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Devolopment of Self -Compacting Concrete Using Sewage Sludge Ash and Cotton Stalk Ash

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Abstract : This paper aims to evaluate the effect of sewage sludge ash (SSA) and cotton stalk Ash (CSA) as a replacement ratio by weight of cement content on self-compacting concrete (SCC). SSA and CSA were seperately used as a partial replacement of cement in concrete mixes. The produced concrete mixes were experimentally tested via various mechanical and physical tests such as compressive strength, water absorption etc. SSA and CSA were sieved through sieve size of 90µm, and added to the concrete mixes with 5,10and 15% as cement replacement of cement content. 2% of a superplasticizer and 1% of viscosity modifying agent was added to the concrete mixes. The concrete mixes containing 5 and 10% of CSA and 2.5 and 5% of SSA as cement replacement showed increments in compressive strength compared to control mix at the age of 28 days. The increments were 4.29, 10.05% and 0.55, 5.36% for CSA and SSA mixes, respectively. Water absorption of SSA and CSA concrete samples also showed a decrease in water absorption percentage compared to control concrete samples. Therefore, SSA and CSA were found to have the potential to be used as partial cement replacement in making SCC, which leads to impact on solid waste management in landfill process.

***Keywords* : Self-compacting concrete(SCC), Sewage sludge ash(SSA) , Cotton stalk ash(CSA).**

I. INTRODUCTION

In recent years, environmental-friendly concrete has drawn serious attention from researchers to reduce pollution. OPC is responsible for concrete bond and strength. The cement is negatively affected by exposure to severe environments. Moreover, cement manufacturing emits massive quantities of carbon dioxide. In recent, the sewage sludge has been used to produce cement in the concrete production in raw or dried form. Studies on sewage sludge and their results emphasizes the dependence of the end product on the sludge properties. This paper gives effect of SSA and CSA on the mechanical, physical, durability and microstructural properties of SCC as a partial replacement of cement by weight.


cement


Coarse aggregate


Fine aggregate


Sewage sludge ash


cotton stalk ash

Table Chemical composition of cement, sewage sludge ash and cotton stalk ash

Chemical composition	Cement (%)	SSA (%)	CSA (%)
SiO_2	21.3	25.2	30
Al_2O_3	3.8	9.67	-
Fe_2O_3	2.7	6.2	0.2
CaO	62	23.5	30.8
K_2O	0.7	1.2	37
MgO	3.9	7	0.3
P_2O_5	-	21.3	-
Others	5.6	5.6	1.7

Table- Physical properties of Sewage sludge ash and Cotton stalk ash

S.no	Properties	SSA	CSA
1	Specific gravity	2.45	2.79
2	Color	Dark gray	White gray

II. MATERIALS AND METHODOLOGY

2.1 Materials

In this study, OPC 53 grade is used. SSA incinerated at 600 C for two hours was used as supplementary cementing material and CSA are placed in a 700° C furnace for two hours (28). After heating, ashes are cooled in free space at room temperature for 30min. Then the ashes are ground and sieved using sieve analysis; the particles passed from a 90μm sieve. Fig illustrates the visual inspection of SSA and CSA. The physical properties, which are tested by SEM analysis, reveal that SSA and CSA are microporous and irregular as shown. The chemical composition of SSA and CSA are detected by X-ray diffraction (XRD) as shown in tables. Dune sand with fineness modulus of and specific gravity of . And coarse aggregates with fineness modulus of and specific gravity of are used. Superplasticizer and viscosity modifying admixture (VMA) are used to enhance the mixtures flowability and viscosity, respectively.

2.2 Methodology

Table shows the mix proportion of concrete. Many trial mixes have been conducted in the laboratory to determine the limits of material content to achieve SCC. SSA and CSA are then used as a partial replacement of cement with various percentages to investigate the effects on SCC. The following seven SCC mixes are prepared : control mixture, four mixes containing SSA with the varying percentages of 2.5%, 5%, 7.5% and 10% and three mixes containing CSA with varying percentages of 5%, 10% and 15% as the partial replacement for cement content. Parameters that remained constant are as follows: the ratio of fine to coarse aggregates as, SP and VMA content as 2% and 1% of cement content, respectively. The mixing steps are as follows. Firstly, fine and coarse aggregates are mixed for 2 min. Then cement is added to the dry mixture and mixed for approximately 1 min. The dry mix is mixed using superplasticiser and 60% of water for 3 min. Finally, the mixture is mixed for 5 min using the residual water.

