A Mix Design of Self Compacting Concrete with Copper slag as Fine aggregate and Silica fume as Mineral Admixture

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Abstract— Since there is a scarcity of fine aggregate throughout the country it is essential to find a replacement of fine aggregate. Our idea is to use copper slag as replacement of fine aggregate.Due to several costs of labours for compaction we can go to self compacting concrete. Self compacting concrete is one of the high performance concrete which had an enormous growth in the construction industry in the recent years. Self compacting concrete can be described as a high performance materials that flows under its own self weight, without requiring vibration, to achieve consolidation by completely filling up formworks even when access is hindered by narrow gaps between reinforcement bars. In this present works, for M30 grade concrete beam copper slag is replaced for sand at0%, 20%, 40%, 60%, 80% and silica fume is used as an admixture in concrete. The various concrete workability tests such as slump flow test, T50cm slump flow ,V-funnel test, J-ring and L-box tests were performed.

Key words— Compressible packing model, Packing factor, Nansu method, Superplasticizers.

1 Introduction

When there is a large construction for taller buildings the compaction for such type of concrete requires heavy compaction and labour costs are also high nd it cannot be done by mechanical means. This difficulty can be easily solved by self compacting concrete.The self compacting concrete is a newest innovative high performance concrete that it has ability to spread and self consolidates the formwork without any external vibration. The elimination of vibration causes a reduce of manpower and increase the speed of construction. Replacement of fine aggregates produces reduction in scarcity of river sand.

Copper slag is one of the waste materials that are obtained from copper manufacturing industry. This material is suitable for fine aggregate. Hence it is a waste materials and is eco friendly. European Federation of National Associations Representing for Concrete provides a guidelines for requirements for constituent materials, test methods and check list.The design mix of self compacting concrete based on Nansu method and Compressible packing model for M30 grade concrete is prepared.

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2 MATERIAL PROPERTIES

2.1 Cement

The cement used in this study was 53 grade Ordinary Portland Cement (OPC).The properties of cement used are given in table 1.

Table 1: Physical Properties of Cement

S.No	Properties	Result
1	Fineness of cement	2%
2	Normal Consistency	31.28%
3	Initial setting time of cement	37 minutes
4	Final setting time of cement	590 minutes
5	Specific gravity	3.15

2.2 Coarse aggregate

Locally available 16mm size well graded coarse aggregate were selected for present work. The various properties of coarse aggregate were determined and tabulated in Table 2.

Table 2: Properties coarse aggregate

S.No	Properties	Result
1	Fineness Modulus	3.46
2	Specific Gravity	2.695
3	Bulk Density	1450 kg/m^3
4	Moisture Content	0.25%
5	Water Absorption	0.4%

2.3 Fine Aggregate

Fine aggregate used was river sand passing through IS sieves

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4.75 mm obtained from a loca source. Various properties of fine aggregate are listed in tabe 3.

Table 3: Properties of fine aggregate

S.No	Properties	Result
1	Fineness Modulus	3.18
2	Specific Gravity	2.624
3	Bulk Density	1500 kg/m^3
4	Moisture Content	2.4 %
5	Water Absorption	0.8%

2.4 Copper Slag

Copper slag was collected from Sterlite Industries India Limited (SIIL) Tuticorin, Tamilnadu and used in the present work. Various physical and chemical properties of copper slag are listed in the table below.

Table 4: Physical properties of copper slag

Physical Properties	Copper Slag
Particle shape	Irregular
Appearance	Black and glassy
Specific gravity	3.93
Percentage of voids%	34
Water absorption%	0.18
Moisture content%	0.13
Fineness Modulus	3.28
Bulk density	1900 kg/m^3

Table 5: Chemical properties copper slag

Chemical Composition	% of Chemical Component
SiO_2	23.43
Fe_2O_3	65.23
Al2O3	0.20
CaO	0.13
Na2O	0.5
K2O	0.28
Mn2O3	0.25
TiO2	0.51
SO3	0.16
CuO	1.22
Sulphide sulphur	0.15
Insoluble residue	10.22

2.5 Silica Fume

Silica fume can be added to Portland cement concrete to extend its properties; especially it improves its compression and bonding strength and gives better abrasion resistance. Silica fume is very fine non crystalline silica is produced in electric arc furnace as a derivative of the production of elemental silicon or alloys containing silicon. It is usually a grey coloured powder, somewhat similar to Portland cement. Silica fume of specific gravity 2.2 is used in this study. Because of its intense lineness and high silica content, silica fume acts as a very effective pozzolanic material.

