International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 10 Issue: 07 | Jan 2023 www.irjet.net p-ISSN: 2395-0072

Compressive Strength of Different Grades of SCC Mix Using Portland Slag Cement (70%), GGBS (30%) and Replacing 20% Fine Aggregate with Copper Slag

Ankireddypalli Ganga Chandra Sekhar Reddy[1], Thati Sucharitha[2], Yeragolla Leelavathi[3], Mallepogu Sai Charan[4], Chamarthy Krishnama Raju[5]

[1,2,3,4]Former Student, Department of Civil Engineering, Rajeev Gandhi Memorial College of Engineering and Technology (Autonomous), Nandyal, India
[5]Associate Professor, Department of Civil Engineering, Rajeev Gandhi Memorial College of Engineering and Technology (Autonomous), Nandyal, India

---***---

Abstract – *The effect of Portland Slag Cement, (70%) and GGBS (30%) and replacing 20% of Fine aggregate with Copper Slag on compressive strength of different grades of SCC Mix is not investigated as per the literature cited. The present investigation finds the effect of above proportion on compressive strength, split tensile strength and flexural strength of SCC Mixes M20 to M40 with and without replacement of Copper Slag. The modified Nan-Su mix design for application to PSC concrete is used. For M20 to M40 grades with Copper Slag compressive strength is more than the characteristic compressive strength of concrete except for M35.*

Key Words: Copper Slag, EFNARC *Guidelines, GGBS, Self Compacting Concrete (SCC), GGBS, Slump Flow, Workability properties.*

1. INTRODUCTION

The use of Self Compacting Concrete (SCC) is increasing day by day in India. The workability properties of SCC can be characterized(EFNARC, 2002) by filling ability, passing ability and segregation resistance.

Compressive Strength of Different Grades of SCC Mix Using Portland Slag Cement (PSC) (75%), GGBS (25%) and Replacing 20% Fine Aggregate with Copper Slag is investigated by Chamarthy Krishnam Raju et al.[2], but target mean strength is not achieved for some grades of concrete. Hence present investigation is carried out with 30% of Cement replacement with GGBS.

The modified Nan-Su mix design for application to PSC concrete [2] is used. Master Glenium SKY 8233 super plasticizer is used. Mix grades M20 to M40 are considered in investigation.

2. EXPERIMENTAL INVESTIGATION

2.1 Materials Used

The materials used in the SCC are

i. Portland Slag Cement (JSW company) (IS: 12089)
ii. GGBS
iii. Fine Aggregate
iv. Copper Slag
v. Coarse Aggregate-12.5 mm(70%) and 20 mm(30%)
vi. Master Glenium Sky 8233 (Super Plasticizer)

2.11 Materials Properties

The properties of materials are determined and are shown in Table 1, 2, & 3. Table 4 shows the super plasticizer properties as given by the manufacturer.

2.21 Nan-Su Mix Design

The steps used in Nan-Su Mix Design for M35 Grade are given below.

Step 1: Calculation of Coarse and Fine aggregate contents:

$$W_{fa} = PF \times \Upsilon_{fa}\left(\frac{s}{a}\right) = 848.997 \text{ kg/ m}^3 \quad (1)$$

$$W_{ca} = PF \times \Upsilon_{ca}\left(1-\frac{s}{a}\right) = 716.029 \text{kg/m}^3 \quad (2)$$

Where,
W_{fa} : content of fine aggregates in SCC (kg/m³),
W_{ca} : content of coarse aggregates in SCC (kg/m³),

Table 1: Properties of Cementitious Materials

Cementitious Material	Specific Gravity Of Cement	Initial Setting Time	Final Setting Time	Standard Consistency	Soundness of Cement	Fineness of Cement
Portland Slag Cement (JSW Company)	2.99	1 hr 59 min	7 hrs 28 min	36%	2 mm	2%
GGBS	2.84	> 600 min	-	34%	-	2%
PSC (70%) & GGBS (30%)	3.01 2.945 (formula)	1 hrs 55 min	7 hrs 15 min	34%	2 mm	2%
Ranges (For Cement)	3.00 – 3.15	> 30 min	< 10 hrs	-		< 10%

