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Fresh and mechanical properties of self compacting concrete containing copper slag as fine aggregates

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ABSTRACT

An investigation is carried out on the development of Self Compacting Concrete (SCC) using copper slag (CS) as fine aggregates with partial and full replacement of sand. Six different SCC mixes (60% OPC and 40% Fly Ash) with 0% as control mix, 20%, 40%, 60%, 80% and 100% of copper slag substituting sand with constant w/b ratio of 0.45 were cast and tested for fresh properties of SCC. Compressive strength and splitting tensile strength were evaluated at different ages and microstructural analysis was observed at 120 days. It has been observed that the fluidity of SCC mixes was significantly enhanced with the increment of copper slag. The test results showed that the compressive strength increases up to 60% copper slag as replacement of sand, beyond which decrease in strength was observed. The highest compressive strength was obtained at 20% copper slag substitution at different curing ages among all the mixes, except for 7 days curing. The splitting tensile strength of the CS substituted mixes in comparison to control concrete was found to increase at all the curing ages but the remarkable achievement of strength was detected at 60% copper slag replacement. The microscopic view from Scanning electron microscopy (SEM) demonstrated more voids, capillary channels, and micro cracks with the increment of copper slag as substitution of sand as compared to the control mix.

1 Introduction

Self Compacting Concrete (SCC) is a special concrete, characterized for its unique quality to flow and compact by itself under its own weight in highly dense reinforcement without any application of external or internal vibration. The use of relatively high content of binder as well as high dosages of chemicals admixtures (superplasticizer) as compared to conventional concrete, enhances fluidity and maintains its stability without segregation and bleeding. Nowadays, SCC is widely used in the development of infrastructure due to various benefits such as high-speed construction, less man power, better surface finish and effortless placing. Numerous research work has been carried out to escalate the strength and

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durability properties of SCC using mineral admixture (silica fume, metakaolin, fly ash etc) as partial replacement of cement [1-4]. Like cementitious materials, fine aggregate is also a matter of concern in the production of SCC which contains about 60-65% by volume of total aggregates.

Aggregates perform significant character in enhancing the strength and workability of concrete, as it occupies about 60-70% volume in the concrete matrix. It has been forecasted that about 48.3 billion tons of construction aggregates was generated worldwide in 2015 [5]. Incorporating huge volume of aggregates in construction possibly will lead to scarcity of aggregates in several countries, where natural resources are not adequate to meet up the need of construction industries. Some of the countries are importing sand for the expansion of the infrastructures (roads, building, dams etc) which raises the cost of construction projects. Dubai Palm Island, a mega structure constructed by utilising 94 million cubic metres of sand is a stand out example of aggregates required in construction industries. Abundant sand employed in this mega structure was dredged from the bottom of Persian Gulf, which may trigger destruction in the aquatic life as well as an interruption for a sustainable environment. To eliminate such environmental obstacles originated by man for the need of resources and to overcome the inadequacy of aggregates, either supplementary materials or waste by-products generated from industries can be utilised as aggregates.

Copper slag is one such industrial by-product obtained in bulk quantity during matte smelting and refining process of copper metal. It was estimated that to yield 1 ton of copper, about 2.2 to 3 tons of copper slag is generated as a by-product [6,7]. Approximately 68.7 million tons of copper slag was generated in the year 2015 from the world copper industry and China was the country with an uppermost production of 20.25 followed by Japan 6.18, Chile 5.5 and Russia 3.43 million tons. In India, nearly 2.4 million tons of copper slag was turn out in the same year, which shared about 3.5% of world's copper slag [8]. Copper slag is rich in iron and contains various other types of oxides, which includes SiO_2, Al_2O_3, CaO and Fe_3O_4 [6,7]. In past, Copper slag has been used in construction industry either alternative part to cement or partial/full replacement of sand. Moreover, copper slag is also used for manufacturing of abrasive tools, tiles, granules, cutting tools, pavements, and sand blasting purposes.

