eJSE International

*Electronic Journal of Structural Engineering 13(1) 2013*

# Mixture Proportioning Of Self Compacting Concrete (SCC) Containing Fly Ash, Rice Husk Ash and Blast Furnace Slag

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ABSTRACT:

Self-compacting concrete is a new generation of high-performance concrete with the aim of building durable concrete structures without any skilled laborers for concrete placement. This paper displays mixture proportion of self-compacting concrete and briefly discusses the effects of addition of rice husk ash (RHA), fly ash (FA) and ground granulated blast furnace slag (GGBS) to fresh properties, compressive strength and durability performance of self- compacting concrete.

*Keywords: Self compacting concrete (SCC), mixture proportioning, workability, compressive strength*

## 1 INTRODUCTION

Self compacting concrete, introduced in Japan in the late 80's to solve problems of placement of concrete in high rebar densities, has slowly spread all over the world, showing many other characteristics and attracting attention first in laboratories and then in application (Borroni, 2006) .The construction of durable concrete structures requires very good compacting of fresh concrete. It is not always achievable with normal concrete even by skilled workers. Hence the idea of self- compacting concrete (SCC) was first developed in Japan in 1988 in order to build durable concrete structures (ACI Committee 222, 2000). SCC possesses very high workability due to its low yield stress and moderate viscosity, and well compacted without any external means of compacting (Attiogbe et al, 2002). SCC is an engineered material consisting of cement, aggregates, water, with several new constituents such as pulverized fly ash (PFA), ground granulated blast furnace slag (GGBS), microsilica, metakaolin, as well as chemical admixtures to take care of specific requirements such as high-flowability or workability, compressive strength, enhanced resistance to chemical or mechanical stresses, lower permeability, durability, resistance against segregation, and possibility under dense reinforcement conditions (Kumar, 2006). In this paper SCC, using three different cement contents to achieve suitable SCC with respect to strength and workability were cast. Other variables include incorporation of admixtures (FA, RHA, and GGBS) and different w/b ratio to achieve the desired mix proportioning requirements.

## 2 CONSTITUENT MATERIALS

### *2.1 Aggregates*

The maximum size of granite coarse aggregate used was 14 mm, according to the requirements of compressive strength and workability of self compacting concrete (SCC). The results of the specific gravity and absorption for the coarse aggregate and fine aggregate are presented in Table 1. Test results show high water absorption of the coarse aggregate.

Table1: Specific gravity and water absorption of granite and fine aggregates (river sand)

| Aggregate | Specific gravity | | | |
|---|---|---|---|---|
| | Oven-dry | SSD | Apparent | Absorption (%) |
| Granite | 2.40 | 2.61 | 3.04 | 8.74 |
| Fine aggregate (river sand) | 2.31 | 2.39 | 2.50 | 3.38 |

*2.2 Ordinary Portland cement*

Locally manufactured ordinary Portland cement conforming to MS 522: Part1:2003 Type I was used for all the mixtures of the testing program. All cement used was from the same source, and its chemical composition is shown in Table 2

*2.3 Rice Husk Ash (RHA)*

Rice husk was burned in a ferro cement furnace. After cooling for 24 hours the ash was ground in a Los Angeles machine until it met the fineness requirement of fly ash. Because of the need to fill the pores are very small in the mix (BS EN 450.1995) Chemical analysis of RHA is summarized in Table 2 .The $SiO_2$ content of RHA is approximately 90% and LOI was 2.6%.

*2.4 Fly Ash (FA)*

Fly ash was obtained from YTL Sdn.Bhd. It met the requirement of BS EN 450:1995.

*2.5 Ground granulated blast furnace slag (GGBS)*

GGBS was supplied by YTL Sdn.Bhd and the chemical composition of this material is given in Table 2.

