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Microstructural And Durability Characteristics Of Self-Compacting Concrete Incorporating Wood Waste Ash And Steel Slag

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ABSTRACT
The need of putting set up eco-friendly processes and rules that raise output, enhance the quality of output, and save energy is widely recognized in the construction sector. This paper reports on a research that looked at self-compacting concrete (SCC) utilizing 15% cement and wood waste ash (WWA). Ash from wood waste is categorized as an additive because of its pozzolanic qualities. Paper mills, log-fired power stations, and other businesses that burn wood chips produce wood waste ash as a by-product. As a byproduct of their combustion process. In this investigation, steel slag (SS) was added to self-compacting concrete in different amounts 15%, 30%, and 45% in place of fine particles. Lowermost among the slag from the blast furnace is the SS layer. Many tests were done to evaluate the impacts of replacement and additive materials. The L-box, U-box-funnel, and slump flow tests were among those used to assess the materials' freshness. Tests for compressive strength were also conducted in order to evaluate the strength characteristics. Tests for fast chloride permeability, mass loss, water absorption, and abrasion resistance were used to assess durability attributes. Studies show that adding SS content improves all the hardened properties.

Key words: *Self-compacting concrete, Wood waste Ash, Steel Slag, Compressive strength, Abrasion,*

1. INTRODUCTION
It is feasible to lay out and pour Self-Compacting Concrete (SCC) within a building without using external compaction or vibration, which is one of its unique characteristics. Furthermore, SCC flows effortlessly past barriers like reinforcements and difficult-to-reach places and is very resistant to segregation [1, 2]. The easy-to-pour SCC has become more and more popular lately since it consolidates without the need for extra equipment or experienced labor [3, 4]. Nonetheless, waste and industrial byproducts like fly ash and powdered limestone in SCC, both of which are typical examples of mineral additives. [5, 6].
SCC is often regarded as the main technologically sophisticated material within the contemporary construction industry. The release of carbon dioxide gas during manufacturing of cement is a significant environmental concern. To address this issue, cementitious materials such as admixtures like WWA can be employed as partial cement alternates. This substitution not only decreases the need of cement but also improves characteristics of SCC. Similar to SS is generated as a by-product of the steel manufacturing method, resulting from the removal of impurities. This leads to the formation of liquid slag that subsequently hovers above the surface of steel. SS that is created when molten steel cools, and is then subjected to further processes including crushing and screening, which are often used to generate the appropriate particle size. The specific gravity of the SS is measured to be 3.2, while its unit weight is determined to be 1720 kg/m^3. CaO, Al_2O_3, SiO_2, and Fe_2O_3 among the elements that make up the chemical makeup of the SS.According to research, [7] employing the addition of steel slag to concrete increased its tensile, flexural, and compressive strengths in substitution of some fine aggregate. Careful observation provided proof of this. The investigation conducted [8] examines the impact of incorporating SS and walnut shell on the strength properties of concrete. The study concludes that a composition consisting of 40 SS and 20% walnut shell demonstrates optimal performance in manners of both compression and tensile parameters. The density of the concrete was increased by adding additional material (steel slag) to both cube and cylinder forms. High density concrete was used to accomplish this [9]. Following the 28-day period, flexural strength rose to 7.88 MPa to 33.55 MPa, the compressive strength from 33.45 to 36.42 MPa, and the split strength from 3.75 to 4.17 MPa. Reduced permeability coefficient was the outcome of slag filling the holes and blocking their linking. Crushed aggregate is now 39% cheaper thanks to slag [10].
According to Owaid et al. (2021), the assessment of the work-ability of mixes utilizing waste paper ash and wood ash revealed no significant differences in contrast to the test mix. However, study revealed that the inclusion of up to 50% waste paper ash or 25% WWA in control mixes observed in a partial decrease their mechanical

properties, namely their flexural and compressive strengths. The findings suggest that it is possible to partially replace fly ash with up to 50% WWA or 25% waste paper ash in the concrete preparation process [11]. Based on the findings of [12], noted highest compressive strength gained in high strength concretes was 83 N/mm^2 when using a concrete mixture consisting of 10% wood ash and 20% metakaolin. Making incorporation of wood ash as a cement alternative in steel fiber reinforced concrete was the subject of an investigation that was carried out by [13]. The authors of the research evaluated the consequences of this substitution. The wood ash was added in increments of 5% ranging from 0% to 20%. Outcomes of the study revealed that 10% parts of cement replaced with wood ash led to significant improvements in both CS and flexural strength of the concrete. Addition of wood ash into concrete in different percentages—ten, fifteen and twenty percentages by mass of cement resulted in enhancement of 8.24% in CS after 28-day of curing. The researchers concluded that incorporating 15% wood ash in concrete is both viable and sustainable, suggesting its potential as a part replaced material for cement [14]. Research revealed that the CS test, when applied to a mixture comprising forty percent metakaolin and 10% wood ash, yielded values of 9.27 MPa, compared to the reference sample's 6.65 MPa. This finding leads to the conclusion that substituting Portland cement with these materials holds promise as a viable strategy. Wood ash enhances the workability, water absorption, drying shrinkage, carbonation, and hardened concrete's resilience to compression and bending, as well as its chloride permeability [15]. According to incorporating steel slag at a replacement ratio of 50% or more was shown to reduce workability. SS added as fine aggregate to concrete increased its compressive and tensile strengths, which changed with mix compositions. Researchers found that lean concrete's compressive and tensile strengths were significantly enhanced when fine aggregate made of steel slag was added [16]. The outcomes of this examination [17] demonstrated that, when compared with concrete mixes that employed crushed limestone aggregate, those that used steel slag had a greater specific bulk gravity. The aggregate ratio proved to be a useful indicator of compressive strength for concrete mixtures that included steel slag. The elastic modulus and fracture tensile strength of the concrete being compared were almost indistinguishable from those of the reference concrete. A minor enhancement in compressive strength was checked and compared to the initial controlled sample. Density of concretes that use slag as an aggregate is around 2.5 milligrams per cubic meter of material [18]. Tests conducted experiments to figure out what effect there is on concretes static and dynamic strength of swapping SSFA for NFA. The research proved that adding SSFA to concrete increased either its static and dynamic compressive strengths. The ideal SSFA replacement ratio under static and dynamic loading scenarios was 20%. Finally, SSFA has the potential to increase concrete's elastic modulus and stiffness [19].

2. EXPERIMENTAL PROGRAMME

2.1 Cement

OPC (43 grade) was added in this research in accordance with BIS: 8112-1989 [20]. Outcomes shown in Table 2.1

Table. 2.1: Physical parameters of OPC

Physical Properties	BIS-8112-1989	Test Result
Soundness	10.0 Max	1.7
Setting time (mins)		
Initial	30 Min.	81
Final	600 Max	492
Specific gravity	_	3.27
Standard Consistency (%)	_	36%
Compressive Strength (N/mm^2)		
3 day	16	12.9
7 day	22	30.2
28 day	33	43.9

2.2 Fine aggregates

As fine aggregates, river sand that was readily accessible in the local area was utilized. It complied with the zone-II requirements of BIS: 383-1970 [21]. It had a specific gravity of 2.66 and a refinement modulus of 2.70, respectively.