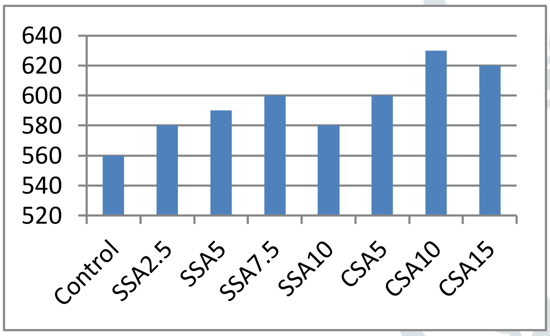
Mix	Cement (kg/m^3)	SSA (kg/m^3)	CSA (kg/m^3)	Water (kg/m^3)	Coarse aggregate (kg/m^3)	Fine Aggregate (kg/m^3)	Superplasticizer (kg/m^3)	Viscosity modifying agent (kg/m^3)
Control	438.13	-	-	174.16	908.6	898.86	8.762	4.381
SSA2.5	427.18	10.95	-	174.16	908.6	898.86	8.543	4.271
SSA5	416.23	21.90	-	174.16	908.6	898.86	8.324	4.162
SSA7.5	405.28	32.85	-	174.16	908.6	898.86	8.105	4.052
SSA10	396.13	43.81	-	174.16	908.6	898.86	7.926	3.961
CSA5	416.23	-	21.9	174.16	908.6	898.86	8.324	4.162
CSA10	396.13	-	43.81	174.16	908.6	898.86	7.926	3.961
CSA15	372.43	-	65.70	174.16	908.6	898.86	7.448	3.721

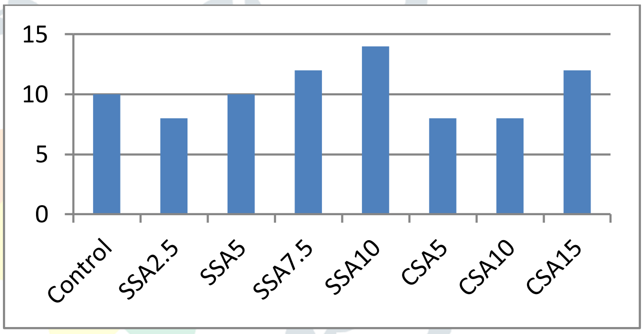
2.3 Testing procedure

Fig. shows fresh concrete properties of SCC, slump flow, T50 and V-funnel tests (for filling capability), L-box (for passing capability) and U-Box test (for segregation resistance). All these tests are performed according tothe EFNARC (2002) [34].

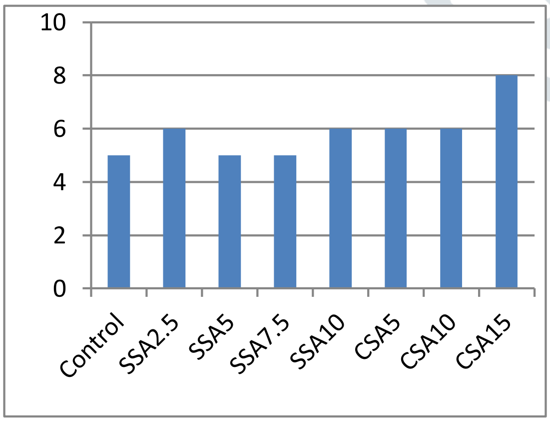
Hardened concrete properties of SCC are measured in test samples by compression test at 3, 7 and 28 days using 100×100×100 mm cubes. Splitting tensile test is performed on 150×300 mm cylinder on the 28th day. Moreover, the flexural strength test is performed on concrete beams with dimensions of 100×100×500 mm on the 28th day. The tests are conducted according to the European Standard EN 2390-3[35] and ECP 203–2016. The microstructure of SCC specimens is obtained using SEM analysis. The EDX is used as an additional tool for the semi-quantitative analysis. The results obtained from EDX analysis are the atomic percentage of each element.

