"Investigating The Performance Of High-Strength Self-Compacting Concrete (HSSCC) Incorporating Copper Slag And Fibres Involves Assessing Various Aspects To Understand The Effects On Mechanical Properties"

Mr. Vaibhav Shelar[1*], Dr.G. V. Mulgund[2], Dr S S Deshmukh[3]

[1*]Research Scholar, Shridhar University, Pilani
[2]Professor, St John College of Engineering & Management, Palghar,
[3]Professor, Trinity Academy of Engineering, Pune

***Corresponding Author:** Mr. Vaibhav Shelar
*Research Scholar, Shridhar University, Pilani

Abstract:
Investigating the performance of high-strength self-compacting concrete (HSSCC) with the incorporation of copper slag and fibres seems to address both environmental and structural concerns. Copper slag, as a partial replacement for fine aggregate, not only offers a sustainable solution by reusing industrial by-products but also has the potential to enhance certain properties of concrete. Additionally, the addition of fibres could improve the concrete's mechanical strength and durability.

Keywords: high-strength self-compacting concrete, copper slag, Fibres, mechanical properties, durability properties, sustainable concrete.

1. Introduction:

1.1 Background:

The evolution of concrete technology and the ongoing quest for enhanced performance and durability. High-performance concrete (HPC), as pioneered by Al-Jabri et al. (2009), represents a significant advancement in this field. Its superior properties, including higher strength, greater durability, and improved workability, offer promising solutions to address the limitations of conventional concrete.

The shift towards self-compacting concrete (SCC) is particularly noteworthy, as it addresses several key challenges in concrete construction, such as achieving proper consolidation in congested reinforcement areas and ensuring uniformity without the need for excessive vibration. SCC not only offers improved mechanical properties and durability but also enhances construction efficiency and quality by reducing labor requirements and minimizing the risk of defects like honeycombing

It's important to recognize the ongoing efforts to optimize HPC and SCC formulations to meet specific project requirements while balancing factors like cost, availability of materials, and environmental considerations. Advances in concrete technology continue to expand the possibilities for sustainable and resilient construction practices, contributing to the longevity and performance of infrastructure worldwide.

1.2 Significance of the study:

The context you've provided underscores the urgency of finding sustainable solutions to address the increasing demand for infrastructure in India, particularly concerning the scarcity of natural aggregates for concrete production. Given that aggregates constitute a substantial portion of concrete, exploring alternative materials like copper slag could offer a viable solution to mitigate the pressure on natural resources while addressing environmental concerns associated with aggregate extraction.

Developing a standard procedure for incorporating copper slag into self-compacting concrete (SCC) holds significant promise. Copper slag, as an industrial by-product, not only offers a sustainable alternative to natural aggregates but also has the potential to enhance certain properties of concrete when used appropriately. Through systematic investigation and testing, a standardized approach can be established to optimize the utilization of copper slag in SCC production

Key aspects of this investigation might include determining the optimal percentage of copper slag replacement for fine aggregate, evaluating its influence on the fresh and hardened properties of SCC, assessing its impact on mechanical strength, durability, and workability characteristics, and considering any environmental benefits or drawbacks associated with its use.

By establishing clear guidelines and protocols for incorporating copper slag into SCC production, this research endeavor could contribute significantly to the development of sustainable construction practices in India and beyond. It has the potential to not only alleviate the pressure on natural aggregates but also enhance the performance and longevity of concrete structures, thereby addressing the growing infrastructure needs while promoting environmental stewardship.

1.3 Objectives:

The objectives outline a comprehensive experimental investigation into the use of copper slag in self-compacting concrete (SCC), considering both fresh and hardened states as well as durability aspects

i) This objective aims to establish mix designs for SCC with varying strengths, ranging from M30 to M100. By formulating these mix proportions, you'll be able to assess how changes in concrete composition affect its properties at both fresh (workability, slump flow, etc.) and hardened (compressive strength, tensile strength, etc.) states. This step is crucial for understanding the behavior of SCC across a range of strength grades.

ii) Explore the potential of using copper slag as a partial replacement for fine aggregate in SCC, both with and without the addition of steel fibres. By varying these factors, you can determine how copper slag affects the fresh and hardened properties of SCC, including its durability. This investigation is essential for understanding the compatibility of copper slag with SCC and its impact on key performance indicators.

iii) If the results demonstrate that copper slag can be effectively used in SCC without compromising its strength and durability, this objective aims to identify the optimal proportion of copper slag that can be added to the SCC mix. Finding this optimum proportion is critical for maximizing the benefits of copper slag while maintaining the desired properties of SCC

2. Literature Review

2.1 Self-compacting concrete (SCC)

Prof. Okamura of Kochi University of Technology in Japan was the first to invent self-compacting concrete back in 1986. Ozawa and Maekawa (1989) from the University of Tokyo conducted research on the feasibility and development of SCC. The requirement for admixtures in SCC has been reported by researchers all around the world.

The impact of super plasticizers on the equilibrium between the flowability and viscosity of mortar in SCC has been studied by Okamura & Ouchi (1997) (Nan Su et al.; 2001). 32

Mix design strategies for the SCC with various mineral admixtures have been provided by Okamura (2003) and EFNARC recommendations (2002 & 2005). The usage of fly ash, GGBS, etc., as filler materials in SCC has been documented by several researchers.

2.2 Copper slag as a supplementary cementitious material

Recycling, making goods with additional value, and dumping or stockpiling slag are the current options for slag management. Gorai et al. (2002), Ayano & Kuramoto (2000), and Tixier et al. (1997) have all employed copper slag in concrete as a replacement for cement based on the qualities of the material. Deja and Malolepszy state that slags with a copper content of less than 0.8% are either dumped as garbage or sold for pennies on the dollar (1989).

