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Effect of Sulphate and Acid on Self-Compacting Concrete Containing Corn Cob Ash

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Effect of Sulphate and Acid on Self-Compacting Concrete Containing Corn Cob Ash

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Abstract. Self-compacting concrete requires high powder content which implies increased cost and increased CO_2 emission into the environment; hence, the need for the inculcation of a supplementary cementitious material (SCM) to the concrete mix such as corn cob ash (CCA) which is obtained by drying, grinding and burning the corn cobs. The chemical composition of the corn cob ash showed that it was pozzolanic as it conformed to the requirements stated in ASTM C618. Replacement of cement with CCA was carried out at levels of 0% (control), 5%, 10%, 15% and 20% and workability test was conducted at each replacement levels. The curing of the cubes was conducted for 7, 14 and 28 days in 3 mediums; water, hydrochloric acid (HCl) and magnesium sulphate ($MgSo_4$). The cubes were weighed and crushed from which it was observed that 5% replacement showed better compressive strength, proving to be the optimum result. Results from 15% and above were unable to attain close enough values to the required strength but showed better resistance when submerged in the sulphate and acid solution. It was also observed that increasing CCA content, reduced the strength deterioration factor (SDF) of the concrete, indicating improved durability and the possible use of CCA for partial replacement of cement in SCC. However, replacement levels from 15% and above require longer curing period to attain better strengths as increase in CCA levels decreases the compressive strength of the concrete.
Keywords: Self Compacting Concrete, Corn Cob Ash, Hardened Concrete, Fresh Concrete, Strength

1. Introduction

Self-compacting concrete was developed as a result of the reduction of skilled labor in japan. It was developed in the 1988 to solve the problem of the decline in available work force in the construction industry [1]. The characteristics of self-compacting concrete are affected by the aggregate content, the ratio of water to binder content, and the introduction of superplasticizers [2]. The use of SCC is however limited due to the high cost of this material. This high cost is as a result of the incorporation of increased powder content. The high cost of this powder content (cement) can be diminished by replacing cement with mineral admixtures [3].

Admixtures generally, control setting and hardening properties of concrete, improve the workability and provide extra cementing properties [4]. The introduction of pozzolanic waste ash in the production of concrete improves the properties of the concrete in its fresh and hardened state [5] and also helps to reduce the negative implications of waste in the environment and improve the productivity of such products. Corn cob is an agricultural waste product that is derived from maze or corn [6]. It is the core of the corn to which the kennels are. Corn cob ash (CCA) is obtained from drying the cob of the corn. Grinding it and burning the ash obtained is used as cement replacement [7].

Concrete is susceptible to attacks due to the environment. Hence it is of great importance to determine the effect of SCC to chloride, sulfate and other chemicals on the durability properties of concrete. These substances come in contact with the concrete through waste products mostly from industrial effluents. Concrete strength can be affected and drastically reduced when it comes into contact with such Chloride, sulphate and other chemicals; hence the need to determine its resistant capacity to such harmful substances.

2. Materials and Methods

2.1 Cement

The cement used for this research work is Dangote brand of cement.

2.2 Coarse Aggregates

The coarse aggregate used was granite having a particle size of 20mm.

2.3 Fine Aggregates

Sharp sand was used. It was air dried for 72 hours in other to reduce the moisture present in it. The sand was also clean and sharp, free from clay, loam, dirt or organic matters and conforms to the requirement of BS EN 12620 (2008).

2.4 Superplasticizer

The super plasticizer used is CONPLAST SP430. It is a brown viscous fluid which spreads out evenly when added in water.

2.5 Water

Tap water from the department of civil engineering's laboratory, Covenant University, Ota, Ogun state was utilized for mixing and curing of the concrete

2.6 Corn Cob Ash

The corn cob used for this experiment was gotten from a farm in Oyo state, Nigeria. The Corn Cob Ash was obtained from the burning of the corn cobs. The cobs were dried and broken down to smaller pieces and burned using open air burning. The ash resulting from the combustion was passed through a number 200 sieves and used in the experiment. The Corn Cob ash was examined using an x-ray fluorescence (XRF) test to determine the oxide composition of the ash.

2.7 Mix proportion

The concrete was mixed with 0% CCA, 5% CCA, 10% CCA, 15% CCA, and 20% CCA replacement levels. The Table 1 presents the mix proportion for the SCC. The superplasticizer percent was increased from 1% to 1.5% to improve the workability of the SCC + CCA concrete as a result of the high absorbency of CCA.