2.6 Super plasticizer

The use of super –plasticizers in concrete is a mile stone in the advancement of concrete technology super-plasticizers. Some high range water reducing admixtures can retard final set by one to four hours and if prolonged setting times are not convenient, the admixture can be combined with an accelerating admixture to counteract the retarding tendencies or even to provide some acceleration of setting. In this present works super plast 840 super plasticizer is used to make concrete more workable with the self compacting characteristics.

2.7 Water

Water is an important ingredient in concrete. Practically all natural water that is safe to drink and has no distinct taste or smell which can be used for mixing water in making concrete. Some water which may not fit for drinking may also still be harmless for mixing concrete. Potable water available from the local source was used in the work.

3 MIX DESIGN PROCEDURE

3.1 NANSU METHOD

Aggregate size = 20 mm size aggregate

Specific gravity of coarse aggregate = 2.7

Bulk density of loose coarse aggregate = 1500 Kg/m^3

Specific gravity of fine aggregate = 2.6

Bulk density of loose fine aggregate = 1410 Kg/m^3

Specific gravity of cement = 3.15

Volume ratio of fine aggregate = 50%

Volume ratio of coarse aggregate = 60%

Specific gravity of super plasticizer = 1.064

Air content in SCC = 1.5%

Design strength of SCC = 30 N/mm^2

Step 1: Calculation of coarse and fine aggregate contents:

Assume packing factor (PF) = 1.15

Amount of fine aggregate needed per unit volume of SCC

$$W_s = PF * W_s L * S/a$$
$$= 1.15 \times 1410 \times 0.6$$
$$= 972.9 \text{ kg/m}^3$$

Amount of coarse aggregate needed per unit volume of SCC

$$W_g = PF * W_g * (1\text{-}S/a)$$
$$= 1.15 \times 1500 \times (1\text{-}0.6)$$
$$= 690 \text{ kg/m}^3$$

Step 2: Determination of cement content

w/c = 0.46

Water content = 215 kg/m^3

Cement = 467.39 kg/m^3

Step 3: Calculation of silica fume content:

SF/SF+C = 0.10

SF = 0.10 (SF + C)

SF = 0.1 SF + 40.53

SF = 45.03 Kg/m^3.

(w/c)max = 0.45

Step 4: Calculation of mixing water content required by cement

W wc = (w/c)xc

W wc = 0.46 x 467.39 = 214.999 = 214.999 kg/m^3

Step 5: Calculation of super-plasticizer dosages:

The solid content of SP is 40%. According to engineering experience, the dosage of super-plasticizers is 1.8% of content of binders.

Dosage of SP used $Wsp = n\% \,(C + Wf + Wb)$

= 0.014 (467.39 + 45.03)

= 7.17 kg/m^3

Step 6: Trial mixes and tests on SCC properties:

Trial mixes can be carried out using the contents of materials calculated as above. Then, quality control tests for SCC should be performed to ensure that the following requirements are met.

1. Results of slump flow, U-Box, L-flow, and V-funnel tests should comply with the specifications of the JAS.
2. The segregation phenomenon of materials should be satisfactorily.
3. Water-binders ratio should satisfy the requirements of durability and strength.
4. Air content should meet the requirements of the mix design.

Step 7: Adjustments of mix proportions:

If the results of the quality control tests mentioned above fail to meet the performance required of the fresh concrete, adjustments should be made until all properties of SCC satisfy the requirements specified in the design. For example, when the fresh SCC shows poor flowability, the PF value is reduced to increase the binder volume and to improve the workability.