Ayano and Sakata explored how copper slag affected the drying time of cement (2002). The insoluble residue at 0.15 mm was found to be easily removed by simply washing the slag. This research demonstrated that the setting time of cement was affected by the particle size of copper slag, with smaller particles creating a longer delay. Several washes of the slag mitigated the impact on the setting time, nevertheless.

According to reports by Al-Jabri (2002) and Shoya et al. (2005), researchers from a variety of nations have studied the use of copper slag in cement concrete and mortar, and they have also studied high strength concrete and high performance concrete (HPC) (1997). Unfortunately, there is a lack of data on the use of copper slag in high strength concrete in India. 36 Akihiko and Toshiki (2008) have reported the use of copper slag as a replacement material for cement, fine aggregate and coarse aggregate in concrete, depending on the material's properties. Slags with less than 0.8% copper are either disposed of as waste or sold inexpensively, as reported by Al-Jabri et al. (2011). According to the findings of Persson et al., the field of cementitious matrix materials has been actively studying since 1930 to produce cementitious matrix materials that give excellent mechanical performance (2001). This study has resulted in the creation of a new type of extremely long-lasting concrete called reactive powder concrete in recent years (RPC). This type of concrete has compressive capabilities equivalent to some forms of steel and has been categorized as ultra-high-performance fibre reinforced concrete (UHPFRC) (UHPFRC). Witte and Backstrom emphasize that these materials successfully deal with the durability problems that are typical of both NSC and HPC (1951).

There are several uses for copper slag, including in the production of a variety of tools and implements, as well as in the production of glass, tiles, road foundation, train ballast, cement, asphalt pavements, and concrete. The effect of copper slag as a pozzolanic material on hydration processes and as a partial replacement for regular Portland cement have both been described in studies. Copper slag has been studied to see how its incorporation as both fine and coarse particles into conventional concrete would affect the material's mechanical and long-term properties. Certain drawbacks, including a longer setting time, have been found when just copper slag has been used as a fine aggregate, despite the advantages of utilizing it in both forms.

3. Experimental Methodology

3.1Materials

Cement: The Cement grade and its characteristics are indeed crucial factors in determining the overall performance of concrete, especially in self-compacting concrete (SCC) where workability and strength development are paramount .The cement utilised in this investigation was a 53-grade Ordinary Portland cement because it was readily accessible in the local market. Even 2 when high-quality materials are utilised, the quality of the cement paste has a huge impact on how strong and permeable the resulting concrete will be. As this is the case, the cement's mineralogical composition and physical features are essential. Cement with a finer grind is preferable when making SCC. The mineral makeup and physical characteristics of the cements tested in this investigation are detailed in Tables 5.1 and 5.2. Cement used in this investigation has been tested for various proportions as per IS: 4031 (Part IV) - 1988 and found to be confirming to various specifications of IS: 12269-1987, ASTM C150 / C150M – 12 (2012)

Table 3.1.1 Mineralogical composition of cement

Compound	**Percentage Composition (%)**	**Requirements as per IS:12269-1987**
C_3S	50±5	Minimum 45% by mass
C_2S	30±5	-
C_3A	9±1	Maximum 10% by mass
C_4AF	12±3	Minimum 8% by mass
Free lime	1±0.5	-

Fine Aggregate

The grading of fine aggregates is crucial in the production of self-compacting concrete (SCC), impacting its workability, strength, and overall performance. The fine aggregate used in SCC must be properly graded and free of hazardous components including clay, silt content, and chloride contamination in order to reach the minimal voids ratio. Coarser sand is preferable since SCC is predominantly cement and fine particles like micro silica

Table 3.1.2 Sieve Analysis of Fine aggregate

IS Sieve designation	Cumulative Percentage		Specification as per IS383:1970 For zone II
	Retained	Passing	
4.75mm	-	100	90–100
2.36mm	9.14	90.86	75–100
1.18mm	32.48	67.52	55–90
600 µm	48.72	51.28	35–59
300 µm	82.22	17.78	8–30
150 µm	99.47	0.53	0–10

Coarse Aggregate

Crushed blue granite aggregates from regional sources meeting ASTM C33/C33M13 (2013) specifications were used for the studies, with a mean size distribution of 8-12.5 mm. An angular form, specific gravity of 2.70, fineness modulus of 6.013, dry rodded bulk density of 1526 kg/m3, loose bulk density of 1437kg/m3, and water absorption of 0.4% are all characteristics of the coarse aggregates. The coarse aggregate meets the guidelines set forth by Mehtaetal (1990)for maximum grain size and fineness modulus, with a value of 6.4. Coarse aggregates made from granite's equidimensional particles frequently meet or exceed expectations. The findings of the coarse aggregate sieve analysis are shown in Table 5.4, and the characteristics of the coarse aggregates employed in this experiment are listed in Table3.1.3.

Table 3.1.3 Sieve analysis of coarse aggregate

IS Sieve designation	Cumulative Percentage		Specification as per IS383:1970
	Retained	Passing	
20 mm	-	100	100
12.5mm	16.24	83.76	85–100
10 mm	82.22	17.78	0–45
4.75mm	98.46	4.54	0–10

Fly Ash

Indeed, fly ash utilization in concrete production offers numerous benefits, both economic and technical, while also addressing environmental concerns associated with waste disposal. Here are some key advantages of using fly ash as a pozzolanic material in concrete .Its benefits include less bleeding, less heat evolution, and a reduced need for water to achieve the same level of workability. In order to control the heat of hydration-induced expansion and reduce the likelihood of early-age cracking, fly ash has found a home in mass concrete applications and big volume placement.