Table 2: Properties of Coarse Aggregate (IS: 383-2016)

Properties		Size			Standard range
		20 mm	**12.5 mm**	20mm-30% and 12.5mm-70%	
Specific gravity of Coarse Aggregate		2.785	2.711	2.735 (from experiment)	2.5-3.0
Bulk Density of Coarse Aggregate tightly packed (Kg/m³)		1538.1	1456.1		-
Bulk Density of Coarse Aggregate loosely packed (Kg/m³)		1354.5	1322.2	1331.899 (from formula)	-
Shape Tests	a) Flakiness Test	19.26 %	18.50%		< 40%
	b) Elongation Test	13.96%	15.63%		< 40%
Impact Test		14.05 %			< 35%
Crushing test		14.84%			< 45%
Abrasion Test		13.48%			< 40%

Table 3: Properties of Fine Aggregate & Copper Slag (IS: 383-2016)

Properties	Fine Aggregate (Sand)	Copper Slag	Standard range
Specific Gravity	2.672	3.72	2.5 to 3
Bulk Density, (kg/m³) Loosely Packed	1457.755	2007.94	-
Bulk Density, (kg/m³) Tightly Packed	1629.100	2149.20	-
Fineness Modulus	3.100 (Zone –I)	3.16 (Zone-I)	2.9 – 3.2 (Coarse Sand)

Table 4: Master Glenium Sky 8233(Super Plasticizer)

Properties	Test Results of Manufacturer Catalogue
Appearance	Reddish Brown Liquid
pH Value	≥ 6
Solubility	Readily Soluble In Water
Relative Density	1.08 ± 0.02 at 25°C
Chloride Content	0%
Solid	$50 \pm 1\%$

Υ_{fa} : unit volume weight of loosely piled saturated surface-dry fine aggregates in air (kg/m³), = 1457.755 kg/ m³
Υ_{ca} : unit volume weight of loosely piled saturated surface-dry coarse aggregates in air (kg/m³), =1331.90 kg/ m³
PF : packing factor, the ratio of mass of aggregates of tightly packed state in SCC to that of loosely packed state in air,= 1.12 (Assumed)
$\frac{s}{a}$: volume ratio of fine aggregates (sand) to total aggregates, which ranges from 50% to 57%. = 52% (Assumed)

Step 2: Calculation of Cement Content:

$$W_c = 1.5\frac{f_c'}{20}(for\ PSC\ Cement) \quad =470.474\ kg/\ m^3 \qquad (3)$$

Where,
W_C= Cement content (kg/m³);
f'_c = designed compressive strength (psi). =6272.98 psi (43.25 MPa Target Mean Strength Obtained from IS: 10262-2019)

Step 3: Calculation of mixing water content required by cement:

$$W_{wc} = \frac{W}{C} \times W_C \quad = 176.428\ kg/\ m^3 \qquad (4)$$

Where,
W_{wc} = content of mixing water content required by cement (kg/m³),
$\frac{W}{C}$= the water/cement ratio by weight = 0.375 (After Trial mixes)

Step 4: Calculation of SP dosage, W_{sp} :

W_{sp} = n% × C = 0.00455x470.474 = 2.141 kg/ m³ (5)
Where,
n% = Dosage of SP = 0.455 % (Assumed and fixed after trials)
C = Cement content in kg/m³
Amount of water in SP W_{wsp} = (1-m%)W_{sp} = 1.070 kg/m³ (6)
Where,
m% = Amount of binders and its solid content of SP taken as 50%.

