COMPRESSIVE STRENGTH OF M25 SCC MIX WITH PARTIAL REPLACEMENT OF FINE AGGREGATE BY COPPER SLAG AND USING PORTLAND SLAG CEMENT

A MINI PROJECT REPORT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF DEGREE OF

BACHELOR OF TECHNOLOGY

IN

CIVIL ENGINEERING

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(Approved by AICTE, Accredited by N.B.A, NewDelhi, NAAC-A+ Grade)

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CERTIFICATE

This is to certify that the Mini Project Report entitled "COMPRESSIVE STRENGTH OF M25 SCC MIX WITH PARTIAL REPLACEMENT OF FINE AGGREGATE BY COPPER SLAG AND USING PORTLAND SLAG CEMENT" that is being submitted by

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in partial fulfillment of the requirement for the award of B.Tech in Civil Engineering to the **RAJEEV GANDHI MEMORIAL COLLEGE OF ENGINEERING AND TECHNOLOGY (AUTONOMOUS)**, Nandyal (Affiliated to J.N.T University, Anantapur) is a bonafide record of confide work carried out by them under our guidance and supervision. The results embodied in this project report have not been submitted to any other university or institute for the award of any Degree.

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Professor and HOD

Examiner:
Date:

Dedicated to my beloved parents, and teachers who have worked hard throughout my education.

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ABSTRACT

In recent times the alternative and recyclable uses of by-products that are being produced in the factories manufacturing metals and power for nation building. For example, to tackle the issue of depleting sand reserves on the river beds for construction of modern towns and cities, green materials like copper slag have been tried and tested to substitute the shortage.

Copper slag is an economical, established and the most widely accepted alternative to the natural aggregate (sand, crushed from natural rocks). It is finding increasing operational acceptance by the ready-mix concrete manufacturers and in government road projects for concrete applications as prescribed by BIS IS 383:2016 (Bureau of Indian Standards) for the past few years now. It is being employed in the Madurai Tuticorin industrial corridor project, thereby, eliminating the need to deplete the existing topography of the region. This will also play a pivotal part in reducing greenhouse gas emissions and global warming by preserving the green cover on hills and the river beds.

In view of the above, the present work titled **Compressive Strength of M25 SCC Mix with Partial Replacement of Fine Aggregate by Copper Slag and using Portland Slag Cement ,** is considered. In the present study workability properties and compressive strength of SCC Mix isdetermined by varying the Copper slag from 0% to 50% in steps of 10% and using Portland Slag Cement (JSW Cement).

Workability Fresh properties of SCC like Slump Flow, T-50 Slump Flow, J-ring, V-Funnel, V-Funnel T5minutesand L-box tests are conducted and all the above workability properties satisfied European Federation of National Association Representing for Concrete (EFNARC) Guidelines. Cubes are casted and cured for respective days using normal curing. The compressive strength is determined for different Copper Slag Replacement and results are compared.

KEYWORDS: Self Compacting Concrete (SCC), Copper Slag, EFNARC, Slump Flow Test, T-50 Slump Flow Test, J-ring Test, V-Funnel Test, V-Funnel T5minutes Test and L-box Test.

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GLOSSARY

SCC—–Self-Compacting Concrete
HPSCC—High Performance Self Compacting Concrete
EFNAR—European Federation of National Association Representing for Concrete
GGBS—-Ground Granulated Blast Furnace Slag
W/P—–Water-Powder ratio
SP——Super Plasticizer
HRWRA—High Range Water Reducing Admixtures
ASTM—-American Standard of Testing Materials
PF —–Packing Factor
PSC—– Portland slag cement

Chapter 1

INTRODUCTION

1.1 Introduction of Self Compacting Concrete

Self Compacting Concrete (SCC) is developed three decades back. Okumara in japan first proposed the necessity of SCC in 1986 to cater for the reduction in skilled workers and to increase concrete durability by increasing the workability of concrete (Ozawa ct al.,1989). According to act ACI 237R-07(2007), SCC is highly flowable, non-segregating, fill the form work and encapsulate the reinforcement without any mechanical consolidation. Ozawa and Maekawa produced the first prototype of SCC at the university of Tokyo in 1988 (Ozawa et al., 1989; RILEM TC 174 SCC,2000)

Concrete is a composite material. Properties of concrete are durability, strength and workability etc.In huge construction placing of concrete is a major problem. Concrete doesnt pass properly through the reinforcement spacing though compaction is done by vibrating machine.

Self Compacting Concrete (SCC) is a concrete that can flow under its own weight and does not require external vibration to under go compaction.

In recent times the alternative and recyclable uses of by-products that are being produced in the factories manufacturing metals and power for nation building. For example, to tackle the issue of depleting sand reserves on the river beds for construction of modern towns and cities, green materials like copper slag have been tried and tested to substitute the shortage.

Copper slag is an economical, established and the most widely accepted alternative to the natural aggregate (sand, crushed from natural rocks). It is finding increasing operational acceptance by the ready-mix concrete manufacturers and in government road projects for concrete applications as prescribed by BIS IS 383:2016 (Bureau of Indian Standards) for the past few years now. It is being employed in the Madurai Tuticorin industrial corridor project, thereby, eliminating the need to deplete the existing topography of the region. This will also play a pivotal part in reducing greenhouse gas emissions and global warming by preserving the green cover on hills and the river beds.

1.2 Aim and Scope of the Project

In the light of the above, the present work titled "COMPRESSIVE STRENGTH OF M25 SCC MIX WITH PARTIAL REPLACEMENT OF FINE AGGREGATE BY COPPER SLAG AND USING PORTLAND SLAG CEMENT" is considered.

In the present study properties of SCC M25 grade is determined (Coarse Aggregate 20mm-40%, 12.5mm-50%, 6mm-10%) by replacing Fine Aggregate with Copper Slag in propotions of 0%, 10%, 20% , 30%, 40%, 50% .

The "Nan-su" mix design method is used. Fresh properties are determined to satisfy European Federation of National Association Representing for Concrete (EFNARC) guidelines. Compressive Strength of mixes is determined at ages of 3, 7 & 28 days.

1.3 Organization of Report

The present work is organized into different chapters.
Chapter 2 deals with Literature Review
Chapter 3 describes the Mix Design Methods of SCC, Fresh and Hardened Properties of SCC
Chapter 4 includes the Material Properties, Describes Mix Design of M25
Chapter 5 includes Results and Discussions
Chapter 6 Presents the Conclusions of the present work.

Chapter 2

LITERATURE REVIEW

1. Nan Su, Kung-Chung Hsu, His-Wen Chai (2001) proposed a new mix design methodology on self-compacting concrete ”Simple mix design method for Self-Compacting Concrete”. At first the quantity of aggregates required was determined, and also the paste of binders was then filled into the voids of aggregates to confirm that the concrete thus obtained has flow ability, self-compacting ability and alternative desired SCC properties. Slump flow, V-funnel, L-box, U box and compressive strength tests are conducted to examine the performance of SCC, and also the results indicated that the proposed methodology might be used to produce successfully SCC of top quality. Compared to the strategy developed by the Japanese Ready-Mixed Concrete Association (JRMCA), this methodology is less complicated, easier for implementation and less time-consuming, needs a little amount of binders and saves price.

2. B. Bhavani.et.al (2016) did an investigation study on ”Properties of SCC at different proportions of class-f Fly ash and GGBS”. The better mechanical properties are obtained for Mix M1 as shown in Table 2.1.