2.3 Coarse aggregates

Aggregates with a larger size of 12 millimeters were sourced from the surrounding area. Both its specific gravity and its fineness modulus were measured to be 2.69 and 6.93

2.4 Steel Slag (SS)

A nearby steel and steel rolling factory provided the source for the collection of steel slag. It had the same specific gravity as SS, which was 2.49, and a black color. The following are the findings of the sieve analysis performed on steel slag. The primary components of SS are (Fe_2O_3), (SiO_2), (Al_2O_3), and (CaO).

2.5 Wood Waste Ash (WWA) - wood waste ash collected from different places nearby in Punjab, mainly local wood like shisham, mango tree, wood chips etc. and then they burned and ash collected was used in this study

2.6 Admixture

Polycarboxylic ether polymer including long lateral chains is the basis for this material. Aura-mix 400 is a novel blend of super plasticizer from the most recent generation. It has a bright yellow color, a pH of 6.0, and contain no chloride

3 MIXTURE PROPORTIONS

The selection of the mixing percentage of self-compacting concrete (SCC) was based on a series of experimental experiments. The proportions of the combination are shown in Table 3. The control mixture was formulated with the objective of attaining a CS of 30 MPa after 28-day. In this study, three different proportions of river sand, namely 15%, 30%, and 45%, were substituted with SS. Additionally, WWA was included in combinations at a weight ratio of 15% relative to the cement content. Furthermore, a consistent amount of water was added to all SCC mixtures. In order to make sure the optimal performance of SCC mixes, a super-plasticizer was added at amount of 1.1% relative to mass of cement.

Table: 3.1 Mix proportion of SCC with SS

Mixture ID	SCCSS-0	SCCSS-15	SCCSS-30	SCCSS-45
Cement (kg/m^3)	460	460	460	460
WWA (kg/m^3)	70	70	70	70
Sand (kg/m^3)	950	807.5	665	522.5
SS (kg/m^3)	0	142.5	285	427.5
SS (%)	0	15	30	45
Coarse	800	800	800	800
W/P ratio	0.44	0.44	0.44	0.44
Admixture (%)	1.1	1.1	1.1	1.1

SCCSS-Self-Compacting Concrete Steel Slag

4 TEST PROCEDURES

Prior to the casting procedure, the entire set of test prototypes was evaluated in depth. A roller mixer was utilized to combine concrete components. Immediately following the mixing procedure, the fresh concrete qualities of SCC were conducted slump test, L-box, U-box, and V-funnel experiments in accordance with EFNARC [22] guidelines.

To evaluate compressive strength, water absorption, and sulphate resistance, 15cm x 15cm x 15cm cubic moulds were utilized. 10cm x 20cm cylinders were created for the purpose of evaluating rapid chloride permeability, water absorption, and mass loss. Throughout the curing process, measurements were conducted on all samples at ages 7, 28, and 91 days.

4.1 Compressive Strength (CS)
BIS: 516-1959 [23] standard, evaluation of the CS of concrete samples was conducted after rime span of 28-day, and 91 days.

4.2 Water absorption (WA)
WA test was done in accordance with ASTM C642-97[24], the established standard. The concrete samples were subjected to a dehydrating procedure in an oven at which a specific temperature was kept varying from 100 to 110 degrees Celsius till they got a condition of constant weight. The samples were then submerged in a water tank until the difference in mass between two 24-hour interval measurements of the mass of the surface-dried portions was less than 0.5% of the lowest recorded value. This was performed to assure the accuracy of the results. After the final drying, refrigeration, and mass determination procedures have been completed, the specimen must be submerged in water at approximately 21 degrees Celsius of a minimum of 48 hours. Continue the immersion process until two consecutive mass measurements of the surface-dried sample, taken at 24-hour intervals. After towel-drying the specimen to remove surface moisture, the mass should be estimated. The specimen must first be surface-dried to eliminate any surface moisture.

4.3 Rapid chloride permeability test (RCPT)
RCPT was tested following guidelines published in ASTM C 1202-10[25]. The aim of research is to check the total electric charge, measured in coulombs, that has traversed through a concrete specimen with a thickness of 50mm and a diameter of 100mm during a time period of 6 hours. A direct current potential difference of 60 volts was consistently applied across the terminals of the specimen. The experimental setup included submerging one side of the sample in mix of sodium chloride, while the other end was submerged in mix of sodium hydroxide. The correlation between total charges in coulombs that traversed the samples and their resistance to chloride ion penetration was observed.

4.4 Abrasion Resistance (AR)
AR of concrete was checked using the methodology specified in document number 1237-2012[26] from the Bureau of Indian Standards (BIS). The specimens were weighed precisely using a digital balance with 0.1 g of precision. After the initial dehydrating procedure, the specimens' thickness was measured at five distinct locations, including the center and four extremities. The abrasion-testing machine's disc was uniformly coated with twenty gram layer of aluminum abrasive powder. Specimens were secured within restraining apparatus of the abrasion machine, and a 300 N force was applied. To keep the abrasive powder properly spread down the track, it was repeatedly reintroduced into the grinding process, which corresponds the test specimen's width. The specimens' size and weight were determined through measurements. One way to determine the extent of abrasion was to compare the thickness measurements made before and after the process. Using the prescribed formula, the reduction in thickness of the specimens was further validated by calculating the average loss in size of the samples. $T = \frac{W_1 - W_2}{W_1} \times \frac{V_1}{A}$

5. RESULT AND DISCUSSIONS

5.1 Fresh Concrete Properties
Impacts of incorporating SS into self-compacting concrete (SCC) were evaluated via testing the SCC with different amounts of SS. The characteristics of fresh concrete, including slump flow, V-funnel, U-Box, and L-box, were examined to assess impact of SS as a substitute for cement in the mixture.

Table 5.1 presents the findings pertaining to the fresh characteristics shown by all self-compacting SS concrete. The table presents several attributes, such as slump flow, V-funnel flow rates, L-box, and U-box. The slump flow measurements indicated that all SCC exhibited slump flows within the permitted range of 550–800 mm, demonstrating favorable deformability characteristics.

Table: 5.1: Fresh concrete properties (SS)

	Average value			
	Slump (mm)	**V-funnel (seconds)**	**L-Box**	**U-box(H1-H2)**
SCCSS-0	740	11	.9	29
SCCSS-15	725	12	0.9	31
SCCSS-30	702	12	.85	35
SCCSC-45	635	13	.85	38

According to EFNARC, SCC can be completed in between 6 and 12 seconds. The flow times of the V-funnels ranged from 6 to 13 seconds. The investigation's test results showed that every SCC mix complies with the allowed flow time limits. The last high size of coarse aggregate used in the L-box was kept at 16 mm to avoid a stoping effect. In the L-box test, gap 35 mm between each re-bar. The mixtures' L-box ratio H2/H1 exceeded 0.8, which is acceptable under EFNARC criteria. The concrete's height in both the compartments of the U-box ranged 5 and 40 mm. All of the novel characteristics of concrete values matched those of the values specified by European regulations. Figs. 5.1-5.4 shows the findings of fresh concrete properties.