Table3.1.4 Properties of fly ash

Property		Detail	ASTM requirement C618(%) / IS:3812 (Part 1) :2003
Physical properties			
Specific gravity		2.23	-
Fineness(m^2/kg)*		294.35	Minimum200
Colour		Light grey	-
Chemical properties			
Silicon dioxide	SiO_2	70.35	Minimum35%
Aluminum oxide	Al_2O_3	21.61	-

Ferricoxide	Fe_2O_3	3.78	-
Calcium oxide	CaO	0.92	-
Magnesium oxide	MgO	3.88	Maximum5%
Sulfurtri oxide	SO_3	0.08	Maximum5%
Potassium oxide	K_2O	0.19	-
Sodium oxide	Na_2O	0.37	Maximum1.5%
Titanium oxide	TiO_2	1.29	-
Loss on ignition		0.97	Maximum5%
SiO_2+Al_2O_3+Fe_2O_3		95.55	Minimum70%

Copper Slag

Copper slag used in this investigation has been collected from M/s Sterlite Industries India Limited (SIIL), Tuticorin, Tamil Nadu. The test sieve analysis of copper slag is shown in Figure5.1.

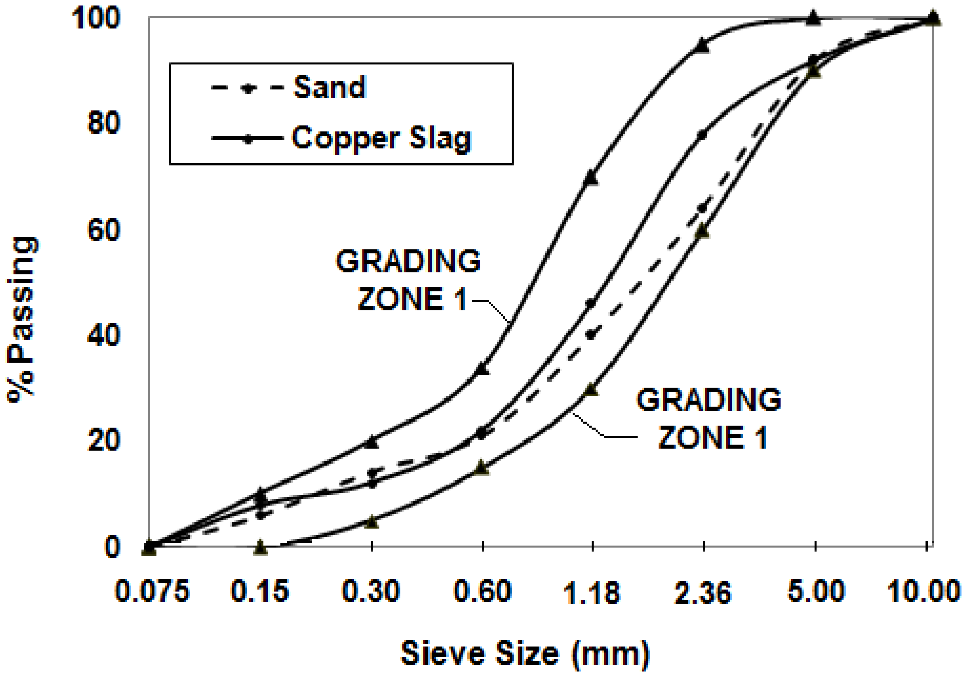

Figure3.1.1Sieve analysis of copper slag and sand

Water

Absolutely, water is a vital component in the production of self-compacting concrete (SCC) and plays a crucial role in the hydration process of cement. Here's a closer look at its significance. Concrete's strength originates in the binding action of the cement hydrates gel. Pure drinking water meeting the standards of ASTMC1602/ C1602M-12 was utilised.

Steel Fibres

The addition of steel fibres to concrete indeed offers several advantages, particularly in enhancing flexural capacity, toughness, and crack steel fibres offer a versatile and effective solution for improving the mechanical properties and durability of concrete structures, whether used as a standalone reinforcement or in combination with traditional reinforcements for crack control. Their widespread adoption across different construction sectors highlights their effectiveness in enhancing structural performance and ensuring the long-term reliability of concrete infrastructure.

Chemicals-Acids, H_2SO_4, HCl

Acids like 0.1% sulphuric acid and hydrochloric acid have been used in this experimental work.To test the durability of SCC mixes, the above acids are necessary.

Superplasticizer

To facilitate the flow of the material, a reasonable dosage of super plasticizer has been added. A new generation based modified polycarboxylic ether (PCE), named GLENIUMB 23 3 is used as super plasticizer and the properties are given in Table 3.1.5

Table 3.1.5 Properties of superplasticizer

Property	Test result*
Colour	Light brown in colour,free flowing liquid

Specific gravity	1.20
Relative density at 25ºC	1.09 ±0.01
Chloride iron content	<0.2%
pH	> 6.0

* Test results given by the manufacturer

2.1 Mix Proportioning :

A rational mix design method is crucial for the successful production of self-compacting concrete (SCC) using a diverse range of materials. Okamura &Ozawa (1995) proposed a simple mix proportioning system. The coarse and fine aggregate contents are fixed so that self-compatibility can be achieved easily by adjusting the water-powder ratio and super plasticizer dosage only. In the current investigation, the mix proportioning has been done as per the Rational Mix Design Method proposed by Okamura & Ozawa (1995). Mix proportioning has been arrived at as per the following sequence.