Table 2.1: Investigation done by B. Bhavani, et.al

<table>
<tr><th rowspan="2">Concrete Grade</th><th rowspan="2">Mix</th><th colspan="2">Binders</th><th rowspan="2">C.A</th><th rowspan="2">F.A</th><th>Chemical Admixture</th><th rowspan="2">Mix Design</th><th rowspan="2">w/p ratio</th></tr>
<tr><th>F%</th><th>GGBS%</th><th>S.P</th></tr>
<tr><td rowspan="6">M25</td><td>M1</td><td>100</td><td>0</td><td rowspan="6">12.5 – 20 mm</td><td rowspan="6">Zone-II</td><td rowspan="6">Conplast SP-430</td><td rowspan="6">NANSU (2001)</td><td rowspan="6">0.421</td></tr>
<tr><td>M2</td><td>80</td><td>20</td></tr>
<tr><td>M3</td><td>60</td><td>40</td></tr>
<tr><td>M4</td><td>40</td><td>60</td></tr>
<tr><td>M5</td><td>20</td><td>80</td></tr>
<tr><td>M6</td><td>0</td><td>100</td></tr>
</table>

3. S. Dhiyaneshwaran et.al (2013) investigated on "Study on Durability Characteristics of Self-Compacting Concrete with Fly Ash".
   The durability tests of concrete are done by sulphate attack, acid resistance and saturated water absorption at the ages of 28, 56 and 90 days. The better results are obtained for Mix M4 as shown in Table 2.2.

Table 2.2: Investigation done by S. Dhiyaneshwaran, et.al

Concrete Grade	Mix	Binders		C.A	F.A	Chemical Admixture		Mix Design	w/b ratio
		C%	RHA%			S.P	VMA		
M30	M1	100	0	12.5 mm	Zone-II	Glenium B233	ENC 180	EFNARC 2002	0.45
	M2	90	10						
	M3	80	20						
	M4	70	30						
	M5	60	40						
	M6	50	50						
Workability Properties			Slump Flow, V-Funnel, L-Box, T50 and U-Box tests					Satisfies EFNARC specifications	

4. G.Asif Hussain et.al (2019) studied on "Propeties of M60 High Performance Self Compacting Concrete with partial replacement of Cement by Silica Fume" as shown in Table 2.3.
   Mix with 5% cement replacement with silica fume yielded better compressive strength

Table 2.3: Investigation done by Asif under the Guideniess of Krishnaraju ,B-Tech thesis et.al

Concrete Grade	Mix	Binders			C.A	F.A	Chemical Admixture	Mix Design	w/p ratio
		C%	SF%	GGBS (kg)			S.P		
M60	M1	100	0	77	12.5 mm	Zone II	Polycarboxylic Ether	NANSU	0.37
	M2	97.5	2.5						
	M3	95	5						
	M4	92.5	7.5						
	M5	90	10						

   compared to other mixes. But the target mean strength is not achieved.

5. Venkateswara Rao, et.al (2010) investigated on "Effect of Size of Aggregate and Fines on Standard and High Strength Self Compacting Concrete".
   Better mechanical properties obtained at 52% of Fly Ash at 10mm size for M30 SCC.

Better mechanical properties obtained with 31% of Fly Ash at 16mm size aggregate for M70 SCC as shown in Table 2.4.

Table 2.4: Investigation done by Venkateswara Rao, et.al

<table>
<tr><th rowspan="2">Concrete Grade</th><th rowspan="2">Mix</th><th colspan="2">Binders</th><th rowspan="2">C.A</th><th rowspan="2">F.A</th><th colspan="2">Chemical Admixture</th><th rowspan="2">Mix Design</th><th rowspan="2">w/b ratio</th></tr>
<tr><th>C%</th><th>F%</th><th>S.P</th><th>VMA</th></tr>
<tr><td rowspan="6">M30</td><td>M1</td><td>50</td><td>50</td><td rowspan="12">12.5 – 20 mm</td><td rowspan="12">Zone-II</td><td rowspan="12">Conplast SP-430</td><td rowspan="12">Glenium Stream-II</td><td rowspan="12">NANSU (2001)</td><td rowspan="6">0.435</td></tr>
<tr><td>M2</td><td>45</td><td>55</td></tr>
<tr><td>M3</td><td>40</td><td>60</td></tr>
<tr><td>M4</td><td>35</td><td>65</td></tr>
<tr><td>M5</td><td>20</td><td>70</td></tr>
<tr><td>M6</td><td>25</td><td>75</td></tr>
<tr><td rowspan="6">M70</td><td>M1</td><td>80</td><td>20</td><td rowspan="6">0.250</td></tr>
<tr><td>M2</td><td>70</td><td>30</td></tr>
<tr><td>M3</td><td>60</td><td>40</td></tr>
<tr><td>M4</td><td>50</td><td>50</td></tr>
<tr><td>M5</td><td>40</td><td>60</td></tr>
<tr><td>M6</td><td>30</td><td>70</td></tr>
</table>

6. Bhoshale Mahesh Bhimarao(2020) did an investigation on "Replacement of Copper Slag with Fine Aggregate". Fine aggregate is replaced with 20%, 30%, 40%, 50%, 60%, 70% of copper slag. Normal mix design used in this investigation. The mix design of M25 grade of concrete gives High Permeability Concrete when replacement of copper slag is 50%. In this case the copper slag behaves like river sand. When increasing percentage replacement of fine aggregate by copper slag the unit weight of concrete is gradually increases.

Table 2.5: Investigation done by Bhoshale Mahesh Bhimarao

Sr.No.	Percentage Replacement	Compressive Strength (Mpa)
01.	20%	28.65
02.	30%	33.50
03.	40%	31.40
04.	50%	38.75
05.	60%	28.75
06.	70%	26.85

7. Shanmuga Nathan N (2017) investigated on "Partial Replacement of Copper Slag as Fine Aggregate". Normal Mix Design is adopted in this investigation. This investigation is done to know the strength and durability of partial replaced Copper Slag. The concrete was prepared for the M25 grade concrete with partial replacement of fine aggregate by copper slag with various percentages of 0%, 10%, 15%, 20%.

Table 2.6: Investigation done by Shanmuganathan

SI.NO	Curing Days	Average compressive Strength in N/mm^2			
		Control Concrete	Copper Slag Concrete		
			10%	20%	30%
1	7	20.44	17.34	24.22	25.3
2	14	22.667	22.22	26.22	27.11
3	28	24.889	26.67	27.11	28.44

Chapter 3

MIX DESIGN METHODS OF SCC, FRESH & HARDENED PROPERTIES OF SCC

There is no standard method for SCC mix design and many academic institutions, admixture, ready-mixed, precast and contracting companies have developed their own mix proportioning methods. Using the properties of cement, aggregate, concrete mix of required grade was designed as per IS 10262-2019 and self compact ability was achieved by varying the mix parameters, such as Super Plasticizers, Water/Powder ratio and fine aggregate and coarse aggregate contents. VMA is also used to reduce the segregation of concrete.
Some of the available SCC mix design methods are listed below.

1. General Purpose Mix Design Method,
2. UCL Method of Proportioning of SCC,
3. JSCE Method,
4. EFNARC 2005 Method.
5. American Concrete Institute Method and
6. NAN-SU method.

3.1 Basic Principles and Requirements of SCC

With regard to its composition, SCC consists of almost same constituent materials as conventional concrete, which are cement, aggregates, water and with the addition of chemical and mineral admixtures (fly ash, silica fume, GGBS, lime stone powder, Metakaoline etc.) in different proportions. Usually, the chemical admixtures used are High-Range Water Reducers (HRWR) also called Super Plasticizers and Viscosity-Modifying Agents (VMA), which change the properties of concrete. Mineral admixtures are used as an extra fine material, besides cement, and in some cases, they replace cement. However, high volume of super plasticizer 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.

Three approaches have been identified to produce SCHPC (Self-Compacted High Performance Concrete):

1. Powder-type SCC using limited coarse aggregate content and increased amount of binder (Okamura and Ouchi 2003), This is achieved by using greater amount of fine aggregate and cementing material along with HRWR at low W/B ratio.

2. VEA-type SCC using VEA (Okamura and Ozawa 1995), A VEA (Viscosity Enhancing Admixture) is used with HRWR without increasing the content of binder or cementing material to produce SCC.

3. Combination-type SCC using both VEA and increased amount of binder (Nagamoto and Ozawa 1999), A VEA and an increased amount of cementing material are used with HRWR at low W/B ratio.