Table 1 Mix proportion for self-compacting concrete

MIX/MATERIALS	CEMENT (Kg)	CORN COB ASH (Kg)	FINE AGGREGATES (Kg)	COARSE AGGREGATES (Kg)	WATER-CEMENT RATIO (%)	SUPERPLASTICIZER (%)
SCC	484.38	0.00	843.75	796.88	0.4	1.00
SCC + CCA 5%	460.16	24.22	843.75	796.88	0.4	1.5
SCC + CCA 10%	435.94	48.44	843.75	796.88	0.4	1.5
SCC + CCA 15%	411.72	72.66	843.75	796.88	0.4	1.5
SCC + CCA 20%	387.50	96.88	843.75	796.88	0.4	1.5

L- box test, V-funnel test and slump flow test was conducted on the freshly mixed concrete to determine the passing ability, filling and flow abilities of the freshly mixed concrete in accordance to the [8] specifications.

The fresh concrete was poured into a mold of 150mm × 150mm × 150 mm and allowed to harden for 24 hours. After the cubes had become hardened, they were taken out of the mold and placed in 3 different solutions; water, 5% HCl acid solution and 3% $MgSO_4$. The cubes were immersed for the duration of 7 days, 14 days and 28 days. The cubes were taken out after the durations in which they were immersed in the solutions, they were weighed and compressive strength test was conducted.

3. Results

3.1 Chemical composition of the corn cob ash

The determination of the chemical composition of the CCA by using an X-ray fluorescence (XRF) machine is presented in the Table 2.

Table 2 Chemical composition of corn cob ash

Oxide	Percentage Composition (%)
Silicon dioxide (SiO_2)	59.54
Aluminium Oxide (Al_2O_2)	6.53
Ferrric Oxide (Fe_2O_3)	4.93
Calcium Oxide (CaO)	5.96
Magnesium Oxide (MgO)	2.32
Potassium Oxide (K_2O)	6.67
Sodium Oxide (Na_2O)	0.43
Sulphur trioxide (SO_3)	1.04
Loss on Ignition (LOI)	9.37

3.1 Fresh properties results

The results for the different test carried out on the fresh SCC is as related in the Table 3.

Table 3. Workability test results for SCC

Mix	Slump (mm)	Blocking ratio (H2/H1)	V-funnel (sec)
SCC (Control)	612.50	0.89	4.41
SCC + CCA 5%	588.50	0.87	4.97
SCC + CCA 10%	552.50	0.78	5.64
SCC + CCA 15%	537.00	0.7	6.13
SCC + CCA 20%	519.50	0.63	7.76

According to the EFNARC standard for SCC slump flow test, all mixes fall within the range of acceptable values with the exception of SCC + CCA 15% and 20%. It can be seen that increased percentage of CCA content, led to a reduction in workability of the SCC fresh concrete.

The results show decreasing blocking ratio with increasing CCA replacement levels. According to the EFNARC recommended standard, only 5% replacement satisfied the limits ($H_2/H_1 \geq 0.8$). This indicates that increasing percent replacement levels reduced the passing ability of the fresh concrete and thus indicating decreased workability. However, according to [9], blocking ratios falling within the range of 0.6-1.0 is acceptable to attain filling abilities that are satisfactory. Hence, it can be said that all replacement levels showed satisfactory results based on the above stated conditions. The results above show increasing flow time with increasing percent replacement levels of CCA. All replacement levels can be seen to fall

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within the recommended EFNARC standards and all fall into the category VF1 (≤ 8sec). Hence, they all satisfy the v-funnel requirements.

3.2 Compressive strength

The findings from the compressive strength test performed on the hardened concrete is presented in Figure 1.