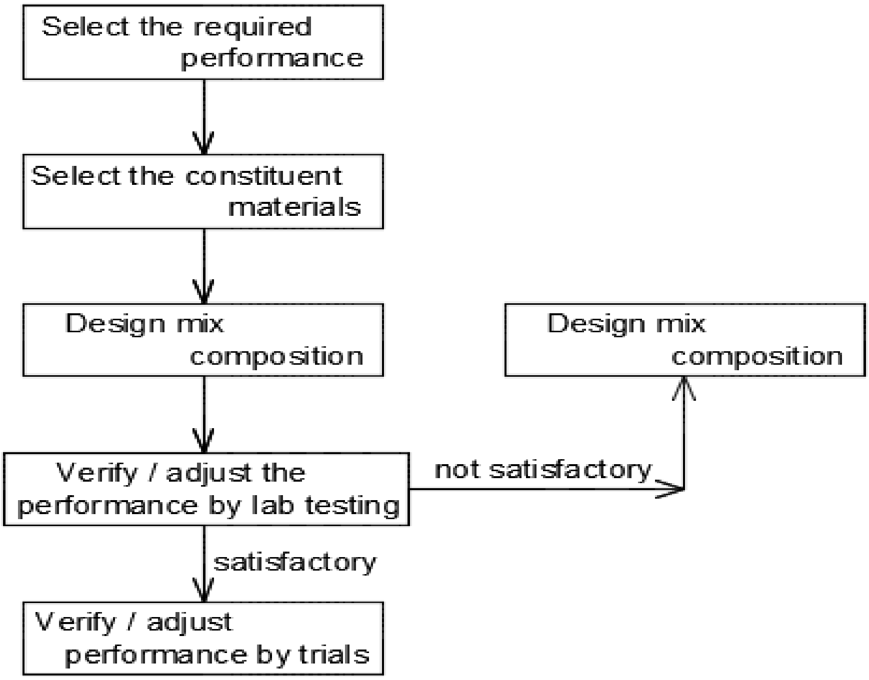

Figure3.2 Mix design procedure

SCC Mix Proportions

The mix proportion of SCC mixes M1 to M8 used in the current investigation is listed in Table3.2

Table3.2 Mix proportion for SCC mixes M1 to M8 (per m^3)

MixID	Cement	Fly ash	Fine Aggregate	Coarse Aggregate	Water	Superplasticizer	VMA	Remarks
	kg	kg	kg	kg	lit	lit	lit	Fine aggregate is replaced by copper slag by weight from 0%to 100% in all mixes
M1	228.30	226.55	905.08	873.00	182.1	1.37	0.41	
M2	275.80	236.49	901.31	874.94	180.17	1.67	0.50	
M3	321.43	243.6	860.07	880.83	178.05	1.90	0.57	
M4	356.28	253.75	830.99	887.13	177.64	2.02	0.64	
M5	388.76	258.11	829.01	892.2	176.73	2.49	0.75	
M6	413.40	264.9	792.31	889.3	177.70	2.51	0.75	
M7	444.10	273.03	775.66	907.41	177.70	2.68	0.79	
M8	469.54	280.14	761.25	908.42	177.70	2.78	0.90	

The total weight of copper slag consumed for casting the test specimen was approximately 5300kg.

2.2 Specimen Preparation

The sequence of adding materials can impact the uniformity and workability of the mix, coarse aggregate was initially placed inside the concrete mixer then followed by fine aggregate. Then about 20% of the total quantity of water was added. The concrete mixer was then allowed to rotate a few times after which fly ash and cement was added. Approximately 40% of the total quantity of water was added into the concrete mixer and the materials were thoroughly mixed for about 1 minute. Superplasticizer and VMA were added in the remaining quantity of water and added to the mixer. Mixing was continued for another 2 minutes.

2.3 Testing Program:

Testing the properties of fresh concrete is essential to ensure that the mixture meets the desired criteria for workability, consistency, and other performance characteristics as per EFNARC guidelines. The details of the tests are given in Table 3.4 Slump flow, L–box, U–box, and V–funnel test were used to evaluate the fresh concrete properties of SSC.A concrete mix can only be classified as SCC if the requirements for all the following three workability properties are fulfilled (EFNARC,2002)

i) Filling ability
ii) Passing ability and
iii) Resistance of Segregation

Table 3.4 List of test methods for workability properties of SCC and acceptance Criteria for SCC

Sr. No	**Property of SCC**	**Test Method**	**Unit**	**Typical range of values**	
				Minimum	**Maximum**
1	Fillingability	Slump Flow Test	Mm	660	810
		T_{50cm} Slump FlowTest	Sec	2	5
		V-Funnel Test	Sec	6	12
		Orimet Test	Sec	0	5
2	PassingAbility	L-Box Test	h_2/h_1	0.82	1.0
		U-Box Test	(h_2-h_1)mm	0	30
		Fill Box Test	%	90	100
		J-Ring Test	Mm	0	10
3	Segregation Resistance	V-FunnelTestat5minutes	Sec	0	+3
		GTM Screen Stability Test	%	0	15

4. Results and Discussion:

Test methods are commonly used to study the characteristics of fresh concrete. These methods help assess properties such as workability, consistency, and air content, providing valuable insights into the behavior of the concrete mixture. Here are some commonly used test methods slump test, U – box V – funnel and L – Box. These tests had been conducted to determine the filling ability, passing ability and resistance to segregation of the SCC mix. The results of workability tests on fresh SCC mixes M1 to M8 are listed. Without steel fibres, for mix M4 with 100 % sand + 0 % copper slag, the slump flow was 660 mm and for mix M4 with 0 % sand + 100 %copper slag, the slump flow was 690 mm.With the addition of steel fibres, for mix M4 with 100 % sand + 0 % copper slag, the slump flow was 670 mm and for mix M4 with 0% sand + 100% copper slag, the slump flow reduced to 665 mm. The workability of SCC increases with the increase in copper slag percentage. Moderate bleeding without segregation was noticed for SCC mixes with 80 % to 100 % copper slag. Addition of steel fibres, reduced the flow ability and passing ability but satisfying the suggested limits for SCC.Copper slag has water absorption 0.27% and fine aggregate has water absorption 1.04%. Hence when the percentage of copper slag increases, the free water content in SCC mix also increases, resulting an increase in the workability of the concrete. The increase in free water content in the SCC mix could be the reason for the moderate bleeding noticed for SCC mixes with 80% to 100 % of copper slag. The variation of workability for SCC mixes M1 toM8 with copper slag proportions without steel fibres is shown in Figure 4.1.The variation of workability for SCC mixes M1 to M8 with copper slag proportions and with steel fibres is shown in Figure 4.2

