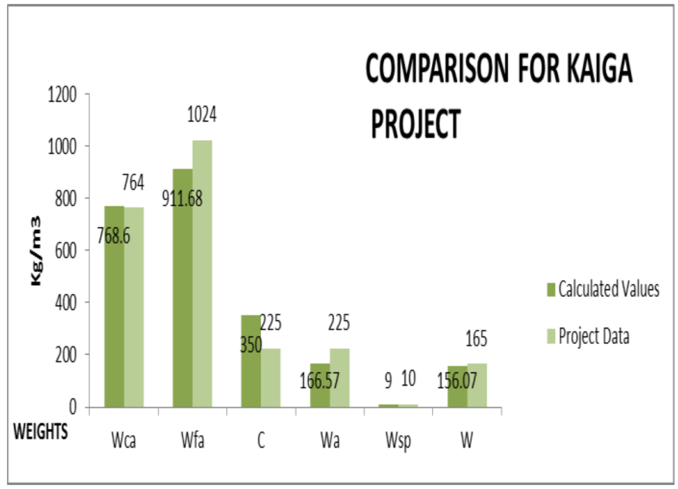

Fig. 3 Graph for comparison for Kaiga project

TABLE 1 COMPARISON BETWEEN CALCULATED VALUES AND PROJECT VALUES FOR CONSTRUCTION PROJECTS.

SCC Mix Design	Delhi Metro Project		Tarapur Project		Kaiga Project	
Weights (kg/m3)	Calculated Values	Project Data	Calculated Values	Project Data	Calculatd Values	Project Data
W_{ca}	768.6	764	734.44	664	768.6	764
W_{fa}	911.68	917	944.832	976	911.68	1024
C	350	350	350	300	350	225
W_a	113.70	150	138.25	200	166.57	225
W_b	0	0	24.4	25	0	0
W_{sp}	11	10	12	10	9	10
W	179.6	173	157	175	156.07	165

IV. Verification of SCC Mix Design

'Qt Creator' is a cross-platform C++ integrated development environment which is being used to make an user interface software for SCC mix design. The outcome of the whole coding in QT creator can be seen as a full flourished software. There are six different windows in the software. The first four i.e. "mainwindow", "mydata", "mydata2", and "designdata",are there for taking the input values and rest two i.e. "details" and "mixproportion" are there for depicting the results of SCC mix design. The different windows are depicted in following figures:-

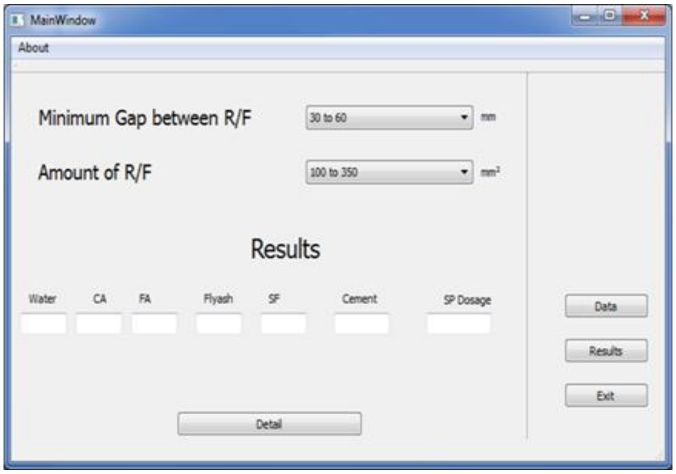

Fig 4.1 Final software window of “mainwindow”

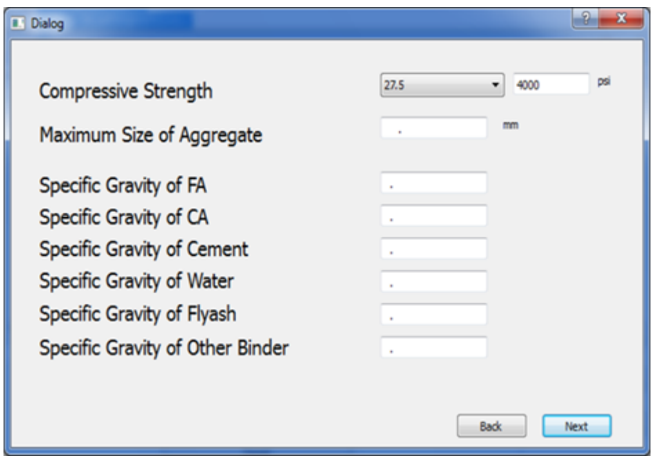

Fig 4.2 Final software window of “mydata”

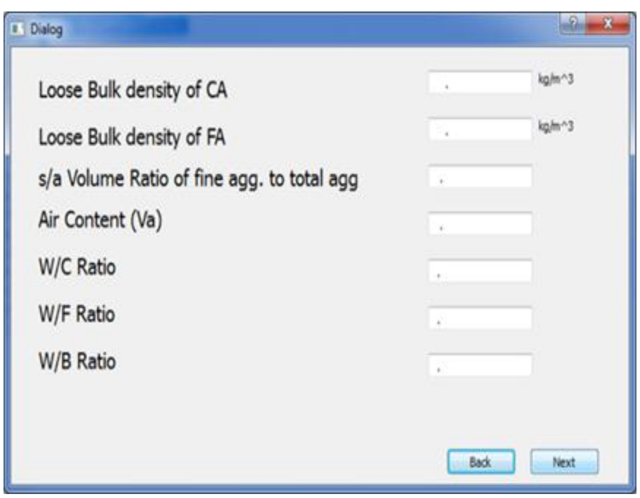

Fig 4.3 Final software window of “mydata2”