Table 2: Chemical composition properties of binder materials

| Constituents (wt %) | OPC | RHA | (FA) | GGBS |
|---|---|---|---|---|
| $SiO_2$ | 16.5 | 90.55 | 25.0 | 29.35 |
| $Fe_2O_3$ | 3.633 | 0.91 | 12.36 | 0.52 |
| CaO | 69.43 | 1.23 | 1.0 | 49.76 |
| MgO | 1.29 | 0.44 | 2.62 | 4.20 |
| $K_2O$ | 0.489 | 5.52 | 2.49 | 0.46 |
| $SO_3$ | 4.23 | 0.81 | 3.0 | 2.09 |
| $Al_2O_3$ | 3.65 | 0.67 | 23.59 | 11.72 |
| LOI | 2.14 | 2.62 | 2.5 | 1.42 |

## 3 MIX PROPORTIONING

Mix design for self compacting concrete is very complex because of the wide variability of the constituent materials. The result from the aggregate characterization was used to conduct trial mixes. Twenty seven mixes were cast and the results are shown in Table 3. The procedure adopted in the study is as follows:-

1) Using Japanese method of mix design (Okamura and Ozawa, 1995), initial mix trial was carried out with coarse aggregate content of 45 percent by volume of concrete and fine aggregate content of 55 percent by volume of mortar in concrete; these mixes were cast with superplasticizer content of between 1% to 2% of the cement content.

2) To proceed towards achieving reference normal self compacting concrete (RNSCC) the coarse aggregate content was kept constant at 45% by volume of concrete . Fine aggregate content was kept constant at 55% by volume in concrete and superplasticizer content at 2 percent of powder content (mixes RNSCC1 to RNSCC3)

. 3) Mixes TR1 to TR 6 are SCC mixes containing fly ash. The powder content of these mixes is very high. Coarse aggregate content was further reduced and fine aggregate content was decreased until a slump flow of 250-500 mm was achieved. For each mix, slump flow test and compressive strength test were carried out. For mixes TR7 to TR9, different aggregate ratios fine and coarse aggregate respectively were employed (55:45, 60:40, 50:50). Mixes TR10 to TR15 fulfill all the requirements of the SCC concrete.

Mixes SCCFA5, SCCFA10, SCCFA15 satisfy all the requirements of SCC mixes with fly ash (FA). SCCRHA mixes contain 5%, 10%, and 15% replacement of cement with RHA. SCCRHA10 achieved the requirement of SCC with respect to strength and workability. For ground granulated blast furnace slag (GGBS) mixes the mix at 5% GGBS content achieved the requirement of SCC.

## 4 EXPERIMENTAL PROGRAM

In this work, four types of SCC were cast. They contained Ordinary Portland Cement (OPC),Fly Ash (FA), Rice Husk Ash (RHA), or Ground Granulated Blast furnace Slag (GGBS) For (SCCOPC) three mixes at different quantity of cement were cast.

For FA, RHA and GGBS mixtures, three cement replacement levels have been used. Details of the mixes are tabulated in Table 4.

Table 3: Mix Proportions of SCC mixes (weight per 1m³ of concrete)

