Compressive Strength of M25 SCC Mix For Different Brands of OPC 53 Grade Cement With 20% Replacement of Fine Aggregate with Copper Slag

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Abstract – *The effect of different brands of OPC 53 grade cement on compressive strength of M25 SCC Mix is not investigated as per the literature. The present investigation finds the effect of different brands of OPC 53 grade cement on compressive strength of M25 SCC Mix. The Nan-Su mix design is used. The present work identifies the need to use different mix design for different brand of cement for optimal design. Also establishes the use of Cooper Slag, an an industrial by product which is used in the Madurai Tuticorin industrial corridor project, as mineral admixture to concrete.*

Key Words: Self Compacting Concrete (SCC), GGBS, Copper Slag, Different Brands of OPC 53 Grade Cement, Nan-Su Mix Design, EFNARC Guidelines, Slump Flow Test, J-Ring Test, V-Funnel Test and L-Box Test.

1. INTRODUCTION

Self Compacting Concrete (SCC) is highly flowable, non-segregating, fill the formwork and encapsulate the reinforcement without any mechanical consolidation. The fresh properties of SCC can be characterized by the three properties (EFNARC, 2002): filling ability, passing ability and segregation resistance. Additional properties, such as robustness and consistence retention, are also important in applications of SCC.

The effect of different brands of OPC 53 grade cement on compressive strength of M25 SCC Mix is not investigated as per the literature. Five different brands (Dalmia Cement, Priya Cement, Zuari Cement, JSW Cement, Chettinad Cement) of OPC 53 Grade are considered for investigation.

2. EXPERIMENTAL INVESTIGATION

2.1 Materials Used

The materials used in the SCC are

i. Different brands of OPC (Dalmia Cement, Priya Cement, Zuari Cement, JSW Cement, Chettinad Cement)
ii. GGBS
iii. Fly Ash
iv. Fine Aggregate
v. Copper Slag
vi. Coarse Aggregate (12.5 mm and 20 mm)
vii. Master Glenium Sky 8233 (Super Plasticizer)

2.11 Materials Properties

The properties of materials are determined and are shown in Table 1, 2, 3 & 4. Table 5 shows the super plasticizer properties as given by the manufacturer.

2.21 Nan-Su Mix Design

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

Step 1: Calculation of Coarse and Fine aggregate contents:

$$W_{fa} = PF \times \Upsilon_{fa}\left(\frac{s}{a}\right) = 917.70 \text{ kg/ m}^3 \quad (1)$$

$$W_{ca} = PF \times \Upsilon_{ca}\left(1-\frac{s}{a}\right) = 713.30 \text{ kg/ m}^3 \quad (2)$$

Where,

W_{fa} : content of fine aggregates in SCC (kg/m^3),
W_{ca} : content of coarse aggregates in SCC (kg/m^3),
Υ_{fa} : unit volume weight of loosely piled saturated surface-dry fine aggregates in air (kg/m^3), = 1545.99 kg/ m^3

Table 1: Properties of Different Brands of Cement

Different Brands Of 53 Grade Cement	Specific Gravity Of Cement	Initial Setting Time	Final Setting Time	Standard Consistency	Fineness of Cement
Dalmia Cement	3004	2 hrs 36 min	6 hrs 49 min	31%	2%
Priya Cement	3.110	2 hrs 16 min	6 hrs 24 min	35%	2%
Zuari Cement	3.029	2 hrs 42 min	6 hrs 39 min	33%	3%
JSW Cement	2.970	2 hrs 10 min	7 hrs 15 min	31%	2%
Chettinad Cement	3.004	2 hrs 38 min	7 hrs 15 min	31%	2%
Ranges	3.00 – 3.15	> 30 min	< 10 hrs	-	< 10%

Table 2: Properties of Coarse Aggregate (IS: 383-1970)

Properties		Size			Standard range
		20 mm	12.5 mm	30% of 20 mm & 70% of 12.5 mm	
Specific gravity of Coarse Aggregate		2.875	2.84	2.85	2.5-3.0
Bulk Density of Coarse Aggregate tightly packed (Kg/m^3)		1554.7	1441.4	-	-
Bulk Density of Coarse Aggregate loosely packed (Kg/m^3)		1471.9	1305.3	1355.0	-
Crushing test		14.07%			
Shape Tests	a)Flakiness Test	13.85 %	33.65%	-	< 35%
	b)Elongation Test	24.98%	38.56%	-	< 40%
Impact Test		14.05 %			< 35%

Table 3: Properties of Fine Aggregate (IS: 383-1970)

Properties	Property Value	Standard range
Specific Gravity	2.6	2.5 to 3
Bulk Density, (kg/m^3) Freely Poured	1545.99	-
Fineness Modulus	2.60 (Zone –II)	2.2 – 2.6 (Fine Sand)