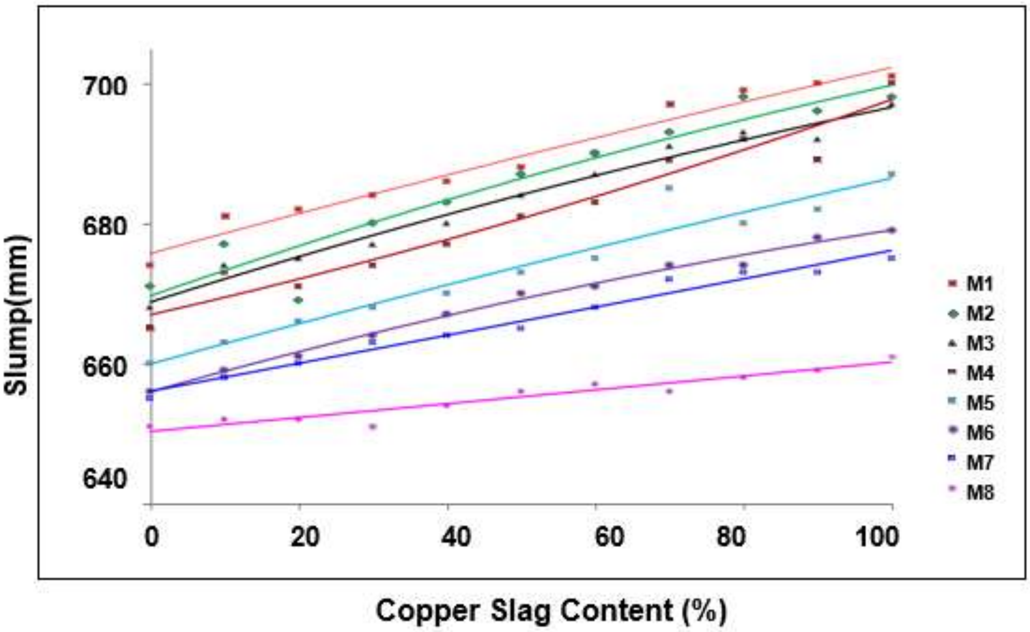

Figure 4.1 Variation of workability with copper slag proportions for SCC mixes M1 to M8 (without steel fibres)

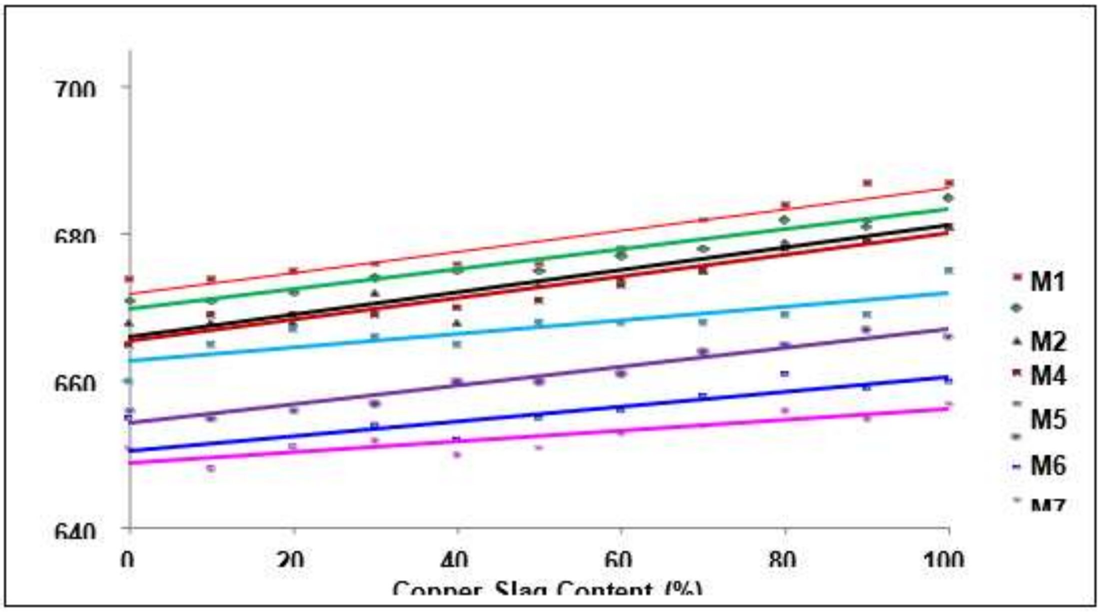

Figure 4.2 Variation of workability with copper slag proportions for SCC mixes M1 to M8 (with steel fibres)

Density

Figure 4.3 shows the variation of density of SCC mixes M1 to M8.Without steel fibres, for mix M4 with 100 % sand + 0 % copper slag, the density was 24.73 kN/m3 and for mix M4 with 0% sand+100% copper slag, the density increased to 25.00 kN/m3.