Some literature is available on the use of copper slag either as partial replacement of cement or partial/full replacement of sand for Normal Vibrated Concrete (NVC) and High Performance Concrete (HPC). High performance concrete was developed using copper slag as replacement of sand from 0 to 100%, with the addition of 11% silica fume by weight of cement. The result shows that compressive strength and splitting tensile strength increased up to 50% substitution of copper slag, whereas flexural strength decreased in comparison to control concrete. It was also observed that up to 40% copper slag, water absorption reduced [9]. Lime stone aggregate was replaced by copper slag as coarse aggregate in high strength concrete. It was found that compressive and splitting tensile strength of concrete containing copper slag aggregate has more strength than lime stone aggregates [10]. The replacement of sand by 40% copper slag was observed to be optimum content for high strength concrete [11]. It was found that copper slag can be utilised as replacement of sand for all grades of concrete [12]. Incorporation of 5% copper slag (CS) as replacement of cement has more or comparable compressive, splitting tensile and flexural strength than concrete mix containing 100% cement at different w/b ratios. Tertiary mix containing 1.5% Cement By-Pass Dust (CBPD), 13.5% CS and 85% cement had lowest strength than control concrete [13]. The dynamic compressive strength of copper slag reinforced concrete (CSRC) increased up to 20% replacement of sand by copper slag though strength was comparable to control mix up to 40% replacement, beyond which strength reduced. It was also found that with an increase in the percentage of copper slag, especially when substitution rate exceeds 20%, voids, micro cracks and capillary channels were more in CSRC compared to control concrete [14]. The addition of 20% copper slag as supplementary cementing material in concrete increased compressive strength and splitting tensile strength, whereas absorption by capillary and carbonation reduced [15]. The reduction in mechanical properties was found in comparison to control concrete by utilising copper slag as partial replacement of cement at 5%, 10% and 15% whereas slump had almost same values [16]. At similar percentages copper tailing was also used as partial substitute of cement and decrease was observed in mechanical properties [17]. The compressive strength of mortar increases with increase in the copper slag content up to 100%, though mechanical and durability properties of concrete were enhanced up to 40-50% copper slag substitution [18]. Alkali activated slag concrete with granulated blast furnace slag as binder showed highest mechanical properties compared to OPC based concrete, even when sand was completely replaced by copper slag [19].

According to some previous researches on NVC and HPC, copper slag proved to be valuable for its utilisation in concrete up to certain limit. To the best of author's knowledge, no literature has been found on SCC with copper slag as fine aggregates substitute. The prime motive of the paper is to develop SCC by using copper slag as sand replacement from 0 to 100%. To evaluate the behaviour of SCC, fresh and mechanical properties were carried out in addition with microstructural analysis. The fresh properties of SCC mixes were examined with respect to the slump flow diameter, T_{50} time, V-funnel, J-ring and L-box height ratio. Mechanical properties of SCC mixes were tested in terms of compressive and splitting tensile strength though SEM was conducted for microstructure study.

2 Experimental program

2.1 Materials

Ultratech cement of 43 Grade Ordinary Portland Cement (OPC) was used in the concrete mixes satisfying IS 8112 [20]. Physical properties and chemical composition of cement are shown in Table 1 and Table 2 respectively. Class F Fly ash (FA) was used in this investigation as partial replacement of OPC by 40% in each SCC mix to enhance workability. Fly ash was obtained from thermal power plant located in Ropar, Punjab, India. The specific gravity of fly ash was 2.10. The chemical composition of fly ash is shown in Table 2 and the total sum of SiO_2, Al_2O_3 and Fe_2O_3 is more than the minimum requirement of 70%, specified for class F fly ash [21]. Locally available sand was utilised in the SCC mixes conforming IS 383 [22] . As per IS 383, Sand comes across to lie in zone II. The water absorption of sand was 0.80%, fineness modulus of 2.79 and specific gravity of 2.6.

Table 1 - Physical properties of OPC 43 grade

Characteristic Properties	Observed Value	Codal Requirements IS:8112-1989 [20]
Fineness (m^2/kg)	310	225 Minimum
Standard consistency (%)	32	-
Initial Setting time (minutes)	62	30 Minimum
Final setting time (minutes)	270	600 Maximum
Specific gravity	3.15	-
Soundness by Le-Chat Expansion (mm)	1.0	10.0 Maximum
Compressive strength (MPa)		
3 days	24.6	23 Minimum
7-days	34.3	33 Minimum
28-days	45.2	43 Minimum

Table 2 - Chemical composition of cement, fly ash and copper slag

Component	OPC (%)	Fly Ash (FA) (%)	Copper slag (CS) (%)
SiO_2	20.99	57.6	30.53
Al_2O_3	5.98	30.5	2.80
Fe_2O_3	4.10	3.72	57.82
CaO	60.78	1.10	1.60
MgO	0.96	0.38	1.48
SO_3	3.98	0.22	1.59
K_2O	2.20	1.35	0.71
Na_2O	0.86	0.10	0.34
TiO_2	0.25	1.72	0.26
CuO	-	0.017	0.64

Copper slag was used as a replacement of sand from 0 to 100% at an interval of 20%. Copper slag was obtained from Taj Abrasive Industries located in Sikar, Rajasthan, India. Fig. 1 demonstrates particle size distribution of sand and copper slag and Fig. 2 (a) and (b) shows sand and copper slag respectively used in this investigation. The Chemical composition of

Copper slag is shown in Table 2. Copper slag had fineness modulus of 3.33, water absorption 0.36% and specific gravity of 3.51, lying in the Zone I [22] as per. A locally available coarse aggregate of nominal size 12.5 mm and 10 mm was used in the proportion of 40% and 60% respectively. Aggregates were used in the saturated surface dry condition. The water absorption of coarse aggregate was 0.68%, fineness modulus of 6.93 and specific gravity of 2.64. Master Gelnium SKY 8765 was used in different dosages by weight of binder to achieve desirable properties of SCC. It is based on modified polycarboxylic ethers, having chloride content less than 0.2% with a relative density of 1.07, pH≥6 at 25℃ meeting the specification of IS 9103 [23].