3.1.1 General Purpose Mix Design Method

Okumara and Ozawa developed the general purpose mix design method in the university of Tokyo (Okumara et.al , 1993; Okumara and Ozawa , 1994).
This method is suitable for powder type SCC and describes as follows.

1. Air content is assumed to be 4-7% of concrete volume.

2. Coarse aggregate content is 50% of its dry-rodded unit weight.

3. Fine aggregate to mortar volume ratio is 40%.

4. Superplasticiszer dosage and w/p ratio are determined from self-compacting mortar.

5. Superplasticiszer dosage and w/p ratio are subsequently used in the SCC trails and adjusted until a slump flow of 650 mm and a V-funnel time of 10-20 seconds achieved.

3.1.2 University College London (UCL) Method of Proportioning of SCC

Evaluation of mortar tests in general - purpose method is very much useful for the production of successful SCC mixes. on the basis of the importance of mortar, Jin (2002) investigated the relationships between the properties of mortar and SCC at university college London (UCL) in 1994. SCC mixes, with a higher coarse aggregate content of 55-65% of its dry rodded unit weight, were developed.
The procedure is as follows:

1. Coarse aggregate content is choosen.

2. This method is applicable to a coarse aggregate of maximum size of 16-20 mm.

3. Sand to mortar volume ratio is kept 45% (Domone , 2006).

4. Air content is assumed as 1%.

5. W/P ratio, dosage of chemical admixtures is determined from mortar tests.

3.1.3 Japan Society of Civil Engineers (JSCE) Method

JSCE recommends the typical range of constituent materials for SCC with or without VMA as shown in Table 3.1.

Table 3.1: JSCE limits for SCC

Property	SCC without VMA	SCC with VMA
Coarse-aggregate content	0.30-0.32 m^3; maximum size of 20-25 mm	-
Water content	155-175 kg/m^3	<180kg/m^3
Water-powder ratio	28-37% by weight	-
Powder content	0.16-0.19 m^3	Depends on the type and content of VMA
Air content	4.5%	4.5%

3.1.4 EFNARC 2005 Method

Laboratory trials should be performed properties of the initial mix composition if the required SCC fresh properties are not meeting, necessary adjustments should be made to the mix proportion.Typical range of constituents in SCC by weight and by volume is shown in Table 3.2

Table 3.2: EFNARC 2005 Guidelines for SCC

Constituent	Typical range by mass (kg/m^3)	Typical range by volume ($Liters/m^3$)
Powder	380-600	-
Paste	-	300-380
Water	150-210	150-210
Coarse aggregate	750-1000	270-360
Fine aggregate	Typically 45-48% of total aggregate weight	-
Water-powder ratio	-	0.85-1.10

3.1.5 American Concrete Institute (ACI) Method

As per ACI 237R-07 (2007), if the coarse aggregate size is greater than half inch (12.5mm) nominal maximum size is used, then the absolute volume of coarse aggregate should be in the range of 28 to 32% of concrete volume to minimize blocking of SCC through the reinforcement. The necessary powder content for the desired slump is shown in Table 3.4.

Table 3.3: Suggested powder content ranges (ACI 237R-07, 2007)

binder	Slump flow (mm)	Slump flow (mm)	Slump flow (mm)
Powder (kg/m^3)	$<550mm$	550-600 mm	$>650mm$
Powder (kg/m^3)	355-385	385-445	>458

Proportioning guidelines has been summarized and shown in Table 3.5. The values suggested here are only the initial targets for trial mixtures and will vary with locally available materials.

Table 3.4: Typical Ranges of Materials for SCC

Constituent	Typical range
Absolute volume of coarse aggregates	28-32%
Paste fraction (by volume)	34-40%
Mortar fraction (by volume)	68-72%
Typical water-cementious (w/cm) ratio	0.32-0.45
Typical cement (powder) content	386-475 kg/m^3

3.1.6 Mix Design By Nan-Su Method

The following mix design procedure is proposed by Nan-su ,this method is simpler, easier for implementation and less time-consuming, requires a smaller amount of binders and saves cost. The procedure of the mix design method can be expressed as follows:

Step 1: Calculation of fine aggregate content
Calculation of fine aggregate needed per unit volume of SCC,

$$W_{fa} = PF \times W_{SL}(\frac{s}{a}) \tag{3.1}$$

Where,
W_{fa} = content fine aggregate in SCC (kg/m^3)
PF = Packing factor i.e., ratio of mass of aggregate of highly tightly packed state in SCC to that of loosely packed state.
W_{SL}= unit volume mass of loosely piled saturated surface-dry fine aggregate in air (kg/m^3)
s/a= volume ratio of fine aggregate to total aggregates which ranges from 50-58%

Step 2: Calculation of coarse aggregate content
Calculation of coarse aggregate per unit volume of SCC

$$W_{ca} = PF \times W_{GL}(\frac{1-s}{a}) \tag{3.2}$$

Where,
W_{ca}= Content of coarse aggregate in SCC (kg/m^3)
W_{GL} = Unit volume mass of loosely piled saturated surface-dry fine aggregate in air (kg/m^3)

Step 3: Calculation of Cement content
Amount of cement need per unit volume of SCC,

$$C = \frac{f^1c}{20} \tag{3.3}$$

Where,
C = Cement content (kg/m^3)
f^1c = Designed compressive strength (psi)
here f^1c is calculated from IS10262-2009

Step 4: calculation of mixing water content required by cement
Amount of mixing water needed for cement is

$$W_{wc} = (\frac{W}{C}) \times C \tag{3.4}$$

Where,
W_{wc} = content of mixing water required by cement kg/m^3
W/C = Water cement ratio and
C = cement content in kg/m^3

Step 5: calculation of SP dosage
Dosage of SP used $W_{sp} = n\% \times C$
n% = Dosage of SP dosage
C = cement content in kg/m^3

Amount of water in SP W_{wsp} = (1- m%)W_{sp}

Where,
m% = Amount of binders and its solid content of SP taken as 50%.

Step 6: Calculation of Fly Ash (fa) and Ground Granulated Blast Furnace Slag (GGBS) contents

The volume of fly Ash paste (VPF) and GGBS paste (VPB) can be calculated as follows:

$$V_{PF} + V_{PB} = [1 - (\frac{W_g}{1000 \times G_g} + \frac{W_s}{1000 \times G_s} + \frac{c}{1000 \times G_c} + \frac{W}{1000 \times G_w} + V_a)] \tag{3.5}$$

Where,
G_g = specific gravity of coarse aggregate
G_s= Specific gravity of fine aggregate
G_c = Specific gravity of cement

G_w= Specific gravity of water
V_a= Air content in SCC,it is taken as 0.015 as per code(0-5%)

Amount of fly ash and GGBS needed:

$$V_{PF} + V_{PB} = (1 + \frac{W}{F}) \times A\% \times \frac{W_{pm}}{1000 \times G_F} + (1 + \frac{W}{S}) \times B\% \times \frac{W_{pm}}{1000 \times G_G} \tag{3.6}$$

But we find wrong in this formula & we modified and changed the formula as shown in below.

$$V_{PF} + V_{PG} = V_F + V_{WF} + V_G + V_{WG}$$

$$= \frac{W_F}{\Upsilon_W G_F} + \frac{W_{WF}}{\Upsilon_W} + \frac{W_G}{\Upsilon_W G_G} + \frac{W_{WG}}{\Upsilon_W}$$

$$= \left(\frac{W_F}{\Upsilon_W G_F} + \frac{W_{WF}}{W_F} \cdot \frac{W_F}{\Upsilon_W}\right) + \left(\frac{W_G}{\Upsilon_W G_G} + \frac{W_{WG}}{W_G} \cdot \frac{W_G}{\Upsilon_W}\right)$$

$$= \frac{W_F}{\Upsilon_W}\left(\frac{1}{G_F} + \frac{W}{F}\right) + \frac{W_G}{\Upsilon_W}\left(\frac{1}{G_G} + \frac{W}{G}\right)$$

$$V_{PF} + V_{PG} = \left[1 + \left(\frac{W}{F}\right) G_F\right] \times A\% \times \frac{W_{PM}}{\Upsilon_W G_F} + \left[1 + \left(\frac{W}{G}\right) G_G\right] \times B\% \times \frac{W_{PM}}{\Upsilon_W G_G}$$