Mix proportions

CA Kg/m^3	**FA** Kg/m^3	**Cement** Kg/m^3	**Water** lr	**Silicafume** Kg/m^3	**Super-plasticizes** Kg/m^3
690	972.9	467.39	214.999	45.03	7.17
1.48	2.08	1	0.46	0.096	0.02

3.2 Compressible Packing Model Method

Step 1: Calculation of coarse and fine aggregates content:

The content of coarse aggregates in SCC

Wg = PF x ϱ gL (1−Vfa/Va)

= 1.15 x 1500 x (1-0.6)

= 690 Kg/m^3

Assume, PF = 1.15.

The content of fine aggregates in SCC

Ws = PF x ϱ sL x Vfa/Va

= 1.15 x 1410 x 0.6

= 972.9 Kg/m^3.

Step 2: Calculation of cement content:

Generally, SCC used in Taiwan provides a compressive strength of 20psi (0.14 Mpa)/kg cement.

Therefore, the cement content to be used is C = fc'/0.14

= 405.3 Kg/m^3.

Step 3: Selection of water/cement ratio:

Assuming 6Mpa standard deviation from past experience, the required average strength fc' should be:

fcr' [Mpa] = max (fc' + 1.34.S. fc' + 2.33.S – 35)

fcr' = max (30 + 1.34 x 6 fc' + 2.33.S – 35)

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= 38.04 N/mm^2.

w/c = 0.46

W = 0.46 x 405.3 = 186.438 Kg/m^3.

Step 4: Calculation of silica fume content:

SF/SF+C= 0.10

SF = 0.10 (SF + C)

SF = 0.1 SF + 40.53

SF = 45.03 Kg/m^3.

$(\frac{w}{c})max$ = 0.45

Step 5: Calculation of superplasticizer dosage:

SP = C+SF x1.4% = 405.3 + 42 x 1.4% = 13.705 Kg/m^3.

Mix proportions

CA Kg/m^3	FA Kg/ m^3	Cment Kg/m^3	Water lr	Silicafume Kg/m^3	Super-plasticizes Kg/m^3
690	972.9	405.3	186.43	45.03	13.705
1.70	2.4	1	0.46	0.111	0.034

4 EXPERIMENTAL INVESTIGATION

One control and five SCC mixes with various proportions of fine aggregate partially replaced by copper slag were prepared according to the limitation stipulated in the EFNARC guidelines and checked whether it met the criteria for properties of SCC. Mix design calculations were based on several characteristic properties like packing factor, bulk density of loose aggregates, specific gravity, etc. Packing factor of 1.15 was taken by trial basis.

Quantity of cement and water required for cement mixing was calculated as per ACI method. Quantities of other materials were calculated by Nan su tool for mixdesign (Nan Su et al. 2001). Fine aggregate was replaced by copper slag at various proportions such as: 20%, 40%, 60% and 80% with the obtained optimum mix and checked for its workability and durability properties. Table 5 shows the composition of SCC mixes for various proportions of Copper slag replaced for fine aggregate.

Table 6: Mix Proportion for M30 Grade Concret

Mix	Ce-ment kg/m³	FA kg/m³	CS kg/m³	CA kg/ m³	SF kg/ m³	Water ltr	SP ml
0%	405.3	972.9	0	690	45.0	186.4	463.4
20%	405.3	832.4	208.1	690	54.0	186.4	511.5
40%	405.3	664.8	443.2	690	66.6	186.4	524.8
60%	405.3	470.3	705.4	690	85.0	186.4	496.4
80%	405.3	248.6	994.7	690	113	186.4	577.1

4.1 Workability properties

A concrete is said to be SCC based on its workability characteristics at its fresh state. Mix design for SCC can be arrived, based on its workability property to flow under its own weight without any external vibration and to pack the entire form work completely. So in order to comply with the characteristics of SCC the concrete should possess some basic quality such as filling ability, passing ability and segregation resistance. There are some methods to produce the concrete with the above quality.