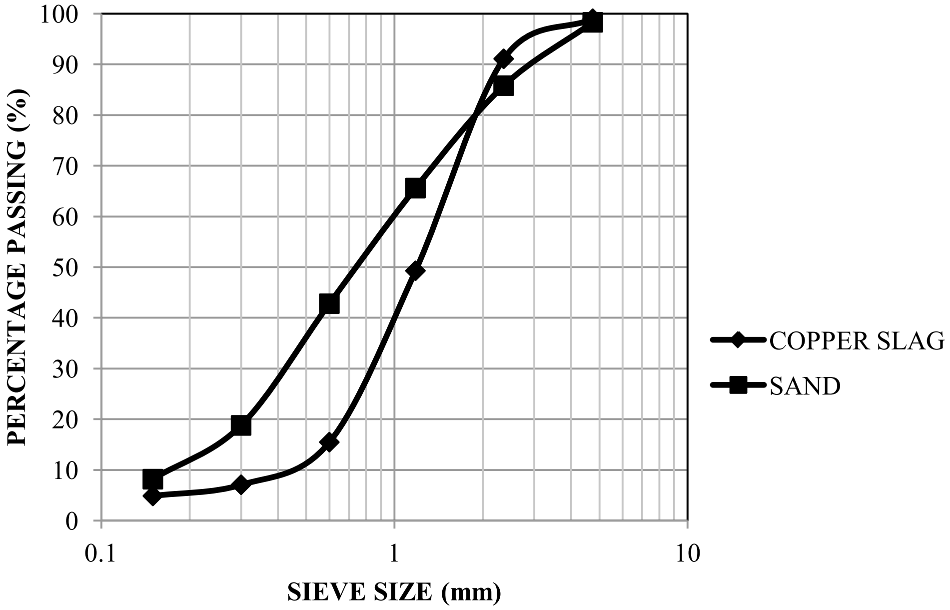

Fig. 1 - Particle size distribution of copper slag and sand

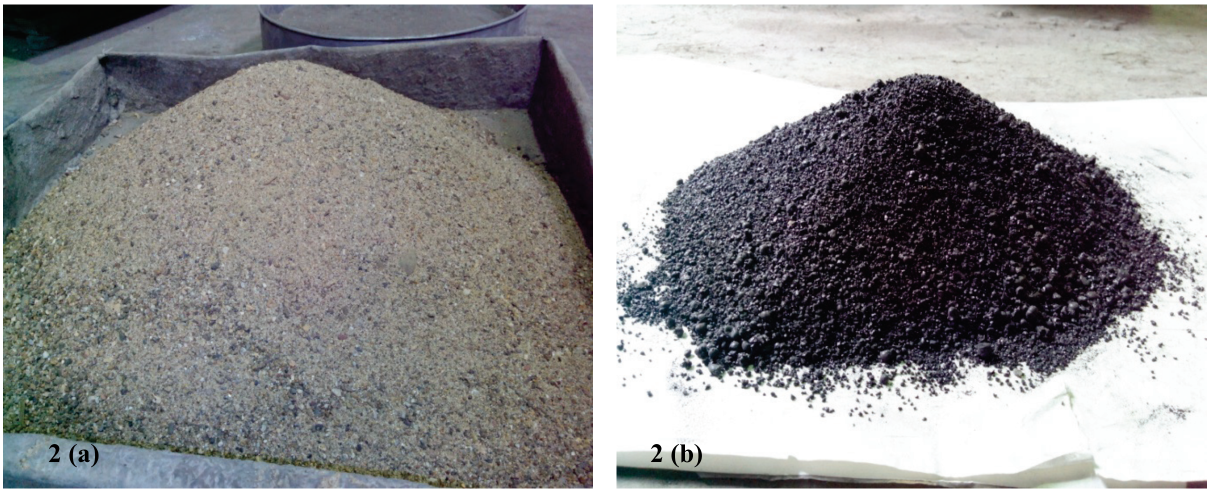

Fig. 2 - (a) Sand and (b) Copper Slag utilised in this investigation

2.2 Mixtures

In the present investigation, six SCC mixes were prepared containing different fractions of copper slag as replacement of sand varying from 0 to 100% at an interval of 20%, by keeping constant cementitious content and w/b ratio of 550 kg/m^3