In the present work we used our modified formula.
Where,
G_F = Specific gravity of fly ash
G_G= Specific gravity of GGBS
W_{pm} = total amount of pozzolanic materials (FA) and ($GGBS$) in SCC (kg/m^3)
$A\%$= Percentage of fly ash by weight
$B\%$ = Percentage of GGBS by weight
$\frac{W}{F}$ = Ratio of fly ash is taken as 0.47
$\frac{W}{S}$ = Ratio of GGBS is taken as 0.47

Fly Ash content W_F = A% $\times W_{pm}$
GGBS content $W_G = B\% \times W_{pm}$

Step 7: Determine the mixing water content required for FA and GGBS.

$$\text{Water content needed for fly ash } W_{WF} = \frac{W}{F} \times W_F$$

$$\text{Water content needed for GGBS } W_{WG} = \frac{W}{S} \times W_G$$

Step 8: Calculation of mixing water content needed in SCC
The mixing water content required by SCC is that the total amount of water needed for cememnt,flyash and GGBSin mixing.It is caculated as follows.

$$W = W_{wc} + W_{WF} + W_{WG} - W_{wsp} \tag{3.7}$$

Among all the above mix design methods of SCC the Nan-Su method is used to design M25 SCC in this experimental programme.

3.2 Workability

Workability is one among the physical parameters of concrete that affects the durability and strength also cost of labour and appearance of the finished product. The property of fresh concrete is indicated by the quantity of useful internal work needed to completely consolidate the concrete without bleeding and segregation within the finished product. A good SCC shall commonly reach a slump flow value exceeding 600mm while not segregation. The amount of fluidness of the SCC is regulating primarily by the dosing of the super plasticizer. But over dosing might result in the chance of segregation and blockage. Consequently, the characteristics of the fresh SCC have to be rigorously controlled using preferably 2 of the various sorts of test.

Following are requirements for good workability in SCC.
. If needed, SCC should remain flowable and self-compactable for a minimum of 90 minutes.
. If needed, SCC shall be ready to with stand a slope of three in case of free horizontal surface.
. If needed, SCC shall be pump able for a minimum of 90 minutes and through pipes with a length of a minimum of 100 meters.

3.3 Tests on Fresh Properties of SCC

SCC differs from traditional vibrated concrete; in this contemporary property are important in determining whether or not it may be placed satisfactorily. The assorted aspects of workability are its filling ability, passing ability and segregation resistance. Fresh properties of SCC as shown in Table 3.2. All have to be carefully controlled to make sure that its ability to be placed remains acceptable.

3.3.1 Filling ability

The ability of fresh concrete to flow into and fill all areas among the formwork under its own weight. Filling ability may be assessed by the T500 time throughout the slump-flow test or assessed by the V funnel flow time.
The value obtained doesn't measure the filling ability of SCC however is related to it by describing the speed of flow. Concrete with a low consistency can have a quick initial flow and then stop. Concrete with a high consistency might continue to creep forward over an extended

time.

3.3.2 Passing ability

The ability of fresh concrete to flow through rigid openings corresponding to areas between steel reinforcing bars without segregation or blocking.

Passing ability describes the capability of the fresh mix to flow through confined areas and slender openings corresponding to areas of engorged reinforcement without segregation, loss of uniformity or causing blockage. In this process the passing ability, it's necessary to think about the geometry and density of the reinforcement, the flowability/filling ability and also the maximum aggregate size.

3.3.3 Segregation Resistance

The ability of concrete to stay consistent in composition whereas in its fresh state. Segregation resistance is prime factor for SCC in-situ homogeneity and quality. SCC can suffer from segregation throughout placing and additionally after placing however before stiffening. Segregation that occurs when placing will be most damageable in tall components however even in thin slabs; it will result in surface defects such as cracking or a weak surface.

3.4 Workability Tests on SCC

The test methods to evaluate the fresh properties of SCC are discussed in this section.

3.5 Tests on Filling Ability

Tests conducted on Filling ability are Slump Flow Test, T50 Slump Flow Test and V- funnel test.

3.5.1 Slump Flow Test

The slump flow test is employed to evaluate the free deformability and flowability. About 6 liters of concrete is needed to perform the test. A standard slump flow cone (height 300mm, base and top diameter 200 mm and 100 mm respectively), is employed for the test and therefore the concrete was poured with in the cone without compaction and levelled. Slump flow value is depicted as the mean of 2 perpendicular diameters of concrete after lifting the cone. A slump value ranging from 650 to 800 mm for a concrete is taken as self-compacted in traditional SCC. By this test additionally to assessing the deformability of the concrete, it's possible to look at segregation of aggregates near the edges and spread out concrete visually as show in Fig 3.1.

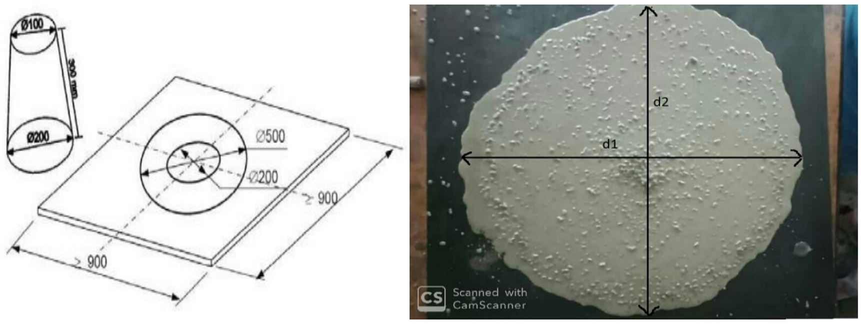

Figure 3.1: T50 Slump Flow Test

3.5.2 T50 Slump Flow Test

This technique is same as that of the slump flow test. Once the cone is lifted, stop watch is to be started and notice the time taken to achieve the 500 mm mark. This is the indication of rate of spread of concrete. Lower time indicates the larger flowability. Acceptable T50 time vary from 2 to 5 sec.

3.5.3 V-Funnel Test

The V-funnel test is employed to determine the deformability through restricted space. The version chosen for estimation during this study had a rectangular crossing tapering to a bottom gap of 65mm 75mm. The funnel was fitted with a trap door. The test result's given as a flow time (sec) as shown in Fig 3.2. The V-funnel deals with mixes containing aggregate of size not more than 25mm. A sample of fresh concrete of between 12 liters in volume is needed. Acceptable value ranges are in between 6 and 12sec.

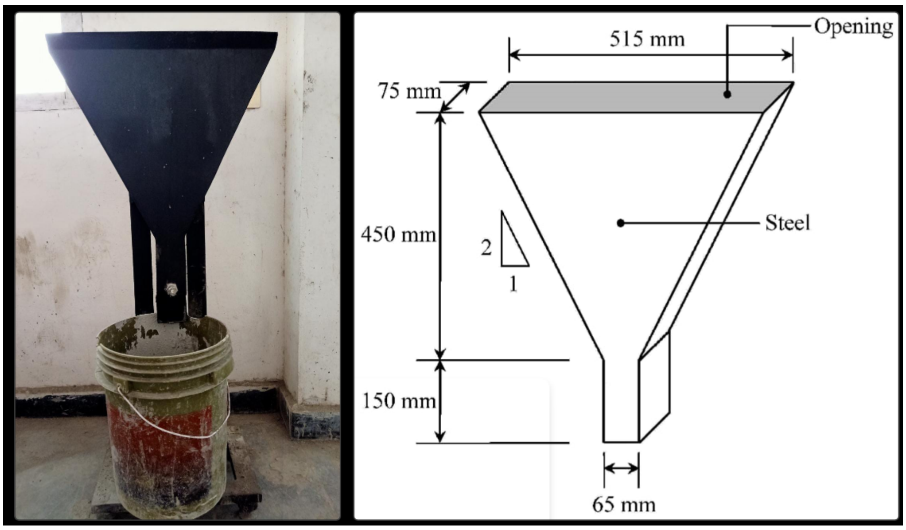

Figure 3.2: V-Funnel Test

3.6 Tests on Passing Ability

Tests conducted on Passing ability are L-Box Test, J Ring Test and U-Box Test.