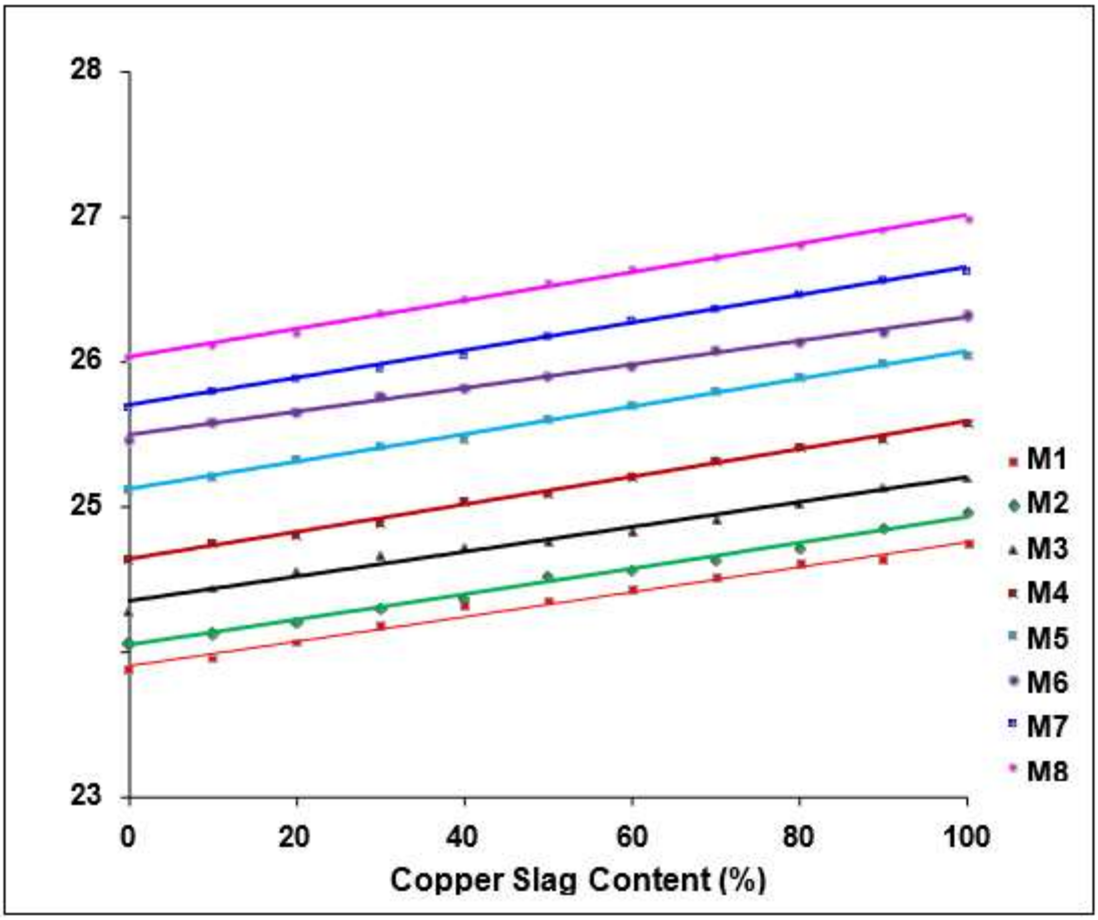

Figure 4.3 Variation of density with copper slag proportions for SCC mixes M1 to M8 on 28thday in MPa (without steel fibres)

With the addition of steel fibres, for mix M4 with 100 % sand + 0 % copper slag, the density was 25.19

kN/m3 and for mix M4 with 0 % sand + 100 % copper slag, the density increased to 25.90 kN/m3.The variation of density with copper slag proportions for SCC mixes M1 to M8 with steel fibres is shown in Figure4.4 Due to the addition of steel fibres, the density of SCC mixes increase approximately 1.9% to 3.3%. Copper slag has as Specific gravity of 3.68, higher than that of OPC (3.09) and fine aggregate (2.78), replacement of FA with copper slag leads to the increase in density of concrete cubes.

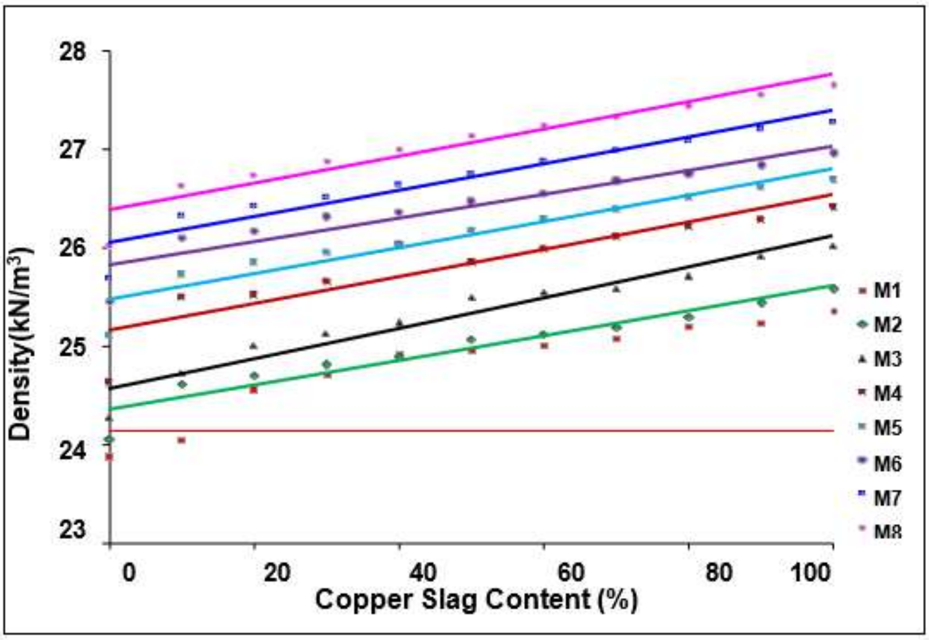

Figure 4.4 Variation of density with copper slag proportions for SCC mixes M1 toM8 on28thday in MPa (with steel fibre)

Compressive Strength

Three cubes, each measuring 150 x 150 x 150 mm had been tested for each of the SCC mixes M1 to M8 to determine the compressive strength on 1, 3, 7, 14, 28, 56 and 90 days. Test results are given in Table A1.9 to Table A1.16 in the appendix. Without steel fibres, for mix M4 with 100 % sand + 0 % copper slag, compressive strength on 28th day was 60.1 MPa. Replacing FA with copper slag, the compressive strength increased up to 65.03 MPa for Mix M4 with70% sand and 30% copper slag. Compressive strength increased approximately by 9%. Further replacement of FA with copper slag resulted in reduction of compressive strength. For Mix M4 with 0% sand and 100% copper slag, the compressive strength was 49.02MPa.The reduction in compressive strength was 21.5% when compared with the compressive strength of mix M4 with 100 % sand + 0 % copper slag. Figure9.4 shows the variation of compressive strength of SCC mix M4 with different copper slag proportions.