Table 4: Properties of GGBS, Fly Ash & Copper Slag

Properties	GGBS	Fly Ash	Copper Slag
Specific Gravity	2.85	2.24	3.805
Bulk Density of Coarse Aggregate tightly packed (Kg/m^3)	-	-	2091.995
Bulk Density of Coarse Aggregate loosely packed (Kg/m^3)	-	-	1912.350
Fineness	6%	26%	-
Consistency	36%	64%	-

Table 5: 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±1%

Υ_{ca} : unit volume weight of loosely piled saturated surface-dry coarse aggregates in air (kg/m³), =1355.054 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%. = 53% (Assumed)

Step 2: Calculation of Cement Content:

$$C = \frac{f_c^{'}}{20}\,(for\ OPC\ Concrete) \quad =229.163\ kg/m^3 \qquad (3)$$

Where,
C= Cement content (kg/m³);
f'_c = designed compressive strength (psi). =4583.264 psi (31.6 MPa Target Mean Strength Obtained from IS: 10262-2019)

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

$$W_{wc} = \frac{W}{C} \times C \quad = 96.249\ kg/m^3 \qquad (4)$$

Where,
W_{wc} = content of mixing water content required by cement (kg/m³),
$\frac{W}{C}$= the water/cement ratio by weight = 0.42 (Assumed)

Step 4: Calculation of SP dosage

Dosage of SP used $W_{sp} = n\% \times W_C$ (5)
Where,
n% = Dosage of SP = 0.7 % (Assumed and fixed after trials)
W_c = Cement content in kg/m³
Amount of water in SP $W_{wsp} = (1\text{-}m\%)W_{sp}$ = 0.802 kg/m³ (6)
Where,
m% = Amount of binders and its solid content of SP taken as 50%.

Step 5: Calculation FA and GGBS contents:

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

= 0.210 m³ (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,
V_a = air content in SCC (%).
As per Nansu Mix Design the formula for calculating W_{PM} is

$$V_{PF} + V_{PG} = \left[1 + \left(\frac{W}{F}\right)\right] \times A\% \times \frac{W_{PM}}{\Upsilon_W G_F} + \left[1 + \left(\frac{W}{G}\right)\right] \times B\% \times \frac{W_{PM}}{\Upsilon_W G_G} \qquad (8)$$

Where A% = percentage of Fly Ash (Weight basis)
B% = percentage of GGBS (Weight basis)
But, the modified formula[1] (8.a) for calculating W_{PM} is used.

$$V_{PF} + V_{PG} = \left[1 + \left(\frac{W}{F}\right) G_F\right] \times A\% \times \frac{W_{PM}}{\Upsilon_W G_F} + \left[1 + \left(\frac{W}{G}\right) G_G\right] \times B\% \times \frac{W_{PM}}{\Upsilon_W G_G} \qquad (8.a)$$

Where, G_G, G_{FA}, are obtained from tests and $\frac{W}{F}$ =0.42 and $\frac{W}{G}$ = 0.42 are assumed, A% =25% and B% =75% are assumed and $V_{PF} + V_{PG}$ obtained from Eq.(7)

W_{PM} = 264.261 kg/m³

$W_F = A\% \times W_{PM}$ =66.065 kg/m³ (9)

$W_G = B\% \times W_{PM}$ =198.196 kg/m³ (10)

Mixing water content required for fly ash paste is obtained from Eq(11)

$W_{WF} = \frac{W}{F} \times W_F$ =27.747 kg/m³ (11)

Mixing water content required for GGBS paste is obtained from Eq(12)

$W_{WG} = \frac{W}{G} \times W_G$ =83.242 kg/m³ (12)

Step 6: 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 the mix. Therefore, it can be calculated from Eq. (14)

$W_w = W_{wc} + W_{WG} + W_{WF} - W_{wsp}$ = 206.436 kg/m³ (13)

3. MIX DESIGN

Concrete grade M25 is considered, and mixes are designed for different brands (Dalmia Cement, Priya Cement, Zuari Cement, JSW Cement, Chettinad Cement) as per the above Nan-Su mix design. Target mean strength as per IS 10262:2019 is used for the mixes in Eq. 3 in place of f'_c. The fine aggregate content calculated from Eq. 1 is replaced with 20% of copper slag. Based on trial mixes W/C ratio and SP dosage is fixed satisfying EFNARC guidelines. The SCC mix proportions for different brands of cement are shown in Table 6.

4. WORKABILITY TESTS

Slump flow test and then J-Ring test is conducted in order by using 6 litres of concrete. V funnel test is conducted by using 14 litres of concrete. L Box test is conducted by using 17 litres of concrete. Fresh properties are determined for the mixes. The results are as show in Table 7 and also in Fig. 1 & 2. All the test results are conforming to EFNARC guidelines for SCC.