Step 5: Calculation of GGBS content:

$$V_G = \left[1 - \left(\frac{W_{ca}}{\Upsilon_W G_{ca}} + \frac{W_{fa}}{\Upsilon_W G_{fa}} + \frac{W_c}{\Upsilon_W G_c} + \frac{W_w}{\Upsilon_W G_w} + V_a\right)\right]$$

$$= 0.068\ m^3 \qquad (7)$$

Where, Υ_w = density of water,
G_{ca} = specific gravity of coarse aggregates,
G_{fa} = specific gravity of fine aggregates,
G_c = specific gravity of Cement,
G_w = specific gravity of water,
(W/G) = Water to GGBS ratio(Assumed).
V_a = air content in SCC (%) = 1.5% (Assumed).
Modified Nansu Mix Design formula for calculating W_G is

$$V_G = \left[1 + \left(\frac{W}{G}\right) G_G\right] \times \frac{W_G}{\Upsilon_W G_G} \qquad (8)$$

Where, G_G, is obtained from tests and $\frac{W}{G}$ = 0.375 is assumed, V_G obtained from (7).

W_G = 94.025 kg/m³

Mixing water content required for GGBS paste is obtained from

$$W_{WG} = \frac{W}{G} \times W_G \quad =35.259\ kg/m^3 \qquad (9)$$

Step 6: Calculation of mixing water content in SCC:

The mixing water content required by SCC is the total amount of water needed for cement, FA and GGBS in the mix. Therefore, it can be calculated from (10)

$$W_w = W_{wc} + W_{WG} - W_{wsp} \quad = 210.617\ kg/m^3 \qquad (10)$$

Step 7: Calculation of total GGBS used in SCC:

$$W_{TG} = 30\%\ x\ W_C + W_G = 141.142 + 94.025 = 235.167\ kg/m^3 \qquad (11)$$

3. MIX DESIGN

Concrete grades M20 to M40 is considered, and mixes M1 to M10 are designed as per Nan-Su mix design. Mixes M1 to M5 are without copper slag and M6 to M10 are with 20% replacement of fine aggregate (sand) with copper slag. Target mean strength as per IS 10262:2019 is used for the mixes in (3) in place of f'_c. Based on trial mixes W/C ratio and SP dosage is fixed to satisfy EFNARC guidelines. The SCC mix proportions for different grades of concrete are shown in Table 5.

4. WORKABILITY TESTS

Slump flow test and then J-Ring test is conducted in order by using 6 litres of concrete. The slump flow is shown in Fig. 1 for mixes M6 to M10. V funnel test is conducted by using 14 litres of concrete. Fresh properties are determined for the mixes M1 to M10. The results are as shown in Table 6 and also in Fig. 2 and Fig. 3. All the test results are conforming to EFNARC guidelines for SCC except V-funnel T5 sec.

Table 5: Mix Proportions of Mixes M1 to M10

Mix Trails	Grades	W/P Ratio	SP Dosage(% C), (Weight basis)	Water (lit/m³)	C, (Cement)(Kg/m³)	Cement (Kg/m³)		Additional GGBS content (Kg/m³)	Fine Aggregate (Kg/m³)	Fine Aggregate (Kg/m³)		Coarse Aggregate (Kg/m³)	Coarse Aggregate (Kg/m³)		Packing Factor
						Cement (70%)	GGBS (30%)			Fine Aggregate	Copper Slag (20%)		12.5mm(70%)	20mm (30%)	
M1	M20	0.420	0.470	221.422	289.355	202.548	86.806	239.458	848.977	848.977	0	716.029	501.220	214.809	1.12
M2	M25	0.405	0.465	218.036	343.745	240.621	103.123	196.590							
M3	M30	0.390	0.460	214.440	416.084	291.258	124.825	136.215							
M4	M35	0.375	0.455	209.76	470.474	329.331	141.142	94.025							
M5	M40	0.360	0.450	206.433	524.864	367.404	157.459	51.841							
M6	M20	0.420	0.470	221.422	289.355	202.548	86.806	239.458		679.197	169.799				
M7	M25	0.405	0.465	218.036	343.745	240.621	103.123	196.590							
M8	M30	0.390	0.46	214.440	416.084	291.258	124.825	136.215							
M9	M35	0.375	0.455	209.76	470.474	329.331	141.142	94.025							
M10	M40	0.360	0.450	206.433	524.864	367.404	157.459	51.841							

