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EFFECT OF SUGARCANE BAGASSE ASH ON ALKALI SILICA REACTION OF CONCRETE WITH SODA LIME GLASS AS AGGREGATES

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ABSTRACT: Utilization of waste materials for construction use has received much attention lately in the hope of contributing to saving the environment by lessening the impact of construction. This study utilized soda lime glass in concrete as substitute for fine aggregates. However, since soda lime glass promotes alkali-silica reaction, its addition to concrete will not come without risk. Sugarcane bagasse, the unused stalk of sugarcane, when burnt into ash, is a good pozzolanic material. It also has the capability to arrest the expansion brought about by alkali-silica reaction. Therefore, when added to concrete with soda-lime glass, it can lessen the alkali-silica reaction. This study employed sugarcane bagasse ash, as partial replacement of cement, in concrete with soda-lime glass. The amount of soda-lime glass in concrete used in the study ranged from 10-40% replacement of sand, while that of sugarcane baggase ash are 5% and 10% replacement of cement. Compressive strength was determined in 7 and 28 days. Scanning electron microscopy (SEM) was conducted to examine the microstructural change in concrete. To investigate the alkali-silica reaction, measurement of mortar expansion using mortar bar test in accordance with ASTM C1260, was conducted. Some of the significant findings of the study are: (1) addition of soda lime glass, up to 30% replacement of sand, contributes to an increase in compressive strength, and (2) length expansion, due to alkali silica reaction, in concrete with soda lime glass was reduced with sugarcane bagasse ash.

Keywords: Sugarcane bagasse ash, Soda lime glass, Alkali silica reaction, Mortar bar test, Pozzolan

1. INTRODUCTION

The use of glass aggregates in concrete as partial replacement for fine aggregates have been shown to be suitable for use in concrete [1]. Using glass aggregates in concrete is one way of utilizing waste materials and seen as contributing to lessening the impact of waste materials to the environment. Study of [2] have shown that using glass aggregates to replace sand can have beneficial effects on mechanical properties for as long as the replacement is kept below 20-30% of sand since it helps reduce the porosity of concrete. However, the use of soda lime glass (SLG), in particular, does not come without complication as it promotes occurrence of alkali silica reaction (ASR) in concrete due to siliceous content of soda lime glass. They [3] have stated that soda lime glass contains approximately 7-10% Calcium Oxide (CaO) which provides Calcium (Ca) needed for ASR gel formation. In this study, to counter the impact of SLG in causing alkali silica reaction, sugarcane bagasse ash (SBA) is employed.

Alkali-silica reaction (ASR) is a reaction in concrete when alkali in cement paste reacts with silica present in most aggregates which causes volume expansion that can lead to cracking. This problem in concrete is considered common, and referred to as “cancer of concrete” [4]. One of the most common ways to mitigate ASR in concrete is by adding very fine siliceous material, like pozzolan, silica fume, or fly ash, which results to a controlled pozzolanic reaction during the early stages of cement setting [5]. These siliceous materials safely react with alkali in cement without any formation of expansive pressure because siliceous in fine particles transform into alkali silicate and into calcium silicate without semipermeable reaction rims [6]. They [4] investigated the effect to ASR of employing sugarcane bagasse ash in concrete. They have shown that 10% and 40% SBA replacement of cement resulted to expansion reduction in mortar bar specimens.

Waste glass, in general, contains alkali and silicon dioxide which may lead to ASR [7]. They showed that soda lime glass is composed of 68.4% SiO2, 14.1% Na2O, 9.5% CaO, while the remaining components are small amounts of several compounds. This high amount of silica in soda lime glass, when used as partial replacement of sand in concrete, promotes ASR. Moreover, they showed that ASR risk with an ASR expansion rate of above 0.2% is present in concrete having 30% glass aggregates as sand. Other researches [2, 8, & 9] have proven that glass aggregates promote the

Table 1. Concrete Design Mix (for 1-m^3 concrete mix) in accordance with ACI 211.1

Mix ID	Portland Cement (kg)	Course Aggregates (kg)	Fine Aggregates (kg)	Water (kg)	Soda Lime Glass (kg)	Sugarcane Bagasse Ash (kg)
B0G00 (control)	8.40	25.21	16.83	4.25	0	0
B0G10	8.40	25.21	15.15	4.25	1.68	0
B0G20	8.40	25.21	13.46	4.25	3.37	0
B0G30	8.40	25.21	11.78	4.25	5.05	0
B0G40	8.40	25.21	10.10	4.25	6.73	0
B5G00	8.40	25.21	16.83	4.25	0	0
B5G20	8.11	25.21	13.46	4.25	3.37	0.29
B5G30	8.11	25.21	11.78	4.25	5.05	0.29

Note: B – sugarcane Baggase ash; G – soda lime Glass. B5G20 means sugarcane bagasse ash replaces 5% of cement, and soda lime glass replaces 20% of fine aggregates. All replacements were made by weight.

occurrence of ASR.