| Mix .No | W/b | Cement (kg) | Fine aggregate (kg) | Coarse aggregate (kg) | Water (kg) | SP % | Fly ash (kg) |
|---|---|---|---|---|---|---|---|
| RNSCC1 | 0.50 | 440 | 916 | 750 | 220 | 2 | 0 |
| RNSCC2 | 0.52 | 432 | 900 | 679 | 225 | 2 | 0 |
| RNSCC3 | 0.53 | 406 | 895 | 732 | 215 | 2 | 0 |
| TR1 | 0.37 | 500 | 752 | 600 | 235 | 1.1 | 130 |
| TR2 | 0.39 | 505 | 745 | 570 | 247 | 1.1 | 130 |
| TR3 | 0.41 | 510 | 725 | 540 | 265 | 1.1 | 130 |
| TR4 | 0.36 | 390 | 780 | 605 | 187 | 1.1 | 130 |
| TR5 | 0.43 | 505 | 700 | 550 | 273 | 1.1 | 130 |
| TR6 | 0.45 | 510 | 670 | 540 | 286 | 1.1 | 130 |
| TR7 | 0.45 | 418 | 920 | 752 | 208 | 2 | 44 |
| TR8 | 0.45 | 418 | 1002 | 670 | 207 | 2 | 43 |
| TR9 | 0.45 | 418 | 837 | 837 | 208 | 2 | 44 |
| TR10 | 0.45 | 410 | 920 | 752 | 205 | 3 | 50 |
| TR11 | 0.45 | 400 | 931 | 761 | 203 | 3 | 50 |
| TR12 | 0.50 | 418 | 890 | 728 | 229 | 3 | 40 |
| TR13 | 0.46 | 404 | 900 | 679 | 210 | 3 | 50 |
| TR14 | 0.46 | 404 | 945 | 632 | 210 | 3 | 50 |
| TR15 | 0.46 | 385 | 923 | 699 | 200 | 2 | 50 |
| SCCFA15 | 0.46 | 380 | 895 | 732 | 201 | 2 | 57 |
| SCCFA10 | 0.48 | 380 | 895 | 732 | 201 | 2 | 38 |
| SCCFA5 | 0.51 | 380 | 895 | 732 | 201 | 2 | 18 |
| SCCRHA15 | 0.51 | 380 | 895 | 732 | 456 | 2 | 58 |
| SCCRHA10 | 0.51 | 380 | 895 | 732 | 494 | 2 | 38 |
| SCCRHA5 | 0.51 | 380 | 895 | 732 | 570 | 2 | 18 |
| SCCGGBS15 | 0.46 | 380 | 895 | 732 | 201 | 2 | 58 |
| SCCGGBS10 | 0.48 | 380 | 895 | 732 | 201 | 2 | 38 |
| SCCGGBS5 | 0.51 | 380 | 895 | 732 | 201 | 2 | 18 |

Table 4: Selected Mix proportion for SCC mixes (per m³)

| Mix no | W/b | Cement (kg) | F.A (kg) | C.A (kg) | Wa-ter (kg) | SP % | SCM (kg) |
|---|---|---|---|---|---|---|---|
| SCCOPC1 | 0.5 | 440 | 916 | 750 | 220 | 2 | 0 |
| SCCOPC2 | 0.52 | 432 | 900 | 679 | 225 | 2 | 0 |
| SCCOPC3 | 0.53 | 406 | 895 | 732 | 215 | 2 | 0 |
| SCCFA5 | 0.53 | 380 | 895 | 732 | 201 | 2 | 18 |
| SCCFA10 | 0.53 | 380 | 895 | 732 | 201 | 2 | 38 |
| SCCFA15 | 0.53 | 380 | 895 | 732 | 201 | 2 | 57 |
| SCCRHA5 | 0.53 | 380 | 895 | 732 | 201 | 2 | 18 |
| SCCRHA10 | 0.53 | 380 | 895 | 732 | 201 | 2 | 38 |
| SCCRHA15 | 0.53 | 380 | 895 | 732 | 201 | 2 | 58 |
| SCCGGBS5 | 0.53 | 380 | 895 | 732 | 201 | 2 | 18 |
| SCCGGBS10 | 0.53 | 380 | 895 | 732 | 201 | 2 | 38 |
| SCCGGBS15 | 0.53 | 380 | 895 | 732 | 201 | 2 | 58 |

## 5 RESULTS AND DISCUSSION

### *5.1 Mix design*

Self compactability can be largely affected by the characteristics of materials and the mixture proportions. A rational mix-design method for SCC using a variety of materials is necessary. In this paper proposed mix design for SCC should consist the following:

- Coarse aggregate content is fixed at 45% of the solid volume;
- Fine aggregate content is fixed at 55% of the mortar volume;
- Water-binder ratio in volume is assumed as 1.2 to 2.0 depending on the properties of the powder and cement.
- Superplasticizer dosage and the final water-binder ratio are determined so as to ensure self-compactability
- Slump flow value of 650±30 mm and the V-funnel time of 11±2 sec are required. Table 5 presents the optimum OPC, FA, RHA and GGBS SCC mixes

with regards to workability and compressive strength requirements.