and 0.45 respectively. SCC mix with 0% copper slag was considered as control concrete. OPC and FA were fixed at 330 and 220 kg/m^3 respectively after carrying out several trial mixes to obtain desirable SCC properties conforming EFNARC [24]. Mix proportion of SCC mixes in kg/m^3 is shown in Table 3 and quantities of sand and copper slag were varied by equivalent volume approach. The total coarse aggregate of 700 kg/m^3 and water content of 247.5 kg/m^3 were kept constant for the entire mixes. Initially coarse aggregates, sand, and copper slag were dry mixed for a minute in the laboratory mixer. Afterwards, OPC and FA were added together in the concrete mixer and rotated for 2 more minutes to achieve homogeneous mixing. Out of total water content, 70% water was discharged in the mixer and rotated for 3 minutes. Subsequently, left over 30% water mixed together with required dosages of superplasticizer was added and finally mixed for another 2 minutes. SCC was poured into the well-oiled moulds and demoulded after 24 hours. Samples were water cured in temperature controlled curing tank at 27±2°C till the age of testing.

Table 3 - Mix proportion in kg/m^3

Mix No	OPC	FA	CS (%)	S	CS	Coarse Aggregate		Water	SP
						10 mm	12.5 mm		
1	330	220	0	1020	-	420	280	247.5	4.4
2	330	220	20	816	284.4	420	280	247.5	4.4
3	330	220	40	612	568	420	280	247.5	3.3
4	330	220	60	408	853.2	420	280	247.5	2.75
5	330	220	80	204	1137.6	420	280	247.5	2.2
6	330	220	100	-	1422	420	280	247.5	2.2

Note: OPC- Cement, FA- Fly ash, CS- Copper slag, S- Sand, SP- Superplasticizer

2.3 Test methods

2.3.1 Fresh properties

To assess the fresh properties of SCC, slump flow and V-Funnel test were conducted for filling ability, whereas, J-Ring test and L-Box test were performed for passing ability. Slump flow cone was filled with fresh concrete, lifted upward and then, the spread of concrete was measured in two perpendicular directions. Simultaneously, T_{50} time was also noticed for concrete to reach spread diameter of 500 mm. The range for slump flow value and T_{50} value, according to EFNARC [24] are shown in Table 4. V-Funnel was completely filled with concrete and time was recorded to empty the whole funnel. J-ring test and L-box test were done to evaluate the behaviour of concrete in congested reinforcement. A circular ring of diameter 300 mm and height 100 mm was placed outside the slump cone. Passing ability of concrete was examined by filling the cone with concrete, and then lifted upward allowing concrete to flow through circular J ring having reinforcing bars of diameter 10 mm placed at 48 mm apart. J_{50} time was recorded for concrete to reach 500 mm spread circle. L-box was used to check the passing ability by filing the vertical part of the L-box and lifting the sliding gate to flow concrete through bars into the horizontal part. The vertical height was measured at the start and end of the horizontal portion of the box. Blocking ratio was obtained by taking the ratio of two vertical heights. The upper and lower limit for J Ring and L-Box as per the recommendation of EFNARC are given in Table 4.

Table 4 - Criteria for SCC [24]

S. No	Test	Property	Range
1	Slump flow test	Filling ability	650 - 800 mm
2	V funnel test	Filling ability	6 - 12 sec
3	T_{50}	Filling ability	2 - 5 sec
4	J ring test (J_{50})	Passing ability	3 - 6 sec
5	L box test	Passing ability	0.8 - 1

2.3.2 Mechanical properties

Compressive strength and splitting tensile strength was carried out on specimens of size 100 mm cube and 100 x 200 mm cylinder respectively at 7, 28, 56, 90 and 120 days of curing. For each curing period, triplicates for compressive and splitting tensile strength were tested as per IS 516 [25] and IS 5816 [26] respectively on compression testing machine of capacity 2000 tons.

2.3.3 Microstructural observation

The microstructure analysis of samples was carried out using scanning electronic microscope (SEM) on JOEL JSM-6510LV. Samples were procured during compressive strength. Before SEM analysis, moisture was removed from the samples and then samples were made conductive by gold coating. Secondary electron detector was used at high vacuum to examine the samples at an accelerating voltage range of 15 KV to 20 KV with working distance of 12 mm. SEM analysis of samples were conducted after 120 days of curing.