Sugarcane bagasse ash (SBA) is a by-product from combustion boilers in sugar industries. SBA is found to be rich in reactive silica giving it a cementitious property, hence, making it a suitable supplementary cementitious material. The use of supplementary cementitious materials (SCM), like sugarcane bagasse ash, is a common method to address ASR [10]. Study of [11] showed that the use of SCM reduces alkali concentrations in concrete hence, reducing the element responsible for producing hydroxyl ions that reacts with siliceous aggregates resulting to ASR. This potential of sugarcane bagasse ash, a waste material, in addressing ASR in concrete is seen as a good compliment for the use of another waste material – soda lime glass in concrete. SBA, through this study, is able to show that ASR caused by employing soda lime glasses in concrete can be mitigated by employing SBA in the same concrete.

2. MATERIALS AND METHODS

Sugarcane bagasse ash were obtained from local juice vendor. Literatures [12, 13] have established that the optimal percentage of replacement of SBA to cement ranges from 5 to 10%, hence, this study opted to adopt 5%.

The soda lime glass used in this study was derived from beer bottles, soda bottles, and juice bottles bought commercially.

Table 2. Slump test of concrete with SBA & SLG

Mix ID	Slump (mm)
B0G00	86
B5G00	52
B0G20	75
B5G20	56
B0G30	97
B5G30	70
B0G40	112
B0G10	65

These were crushed manually into bits using a hammer. After crushing, it was sieved to ensure that it is comparable to particle size of fine aggregates. Partial replacement of sand with SLG was done at 10% to 40% replacement by weight, at 10% interval. Portland cement (Type I) was obtained from local hardware store, along with coarse aggregates, and fine aggregates. Physical characterization of materials (i.e. determination of moisture content, unit weight, and specific gravity) used in producing concrete were made prior to designing the concrete mix proportions and were all conducted in accordance with appropriate ASTM standards. Concrete mix proportion were made in accordance with ACI 211.1 (Table 1).

Table 3. Summary of strength results

Mix ID	Compressive strength (MPa)		Tensile strength (MPa)
	7 day	28 day	
B0G00	16.98	17.97	2.92
B0G10	12.39	23.19	1.86
B0G20	15.75	25.30	2.34
B0G30	15.97	24.07	1.87
B0G40	13.84	17.77	1.55
B5G00	19.89	25.42	2.28
B5G20	17.88	24.43	1.29
B5G30	18.29	26.21	1.79

To figure out the effect of adding soda lime glass to concrete in terms of workability, slump test was conducted on fresh concrete. Justifying the use of alternative materials in concrete requires that the mechanical properties are not compromised. Hence, this study investigated compression and split tensile strength of concrete with 5% sugarcane bagasse ash and soda lime glass which ranged from 10 to 40% at 10% interval. Compressive strength, in accordance with ASTM C39, was tested in 7th and 28th day. Split tensile strength, in accordance with ASTM C496, was