Table 5: Optimum mix proportion for the self compacting concretes (per m³ of concrete)

| Mix .no | W/b | Cement (kg) | F.A (kg) | C.A (kg) | Water(kg) | S.P % | SCM (kg) |
|---|---|---|---|---|---|---|---|
| SCCOPC | 0.53 | 406 | 895 | 732 | 215 | 2 | 0 |
| SCCFA15 | 0.53 | 380 | 895 | 732 | 201 | 2 | 57 |
| SCCRHA10 | 0.53 | 380 | 895 | 732 | 201 | 2 | 38 |
| SCCGGBS5 | 0.53 | 380 | 895 | 732 | 201 | 2 | 18 |

*5.2 Workability properties of SCC containing FA, RHA and GGBS*

To characterize the properties of SCC no single method has been found until date, which characterizes all the relevant workability aspects, and hence, each mix has been tested by more than one test method for the different workability parameters. Presents workability of SCC is measured by slump flow and the normal slump, the basic equipment used is the same as for the conventional slump test. 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 .V funnel is the other test that gives into account the filling capacity flowability time $T_{50cm}$ which is a secondary indication of flow-funnel, that indicates the tendency for segregation. Wherein the funnel can be refilled with concrete and left for 5 minutes to settle .The L-box test 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.

Finally the slump flow and the normal slump are not enough to determine the flowability SCC and that means other tests are required to make sure of workability of SCC such as slump flow, V-funnel and J-Ring tests.

Table 6: Results of workability tests of SCC

| Mix-no | V-funnel (sec) | $T_{50}$ sec | slump flow mm | L-BOX % | Segregation % | J-Ring test mm | normal slump mm |
|---|---|---|---|---|---|---|---|
| SCCOPC | 5 | 4 | 610 | 75 | 4% | 10 | 250 |
| SCCFA15 | | 5 | 610 | 79 | 6% | 10 | 260 |
| SCCGGBS5 | 9 | 6 | 630 | 81 | 7% | 13 | 270 |
| SCCRHA10 | 15 | 9 | 650 | 82 | 15% | 15 | 280 |

*5.3 Compressive strength of SCC*

The compressive strength of self compacting concrete mix containing different pozzolanic materials (FA, RHA and GGBS) are presented in Table 7 and Figure 1 respectively. Data showed that the compressive strength of these concrete achieved the strength requirement of SCC at 40 MPa. Incorporation of GGBS only slightly improves the long term strength of SCC. Inclusion of RHA marginally improves the long term strength (180 d) of SCC. Incorporation of fly ash gave superior performance amongst the four concrete mixes. These types of concrete show improvement in the workability of concrete in the fresh state and exhibited marked improvements in late strengths.

Table 7: Relationship between the compressive strength and curing ages

| Mix. No | Compressive strength (MPa) | | | |
|---|---|---|---|---|
| | 7d | 28d | 90d | 180d |
| SCCOPC | 34 | 44 | 50 | 50 |
| SCCFA15 | 38 | 49 | 59 | 69 |
| SCCRHA10 | 33 | 40 | 42 | 47 |
| SCCGGBS5 | 32 | 41 | 43 | 43 |

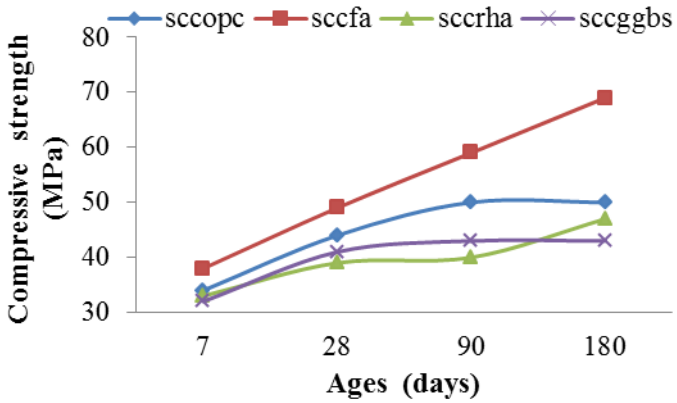


Figure 1: compressive strength development of concrete specimens under curing ages

## 6 CONCLUSIONS

1. In order to get self compacting concrete (SCC) in accordance to the Japanese mixing procedure trial and error and adjustments to concrete ingredients had to be performed to achieve the required workability and strength requirements .

2. Concrete containing 15%, 10%, 5% of FA, RHA and GGBS respectively produce self compacting of SCC grade 40.

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