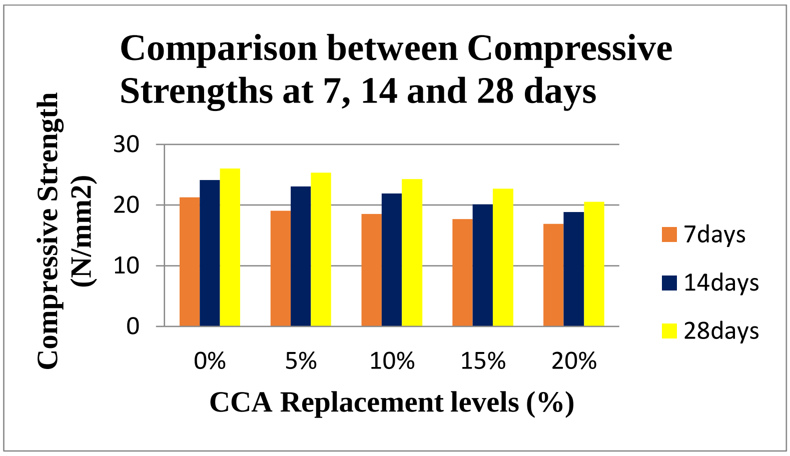

Fig. 1 Comparison between compressive strengths at 7, 14 and 28 days

Replacements levels up to 10% showed strengths very close to the targeted class at 28 days (M 25 and M30). However, all replacement levels attained good strength levels. In contrast to rice husk ash (RHA), increase levels of CCA replacement led to decreased compressive strengths but increased with increasing curing duration. Whereas [3] recorded increased strengths with increasing levels of RHA. Optimum levels were established at 5% for replacement with CCA. Previous literatures inculcated corn cob ash in ordinary concrete. [10] recorded optimum compressive strength at 5% replacement for 28 days attaining a strength of 21.44N/mm^2. [11] also recorded optimum results at 7.5% replacement. It was observed that increasing curing days increased the compressive strength of the corn cob ash concrete.

3.3 Cubes immersed in HCl solution

The Figure 2 and the Figure. 3 present the loss in weight of SCC and the comparison between SDF for the selected days of curing respectively.

Csw – Compressive strength in water

Csa – Compressive strength in acid

$$\text{SDF}(\%) = \frac{\text{Csw} - \text{Csa}}{\text{Csw}} \times 100$$

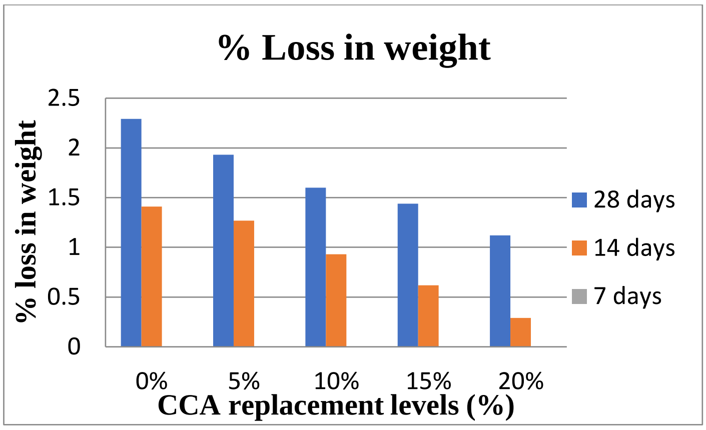

Fig. 2 loss of weight of cubes immersed in HCl solution

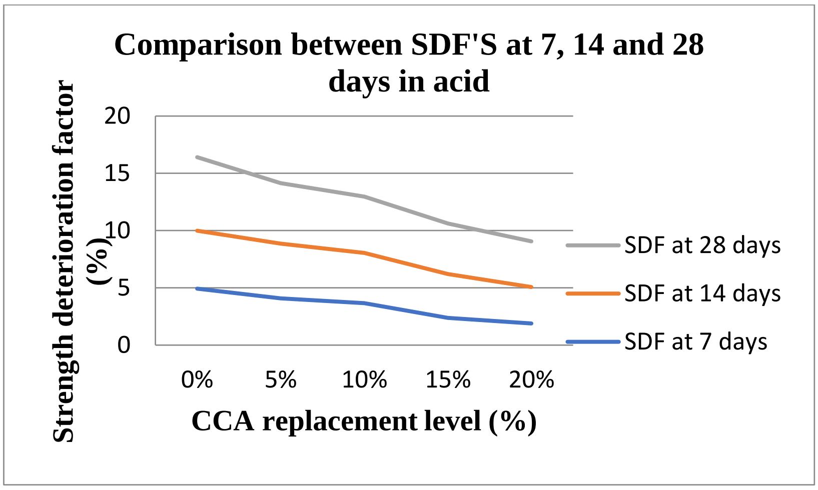

Fig. 3 Comparison between SDF at 7, 14 and 28 days in HCl solution

Admixtures improve the durability properties of the concrete. From Figure 2 and the Figure 3, the increasing replacement levels of CCA showed reduced effects of the acid on the strength and weight properties of the concrete cubes. The details from the graph and table show a decreasing difference in weight and compressive strength of the cubes cured in acid when compared to that cured in water. Hence, improved durability was observed.