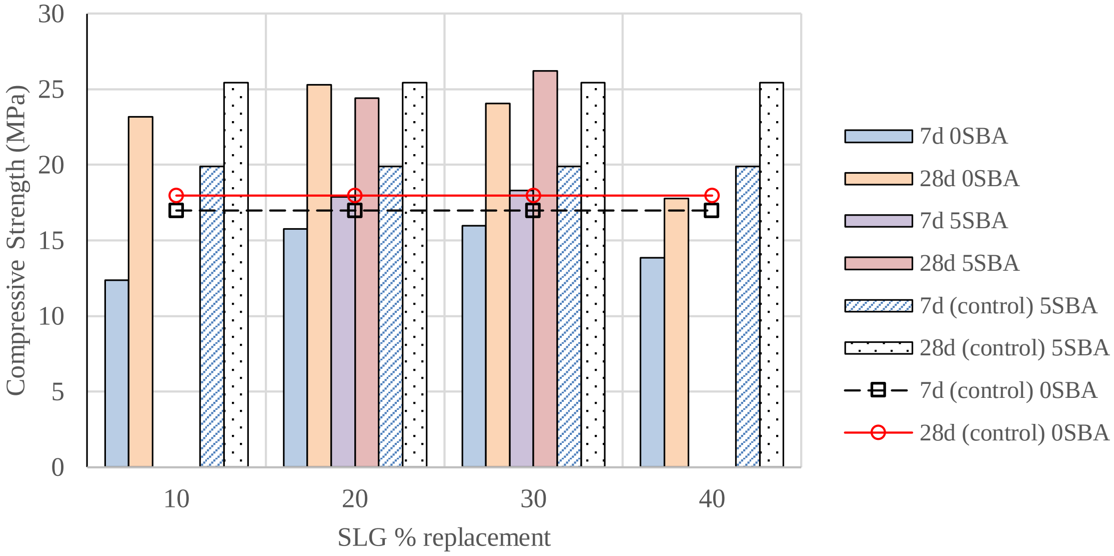

Fig. 1 7th & 28th day compressive strength of concrete with sugarcane bagasse ash and soda lime glass

tested at 28th day. Three (3) samples were prepared for each mix proportion. All samples were cured in water.

ASTM C1260 is a standard test for determining the potential alkali reactivity of aggregates using mortar bars. Similar to concrete, three (3) specimens were prepared for each mortar mix. The samples were initially immersed in a water bath for 24 hours before it was cured in NaOH solution in an oven for fourteen (14) days. During NaOH solution curing, temperature was maintained at 80 degrees Celsius. Length readings were taken three times (3x) daily.

In addition to mortar bar test of potential alkali reactivity, scanning electron microscopy (SEM) was employed to acquire high resolution images of mortar's microstructure to detect the development of ASR gel from the reaction of silica in soda lime glass and alkali in cement.

3. DATA AND ANALYSIS

3.1 Concrete Test Results

Table 2 shows the slump test result for concrete with 0% and 5% SBA, and varying amount of soda lime glass.

Table 4. Length expansion of mortar bar specimens with sugarcane bagasse ash and soda lime glass

Mix ID	Ave. Length Change	Ave. Expansion	Interpretation of Expansion
B0G00	0.663 mm	0.231%	Potentially harmful
B5G00	0.433 mm	0.150%	Safe with slight chance of being harmful
B5G20	0.500 mm	0.173%	Safe with slight chance of being harmful
B5G30	0.537 mm	0.187%	Safe with slight chance of being harmful

It shows that the addition of sugarcane bagasse ash reduces slump supporting the claims of [9], and [14] that sugarcane bagasse ash consumes water that is supposed to be for mixing, hence, reducing workability. Another observation made was increasing the amount waste glass resulted to increase in slump. This implies that glass aggregates promote workability.

Compressive strength test of concrete with SLG and SBA can be seen in Figure 1. Comparison between compressive strength of concrete with and without sugarcane bagasse ash revealed that there is no significant difference between the two. This implies that 5% replacement of cement with sugarcane bagasse ash will not compromise the compressive strength. For both 7th and 28th day strength, the highest strength can be observed at 20% SLG replacement, followed closely by strength values at 30% replacement. SLG replacement appeared to be viable for 20 to 30% replacement as its strength is higher compared to that of control concrete. At 40% replacement, strength fell below that of controlled concrete. All 28-day strength exceeded that of typical normal strength of 21 MPa and that of 28-day control concrete. In this study, it was not established that increasing SLG compromises strength though it was clear that at 40% SLG replacement of sand,