Test	Control	SSA2.5	SSA5	SSA7.5	SSA10	CSA5	CSA10	CSA15
Slump flow(mm)	560	580	590	600	580	600	630	620
V-funnel	10	8	10	12	14	8	8	12
T50	5	6	5	5	6	6	6	8
L-Box	0.81	0.84	0.84	0.83	0.81	0.86	0.88	0.85
U-Box	1	1	1	0.95	0.95	1	1	1

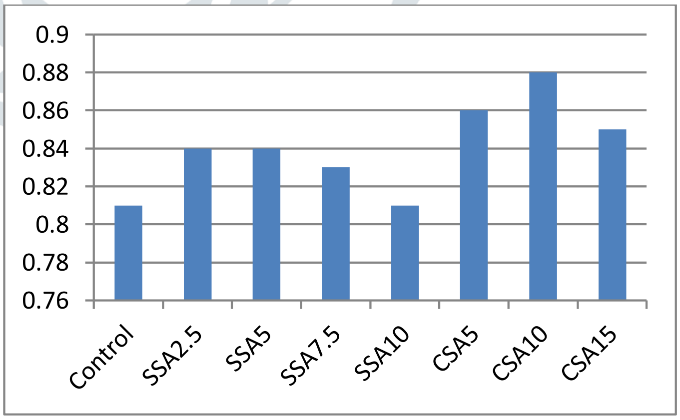




Slump flow results for all mixes V-funnel flow time results for all mixes



T50 cm results for all mixes



L-Box results for all mixtures

IV. RESULTS AND DISCUSSION

4.1 Fresh properties of SCC

Table shows the results for the fresh properties of SCC. Slump flow, T_{50} and V-funnel tests of SCC mixes. Figs. 7–9 show the slump flow, T50 and V-funnel findings for the SCC mix, respectively. Slump flow is from 750 mm to 600 mm. The T50 results of the mixes are confined in the range of 3–7 s. The V-funnel results are in the range of 7.3–14.4 s. A comparison with the control mix shows that filling capability is decreased when SSA and CSA are used as the replacement ratios for cement content. The low workability is probably due to the appearance of high specific surface areas, which are about six times of those in the cement mix and the mixes with irregular shapes, as shown in Fig. Moreover, when SSA and CSA contents are increased, the specific surface area and the volume fraction of the binder are also increased because of the high surface area and the large amount of adsorbed water, and the quantity of free water in the mortar is decreased. Additional water content is therefore utilised to achieve an acceptable filling capability of SCC.

show the passing capability results of SCC mixes for L-box. The use of SSA and CSA in SCC reduces the passing capability in contrast with that in the control mixture. The L-box results obtained from (h2/h1) ratios start from 0.95 to 0.80 for 5% to 20% of SSA, respectively. The L-box results of SCC mixes agree with EFNARC.

4.2 Hardened properties of SCC

The hardened propertied of SCC results are studied. Table 6 shows the results obtained from experimental tests, such as unit weight and compressive, tensile and flexural strengths

Compressive strength

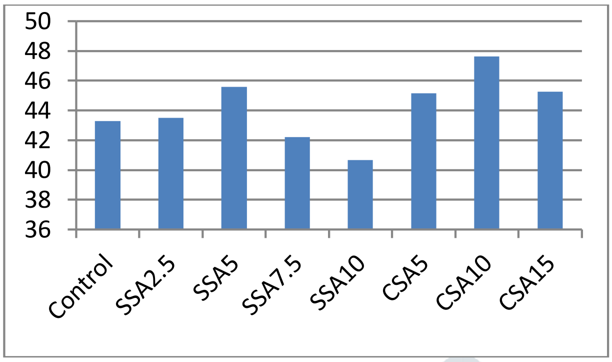
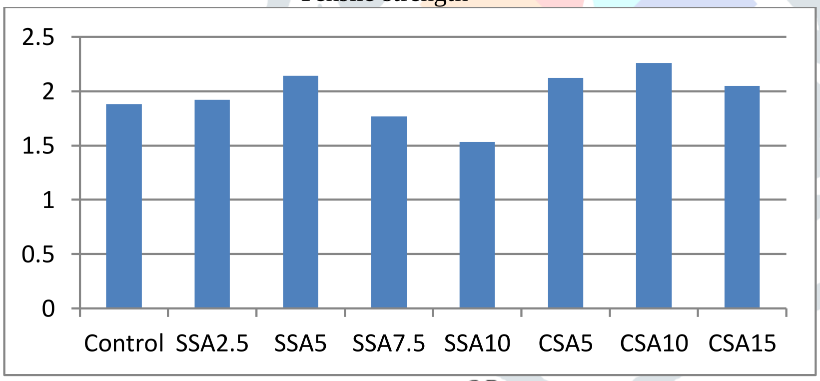