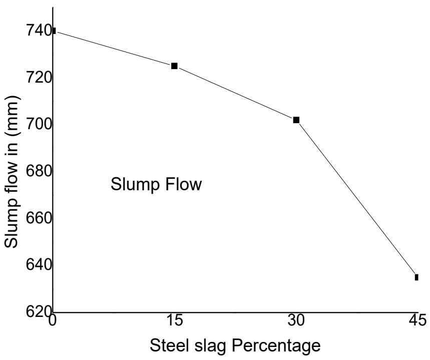

Figure 5.1 The impact of SS on slump values

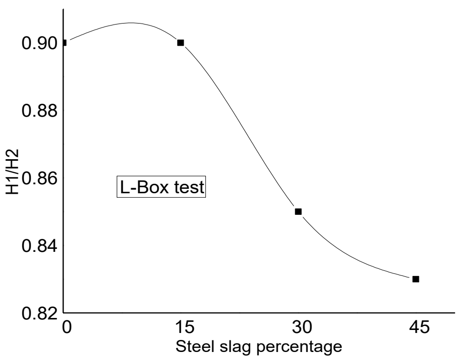

Figure 5.2 The impact of SS on slump values

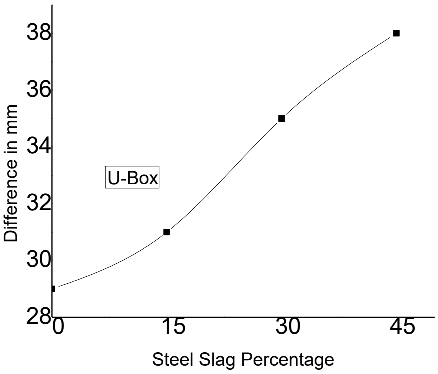

Figure 5.3 The impact of SS on U-box values

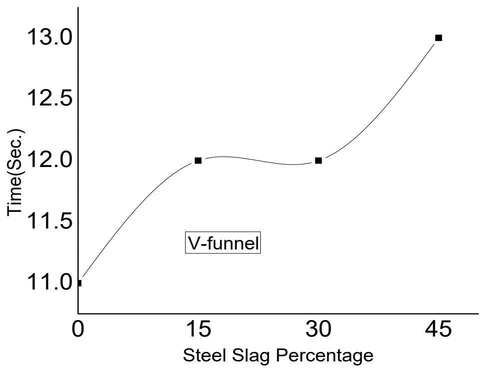

Figure 5.4 The impact of SS on V-funnel values

5.2 Compressive Strength (CS)

Figure 5.5 shows that SS's CS develops similarly to control mixes at all sand replacement levels. The findings demonstrate that SS concrete mixes' CS increases continuously and considerably with curing age. SCC mixes containing 15, 30, and 45% SS fine aggregates improved in CS by 3.1, 7.9, and 15.8%, respectively, during 7 days. 28-day-old SCC mixes containing 15, 30, and 45% SS fine aggregates had 1.1%, 13.1%, and 19.9% higher CS than those without. The CS of 91-day-old SCC mixes containing fine aggregates of 15, 30, and 45% SS improved by 2.1, 10.95%, and 16%, respectively, compared to those without. SCC combinations with SS had higher CS % than control mixes at 28 and 91 days. The reactive silica in SS and cement's alkali calcium hydroxide form calcium silicate and aluminates hydrates over time. Interfacial transition zone gaps are closed, improving CS, via the chemical procedure that creates stable calcium silicate and aluminates hydrates from cement paste and aggregates.

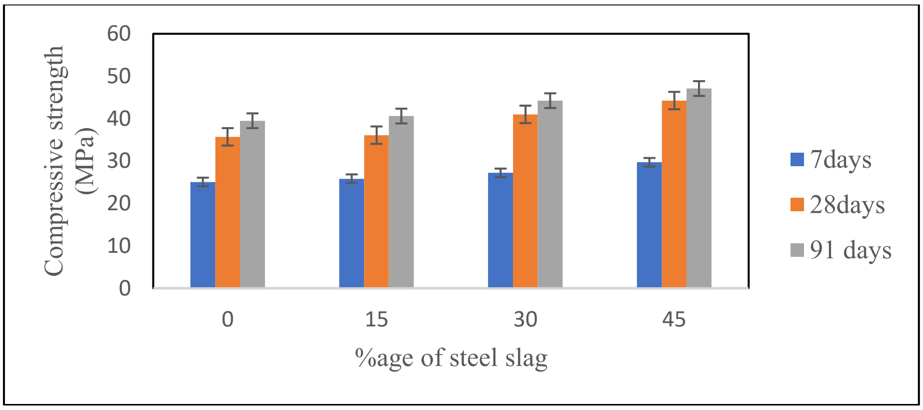

Figure 5.5 Effect of SS on CS

5.3 Water Absorption (WA)

The outcomes of SS in self-compacting concrete mixes for a duration of 365 days are shown in Figure 5.6. The findings from water absorption experiments suggest that the ratio of SS is inversely related to one another and the level of water absorption in all SCC combinations, regardless age of specimens. After a period of 7 days, the SCCSS-0 exhibited a water absorption rate of 5%. At equivalent ages, the water absorption values for self-compacting concrete (SCC) mixes including 15%, 30%, and 45% SS were determined to be 1.1%, 4.3%, and 2.93%, respectively. These values were found to be lower than the water absorption of the SCCSS-0 mixture. Furthermore, it is worth noting that after a period of 28-day, WA of control SCC was measured to be 4.81 percent. However, WA of the SCC samples containing 15, 30, and 45 percent SS exhibited a drop of 1.49, 13.12, and 16.13 percent, respectively. The attainment of self-compacting concrete (SCC) was seen after a curing period of 91 days, using fine aggregates consisting of 15%, 30%, and 45% iron slag. A drop of 0.9%, 4.1%, and 15.3% in water absorption was noted for the self-compacting concrete (SCC) control sample during three time intervals.