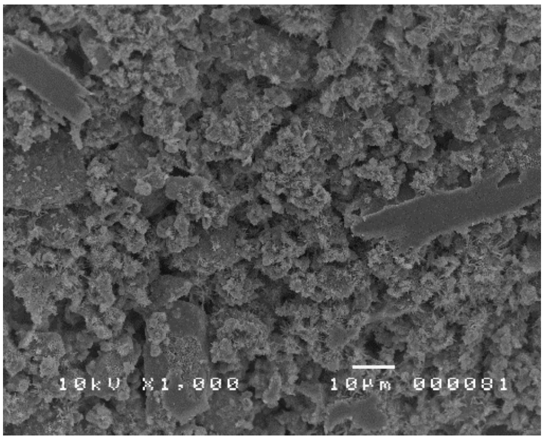

Fig. 2 (1A) B0G00 mortar structure before immersion to NaOH

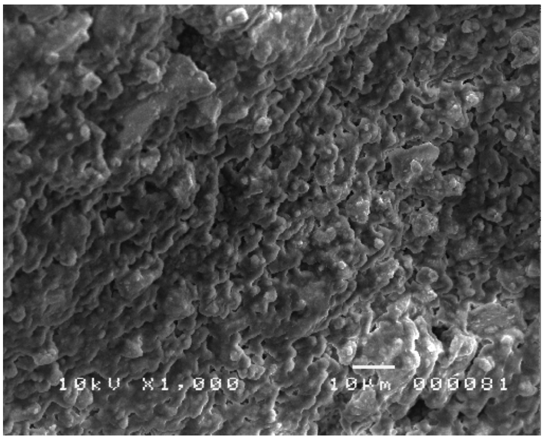

Fig. 3 (1B) B0G00 mortar structure after immersion to NaOH for 14 days

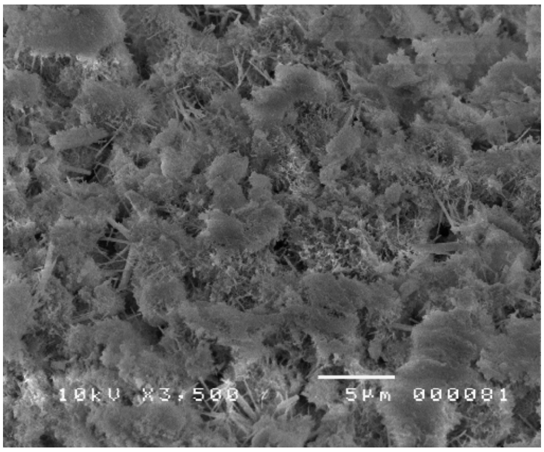

Fig. 4 (2A) B5G00 mortar structure before immersion to NaOH

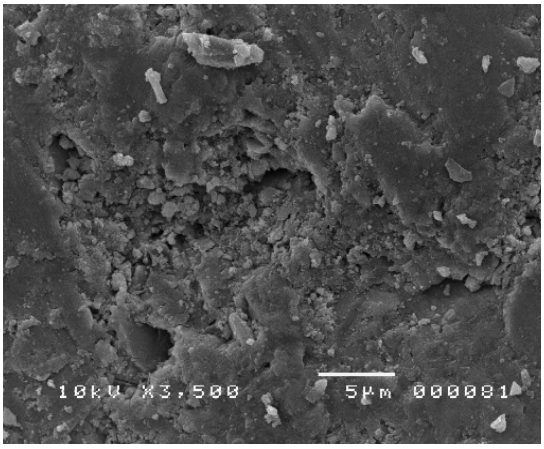

Fig. 5 (2B) B5G00 mortar structure after immersion to NaOH for 14 days

Fig. 6 (3A) B5G20 mortar structure before immersion to NaOH

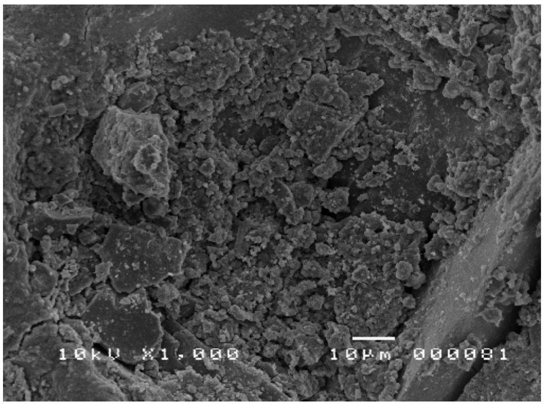

Fig. 7 (3B) B5G20 mortar structure after immersion to NaOH for 14 days

strength decreases significantly. Table 3 summarizes the strength results for 7 and 28-day compressive strength and 28-day split tensile strength.