Table 6: Workability Properties of Mixes

	WITHOUT COPPER SLAG				WITH COPPER SLAG					
Grade	Mix	Slump Flow (mm)	Slump Flow T500 (sec)	J-Ring (mm)	Mix	Slump Flow (mm)	Slump Flow T500 (sec)	J-Ring (mm)	V-Funnel (sec)	V-Funnel $T_{5minutes}$ (see)
M20	M1	705.0	5.0	4.0	M6	707.5	5.0	6.0	9	12
M25	M2	700.0	3.5	5.0	M7	695.0	3.5	5.0	11	16
M30	M3	725.0	3.0	4.0	M8	700.0	4.5	6.0	10	17
M35	M4	720.0	4.0	6.3	M9	685.0	4.5	5.3	9	20
M40	M5	720.0	5.0	5.5	M10	712.5	4.5	6.5	12	19
Ranges		650 -800 mm	2-5 sec	0-10 mm		650-800 mm	2-5 sec	0-10 mm	6-12 sec	+3 sec

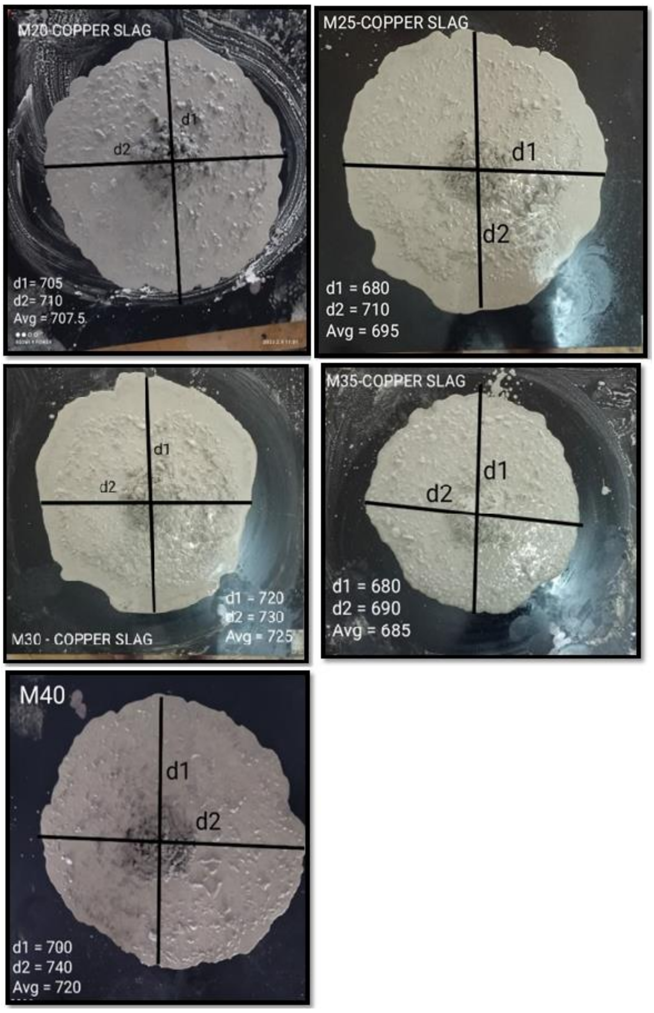

Fig. 1 Slum flow for M6 to M10 mixes

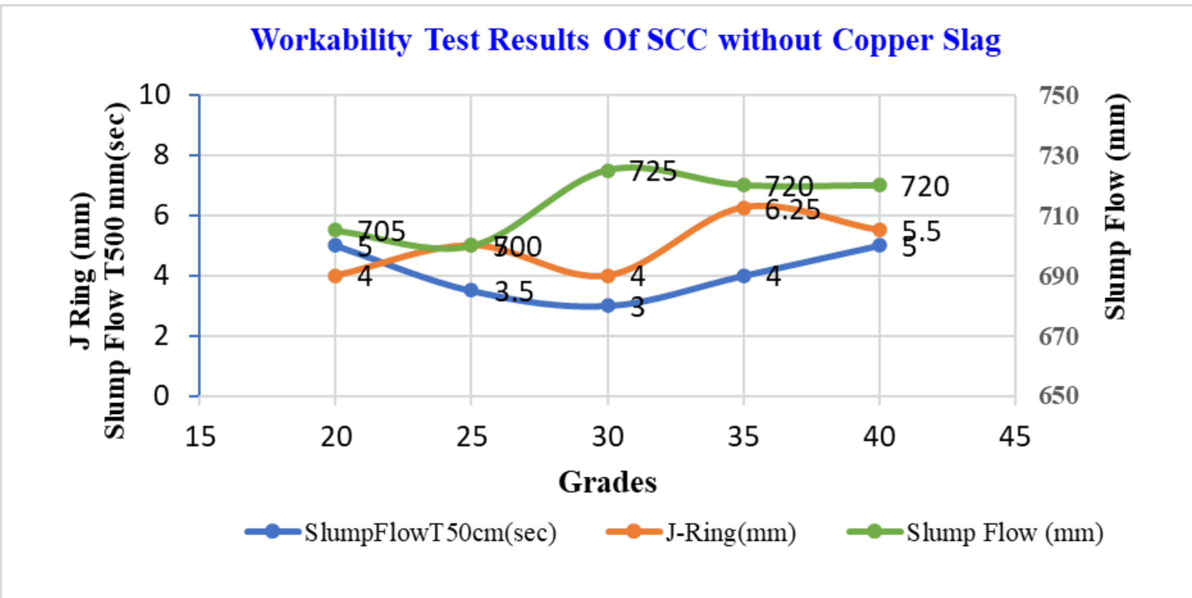

Fig. 2 Workability Test Results of SCC without Copper Slag

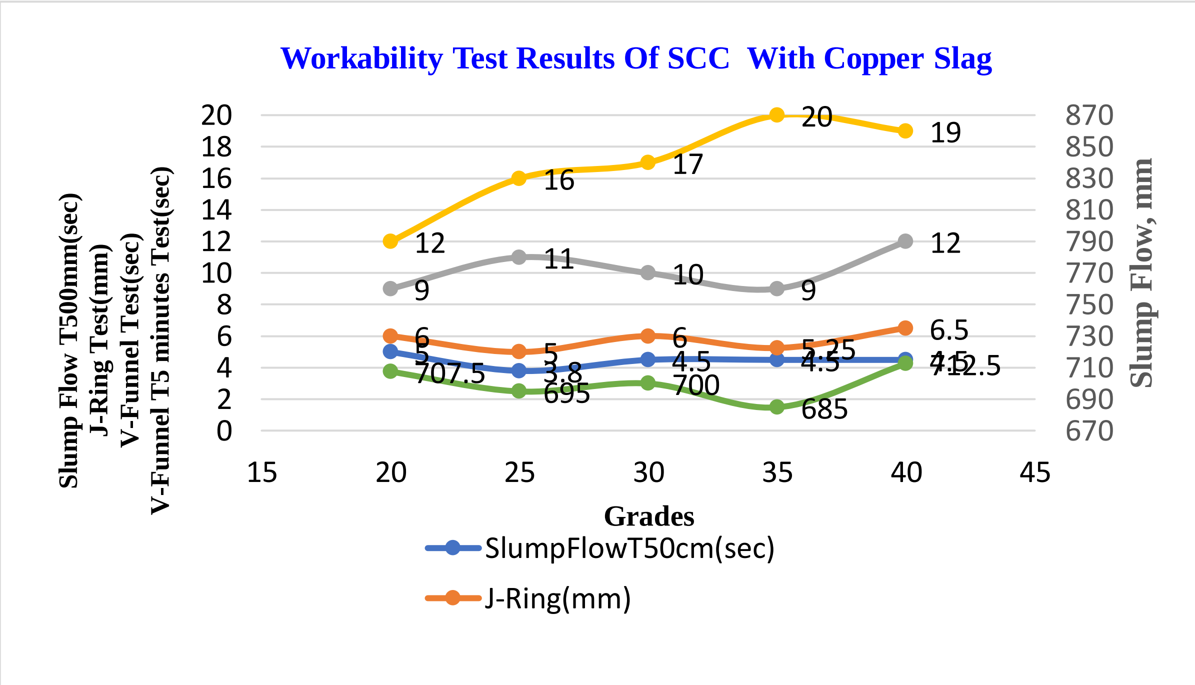