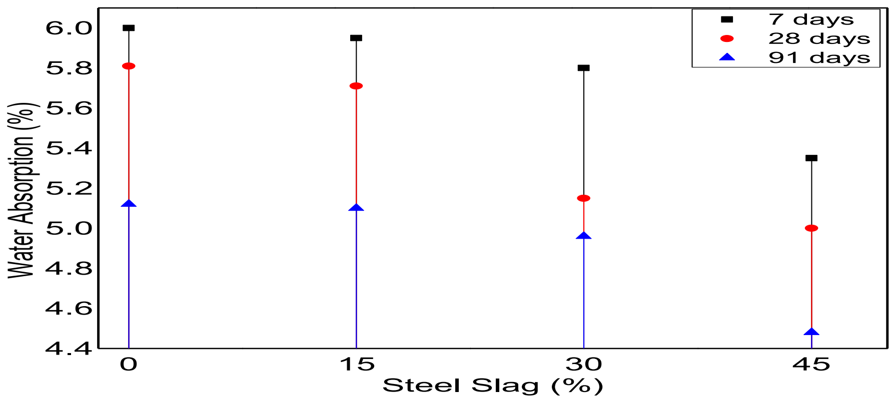

Figure 5.6 Impact of SS on water absorption of SCC

5.4 Sulphate Resistance (SR)

The figures shown in Figure 5.7 and 5.8 depict the outcomes of CS after chemical bath in a solution of magnesium sulphate. Additionally, Figure 5.7 illustrates the percentage reduction in CS subsequent to immersion in a 10% magnesium sulphate solution. The findings indicate that there is a direct relationship between the rise in SS concentration in SCC mixes and the corresponding decrease in CS. However, a little decrease in CS was seen in all self-compacting concrete (SCC) combinations when compared to water-cured mixtures. This drop in CS did not exceed 4% after a period of 7 days. Moreover, when the self-compacting concrete (SCC) specimens with no SS replacement were subjected to immersion in a 10% magnesium sulphate solution for 28-day of curing, a reduction in CS of 7.16% was observed compared to water-cured specimens with the same replacement percentages of 15%, 30%, and 45% of SS in river sand. The CS of the self-compacting concrete (SCC) specimens decreased by 7.05%, 7.37%, and 7.59% correspondingly when they were submerged in a 10% magnesium sulphate solution, in comparison to specimens with the same replacement level that were cured with water. During the 91-day immersion period in a magnesium sulphate solution, a reduction in CS was observed. Specifically, the loss of CS was found to be 15% for specimens with 0% replacement of SS with fine aggregates, 10.27% for specimens with 15% replacement, 10.31% for specimens with 30% replacement, and 10.25% for specimens with 45% replacement. These results were compared to the CS of SCC specimens cured in normal water. The CS of all self-compacting concrete (SCC) combinations, after being submerged in a magnesium sulphate chemical bath for a period of 28 days, exhibited a smaller percentage increase compared to the SCC mixture that was cured in water.

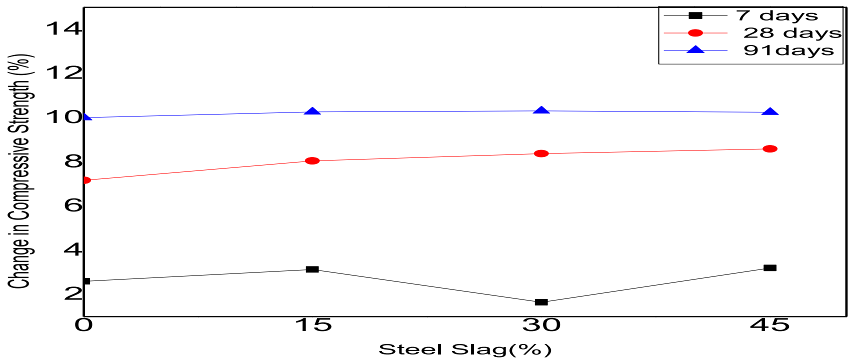

Figure 5.7 Change in the Percentage of Compressive strength due to Mg_2SO_4 immersion

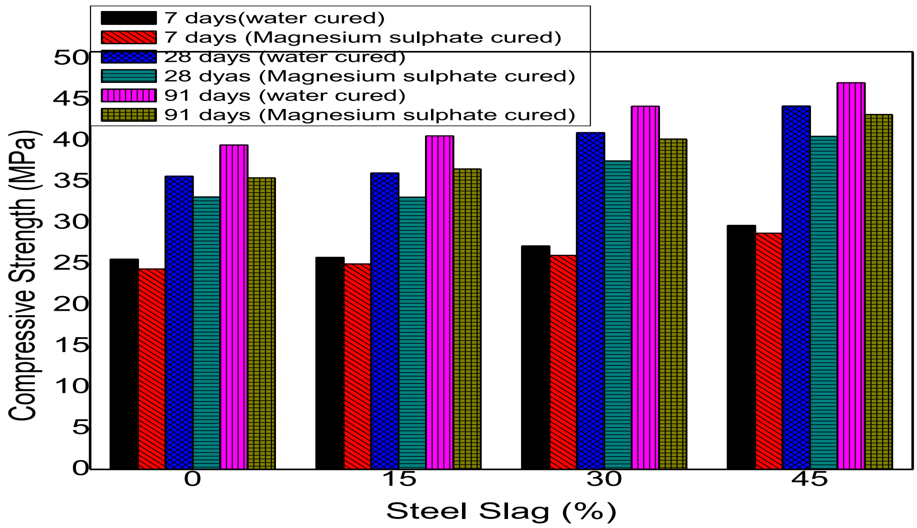

Figure 5.8 Comparing the compressive strength of water-healed SCC mix samples to those treated with 10% magnesium sulphate.

5.5 Rapid Chloride Permeability Test (RCPT)

Table 5.1 and Figure 5.9 and 5.10 indicates the findings of RCPT on SCC with and without SS concentration. It indicates that permeability drops at part replaced of sand with SS and that permeability declines with increasing curing time at all substitution levels. It reveals that the results after 7 days are 1558, 1478, 1445, and 1395 coulombs at 0, 15, 30, and 45% sand replacement with SS, and the results after 28 days are 1321, 1300, 1275, and 1225 coulombs at 0, 15, 30, and 45% sand replacement with SS. Furthermore, after 91 days, values are

1205, 1186, 1103, and 1086 coulombs for SCCSS-0, SCCSS-15, SCCSS-30, and SCCSS-45 sand replacement with SS.

Table. 5.1Charge passed through SCC samples

Mixture ID	Coulombs passed at different ages (days)		
	7	28	91
SCCSS-0	1558	1321	1205
SCCSS-15	1478	1300	1186
SCCSS-30	1445	1275	1103
SCCSS-45	1395	1225	1086