Table 6: Mix Design of Different Brands of OPC 53 Grade Cement

S.No	Different Brands of OPC 53 Grade Cement	Water (kg) (as per mix design)	Water (kg) (actually added)	Sp content (%)	GGBS(kg) 75% of Admixtures	Fly Ash(kg) 25% of Admixtures	W/p Ratio	W/c Ratio	Packing factor	Cement Content	Fine Aggregate (kg)		Coarse Aggregate (kg)
											Copper Slag (20%)	Sand (80%)	
1	Dalmia Cement	207.28	206.4	0.7	198.1	66.06	0.42	0.42	1.12	229.163	183.54	734.16	713.30
2	Priya Cement	208.64	207.8	0.75	200.6	66.88	0.42						
3	Zuari Cement	207.63	206.7	0.8	198.7	66.26	0.42						
4	JSW Cement	206.83	205.9	0.8	197.3	65.79	0.42						
5	Chettinad Cement	207.29	206.1	0.8	198.3	66.11	0.42						

Table 7: Workability Properties

S.NO	Different Brands of OPC 53 Grade Cements	J Ring Test (mm)	L- Box Test	V- Funnel Test (sec)	T50 Slump Flow Test (sec)	Slump Flow Test (mm)	V funnel at T5 minutes
1	Dalmia Cement	8	0.88	7	4	685	10
2	Priya Cement	6	0.831	9	4	665	12
3	Zuari Cement	10	0.963	11	5	667	11
4	JSW Cement	8	0.85	8	5	672.5	13
5	Chettinad Cement	7	0.844	6	3	663	12
EFNARC Guidelines		0-10	0.8-1.0	6-12	2-5	650-800	+3