3.6.1 L-Box Test

The test assesses the impact of reinforcement on free flow of concrete affected by formwork. A sample of fresh concrete of between 14 liters in volume is needed. By this test it's attainable to measure different properties like flow ability, block and segregation of the concrete. Concrete is allowed to move steadily from the vertical column section into the horizontal trough. The basic test result's the 'blocking ratio' h2/h1. it's the quantitative relation between the height of the concrete surface with in the vertical column a part of the apparatus (h1) and the height of the concrete surface within the through at its far end (h2), after the passage through vertical reinforcing bars. There are 2 extra marks on the horizontal trough at 200 mm and 400 mm from the sliding door quantitative relation between these 2 heights (h2/h1), that is typically 0.7-0.9, was accustomed to evaluate the ability of the SCC mixture to flow around obstruction. This limit, however, has been planned to be within 0.8 and 1.0 by EFNARC guidelines as shown in Fig.3.3.

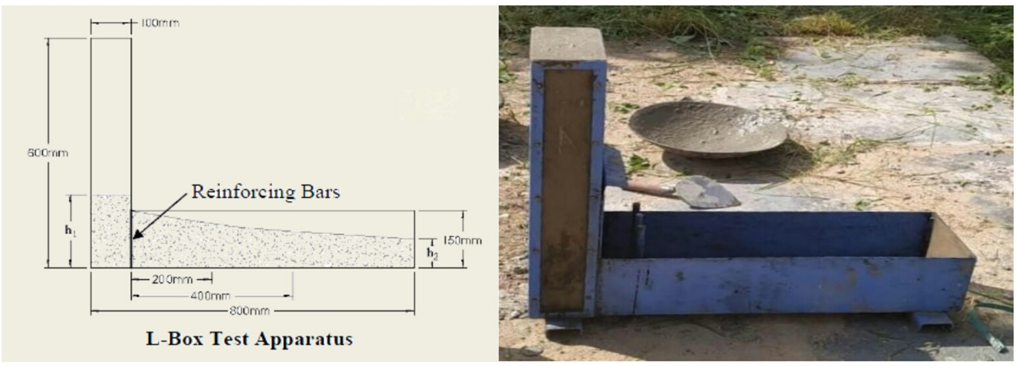

Figure 3.3: L-Box Test

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3.6.2 J-Ring test

The J-ring test is employed to determine the passing ability of the SCC. About 6 liters of concrete is needed to perform the test. The instrumentation consists of a rectangular section having dimensions 30 mm 25 mm open steel ring, drilled vertically with holes to accept the threaded sections of reinforcement bar. These sections of bar will be having different spaced at different intervals; in accordance with normal reinforcement concerns, 3 (the max. aggregate size) can be acceptable. The diameter of the ring of vertical bars is 300 mm, and height 100 mm. After the test, the difference in height between concrete inside and that just outside the J ring is measured. This is often an indication of passing ability, or the degree to which passing of concrete through the bars is restricted as show in Fig.3.4.

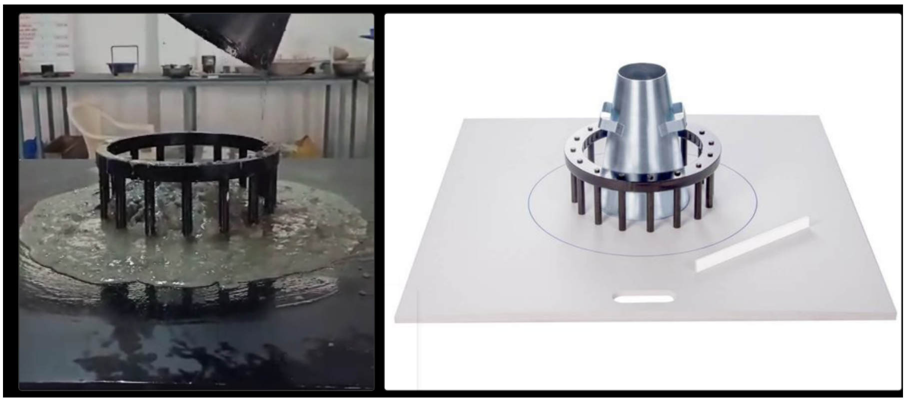

Figure 3.4: J-Ring Test

3.7 Tests on Segregation Resistance

Various test methods have been proposed to examine the segregation resistance such as surface settlement test, penetration test and segregation test. So far, no acceptable methods are available for these tests. The simple test to examine the segregation resistance is measuring T5 min in the V-funnel test.

3.8 Tests on Hardened Properties of SCC

In the design of concrete structures, engineers could refer to number of concrete properties, that aren't always a part of the concrete specification. Some of the relevant hardened properties are explained below.

3.9 Tests on SCC Specimens

3.9.1 Compressive strength of concrete

Compressive strength of concrete is described as the load that causes the failure of a standard specimen divided by the area of cross-section in uni-axial compression underneath a given rate of loading. The compressive strength test is done on standard cube or cylindrical specimens. Compressive strength of specimens is obtained using CTM or UTM.

1. Influence of Type of Cement,
2. Influence of Type of Aggregate,
3. Influence of Surface Condition and Moisture Content of Concrete,
4. Influence of Curing and Age of Concrete and
5. Influence of Carbonation of Concrete Surface

Chapter 4

MATERIAL PROPERTIES

4.1 Materials

4.1.1 Cement

Portland slag cement (PSC)

Portland Slag Cement, commonly known as PSC, is blended cement. Slag is, essentially, a non-metallic product comprising of more than 90% glass with silicates and alumino-silicates of lime.

In this project PSC used is manufactured from JSW Cement. Superior quality slag produced at their steel manufacturing plant, conforming to IS: 12089 is used for producing PSC. It is created with a combination of upto 45- 50% slag, 45% -50% clinker, and 3-5% gypsum. PSC has been voted as the most suitable cement for mass construction because of its low heat of hydration.

PSC is tested for physical properties as per IS: 4031 - 1988 and the results are as shown in Table 4.1.

Table 4.1: Test Results on Cement (IS:4031-1988)

Properties	Results Obtained	Standard Range
Specific Gravity of Cement	2.92	2.85-2.94
Standard Consistency of Cement	37%	--
Initial Setting Time	129 minutes	Not less than 30 minutes
Final Setting Time	570 minutes	Not more than 600 minutes
Fineness of Cement	4%	Less than 10%
Soundness Test	1mm	Not more than 10mm

4.1.2 Coarse Aggregate

Coarse aggregate chosen for SCC is normally round in shape, is well graded, and smaller in max size than used for conventional concrete could have a maximum aggregate size of 40 mm or more. A rounded aggregate and the smaller aggregate particles aid in the flow ability and deformability of the concrete are aiding in the anticipation of segregation and deformability of the concrete as well as assist in prevention of segregation. Usually, the maximum size of coarse aggregate used in SCC ranges from 10 mm to 20 mm. Regarding to the characteristics of different types of aggregate like crushed aggregates tend to enhance the strength because of the connection of the angular particles, although rounded aggregates improves the SCC flow.

Locally available crushed stones graded of nominal size of 20 mm, 12.5 mm,6 mm are tested for its properties as per IS: 383-2016 and the results are as shown in Table 4.2.