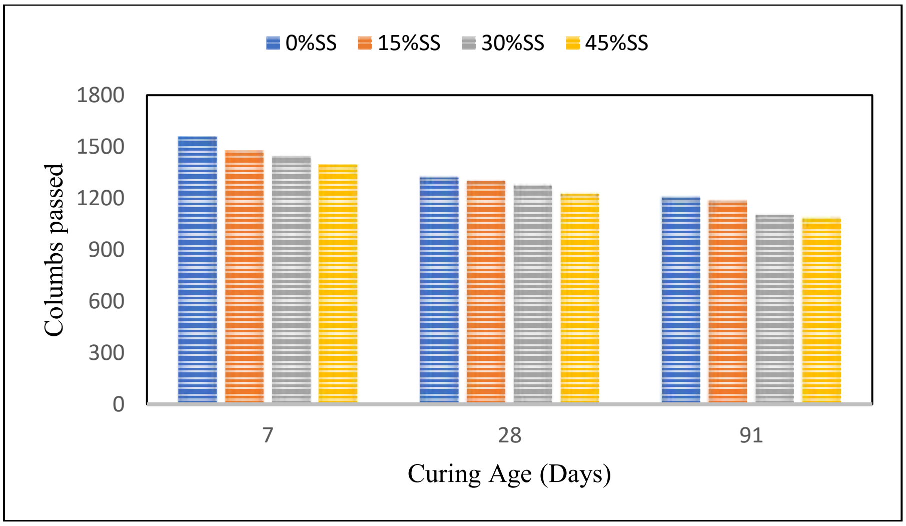

Figure 5.9 Impact of SS on chloride ion penetration in SCC

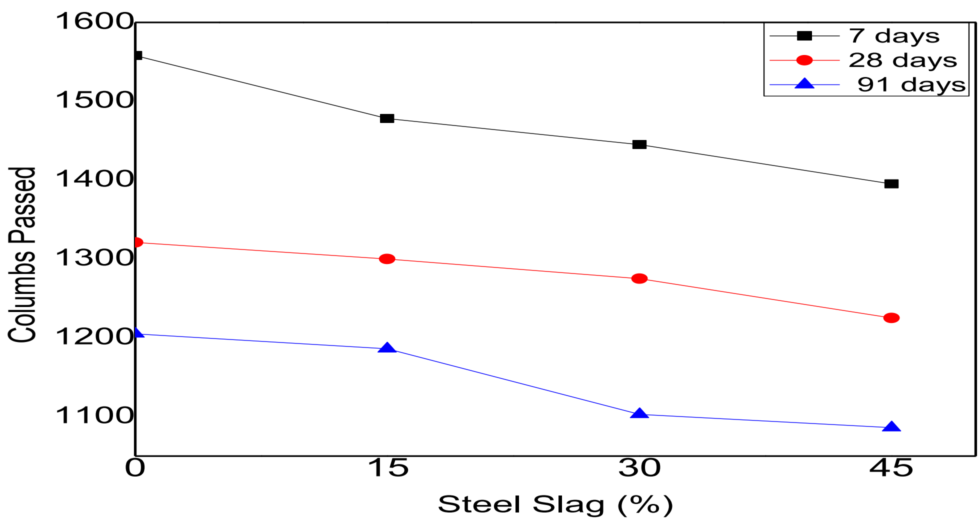

Figure 5.10 Chloride ion penetration of SCC v/s age

5.6 Abrasion Resistance (AR)

External things scrape, rub, wobble, or drag the outermost layer of concrete, causing concrete abrasion. Wear depth quantifies abrasion resistance. Reduced wear depth increases abrasion resistance, whereas increased wear depth decreases it.

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Figures 5.11-5.13 exhibit SS self-compacting concrete (SCC) and SCCSS-0 wear depth test results. The trials showed a favorable link between abrasion time and wear depth. According to the study, the control self-compacting concrete (SCC) combination had a greater mean depth than the mixture with different SS amounts. Wear reduced with SS concentration and time. Time-dependent compaction of the self-consolidating concrete (SCC) matrix may explain the observed reduction in average thickness. The normal rate of wear for samples containing 15%, 30%, and 45% SS was 3.31%, 5.69%, and 12.16% lesser than SCCSS-0 at 0.648 mm after 15 minutes. This discrepancy lasted 7-day. The mean depth of wear at 28 days was 1.09, 10.03, and 13.69% lower than the control self-consolidating concrete (SCC), which had 0.53 mm. After 91 days, self-consolidating concrete (SCC) mixes containing SS had 2.02, 8.17, and 12.65% lower wear depths than the SCCSS-0. Wear depth for the SCCSS-0 was 0.50 mm.

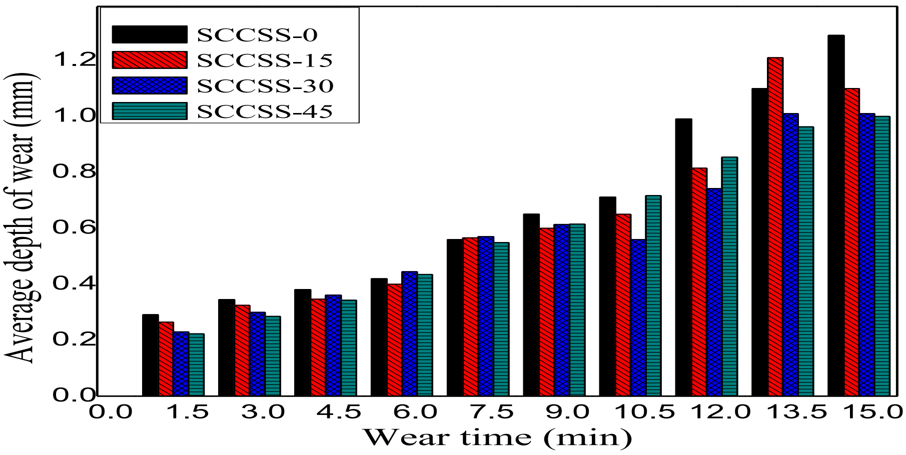

Figure 5.11 Wear depth variation with SS levels in SCC at 7-days curing.

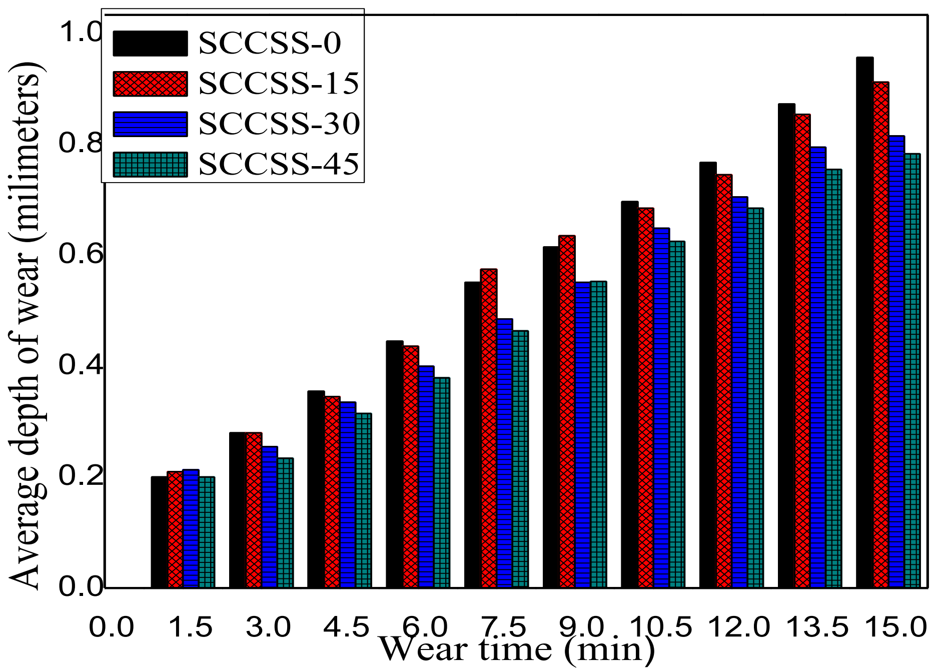

Figure 5.12 Wear depth variation with SS levels in SCC at 28 days curing.