A typical range of values for the workability properties of the fresh SCC as per EFNARC is given in Table 7

Table 7: Typical Acceptance Criteria for SCC as per EFNARC

S.No	Method	Unit	Typical range	
			Min	Max
1	Slump flow test(Filling ability)	mm	650	800
2	T50cm slump flow (Filling ability)	sec	2	5
3	V-funnel test(Filling ability)	sec	8	12
4	J-ring (Passing ability)	mm	0	10
5	L-box	-	0.8	1

4.1.1 Slump flow test and T50 test

A slump cone of size 200 mm diameter at the bottom and 100 mm diameter at the top and 300 mm height was filled with the fresh concrete. Then the slump cone was lifted vertically and the concrete was allowed to flow freely, and the time taken for the concrete to form a circle of 500 mm diameter was noted (this is T50 time). Then the average of the final dimensions of the concrete in both perpendicular directions was calculated (this dimension is the slump flow in mm). The results of slump flow test and T50 Test show that the workability of the SCC is within the typical range and satisfy the criteria for a SCC up to replacement of Fine aggregate by Copper slag at 60%. The variation of slump flow and slump 50 for various percentage of copper slag replacement for fine aggregate are shown in Figure 1 and Figure 3 respectively.

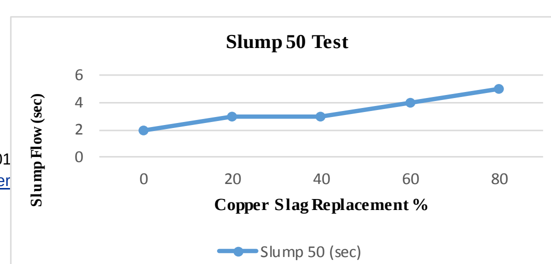


Figure 1 Variation of Slump flow for CS replacement

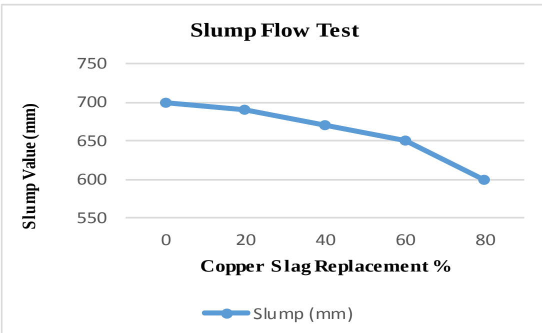


Figure 2 Variation of Slump 50 for CS replacement

4.1.2 V funnel test and T 5minutes test

V funnel is an apparatus used to find the flow ability of the fresh concrete. The dimensions of the V funnel are fabricated as stipulated in the EFNARC. The fresh concrete was filled in the V funnel without any compaction with the top of the funnel is leveled with a trowel. Then the bottom door was opened and the concrete was collected in a bucket placed below. The time taken for concrete for the complete discharge was noted (this is the flow time). The whole process had to be completed within 5 minutes of preparation of the concrete. Then once again, the same process is repeated.

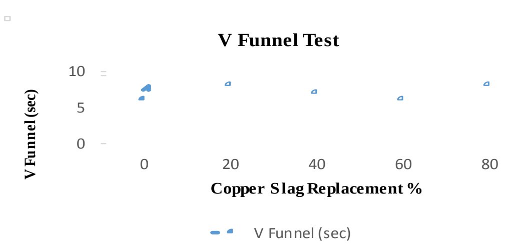
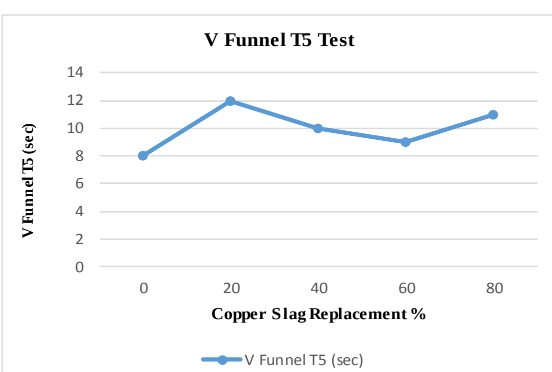