Table 4.2: Test Results on Coarse Aggregate (IS:383-2016)

Properties	Results			Standard Range
	20mm	12.5mm	6mm	
Bulk Density(loosely Packed)	1420.79kg/m³	1393.57kg/m³	1316.27kg/m³	1450-2082kg/m³
Bulk Density(Tightly Packed)	1601kg/m³	1567kg/m³	1360kg/m³	1450-2082kg/m³
Specific Gravity	2.97			2.5-3.0
Impact Test	--	14.20%	--	Less Than 35%
Abrasion Test	11.08%		20.8%	Less Than 40%
Flakiness Index	17.26%	33.15%	--	Less Than 35%
Elongation Index	18.24%	31.57%	--	Less Than 40%

4.1.3 Fine Aggregate

All normal sands are suitable for SCC and both crushed and rounded sands are used. Siliceous or calcareous sands are also used. The amount of fines less than 0.125 mm is to be considered as powder and is very important for rheology of the SCC. A minimum amount of fines is achieved to avoid segregation.

It is formed by the decomposition of sand stones due to various effects of weather. The shape and surface structure of fine aggregate has a greater influence on water demand of concrete than because fine aggregates contain a much higher surface area for a given weight. Smooth and rounded fine aggregate particles are better for workability than sharp and rough particles.

Locally available Fine aggregate tested for its properties as per IS: 383-2016 and the results are as shown in Table 4.3.

Table 4.3: Test Results on Fine Aggregate (IS:383-2016)

Properties	Results	Standard Range
Specific Gravity of Fine aggregate	2.62	2.5-3
Bulk Density(Loosely Packed)	1555 kg/m^3	1200-1750kg/m^3
Bulk Density(Tightly Packed)	1678 kg/m^3	1200-1750kg/m^3
Fineness modulus	2.60(ZONE-2)	2.2-2.6(Fine Sand)

4.1.4 Copper Slag

Copper slag is a by-product obtained during the matte smelting and refining of copper. In India, three copper producers Sterlite, Birla Copper and Hindustan Copper produces around 6-6.5 tons of copper slag.

To produce every ton of copper, approximately 2.23.0 tons copper slag is generated as a by-product material. Utilization of copper slag in applications such as Portland cement substitution and or as aggregates has threefold advantages of eliminating the costs of dumping, reducing the cost of concrete, and minimizing air pollution problems.

The test results are show in table 4.4

Table 4.4: The test results of copper slag

Properties	Results	Ranges
Specific Gravity of Copper Slag	3.28	--
Bulk Density(Tightly Packed)	2270Kg/m^3	--
Bulk Density(Loosely Packed)	2024Kg/m^3	--
Fineness modulus	2.97(Zone-2)	2.9-3.2(Coarse)

4.1.5 Ground Granulated Blast-Furnace Slag (GGBS):

GGBS is non-metallic powder consisting of silicates and aluminates of calcium and different bases. The molten slag is promptly chilled by quenching in water to make glassy sand like material.

The granulated material when additional ground to less than 45 microns can have specific surface concerning 400 to 600 m2/kg. The chemical composition of furnace slag is comparable to that of cement clinker. The performance of slag mostly depends on the chemical composition. Quality of slag is governed by IS 12089 of 1987.

The results are as show in Table 4.5.

Table 4.5: Test on GGBS

Test	Values
Specific Gravity of GGBS	2.71

4.1.6 FLYASH

Pulverized fly ash is a deposit from the combustion of pulverized coal composed by mechanical separators, from the gases of thermal plants. The composition varies with type of fuel burnt, load on boiler and type of the separation. The fly ash consists of spherical glassy particles ranges from 1 to 150 micron in diameter and passes through the 45 micron sieve.

The Fly Ash used for this investigation was collected from Rayala Seema Thermal Power Plant (RTPP) near Kadapa district.,

The results are as show in Table 4.6.

Table 4.6: Test Result on Flyash

Test	Values
Specific Gravity if Fly Ash	2.43

4.1.7 High Range Water Reducers(HRWR) / Super Plasticizer

A number of studies are accomplished on the utilization of various sorts of super plasticizer with or without viscosity modifying agents in self-compacting concrete. Super Plasticizer is crucial for the formation of SCC. The work of SP is to impart a high degree of flow ability and deformability, but the high dosages usually associate with SCC will lead to a high degree of segregation.

POLYCARBOXYLIC ETHER complies with IS 9103-1999(2007). It also complies with ASTM C 494 Type F depending on the dosage used.

PCE is utilized in this project, which is product of AGROSYN Company having a selected gravity of 1.108 0.04. Super plasticizer is chemical compound accustomed increase the workability while not adding additional water i.e. spreads the given water within the concrete throughout the concrete mix resulting to make a uniform mix. SP improves best surface expose of aggregates for cement gel. Super plasticizer acts as lubricating substance among the materials. Typically, so as to extend the workability the water content is to be accumulated provided a corresponding amount of cement is additionally added to keep the water cement ratio constant, in order that the strength remains identical.The properties of SP as shown in Table 4.7

Role of S.P in cement

The main action of S.P is to liquidity the mix and improves the workability of concrete. Portland cement, being in fine state of division can have a bent to flocculate in wet concrete. This flocculation's entraps certain quantity of water utilized in the mix and there by all the water isn't freely accessible to fluidity the mix. Once plasticizers are used, they get absorbed on cement particles. the general result's that the cement particles are deflocculated and therefore the water trapped within the flocks gets discharged and currently accessible to fluidity the mix.

Table 4.7: Properties of Super Plasticizer

Properties	Manufacturer Catalog
Appearance	Pale yellowish to Brownish liquid
pH value	5 to 6
Solubility	Readily soluble in water
Specific Gravity	1.108 ± 0.04
Chloride Content	Below 0.02%
Solid	50 ± 1%

4.1.8 Water

Water is a vital ingredient of concrete because it participates in chemical process with cement, since it helps to make the strength giving cement gel. The quality and amount of water is needed to be looked carefully. Since quality of water affects the strength, it's necessary to go through the standard and purity of water. Potable water is used for mix and curing in this investigation.

4.1.9 MIX DESIGN OF M25

$f_{ck} = 25Mpa$,
${f^1}_c = 31.6MPa$(4590 psi) for 28 days.Here ${f^1}_c$(Target mean strength) is calculated from the IS:10262-2019.
Specific gravity of coarse aggregates is = 2.97
Bulk density of loose coarse aggregates is = 1397 Kg/m^3
Specific gravity of fine aggregates is = 2.62
Bulk density of loose fine aggregates is = 1555 Kg/m^3
Specific gravity of cement = is 2.92
Specific gravity of GGBS is = 2.71
The volume ratio of fine/coarse aggregates is 50/50 (Assumed)
Packing Factor is taken as PF = 1.12
Air content in SCC is = 1.5%. (Assumed)
Amount of binders and its solid content of SP, m% is taken as 50%
W/F and W/G are taken as 0.47 and 0.47 respectively. (Assumed)
W/C ratio = 0.47 (after trails finalised)

Step 1: Calculation of fine aggregate content
Calculation of fine aggregate needed per unit volume of SCC
From Eq.(3.1)

$$W_{fa} = 1.12 \times 1555(\frac{50}{100})$$
$$= 870.8 \text{ Kg}/m^3$$

Step 2: Calculation of coarse aggregate content
Calculation of coarse aggregate per unit volume of SCC
From Eq.(3.2)

$$W_{ca} = 1.12 \times 1397(\frac{1-50}{100})$$
$$= 782.320 \text{ Kg}/m^3$$

Step 3: Calculation of Cement content

We used slag cement in that case we need more amount of cement content for getting good results, that's why we just increased 1.4 of this value