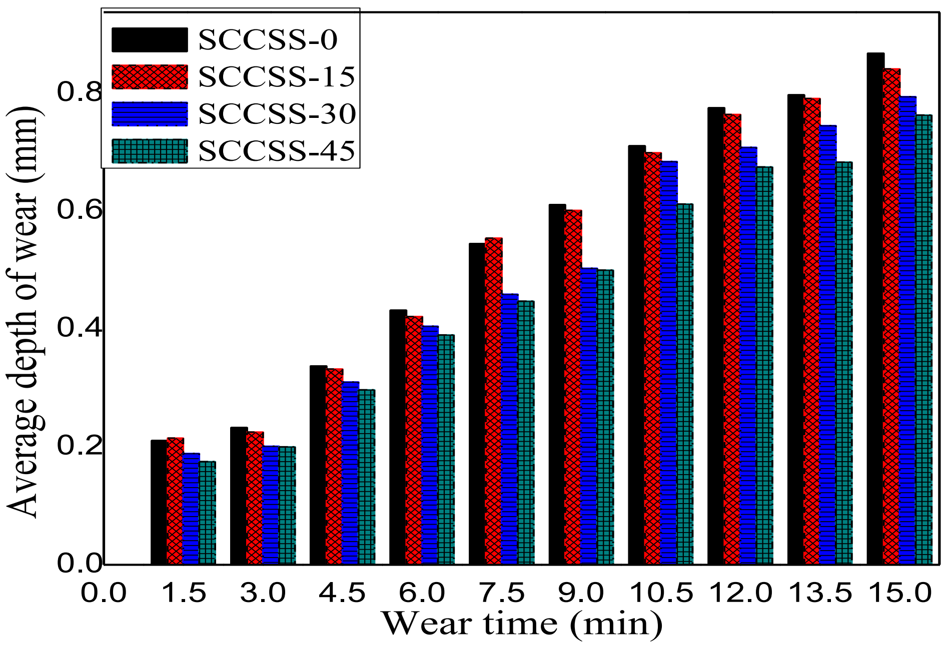

Figure 5.13 Wear depth variation with SS levels in SCC at 91 days curing.

5.7 Statically Analysis of Results

Comparison of the properties of mixtures with regard to their strength and durability (using SPSS)

Mean value of SCC with SCCSS-15, SCCSS-30 and SCCSS-45 was at high side than SCCSS-0 at all parameters and it was seen statistically significant. ($p < 0.05$).

Table 5.2: Comparison of the properties of mixtures with regard to their strength and durability

Mixture ID	Mean±SD	MD±SE	't'- test
CS			
SCCSS-0	36.11±9.16	1.69±0.38	t=4.42,df=3
SCCSS-15,	38.33±9.90		p=.02*
SCCSS-0	36.11±9.16	5.31±1.20	t=4.42,df=3
SCCSS-30	41.95±11.56		p=.02*
SCCSS-0	36.11±9.16	9.28±1.67	t=4.40,df=3
SCCSS-45	45.92±12.45		p=.02*
RCPT			
SCCSS-0	1192.75±265.99	247.73±207.29	t=1.19,df=3
SCCSS-15,	945.02±635.85		p=.31^{NS}
SCCSS-0	1192.75±265.99	77±11.14	t=6.90,df=3
SCCSS-30	1114.65±260.68		p=.00*
SCCSS-0	1193.75±265.99	123.50±27.77	t=4.43,df=3
SCCSS-45	1069.50±229.67		p=.02*
SR			
SCCSS-0	7.60±6.59	0.07±0.39	t=0.19,df=3
SCCSS-15,	7.67±6.31		p=.86^{NS}
SCCSS-0	7.60±6.59	0.01±0.41	t=0.03,df=3

SCCSS-30	7.58±6.45		p=.97[NS]
SCCSS-0	7.60±6.59	0.76±0.51	t=1.49,df=3 p=.23[NS]
SCCSS-45	8.36±7.54		
	Mean±SD	**MD±SE**	**'t'- test**
WA			
SCCSS-0	4.35±0.68	0.08±0.38	t=2.28,df=3 p=.10[NS]
SCCSS-15,	4.27±0.74		
SCCSS-0	4.35±0.68	0.30±0.11	t=2.61,df=3 p=.08[NS]
3SCCSS-0	4.05±0.74		
SCCSS-0	4.35±0.68	0.60±0.09	t=6.34,df=3 p=.00[*]
45%-SS	3.75±0.52		

Comparing the strength and durability of SCC mix is shown in Table 5.2. When compared to SCCSS-15, 3SCCSS-0, and SCCSS-45, the compressive strength of SCCSS-0 was found to be lower on average. The t-test was used to establish the level of static significance (p<.05). Compared to the SCCSS015 value of 945.02, which was lower and not statistically significant (p>.05), the mean SCCSS-0 for fast chloride permeability was 1361.75 at the time. Using the t-test, the mean values of SCCSS-30 and SCCSS-45 were 1114.65 and 1069.50, respectively. These values were statistically significant (p<.05) as slightly lower than the values of SCCSS-0. A mean value of 7.60 was found for 0% sulphate resistance, whereas 15% sulphate resistance, 30% sulphate resistance, and 45% sulphate resistance all had higher mean values (7.67, 7.58, and 8.36, respectively). On the basis of the t-test, the results were showed to be statistically insignificant (p<.05). The water absorption of SCCSS-0 was 4.35, which was higher than the water absorption of SCCSS-15, SCCSS-30, and SCCSS-45, which were respectively 4.27, 4.05, and 3.75. The results exhibit statistical significance with a SCCSS-0 and SCCSS-45 statistical significance level (p<.05).

5.8 Micro-Structure Analysis

Figure 5.14 depicts SCC mix SCCSS-45 replacement at 28 days of age. Clear spread of C-S-H gel and mixture looks denser Fig 5.15 depicts fractures, cavities, and the formation of ettringites, less dense mixture, and embryonic mixture in the absence of SS. In the SE image, tiny pores/voids, CSH gel, and calcium hydroxide plates were observed. Fig 5.16 show SCC mixture with 30% SS at 28-day of curing age, it was found, dissemination of C-S-H gel, tiny cavities and fracture. 28-days old SCC mixture with 15% changes with SS in sand is depicted in Figure 5.17. The image depicts crystals that are well-formed, despite the fact that it is a more developed composite with restricted space. According to these images, the inclusion of SS causes mixture to become denser.