3 Results

3.1 Fresh properties

Fig. 3 (a) to Fig. 3 (d) illustrates Slump flow, V-funnel, J-ring and L-box tests conducted to investigate the fresh properties of SCC incorporating different proportions of copper slag. The results of slump flow test show that with increment in the replacement level of sand by copper slag, the fluidity of concrete increased. The spread diameter of slump flow value for all mixes varied between 705 to 735 mm, satisfying guidelines mentioned for SCC [24]. The highest slump flow value was observed at 100% copper slag substitution while control concrete has the lowest value among all mixes. And the corresponding T_{50} time of the respective mixes recorded to reach 500 mm spread circle was observed to decrease gradually from 3.8 sec (control mix) to 2.18 sec (100% CS substitution). In this investigation, it was found that with an increase in the replacement level of sand by copper slag, V-funnel time taken was less to empty the funnel from 8.55 to 6.43 seconds, which shows that filling ability of SCC enhanced. Moreover, to assess the passing ability of fresh concrete through congested reinforcement J_{50} time was calculated. For all mixes, J_{50} time was in the range of 3-6 sec with lowest and maximum value of 3.06 and 4.27 sec for 0% and 100% copper slag respectively to reach spread diameter of 500 mm passing through the circular ring with bars embedded in it. In addition to J-ring test, L-box test was also conducted to evaluate the passing ability of fresh SCC. The blocking ratio was observed for whole mixes, ranging from 0.87 to 0.96 is shown in Table 5.

Table 5 - Fresh properties of SCC

Mix No	Mix description	Slump flow (mm)	V-funnel (sec)	J-ring (J_{50}) (sec)	T_{50} (sec)	L-box	SP (%)
1	60%OPC+40%FA+100%S+0%CS	705	8.55	4.27	3.8	0.87	0.80
2	60%OPC+40%FA+80%S+20%CS	710	8.12	3.96	3.27	0.89	0.80
3	60%OPC+40%FA+60%S+40%CS	710	7.62	3.72	3.16	0.90	0.60
4	60%OPC+40%FA+40%S+60%CS	720	6.83	3.39	2.84	0.93	0.50
5	60%OPC+40%FA+20%S+80%CS	725	6.68	3.20	2.41	0.95	0.40
6	60%OPC+40%FA+0%S+100%CS	735	6.43	2.94	2.18	0.96	0.40

Note: OPC- Cement, FA- Fly ash, S- Sand, CS- Copper Slag, SP- Superplasticizer

The results of fresh properties revealed that filling and passing ability of SCC mixes was outstanding with an increase in the percentage of copper slag substitution. This may be attributed to the hydrophobic nature of copper slag, resulting in lower absorption of water than sand. Due to its lower water absorption characteristics compared to sand, dosage of superplasticizer was reduced, with rise in the percentage of copper slag content. However, dosage of superplasticizer declined to half for SCC containing 100% copper slag (0.4% by weight of binder) in comparison to 0% copper slag (0.8% by weight of binder) for same the workability.

Fig. 3 - (a) Slump flow test, (b) V-funnel test, (c) J- ring test, (d) L-box test

3.2 Compressive strength

The results of compressive strength for all SCC mixes at the curing age of 7, 28, 56, 90 and 120 days are shown in Table 6. Results show that incorporation of CS as sand replacement up to 60% in SCC, increased compressive strength at each curing period compared to control SCC mix, except early curing period i.e. 7 days. The decrease in early age strength of SCC mixes containing CS may be attributed to the presence of heavy metal in copper slag which delayed hydration of cement [27]. Further, it was found that compressive strength reduces with the increase in the replacement level of sand by copper slag. The highest compressive strength was obtained with 20% substitution of CS from 28 to 120 days of curing with values varying from 34.39 MPa to 42.24 MPa respectively. At 28 days of curing, SCC containing 20% CS and 80% sand had about 12.60% of the increase in compressive strength compared to control concrete. The lowest strength was observed in 100% CS mix at all curing periods, ranging from 18.63 to 38.57 MPa. Beyond 60% replacement of sand by CS, compressive strength decreases at all curing period compared to control concrete, though the difference in later age strength was less compared to 28 days of curing age. The decrease in strength may be due to the glassy and smooth surface of the copper slag particles compared to sand particles, leading to the presence of excess water in mixes with the higher substitution of copper slag. However, increase in the water content with the inclusion of copper slag substantially reduces the demand of superplasticizer for the same workability.

Table 6 - Compressive strength at different curing ages

Mix No	Mix description	Compressive strength in MPa				
		7 days	28 days	56 days	90 days	120 days
1	60%OPC+40%FA+100%S+0%CS	22.89	31.43	35.47	38.07	40.15
2	60%OPC+40%FA+80%S+20%CS	21.50	35.39	38.67	40.72	42.24
3	60%OPC+40%FA+60%S+40%CS	20.81	33.60	37.90	40.19	41.06
4	60%OPC+40%FA+40%S+60%CS	20.09	31.80	36.82	38.58	40.80
5	60%OPC+40%FA+20%S+80%CS	19.93	30.57	35.56	37.43	39.92
6	60%OPC+40%FA+0%S+100%CS	18.63	27.70	32.73	36.75	38.57

Note: OPC- Cement, FA- Fly ash, S- Sand, CS- Copper Slag, SP- Superplasticizer

Superplasticizer being expensive chemical admixture but essential constituent for the production of SCC which further increases the cost of concrete. Utilisation of industrial waste i.e. copper slag reduces the dosage of superplasticizer, and consumption of natural resources which is a realistic solution to reduce the cost of SCC. The variation of compressive strength for different proportions of copper slag with reference to control concrete is shown in Fig. 4.