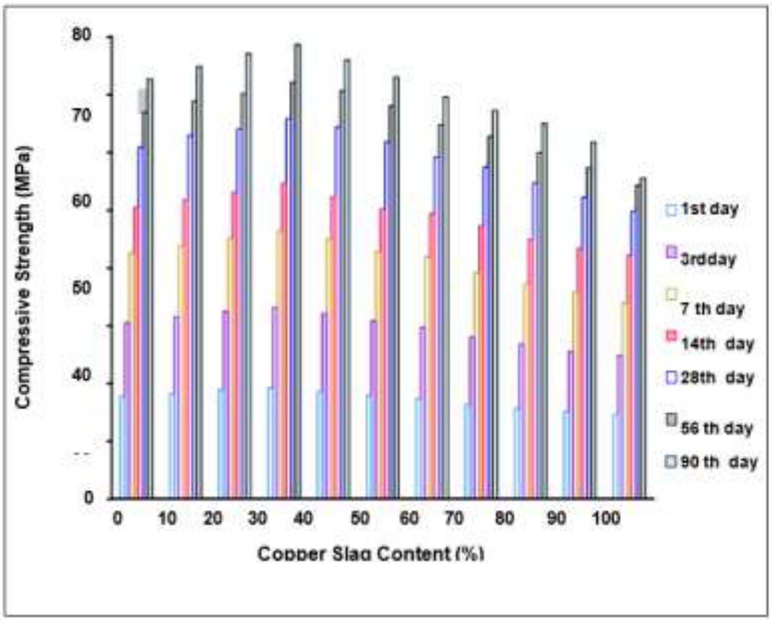

Figure 4.5 Variation of compressive strength with copper slag

Proportions for SCC Mix M4 (without steel fibres)

With the addition of steel fibres, for mix M 4 with100% sand+0% copper slag, compressive strength on 28th day was 61.58 MPa. Replacing FA with copper slag, the compressive strength increased up to 64.61 MPa for Mix M4 with 70% sand and 30% copper slag. Compressive strength increased approximately by 5%. Further replacement of FA with copper slag resulted in reduction of compressive strength. For Mix M4 with 0% sand and 100% copper slag, the compressive strength was 53.72 MPa. The reduction in compressive strength was 14% when compared with the compressive strength of mix M4 with 100 % sand + 0 % copper slag. Figure 9.6 shows the variation of compressive strength of SCC mix M4 with different copper slag proportions.M1to M8 with different copper slag proportions (with steel fibres).

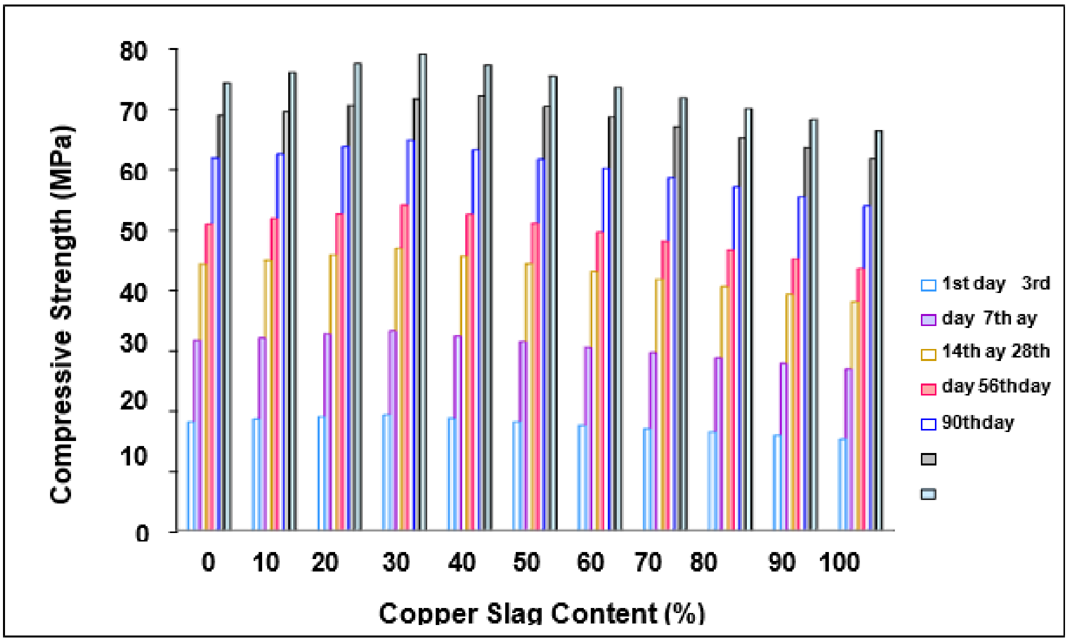

Figure 4.6 Variation of compressive strength with copper slag proportions for SCC Mix M4 (with steel fibres)

3 Conclusions:

The conclusions that follow are based on the results of the experimental investigations.