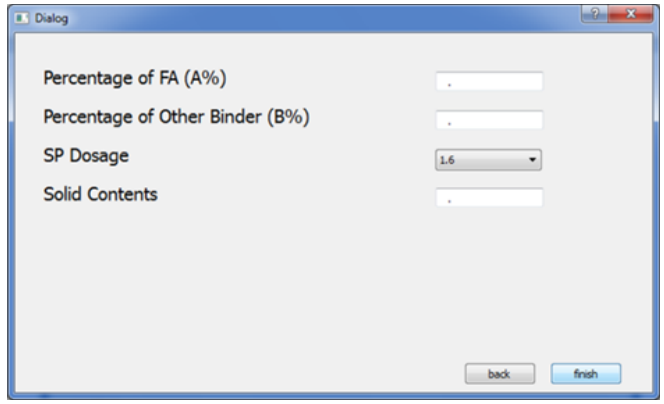

Fig 4.4 Final software window of “designdata”

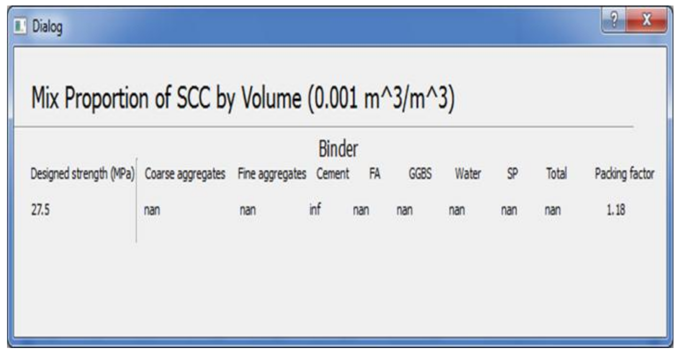

Fig 4.5 Final software window of “mix proportion”

V. Conclusions and Suggestions

The principal consideration of the design method is to fill the paste of binders into voids of the aggregate framework piled loosely. With the proposed software program, all we need is to input material properties, packing factor and reinforcement specifications and SCC with good flowability and segregation resistance can be obtained with self-compacting ability.The importance of software made for SCC mix design can be concluded as follows:-

1. The aggregate PF factor used in the formulation determines the aggregate content and influences the strength, flowability and self –compacting ability.
2. SCC designed and produced with the mix design software contains more sand but less coarse aggregates, thus the passing ability through gaps of reinforcement can be enhanced.
3. In this design, the volume of sand to mortar is in the range of 54 – 60%.
4. The water content of SCC prepared is about 170 – 176 kg/$m^3$for the medium compressive strength.
5. The amount of binders used can be less than that required by other mix design methods due to the increased sand content.

6. This novel mix design software is simpler, requires smaller amount of binders, and saves cost of cement as used in other methods.
7. Because SCC produced with this method contains less coarse aggregates, further studies are needed to evaluate its effect on the elastic modulus of concrete though it has been used in some of the projects after various tests.

The optimal PF for SCC with different requirements merits further investigation as this software is confined only to PF value 1.12 to 1.18 only.

Acknowledgment

The main stimulation for undertaking this project was the desire to explore different ways of SCC Mix Design and find the most suitable method for the SCC mix design for Indian construction conditions. But a final touch for this systematic study was given by Mr. Umesh Kumar Pandey (Faculty, NIT Hamirpur) and Mr. Rahul Dubey (Er. Civil), whose scholarly guidance helped us throughout and sustained our interest in this project. We record our heartfelt gratitude and sincere thanks to them for their valuable suggestion, able guidance and encouragement at every stage.

We also express our gratitude to our teammates Er. Surbhi Goyal, Er. Damini Thakur and Er. Rishabh Gautam for their support, and without whom this project would have been a distant reality.

About Authors:

[RICHA BHARDWAJ]

The strength of SCC is provided by the aggregate binding by the paste at hardened state, while the workability of SCC is provided by the binding paste in fresh state. Therefore, the contents of coarse and fine aggregates, binders, mixing water and SP will be the main factors influencing the properties of SCC.

[ANSHUMAN DOGRA]

The principal consideration of the design method is to fill the paste of binders into voids of the aggregate framework piled loosely. With the proposed software program, all we need is to input material properties, packing factor and reinforcement specifications and SCC with good flowability and segregation resistance can be obtained with self-compacting ability.

References

[1]. http://en.wikipedia.org/wiki/Self-consolidating_concrete
[2]. http://www.theconcreteportal.com/scc.html
[3]. Ozawa, K., Endoh, H., Edamatu, Y., and Yamaguthi, S. "Testing method for quality control of cement for the fresh state of high performance concrete in Proc. of Cement and Concrete", Japan Cement Association, No 47,1993
[4]. Okamura, H., Maekawa K., and. Ozawa,. "High performance concrete" , Gihoudou Pub., Tokyo(1993)
[5]. Sedran, T., de Larrard, F., Hourst, F. and Contamines, C. "Mix design of self-compacting concrete, in Proc. of the Mt. RILEM conf on production methods and workability of concrete", Paisley, EandFN Spon, London, (1996).
[6]. Petersson, O. and Billberg, P. "A model for self-compacting concrete, in Proc. of the Mt. RILEM conf on production methods and workability of concrete", Paisley, Eand FN Spon, London, (1996).
[7]. Hwang, C. L. Lee, L. S., Lin, F. Y., and Liu, J. C.. Densified "Mixture design algorithm and early properties of high performance concrete", in Journal of the Chinese Institute of Civil and Hydraulic Engineering, Vol 8, No2, (1996).
[8]. Hon et al . "Development and applications of self-compacting concrete" in Concrete Journal, (1996)