From Eq.(3.3)

$$C = 1.4 \times (\frac{4590}{20})$$
$$= 320.828\ Kg/m^3$$

Step 4: Calculation of mixing water content required by cement
Amount of mixing water required by cement can be obtained as follows
From Eq.(3.4)

$$W_{wc} = 0.47 \times 320.828$$
$$= 150.789\ Kg/m^3$$

Step 5: Caculation of SP dosage
Dosage can be obtained as follows and water content in SP can be obtained as follows
Dosage of SP used $W_{sp} = n\% \times C \quad = (\frac{1.25}{100}) \times 320.828 \quad =$ 4.010 Kg/m^3
Amount of water needed in SP = W_{wsp} = (1- m%)W_{sp}

$$W_{wsp} = (1 - 0.5) \times 4.010$$

$$W_{wsp} = 2.005\ Kg/m^3$$

Step 6: Calculation of Fly Ash (FA) and Ground Granulated Blast Furnac Slag (GGBS) contents
The volume of Fly Ash paste (VPF) and Ground Granulated Blast Furnac Slag paste (VPB) can be calculated as follows: From Eq.(3.5)

$$V_{PF} + V_{PG} = [1 - (\frac{782.320}{1000 \times 2.97} + \frac{870.8}{1000 \times 2.62} + \frac{320.828}{1000 \times 2.92} + \frac{148.784}{1000 \times 1} + 0.015)]$$

$$= 0.131$$

In this investigation contents of GGBS and Fly Ash is calculated by modified formula (ref(4))

$$\mathrm{V_{GGBS}} + \mathrm{V_{FLYASH}} = \frac{A\%W_{PM}}{\Upsilon_W G_{GGBS}}\left[1 + \left(\frac{W}{G}\right) G_{GGBS}\right] + \frac{B\%W_{PM}}{\Upsilon_W G_{\mathrm{F}}}\left[1 + \left(\frac{W}{\mathrm{F}}\right) G_{\mathrm{F}}\right]$$

$$0.131 = \frac{60\%W_{PM}}{1000\text{x}2.71}\left[1 + \left(\frac{47}{100}\right) 2.71\right] + \frac{40\%W_{PM}}{1000\text{x}2.43}\left[1 + \left(\frac{47}{100}\right) 2.43\right]$$
W_{PM}=152.532kg/m^3

Amount of fly ash content = 0.04×152.532

$$= 61.012 \ Kg/m^3$$

$$\text{Amount of GGBS content} = 0.06 \times 152.532$$
$$= 91.519 \ Kg/m^3$$

Step 7: Determine the mixing water content required for FA and GGBS

Water content needed for fly ash $W_{WF} = \frac{W}{F} \times W_F$

$W_{WF} = 0.47 \times 61.012$

$$W_{WF} = 28.676 \ Kg/m^3$$

Water content needed for GGBS $W_{WG} = \frac{W}{S} \times W_G$

$W_{WG} = 0.47 \times 91.519$

$$W_{WG} = 43.014 \ Kg/m^3$$

Step 8: Calculation of mixing water content needed in SCC

The mixing water content required by SCC is the total amount of water needed for cement,FA and GGBS in mixing.

Total Water $W_W = W_{wc} + W_{WF} + W_{WG} - W_{wsp}$

$$= 150.789 + 28.676 + 43.014 - 2.005$$

$$= 220.474 \ Kg/m^3$$

Table 4.8: Mix proportions as per Nan-Su Mix design for 1cu.m on weight basis

Packing Factor	Coarse Aggregate			Coarse Aggregate (kg/m³)	Water (kg/m³)	Fine Aggregate (kg/m³)	W/C Ratio(As per NANSU)	W/C Ratio	W/P Ratio	Cement (kg/m³)	GGBS (kg/m³)	Fly Ash(kg/m³)	Mix Trails	Fine Aggregate		SP Dosage (%)	SP Content (kg/m³)
	20mm	12.5mm	6mm											% of Fine aggregate	% of Copper Slag		
1.12	40%	50%	10%	782.320	220.474	870.800	0.47	0.469	0.46	320.828	91.519	61.013	M1	100	0	1.25	4.010
													M2	90	10	1.19	3.818
													M3	80	20	1.13	3.625
													M4	70	30	1.07	3.433
													M5	60	40	1.01	3.240
													M6	50	50	0.95	3.048

Chapter 5

RESULTS AND DISCUSSIONS

5.1 WORKABILITY & COMPRESSIVE STRENGTH TESTS

5.1.1 Mixing of Materials

Initially trial mix is designed for W/C =0.49 as per Nan Su method for 0% Copper Slag replacement. 7 liters of Mix is prepared by adding Coarse Aggregate, Fine Aggregate, Copper Slag, Cement, Flyash, GGBS and SP mixed Water in the order in to mixing machine for conducting slump flow test. Slump flow value is 700mm which satisfies EFNARC guidelines.

Second trial mix is designed for W/C =0.45 as per Nan Su method for 0% Copper Slag replacement. 7 liters of Mix is prepared by adding Coarse Aggregate, Fine Aggregate, Copper Slag, Cement, Flyash, GGBS and SP mixed Water in the order in to mixing machine for conducting slump flow test. Mixing of ingredients is not proper in the mixer, hence trial is rejected.

Third trial mix is designed for W/C =0.47 as per Nan Su method for 0% silica fume replacement. 7 liters of Mix is prepared by adding Coarse Aggregate, Fine Aggregate, Copper Slag, Cement, Flyash, GGBS and SP mixed Water in the order in to mixing machine for conducting slump flow test. Slump flow value is 650mm. which satisfies EFNARC guidelines.

5.1.2 Proportioning

From Table 4.6 different mix proportions M1 to M6 are prepared. Copper Slag varied from 0% to 50% and SP dosage varied from 1.25 % to 0.95% respectively for M1 to M6 mixes.

5.1.3 Workability Tests

Slump flow test, Slump flow T50cm and J-Ring test are conducted in order by using 7 liters of concrete. V-funnel Test, V-funnel T5 min and L Box test are conducted in order by using 17 liters of concrete.

Workability Tests are conducted. The results are shown in Table 6.1 and also in Fig 5.1. All the test results are conforming to EFNARC guidelines for SCC.

Table 5.1: Fresh Properties of SCC

Mix Trails	Percentage of Copper Slag	Slump Flow	Slump Flow T50 cm	J-Ring	V-Funnel	V- Funnel T5minutes	L-box
M1	**0**	650	4	2.5	8	11	0.89
M2	**10**	720	3	8.5	6	8	0.95
M3	**20**	740	3	7.5	7	10	0.91
M4	**30**	720	3	8.5	5	8	0.96
M5	**40**	695	3	9.5	6	8	0.89
M6	**50**	700	3	9.5	7	7.5	0.82
--	Ranges	650-800mm	2-5 seconds	0-10mm	6-12	+3	0.8-1

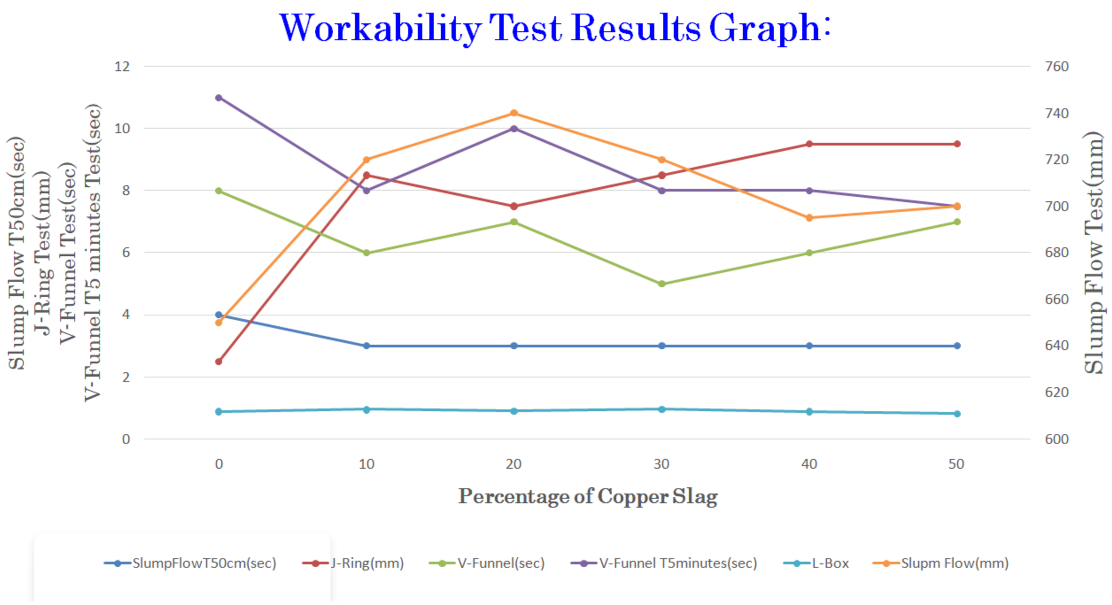

Figure 5.1: Fresh Properties of SCC

5.1.4 Test Results on Compressive Strength

Concrete cubes are prepared as per mix design shown in Table 4.6 for different Copper Slag (0% to 50%) replacements without any compaction. The cubes are tested for compressive strength after 3, 7 & 28 days of curing in water at room temperature.
The Compressive Strength test results are as shown in Table 5.2.