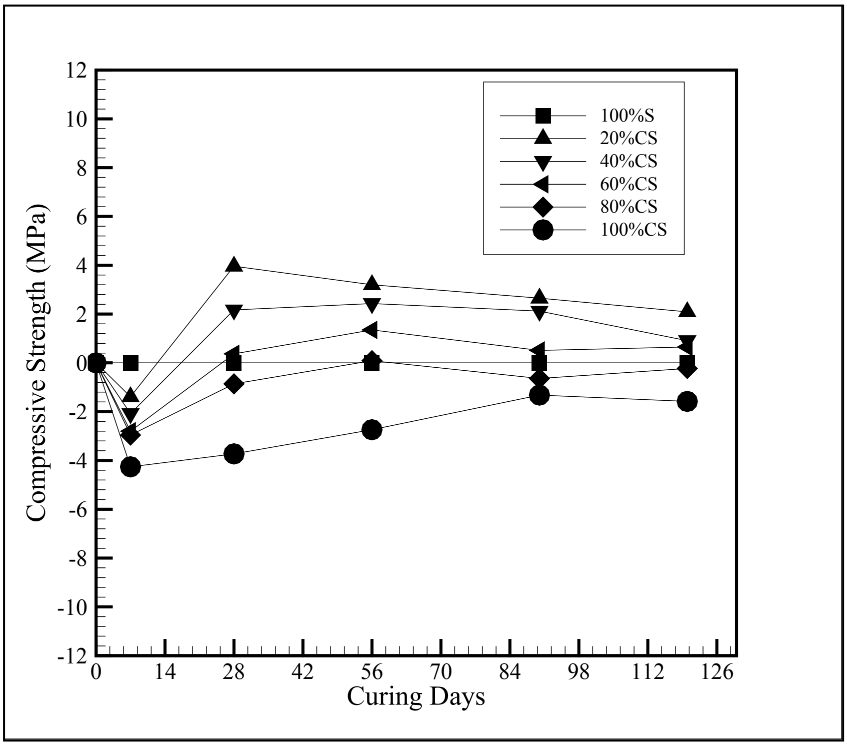

Fig. 4 - Variation of compressive strength of SCC mixes with respect to control concrete at different curing periods

3.3 Splitting tensile strength

The results of splitting tensile strength of six concrete mixes at different curing period are shown in Table 7. It can be seen from Table 7 that splitting tensile strength of all SCC mixes containing different proportion of CS increased compared to control concrete at all curing periods. However, strength decreased beyond 80% CS substitution, though it was still more than control concrete. The highest splitting tensile strength was achieved in concrete mix containing 60% CS as replacement of sand while lowest strength was observed in 100% S i.e. control concrete. The values of splitting tensile strength for SCC mix 4 varied from 1.86 MPa to 4.65 MPa for curing period of 7 to 120 days. It was observed that increase in strength was about 15.91% to 6.67% for mix 2, 18.94% to 11.36% for mix 3, 40.91% to 14.81% for mix 4, in comparison to control concrete at 7 to 120 days of curing. Enhancement in the splitting tensile strength of concrete mixes as copper slag substitution may be attributed to the angular shape of copper slag particle, which increases the cohesion of the concrete matrix, resulting in an improvement in the splitting tensile strength. The variation of splitting tensile strength for different proportions of copper slag with reference to control concrete is shown in Fig. 5.

Table 7 - Splitting tensile strength at different curing ages

Mix No	**Mix description**	**Splitting tensile strength in MPa**				
		7 days	**28 days**	**56 days**	**90 days**	**120 days**
1	60%OPC+40%FA+100%S+0%CS	1.32	3.02	3.44	3.82	4.05
2	60%OPC+40%FA+80%S+20%CS	1.53	3.29	3.91	4.17	4.32
3	60%OPC+40%FA+60%S+40%CS	1.57	3.35	4.06	4.33	4.51
4	60%OPC+40%FA+40%S+60%CS	1.86	3.67	4.10	4.41	4.65
5	60%OPC+40%FA+20%S+80%CS	1.39	3.30	3.96	4.27	4.39
6	60%OPC+40%FA+0%S+100%CS	1.30	3.12	3.73	4.02	4.18