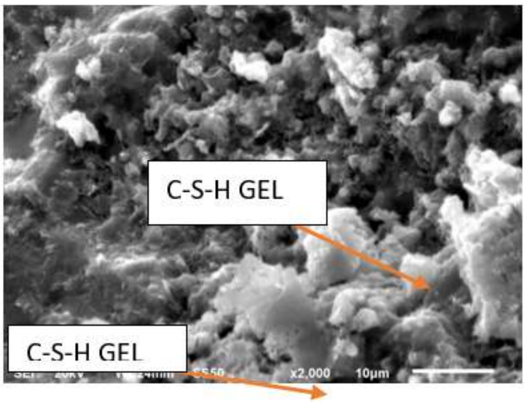

Figure5.14 SEM image of SCCSS-45 at 28 days

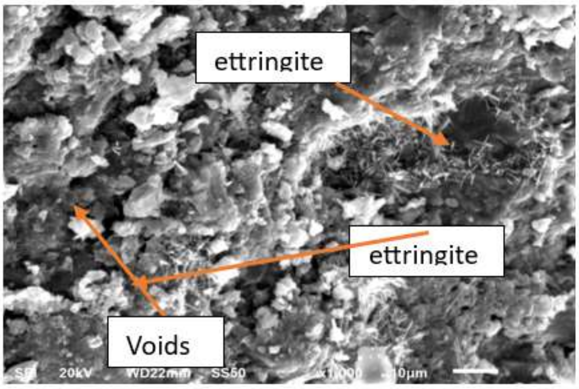

Figure5.15 SEM image of SCCSS-0 at 28 days

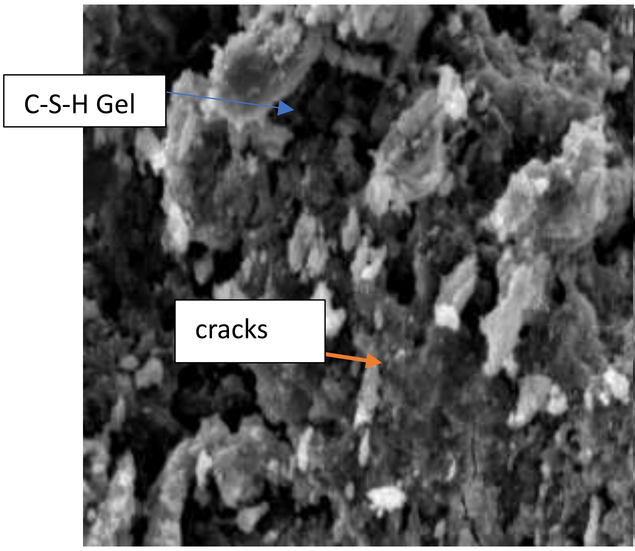

Figure 5.16 SEM image of SCCSS-30 at 28 days

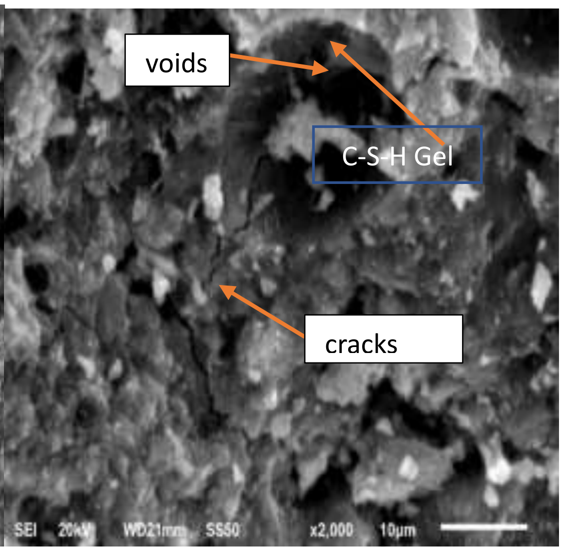

Figure 5.17 SEM image of SCCSS-15 at 28 days

6. FOURIER TRANSFORM INFRARED SPECTROSCOPY

The FTIR analysis of samples SCCSS (0, 15, 30 and 45) revealed distinct absorption bands corresponding to various chemical components. The band at 3339 cm^{-1} represents the O-H stretch of moisture or hydroxides of $Ca(OH)_2$, while the band at 1429 cm^{-1} is attributed to the O-H bending of $Ca(OH)_2$. The 1012 cm^{-1} band is indicative of the Si-O stretch of silica, the 866 cm^{-1} band corresponds to the Al-O stretch of aluminum oxide, and the 773 cm^{-1} band is due to the Fe-O stretch of iron oxide present in the samples (0-45).

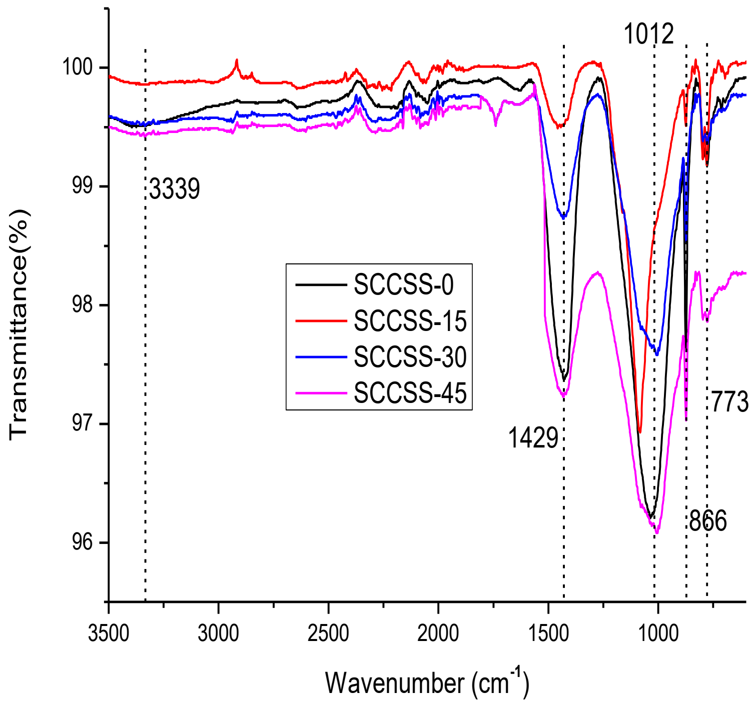

Figure 6.1 Comparison of FTIR peaks at all percentage variation at 28 days (SCCSS-0, 15, 30, 45)

Variations in transmittance across these bands suggest differences in the concentration of these components. By examining the FTIR spectrum, regions of lower transmittance were identified, which correspond to higher absorbance according to the relationship $A = -\log_{10}(T)$. Lower transmittance indicates higher absorbance, meaning more light is absorbed at that wavelength, thus suggesting a higher concentration of the absorbing species. Based on the spectrum, sample SCCSS-45 exhibited the highest concentration of hydroxides (potentially due to $Ca(OH)_2$ or moisture), aluminium oxides, silicon oxides, and iron oxides. Comparatively, the concentration of hydroxides components in sample A was found similar to that in sample SCCSS-30, with sample SCCSS-15 having the least hydroxide content. Specifically, the concentrations of $Ca(OH)_2$, aluminium oxides, silicon oxides, and iron oxides in the samples followed these orders respectively:

- **$Ca(OH)_2$**: SCCSS-45> SCCSS-0 > SCCSS-30 > SCCSS-15
- **Aluminum oxides**: SCCSS-45> SCCSS-0 > SCCSS-30 > SCCSS-15
- **Silicon oxides**: SCCSS-45> SCCSS-0 > SCCSS-30 > SCCSS-15
- **Iron oxides**: SCCSS-45> SCCSS-30 > SCCSS-15 > SCCSS-0

These observations highlight the variations in the chemical composition of the samples, with sample SCCSS-45 having the highest overall concentration of the identified components. This information is valuable for understanding the material properties and potential applications of each sample based on their chemical makeup.

7. CONCLUSIONS

When SS is used as an alternative ingredient in concrete, the newly developed qualities are measured lower than when normal mixture is used. Moreover, the inclusion of SS in the mixture results in a noticeable prolongation of the V-funnel time. The workability of self-consolidating concrete (SCC) mixtures is shown to diminish as the quantity of SS increases, primarily due to the presence of aggregate surfaces that are multi-angle and abrasive in nature. The consequences may emerge due to the interaction between particles.