Figure 3 Variation of V Funnel test for CS replacement

The concrete is allowed to settle in the V funnel for 5 minutes, and then the trap door is opened and the time taken for the total discharge was noted (this is the T 5minutes flow time). The results of V Funnel test and V Funnel T5 Test show that the workability of the SCC is with in the typical range and



satisfy the criteria for a SCC upto replacement of Fine aggregate by Copper slag at 60%. The variation of V funnel test and V funnel T5 test for various percentage of copper slag replacement for fine aggregate are shown in Figure 3 and Figure 4 respectively.

Figure 4 Variation of V Funnel T5 test for CS replacement

4.1.3 L box test

L box is an apparatus to find the flow and passing ability of the fresh concrete. The dimensions of the L box were fabricated as stipulated in the EFNARC. The vertical part of the L box was completely filled with the fresh concrete and allowed to settle for one minute. Then the door at the base of the vertical segment of the L box was opened and the concrete was allowed to flow through the horizontal segment of the L box, and the time taken for the concrete to reach the 200 and 400 mm mark was noted. When the flow of the concrete was completely stopped, the height of the concrete from the base at the face of the vertical portion of the L box was noted as H1 and the height of concrete at other face was noted as H2. The ratio between H2 and H1was calculated as the Blocking ratio. The whole process had to be completed within 5 minutes of preparation of the concrete.

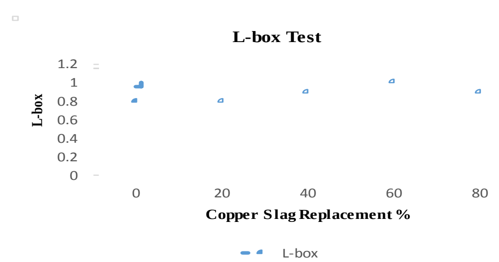


Figure 5 Variation of L-box test for CS replacement

4.1.3 J Ring test

J ring is an apparatus to find the passing ability of the fresh concrete. The dimensions of the J ring were fabricated as stipulated in the EFNARC. The concrete was filled in the slump cone and kept centrally inside the J ring. Then the slump cone was lifted vertically and concrete was allowed to flow freely and wait till the flow of the concrete was completely stopped. Then the average of the final dimensions of the concrete in both perpendicular directions was calculated. Also measure

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the height difference in between the concrete inside the J ring and at the edge of the concrete at four different locations.

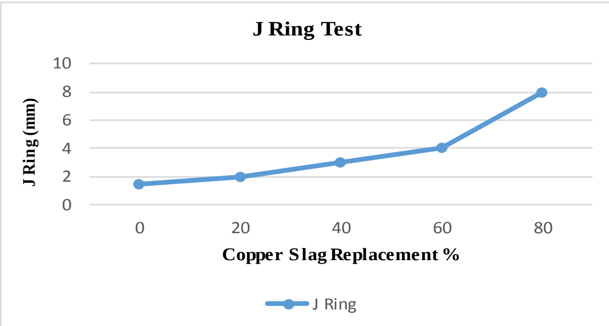

Figure 6 Variation of J Ring test for CS replacement

The results for the workability test for SCC are shown in Table 8

Table 8 Workability Test on SCC

Mix	Slump mm		Vfunnel		J Ring mm	L Box	Remarks
	mm	50 mm	sec	T5 sec			
0%	700	2	6	8	1.5	0.8	Satisfied
20%	690	3	8	12	2	0.8	Satisfied
40%	670	3	7	10	3	0.9	Satisfied
60%	650	4	6	9	4	1	Satisfied
80%	600	5	8	11	8	0.9	Satisfied

5 CONCLUSION

The SCC mixes having copper slag as fine aggregate and containing SF as powder material tested for their fresh properties as per EFNARC. From this it can be concluded that achieving fresh SCC properties is possible by adopting the Nan Su et al. method when these industrial by-products are used.

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