Workability:

The test results for the SCC mixes incorporating copper slag and steel fibres are showing promising characteristics, meeting the requirements for flowability, passing ability, and segregation resistance. The inclusion of copper slag in SCC mixes has led to a significant improvement in workability. This improvement can be attributed to the low water absorption and glassy surface of copper slag, which results in a lower water demand for achieving the desired workability. As the percentage of copper slag in the mix increases, the amount of free water content in the SCC mix also increases, contributing to the enhanced workability of the concrete .Despite the improvement in workability, the SCC mixes containing 80% to 100% copper slag exhibited moderate bleeding without segregation. This moderate bleeding may be attributed to the increased free water content in the mix, resulting from the addition of copper slag. However, the mixes still demonstrated satisfactory segregation resistance, indicating that the concrete remained homogeneous and uniform during placement and consolidation.The addition of steel fibres to the SCC mixes decreased flowability and passing ability, although the mixes still met the recommended limits. Steel fibres are known to increase viscosity and reduce the flowability of concrete mixes due to their bridging effect between aggregates. Despite this decrease in flowability, the SCC mixes maintained acceptable performance characteristics, indicating that the inclusion of steel fibres did not significantly compromise the overall properties of the concrete

Hardened Properties:

The increase in density of self-compacting concrete (SCC) with the inclusion of copper slag is a notable observation. Copper slag has a specific gravity of 3.68, higher than that of OPC (3.09), fine aggregate (2.78) and the replacement of FA with copper slag leads to the production of SCC with higher density.

The observation that replacing fine aggregate with copper slag up to 29% in self-compacting concrete (SCC) mixes resulted in improvements in compressive strength, flexural strength, and splitting tensile strength is significant, in SCC mixes resulted in an improvement in compressive strength of roughly 6-10%, flexural strength of approximately 5-7.5%, and splitting tensile strength of 3-4.5%.

The incorporation of steel fibres into self-compacting concrete (SCC) mixes containing copper slag resulted in further improvements in compressive strength, flexural strength, and splitting tensile strength, the substitution of fine aggregate with copper slag led to a rise in compressive strength of around 5-8% after 28 days. Additionally, flexural strength increased by roughly 4-5.5%, while splitting tensile strength increased by about 3-4.5%.

The observed decline in compressive strength, flexural strength, and splitting tensile strength with additional amounts of copper slag in the mix can be attributed to the increase in free water content and its impact on the overall properties of the self-compacting concrete (SCC)..

The correlation equations provided represent the relationship between compressive strength (fck) and flexural strength (fb) for self-compacting concrete (SCC) mixes under different conditions, the correlation between compressive strength and flexural strength can be expressed as fb=0.897(fck)0.4522. However, with the inclusion of steel fibres, the correlation between compressive strength and flexural strength is represented as fb= 0.868(fck)0.4554

Based on the study, the correlation between compressive strength (fck) and splitting tensile strength (fts) for self-compacting concrete (SCC) mixes consisting of 100% sand and 0% copper slag can be expressed mathematically as fct = 0.751 (fck)0.455. With the incorporation of steel fibres into the mix, the correlation between compressive strength and split tensile strength was expressed as fct=0.790(fck) 0.4371.

wo correlation equations were derived to represent the relationship between the static modulus of elasticity (E) and compressive strength (fck) for self-compacting concrete (SCC) mixes under different conditions, the correlation between static modulus of elasticity and compressive strength can be represented as E= 3594.6fck0.5743. However, with the inclusion of steel fibres in the mix, the correlation between static modulus of elasticity and compressive strength was expressed as E=4275.7fck0.4781.

Durability:

The findings from the current study reveal the impact of sulphuric acid exposure on the compressive strength of self-compacting concrete (SCC) mixes under different compositions and conditions the compressive strength of SCC mixes without steel fibres and containing 100% sand and 0% copper slag decreased by 18% to 19%.On the other hand, for mixes containing 0% sand and 100% copper slag, the compressive strength decreased by 22% to 24%. However, when steel fibres were added to the mix, the compressive strength of SCC mixes with 100% sand and 0% copper slag decreased by 19% to 21%, while for mixes containing 0% sand and 100% copper slag, the compressive strength decreased by 22% to25%.

The study's findings indicate the impact of hydrochloric acid exposure on the compressive strength of self-compacting concrete (SCC) mixes under various compositions and conditions, the compressive strength of SCC mixes without steel fibres and containing 100% sand and 0%copper slag decreased by 20-22%, and for mixes containing 0% sand and 100% copper slag, it decreased by 24-26%. When steel fibres were added, the compressive strength of SCC mixes containing 100%sandand0%copper slag decreased by21-23%, and for mixes containing 0% sand and100% copper slag, it decreased by28-30%.

Based on the findings presented in the investigation, incorporating copper slag as a replacement for fine aggregate in self-compacting concrete (SCC) appears to be a feasible and beneficial option The findings suggest that incorporating copper slag as a replacement for fine aggregate in self-compacting concrete (SCC) results in improvements in compressive, flexural, and split tensile strengths compared to the control mix. Specifically, up to a 30% replacement of fine aggregate with copper slag led to enhancements in these strength properties. However, further additions of copper slag beyond this optimal proportion resulted in a reduction in strengths

Therefore, based on the observed trend, it can be concluded that replacing 30% of fine aggregate with copper slag is the optimal proportion for achieving the desired improvements in strength properties while maintaining overall performance. This proportion offers a balance between enhancing mechanical properties and mitigating potential drawbacks associated with higher replacements.

Overall, the findings support the technical feasibility and benefits of using copper slag as a replacement for fine aggregate in SCC. This approach not only improves the strength characteristics of concrete but also offers potential environmental and economic advantages. However, it's essential to carefully consider mix proportions and conduct further optimization studies to ensure optimal performance and durability in various application scenarios.

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