The CS of SCC combinations with SS is seen to exhibit a 19% increase compared to control samples at the end of 28 days, and a 22% enhancement after 91 days. Improving the characteristics of the interfacial transition zone encompassing aggregates holds promise for augmenting the adhesion between the matrix and particles.

The addition of SS in SCC led to a decline in water absorption when compared with control samples throughout all curing periods.

In the setting of external sulphate attack, the performance of SCC mixtures, when not substituting SS, shown a moderate enhancement. Following a 28-day immersion in magnesium sulphate, the weight loss seen was negligible, but the compressive loss exhibited modest levels. CS of all self-consolidating concrete (SCC) mixtures experienced decrease above 10% after being exposed to a magnesium sulphate solution for a duration of 91-day.

The substitution of SS in conjunction with self-compacting concrete (SCC) demonstrates a notable capacity to impede the ingress of chloride ions. It was found that the total costs of all steel slag mixtures were reduced compared to the control mixtures.

Images obtained using a scanning electron microscope shows the addition of SS causes, matrix of SCC become denser.

REFERENCES

[1] H. Okamura, M. Ouchi, "Self-compacting high performance concrete". Progress in Structural Engineering and Materials, 1(4), 378–383. https://doi.org/10.1002/pse.2260010406.

[2] C.L. Hwang, P. Chang, Y. Peng, Y, "A design consideration for durability of high-performance concrete". Cement and Concrete Composites, 23(4–5), 375–380, 2001. https://doi.org/10.1016/s0958-9465 (00)00089-5.

[3] S. Kou S, K. Poon, "Properties of self-compacting concrete prepared with coarse and fine recycled concrete aggregates". Cement and Concrete Composites, 31(9), 622–627,2009. https://doi.org/10.1016/j .cemconcomp.2009.06.005.

[4] M. Uysal, K. Yilmaz, "Effect of mineral admixtures on properties of self-compacting concrete". Cement and Concrete Composites, 33(7), 771–77, 2011. https://doi.org/10.1016/j.cemconcomp.2011.04.005.

[5] L.Kriskova, Y. Pontikes, Z. Cizer, G. Mertens, W. Veulemans, D. Geysen, P.T. Jones, L. Vandewalle, K. Van Balen, B. Blanpain, "Effect of mechanical activation on the hydraulic properties of stainless steel slags". Cement and Concrete Research, 42(6), 778–788, 2012. https://doi.org/10.1016/j.cemconres.2012.02.016.

[6] C. Lin, H.Y.Wang, "A study of fresh and engineering properties of self-compacting high slag concrete (SCHSC)". Construction and Building Materials, 42, 132–136,2013. https://doi.org/10.1016/ j.conbuildmat.2012.11.020.

[7] V.S Devi, B. Gnanavel, "Properties of Concrete Manufactured Using Steel Slag". Procedia Engineering, 97, 95–104,2014. https://doi.org/10.1016/j.proeng.2014.12.229.

[8] B. Venkatesan, V. Lijina, V. Kannan, P. Dhevasenaa, "Partial replacement of fine aggregate by steel slag and coarse aggregate by walnut shell in concrete". Materials Today: Proceedings, 37, 1761–1766, 2021. https://doi.org/10.1016/j.matpr.2020.07.361.

[9] C.R Sharma, “Study of Characteristic Strength of M30 Grade of Concrete by Partial Replacement of Sand with Steel Slag”. International Journal of Innovative Research in Science, Engineering and Technology, 4(8), 6868–6874, 2015. https://doi.org/10.15680/ijirset.2015.0408023.
[10] T. Subramani, G. Ravi G, Experimental investigation of coarse aggregate with steel slag in concrete. IOSR J. Eng.5 (64-73), 2015.
[11] H. Owaid, M. Al-Rubaye, H. Al-Baghdadi, “Use of waste paper ash or wood ash as substitution to fly ash in production of geopolymer concrete”. Scientific Review Engineering and Environmental Sciences, 30(3), 2021. https://doi.org/10.22630/PNIKS.2021.30.3.39.
[12] V. Kannan, P. Raja, “Evaluation of the permeability of high strength concrete using metakaolin and wood ash as partial replacement for cement”. SN Applied Sciences, 3(1), 2021. https://doi.org/10.1007/s42452-020-04024-y.
[13] S. Umesha, P. Asha,”Behaviour of steel fibre reinforced concrete with wood ash as partial replacement”. IOP Conference Series: Earth and Environmental Science, 822(1), 2021. https://doi.org/10.1088/1755-1315/822/1/012053.
[14] K.Vijay, B. Hari, I. Vidya, “Effect of wood-ash as partial replacement to cement on performance of concrete”. IOP Conference Series: Earth and Environmental Science, 796(1), 2021. https://doi.org/10.1088/1755-1315/796/1/012020.
[15] M. Danraka F.Aziz, M. Jaafar, N. Nasir, S. Abdulrashid, “Application of wood waste ash in concrete making: Revisited”. Lecture Notes in Civil Engineering, 9, 69-78, 2019. https://doi.org/10.1007/978-981-10-8016-6_7.
[16] Qasrawi H, Shalabi F, Asi I (2009) Use of low CaO unprocessed steel slag in concrete as fine aggregate. Construction and Building Materials, 23(2), 1118–1125. https://doi.org/10.1016/j.conbuildmat. 2008.06.003.
[17] M. Maslehuddin, A.M. Sharif, M. Shameem, M. Ibrahim, M. Barry, “Comparison of properties of steel slag and crushed limestone aggregate concretes”. Construction and Building Materials, 17(2), 105–112, 2003. https://doi.org/10.1016/s0950-0618(02)00095-8.
[18] J.T. San-José, I.Vegas, I. Arribas, I.Marcos, “The performance of steel-making slag concretes in the hardened state”. Materials & Design, 60, 612–619, 2014. https://doi.org/10.1016/j.matdes.2014.04.030.
[19] Y. Guo, J. Xie, W. Zheng, J. Li, “Effects of steel slag as fine aggregate on static and impact behaviours of concrete”. Construction and Building Materials, 192, 194–201, 2018. https://doi.org/10.1016 /j.conbuildmat.2018.10.129
[20] BIS: 8112-1989, Indian standard 43 grade OPC specifications, New Delhi, India: Bureau of Indian standards; 1989.
[21] IS: 383-1970, Indian standard specifications for coarse and fine aggregates from natural sources for concrete New Delhi, India: Bureau of Indian standards; 1970.
[22] EFNARC, European guidelines for self-compacting concrete: specification, production and use. Self- compacting concrete European project group; 2005.
[23] BIS: 516-1959, Indian standard method of test for strength of concrete, New Delhi, India: Bureau of Indian standards; 1959.
[24] ASTM C 642-06. Standard test methods for density, absorption and voids in hardened concrete. West Conshohocken, USA: ASTM International.
[25] ASTM C 1202-10. Standard test methods for electrical indications of concrete’s ability to resist chloride ion penetration. West Conshohocken, USA: ASTM International.
[26] BIS: 1237-1980, Method for testing abrasion resistance of concrete, New Delhi, India: Bureau of Indian standards; 1980.