Fig. 3 Workability Test Results of SCC with Copper Slag

5. COMPRESSIVE STRENGTH OF MIXES

The compressive strength of mixes M1 to M10 with normal curing is shown in Table 7 and the variation of compressive strength is shown in Fig 4. For all the mixes the compressive strength is more than the characteristic compressive strength. The compressive strength of mixes without copper slag is more than the mixes with copper slag. The target mean strength is not achieved for mixes M5 and M7 to M10 mixes.

Table 7: Compressive Strength of Mixes M1 to M10

Compressive strength (N/mm²)						
	WITHOUT COPPER SLAG		WITH COPPER SLAG			
Grades	**Mix**	**28 Days**	**Mix**	**28 Days**	**7 Days**	**3 Days**
M20	M1	33.133	M6	28.613	22.320	21.282
M25	M2	38.497	M7	29.107	23.978	23.204
M30	M3	39.261	M8	35.429	29.568	24.336
M35	M4	46.717	M9	34.300	33.636	26.000
M40	M5	47.605	M10	46.460	34.208	28.297

6. SPLIT TENSILE STRENGTH OF MIXES

The split tensile strength SCC (as per IS- 5816:1999) of mixes M1 to M10 with normal curing is shown in Table 8. For all the grades the split tensile strength of SCC mixes without copper slag is more than with copper slag except M40 grade.

7. FLEXURAL STRENGTH OF MIXES

Beams (500 mm x 100 mm x 100 mm) are casted for mixes M1 to M10. The point load is applied at mid span of beam with clear span between the supports as 400 mm. The flexural strength of mixes M1 to M10 is shown in Table 8. For all the grades the flexural strength of SCC mixes without copper slag is more than with copper slag except M30 and 40 grades.