Fig. demonstrates the compressive strength of the SCC mixtures on the 28th day. The use of SSA and CSA as replacements for cement content has a positive effect on compressive strength, especially at the 5% and 10% replacement ratios respectively. The increment ratios in this study are 3.5%, 10% and 14% for the mixes with M-5 SSA, M-5 CSA and M-10 CSA, respectively. The increase in compressive strength of these three mixes may be due to the pozzolanic activity and the microfilling abilities of SSA and CSA. The reduced compressive strength of the M-10 SSA specimen is most likely caused by the extremely high content of available silica reacting with all the produced calcium hydroxide in the hydrated cement. Moreover, calcium dioxide (CaO) percentage, besides SiO2percentage, is a dominant factor of strength development in pozzolanic materials, and it is needed for the completion of pozzolanic reactivity. SSA has a lower amount of CaO (23.5%) than CSA (30.8%) Subsequently, the mixes with CSA have higher strength than those with SSA.

Tensile strength



The load is applied on Split tensile strength (N/mm^2) = $\frac{2P}{\pi LD}$

Where, P is the compressive load on the cylinder in N

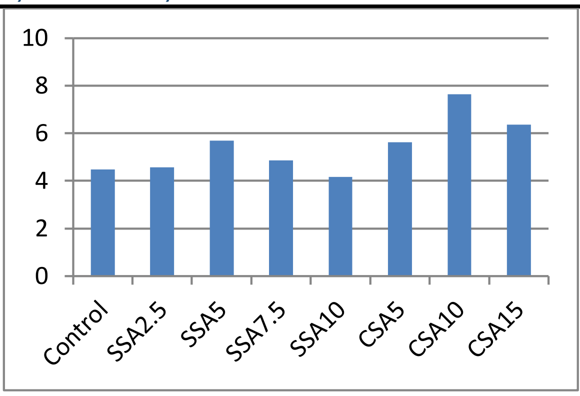
L is the length of the cylinder in mm =300 mm

d is diameter of the cylinder in mm = 150mm

cylinder and the load at failure of cylinder is noted.

The tensile strength of the mixes is in the range of 2.8–3.7 N/mm2 . SCCs with 5%–10% sewage sludge ash(SSA) for the partial replacement of cement were reported previously as satisfactory, i.e. SSA does not significantly change the splitting tensile strength of SCCs. The 5% SSA mix has the highest tensile strength amongst all the mixes and is 13% higher compared with the tensile strength of plain concrete. Meanwhile, the 10% CSA mix has the best ratio in terms of increase in tensile strength. Fig. shows the tensile strength values and the tensile strength to compressive strength ratios derived by this study. The tensile–compressive strength ratios are 12%, 12% and 11% for the M-5, M-10 and M-15 CSA mixes, respectively. The increased tensile–compressive strength ratios can be explained by the lower ratio of potassium oxide K_2O in the CSA mix compared with those in the SSA mix.

Flexural strength



Flexural strength (N/mm^2) = $\frac{Pl}{bd*d}$ (when **a** > 13.33cm for 10cm specimen) or

Flexural strength(N/mm^2) = $\frac{3Pa}{bd*d}$ (when **a** < 13.33 cm but > 11.0cm for 10.0cm specimen) Where as
b is the width of the specimen.
d is the depth of the specimen.
l is the supported length. P P is the maximum load at the fracture point
a is the distance between nearest support at the line of fracture

Fig. shows the flexural strength values and the flexural strength to compressive strength ratios derived in this study. A comparison with the control mix indicates an increase in flexural strength by 15%, 22% and 17% for the M-5, M-10 and M-15 CSA mixes, respectively. Moreover, flexural strength is increased by 15% for the mix with M-5 SSA relative to the control. The flexural–compressive ratios are generally confined between 16% and 21%.

Water absorption

In order to classify the SCC by relative porosity or permeability characteristics, the water absorption studies have been done. The results of the study are given Table. From the recommendation given by the Concrete Society Board (CEB-FIP 1989) it can be noted that all SCC specimens are in average of concrete quality as well as absorption rating.

Sample	Absorption	Absorption rating	Concrete quality
Control	3.95	Average	Average
SSA5	4.67	Average	Average
CSA10	4.24	Average	Average

III. Acknowledgment

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