Note: OPC- Cement, FA- Fly ash, S- Sand, CS- Copper Slag, SP- Superplasticizer

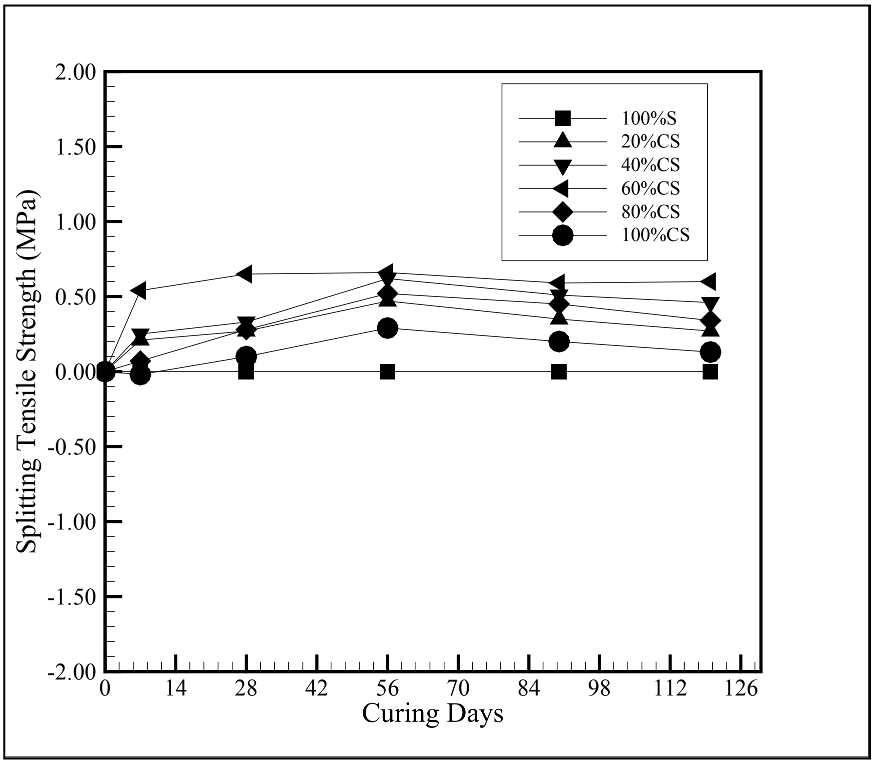

Fig. 5 - Variation of splitting tensile strength of SCC mixes with respect to control concrete at different curing periods

3.4 Microstructral analysis

The microstructural analyses of SCC samples were conducted at 120 days of curing by using SEM. Fig. 6(a) to 6(c) presents the SEM images of SCC containing 0%, 20%, and 100% CS. It was observed from Fig. 6(a) that 0% CS has some cracks and presence of a little amount of needle-shaped structure i.e. ettringite, with uneven formation of C-S-H gel, consequences into the porous internal structure. However, 20% CS has homogenous and dense formation of C-S-H gel, though some semi-spherical voids are visible which is shown in Fig. 6(b) but there is no occurrence of ettringite crystals. Moreover, incorporation of 100% CS resulted into more voids and porous structure with agglomeration of ettringite crystal is shown in Fig. 6c.

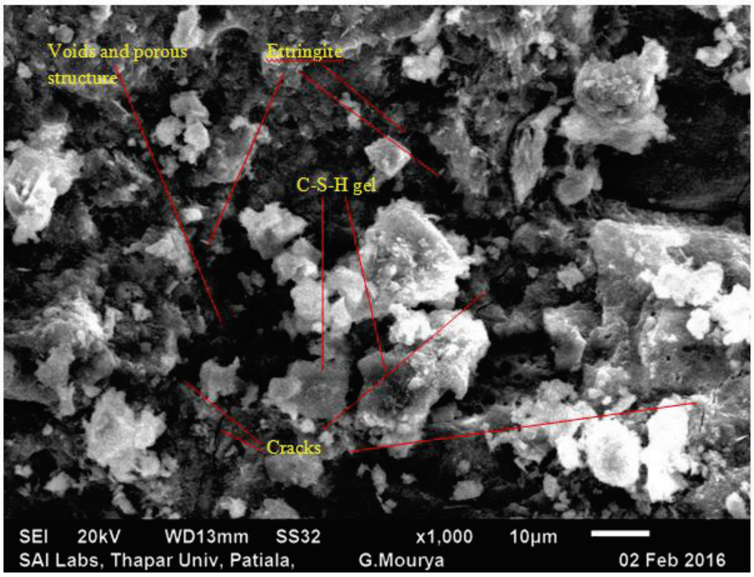

Fig. 6(a) - SEM image of control mix i.e. 0% CS

The interfacial transition zone (ITZ) is considered to be the weakest link in the concrete matrix. As reported earlier water content increases with full replacement of sand and copper slag particles settle down in the concrete matrix due to their heavy weight and water moves to the surface in fresh concrete. The excess water content in the ITZ creates voids, dense microcracks and capillary channels resulting in the formation of a porous structure which may be the reason for decrease in strength. A similar result was also observed in the copper slag reinforced concrete [14].