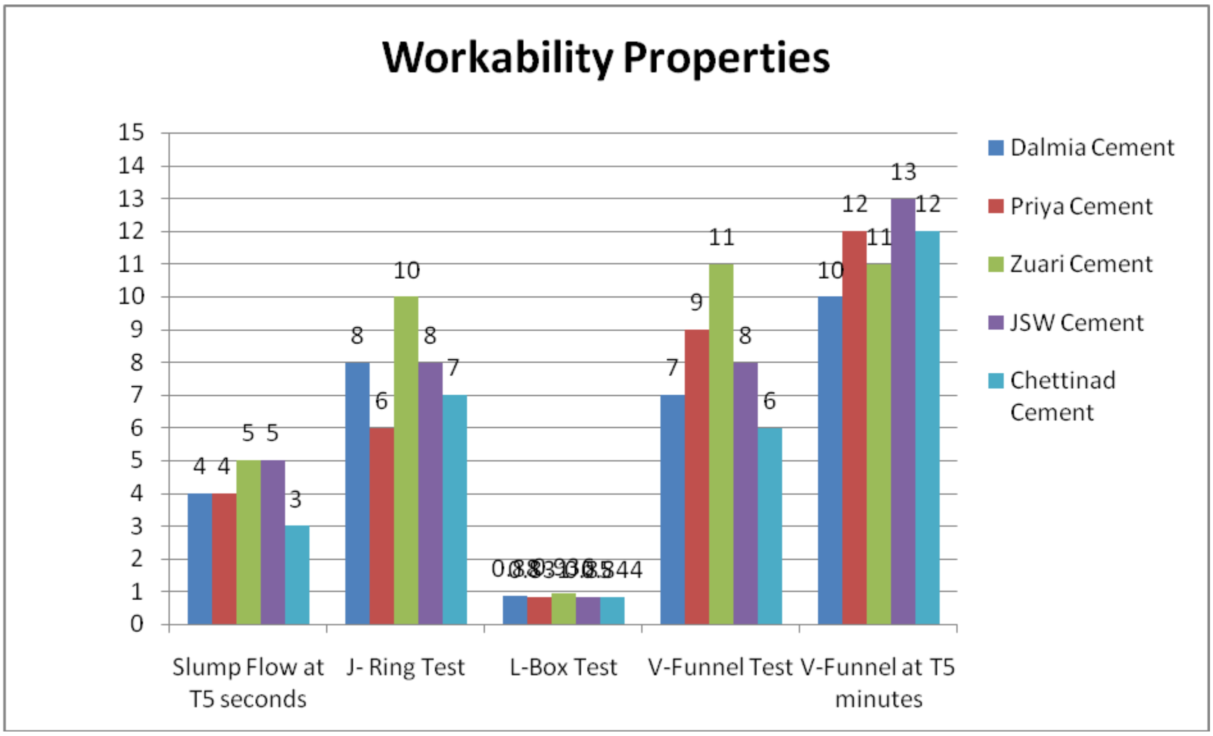

Fig. 1: Workability Properties of Different Brands of Cements

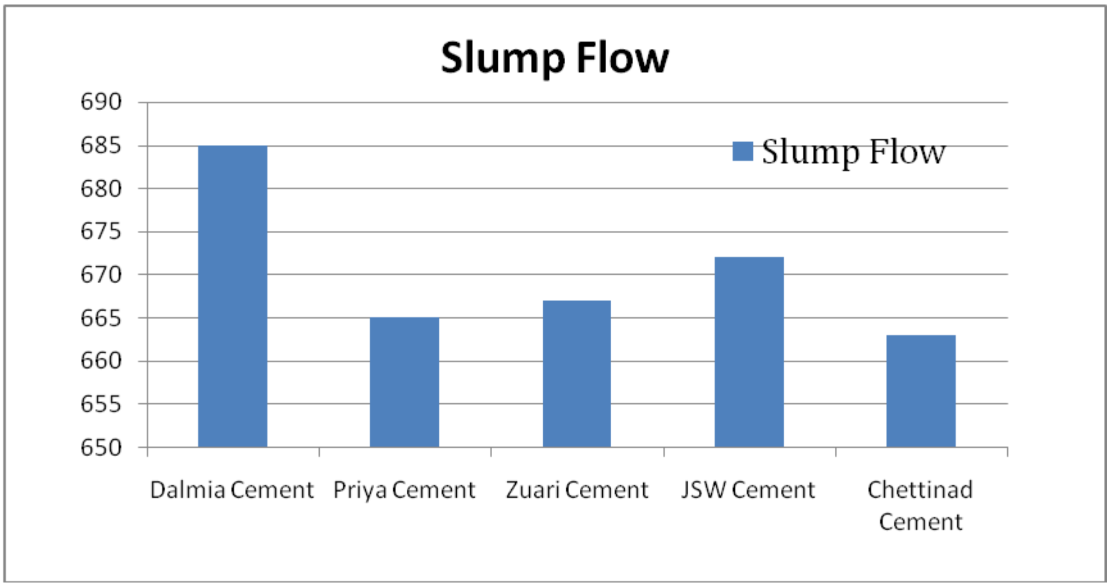

Fig 2: Slump Flow of Different Brands of Cements

5. COMPRESSIVE STRENGTH OF MIXES

Cubes are casted for each mix to determine the 3,7 and 28 days compressive strength. The compressive strength of different brands of cement for 3,7 and 28 days with normal curing is shown in Table 8 and the variation of compressive strength is shown in Fig 3. For all the brands target mean strength of 31.6 N/mm² is achieved. The 3 and 7 days compressive strength is more for JSW Cement. The 28 days compressive strength is more for Chettinad Cement.

Table 3: 3, 7 and 28 Days Compressive Strength of M25 SCC for Different Brands of Cement

S. No	Different Brands of OPC 53 Grade Cement	Compressive Strength (N/mm²)		
		3 Days	7 Days	28 Days
1	Dalmia Cement	21	28.37	34.43
2	Priya Cement	13.52	21.87	39.02
3	Zuari Cement	20.68	26.44	34.83
4	JSW Cement	22.803	28.55	36.19
5	Chettinad Cement	16.176	26.94	46.20

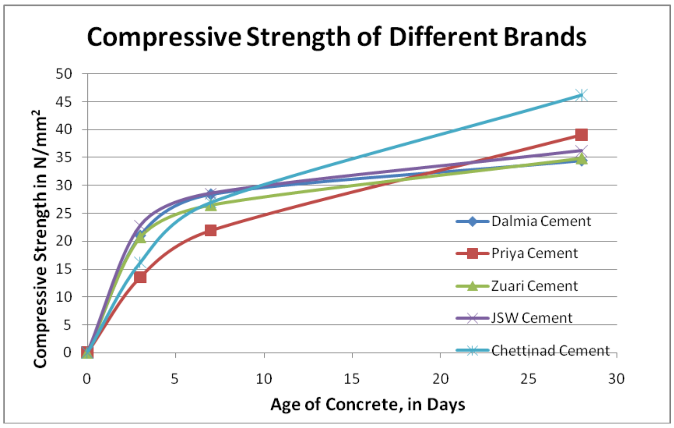

Fig 3. Variation of Compressive Strength with Age of Concrete for Different Brands of Cement

6. CONCLUSIONS

1. For all the brands the compressive strength obtained is more than the target mean strength(31.6 N/mm²) as per IS 10262-2019.

2. The 3 and 7 days Compressive Strength of mix with JSW Cement and the 28 days Compressive Strength of mix with Chettinad Cement is more compared to all other brands.

3. The percentage increase in Compressive Strength for Chettinad mix is 84.8% more compared to Characteristic Compressive Strength.

4. The compressive strength variation is more between some brands, hence different mix design is required for different brand of cement for optimal mix design.

5. Copper slag can be used as mineral admixture for partial replacing fine aggregate.

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