3.4 Cubes immersed in $MgSO_4$

The observations from the curing of the cubes in sulphate solution is presented in Figure 4. And the Figure 5.

Csw – Compressive strength in water

Css – Compressive strength in sulphate

$$\text{SDF}(\%) = \frac{\text{Csw} - \text{Css}}{\text{Csw}} \times 100$$

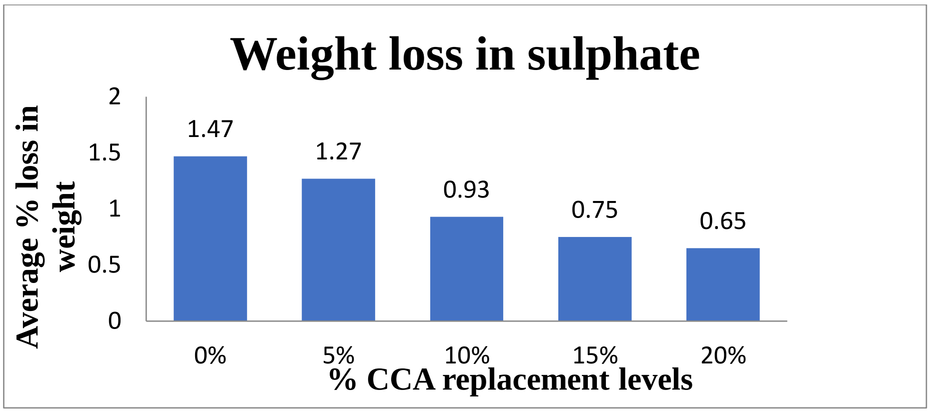

Fig. 4 Weight loss in $MgSO_4$

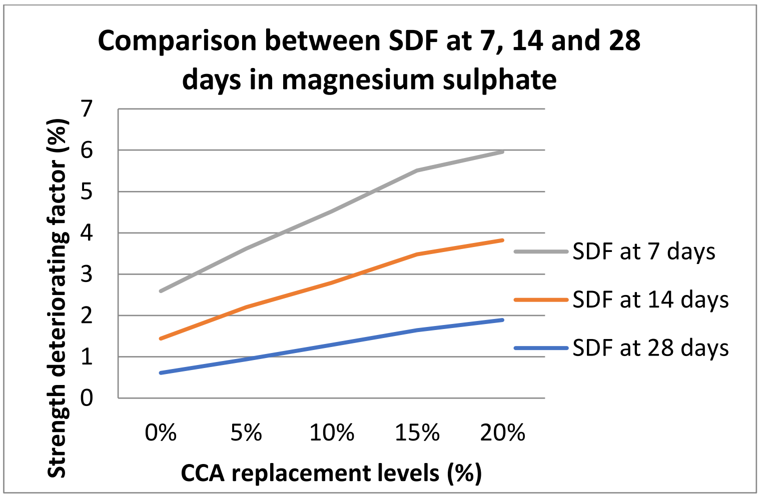

Fig. 5 Comparison between SDF's at 7, 14 and 28 days of cubes immersed in $MgSO_4$

The weight loss of the cubes immersed in sulphate solution increased as curing duration increased and decreased with increasing percentage replacement levels. The weight loss at 7 and 14 days was infinitesimal until the 28th day before a significant difference could be spotted. This could be as a result of low concentration of the sulphate solution or because expansion is not usually associated with magnesium sulphate attack ($MgSO_4$). $MgSO_4$ manifests itself in loss of strength of concrete and is more prominent in pozzolanic mixes [11]**.** Hence as observed in Figure 5, increase in CCA replacement levels, leads to an increase in the SDF and increase in curing days also increases the SDF. The results when compare with [3] are similar as it was also recorded in their work that there was an increase in the strength deterioration factor with increased CCA replacement levels.

4. Conclusion

Based on the findings from this research, CCA at 5% replacement satisfies the requirements of EFNARC for fresh concrete and hardened SCC. The 5% CCA replacement has its results within the required limits for the slump test, blocking ratio and the v-funnel test while its resulting compressive strength at 28days of curing is also satisfactory. The chemical analysis performed on the CCA also established that CCA is a pozzolanic material in line with the specification of ASTM C618 under class N natural pozzolans. The effect of acid and sulphate on SCC reduces with increase in the replacement level of CCA as regards weight loss and SDF.

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