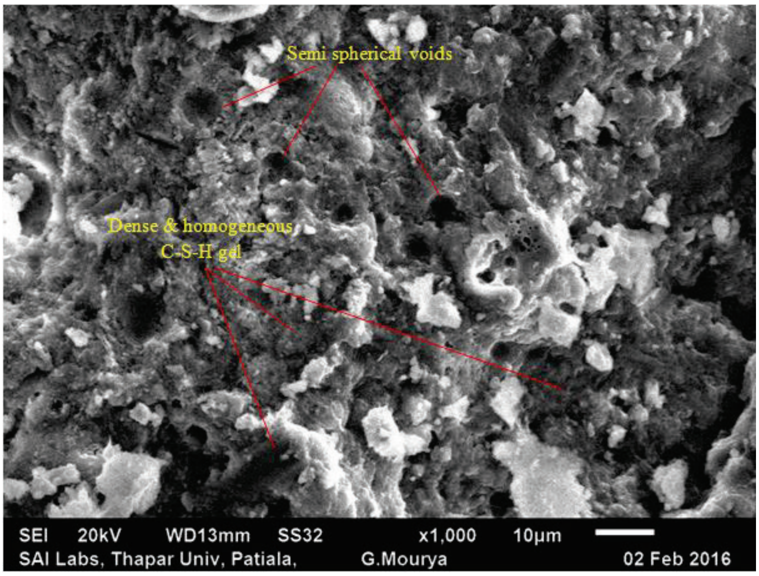

Fig. 6(b) - SEM image of 20% CS

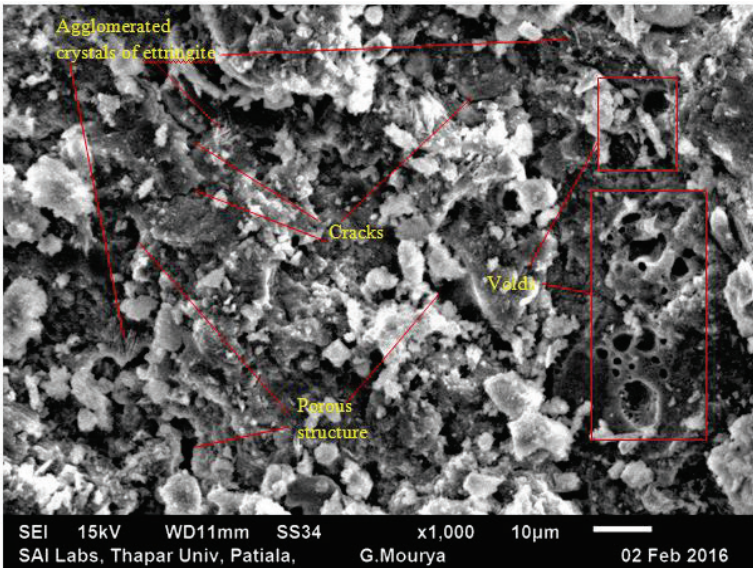

Fig. 6(c) - SEM image of 100% CS

4 Conclusion

In this investigation, the influence of incorporating copper slag as sand replacement were studied on fresh and mechanical properties of SCC, and microstructural analysis. The main conclusions drawn are the following.

- Filling and passing ability of SCC mixes improved with an increase in the replacement of sand by CS, and more importantly decreases demand for superplasticizer for the same range of workability. All mixes were observed to exhibit fresh properties within criteria specified for SCC by EFNARC.

- Compressive strength enhanced up to 60% CS substitution at all curing ages expect 7 days curing. Moreover, further increase in the replacement of sand by CS decreases the strength of concrete. The maximum strength was observed at 20% replacement of sand by CS.
- Splitting tensile strength increased for all mixes in comparison to control SCC mix, though maximum strength was obtained at 60% CS at all curing ages. The improvement in strength may be attributed to the interlocking of copper slag particles due to the angular shape which enhances the cohesion of concrete matrix. Control concrete has lowest strength among all mixes for each curing period.
- The SEM analysis showed that 20% CS has dense and homogeneous C-S-H gel formation though SCC containing 100% CS has large number of voids and cracks which may be the reason for decrease in strength.
- It can be concluded from this study that copper slag has the potential to replace sand in the range of 40-60% to obtain SCC with desirable fresh and strength properties. Utilisation of copper slag (industrial waste) reduces the dosage of superplasticizer, consumption of natural resources which is a realistic solution to decline the cost of concrete and boon for construction industry.

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