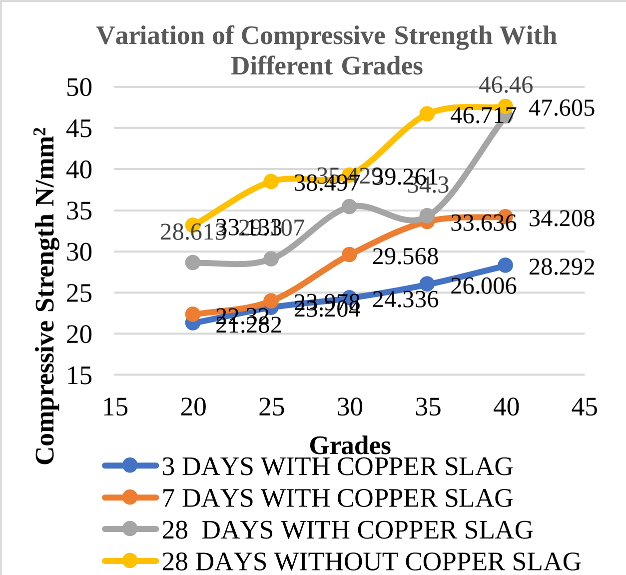

Fig 4. Variation of Compressive Strength with Different Grades of SCC

Table 8: Split Tensile Strength of Mixes M1 to M10

Split Tensile Strength (N/mm²) 28 days				
Grades	**Mix**	**WITH OUT COPPER SLAG**	**Mix**	**WITH COPPER SLAG**
M20	**M1**	2.730	**M6**	2.629
M25	**M2**	2.786	**M7**	2.309
M30	**M3**	2.958	**M8**	2.770
M35	**M4**	2.777	**M9**	2.549
M40	**M5**	2.962	**M10**	3.333
Flexural Strength(N/mm²) 28 days				
M20	**M6**	8.601	**M1**	6.073
M25	**M7**	8.103	**M2**	6.486
M30	**M8**	8.387	**M3**	8.624
M35	**M9**	8.588	**M4**	7.446
M40	**M10**	7.567	**M5**	9.262

8. CONCLUSIONS

1. For all the mixes the compressive strength is more than the characteristic compressive strength, hence copper slag can used as replacement to fine aggregate where it is available in abundant quantity.
2. The target mean strength is not achieved for mixes M5 and M7 to M10 mixes
3. For all the grades the split tensile strength of SCC mixes without copper slag is more than with copper slag except M40 grade.
4. For all the grades the flexural strength of SCC mixes without copper slag is more than with copper slag except M30 and 40 grades.

REFERENCES

[1] Chamarthy Krishnama Raju, et. al.(2023), *"Compressive Strength of Different Grades of SCC Mix Using Portland Slag Cement (70%) and GGBS (30%)"*, International Research Journal of Engineering and Technology(IRJET), Vol. 10, Issue 01, January 2023, pp: 150-155, p-ISSN:2397-0072.

[2] Chamarthy Krishnama Raju, et. al.(2022) investigated on *"Compressive Strength of Different Grades of SCC Mix using Portland Slag Cement (75%), GGBS(25%) and Replacing 20% Fine Aggregate with Copper Slag"*, International Research Journal of Engineering and Technology(IRJET), Vol. 9, Issue 04, April 2022 pp: 3535-3539, p-ISSN:2397-0072.

[3] G. Asif Hussain et.al(2020), *"Properties of M60 High Performance Self Compacting Concrete by using Blends of Different Sizes of Coarse Aggregate"*, National Virtual Conference on Recent Trends in Civil Engineering -2020 (RTCE'20),September 2020 pp 31-36, ISBN: 978-81-942685-2-9.

[4] Bhosale Mahesh Bhimarao, et.al(2020), "*Replacement of Copper Slag with Fine Aggregate*", International Research Journal of Engineering and Technology (IRJET), Vol. 07, Issue.03, March 2020, pp. 4201-4204

[5] B. Chandraiah, C. Krishnama Raju, S. Talha Zaid, *"Variation Of Compressive Strength And Split Tensile Strength Of M40 Self Compacting Concrete With Different Sizes Of Coarse Aggregate"*, International Journal of Engineering Technology Science and Research (IJETSR), Vol. 4, Issue 8, August 2017, pp.279-285

[6] Ambrish E, Dhavamani Doss S, ShanmugaNathan N, & Ganapathi Raj S, *"Partial Replacement of Copper Slag as Fine Aggregate"*, SSRG International Journal of Civil Engineering (SSRG – IJCE) – Volume 4 Issue 3 – March 2017, pp 17-21.

[7] Nan Su, Kung-Chung Hsu and His-Wen Chai (2001) proposed a " *Simple Mix Design Method for Self Compacting Concrete*" Journal of Cement Concrete Research , Vol. 31, No. 12, pp. 1799-1807., Dec. 2001.

[8] IS: 2386 (Part-i, Part-iii, Part-iv)-1963, "Methods of Test for Aggregate for Concrete".

[9] IS: 383-2016, "Specifications for Fine aggregate and Coarse aggregate".

[10] IS: 10262-2019, "Concrete Mix Proportioning - Guidelines".

[11] IS: 4031- 1988, "Methods of Test for Cement" in Bureau of Indian Standards.

[12] IS: 455:2015, "Specifications for Portland Slag Cement".

[13] IS: 516-1959, "Methods of Tests for Strength of Concrete".