Table 5.2: Compressive Strength Test Results on Concrete Cubes

Mix Trails	Percentage of Copper Slag	Compressive strength (N/mm^2) 3 Days	Compressive strength (N/mm^2) 7 Days	Compressive strength (N/mm^2) 28 Days
M1	0	10.57	19.55	24.52
M2	10	12.55	17.73	23.66
M3	20	13.29	19.67	27.09
M4	30	12.68	18.84	24.37
M5	40	13.52	20.05	26.44
M6	50	12.71	19.24	26.5

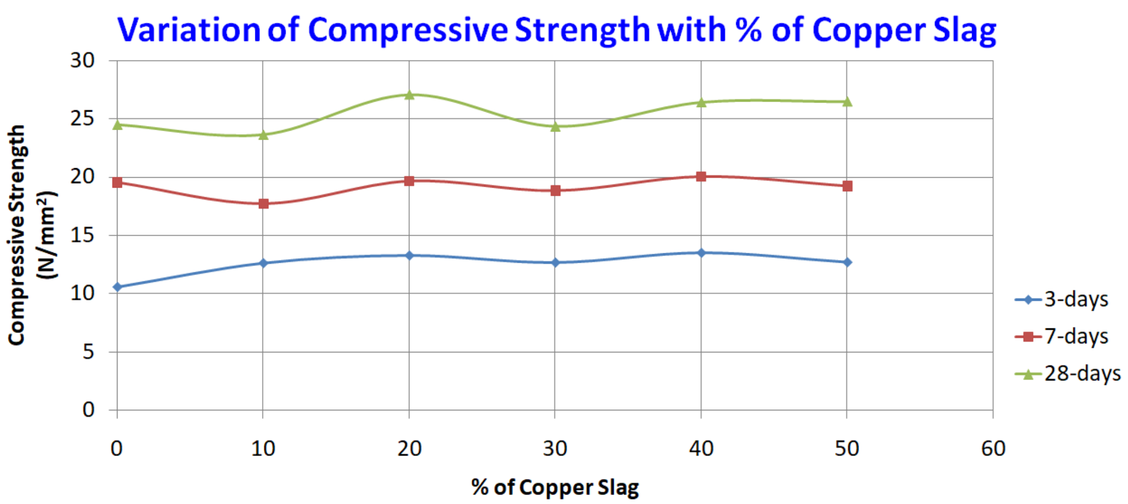

Figure 5.2: Compressive Strength of SCC

From the Figure 5.2, it is observed that 28 days compressive strength of mix with 20% copper slag replacement is more compared to all other mixes and there is an increase of 10.48% compared to mix with 0% copper slag replacement.

Chapter 6

CONCLUSION

1. From the Figure 5.2, it is observed that 28 days compressive strength of mix with 20% copper slag replacement is more compared to all other mixes and there is an increase of 10.48% compared to mix with 0% copper slag replacement.

2. Fresh SCC proporties such as Slump Flow, T50 Slump Flow, J-Ring, V-Funnel, V-Funnel T5min, L-Box tost values satisfies the EFNARC guidelines.

3. Target Mean Strength is not achieved for all the mixes. Hence, NANSU Mix design not suitable for SCC mix design with Portland Slag Cement (even by considering more than 40% of cement given by NANSU mix design).

4. For mixes with 20% to 50% copper slag replacement, 28 days Compressive Strength is more compared to 0% Copper Slag replacement. Hence , Copper Slag can be used as replacement for Fine Aggregate, where Copper Slag is abundant and cheap.

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APPENDIX

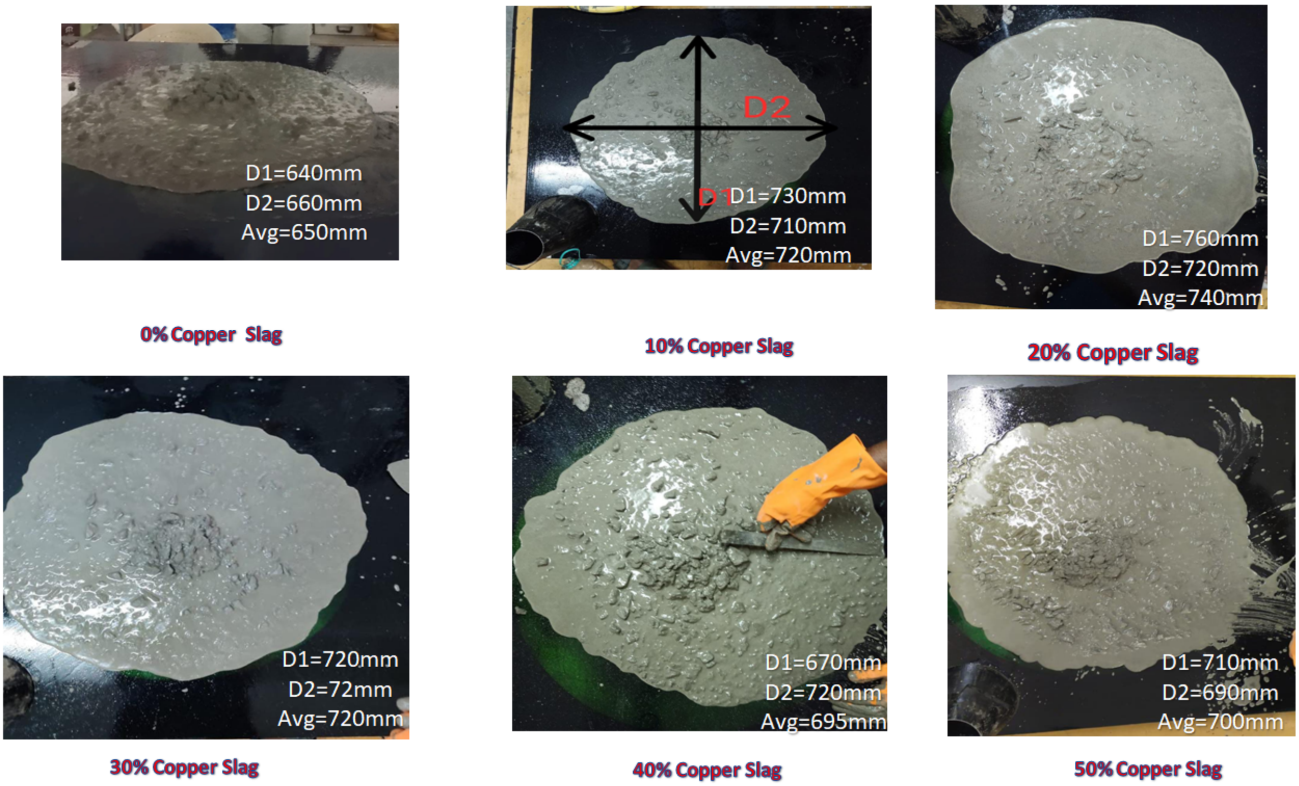

Figure 6.1: Diffrent Proportions of Slump Flow images

Figure 6.2: Diffrent Proportions of J-Ring images