Split tensile strength results showed all samples with SLG have strength lower than that of control sample. Comparison between sample with and without sugarcane bagasse ash show that concrete mix without sugarcane bagasse ash have higher tensile strength. Since this was not observed in compressive strength, it can be stated that for concrete that will utilize tensile strength for a

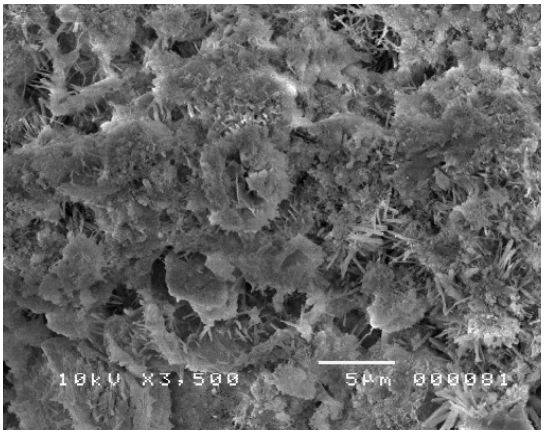

Fig. 8 (4A) B5G30 mortar structure before immersion to NaOH

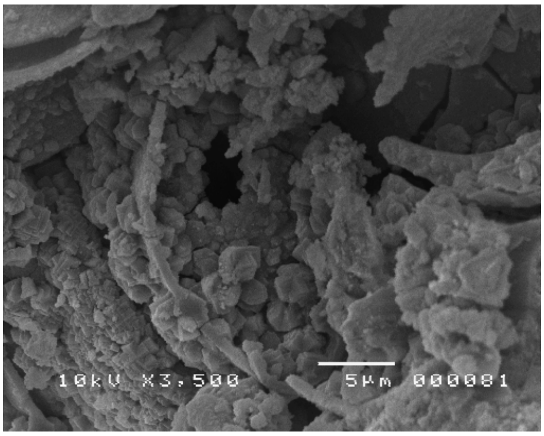

Fig. 9 (4B) B5G30 mortar structure after immersion to NaOH for 14 days

particular purpose, the replacement of cement with sugarcane bagasse ash needs to be investigated thoroughly before application.

3.2 Mortar Test Results

The mortar test based on [15] was done to test if the substitute aggregates (i.e. soda lime glass) are potentially reactive to alkali in cement. Length measurement of mortar specimen, using a length comparator, were done for fourteen (14) days while cured in NaOH solution and kept in an oven to maintain a temperature of 80 degrees Celsius. Table 4 summarizes the result of length measurement. Specimen with no sugarcane bagasse ash experienced the highest average length expansion and was found to be potentially harmful with respect to alkali silica reaction. The test also showed that with increasing soda lime glass in concrete, the average length expansion has also increased. This supports the earlier claim that soda lime glass, with its high siliceous content, will contribute more to the occurrence of alkali silica reaction.

The microstructure of mortar bars was investigated thru SEM before NaOH curing and after 14-day curing in NaOH, as shown from Figure 2 to 9. A common observation from SEM micrographs is the degrading effect of subjecting mortar samples to NaOH after 14 days.

4. CONCLUSION

The call for utilization of waste in construction is getting more attention with times due to continued depletion of resources and the negative impact to the environment. Hence, this study attempted to answer to that call by utilizing soda lime glass in concrete by making it a partial substitute for fine aggregates. However, due to high siliceous content of SLG, the potential reaction of silica with alkali in cement pastes must be addressed as it may lead to alkali silica reaction which leads to concrete cracking. So, in order to address ASR, this study employed sugarcane bagasse ash as partial replacement of cement. Sugarcane bagasse ash (a by-product of sugarcane) is another waste where possible utilization in concrete is also being sought in this study.

Mechanical properties of concrete with 5% SBA and varying SLG showed no compromise in compressive strength. Comparison of compressive strength of concrete with increasing SLG amount showed higher strength for SLG content not exceeding 30% of sand. Limiting the replacement of cement to 5%, by weight, with sugarcane bagasse ash will also not compromise compressive strength. However, split tensile strength demonstrated lower values for concrete with SLG and SBA. Hence, it is recommended by this study that for concrete applications where tensile strength is of critical importance, a thorough investigation of tensile strength must be conducted first.

Mortar bar test, in accordance with ASTM C1260, was also conducted to determine the potential alkali reactivity of mortar with SLG and to assess whether sugarcane bagasse ash contributes in mitigating the alkali silica reaction. Length expansion measurement showed that increasing SLG resulted to increasing length expansion. Sugarcane bagasse ash reduced the length expansion as compared to specimen without SBA.

Finally, SEM of mortar samples revealed deterioration after exposure to NaOH for 14 days in 80 degrees Celsius maintained temperature.

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