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SUGAR CANE JUICE AS A RETARDING ADMIXTURE IN CONCRETE PRODUCTION

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ABSTRACT

Sugar cane juice (SCJ) was investigated as a retarding agent in concrete production. Slump values and compressive strength of concrete with partial replacement of water by sugar cane juice was also investigated. The concrete cubes were prepared by replacing water with SCJ in the following proportions 0, 3, 5, 10 and 15%. The cubes were cured, tested and the physical properties of interest in this study were determined. Results show that the final setting time of concrete was delayed with increase in content of the SCJ in the concrete mix. At 0% SCJ, final setting time was 3½ hours, while final setting time at 15% SCJ was 6 hours, reflecting additional 2½ hours setting time. The compressive strength of the (water:SCJ) concrete decreased with increase in the content of SCJ in the concrete mix, up till 10% SCJ content.

KEY WORDS: sugar cane juice, setting time, slump values, compressive strength.

INTRODUCTION:

The addition of water to cement in the presence of aggregates, makes the mixture to set and harden gradually under normal climatic conditions to form concrete. This mixture when placed in mould or formwork and allowed to cure becomes hard like stone. The hardening is caused by chemical reaction between the water and cement. The fine and coarse aggregates bond with cement and strengthen after curing.

The strength, durability and other features of this conglomerate material depend on the properties of the mix, its constituents, the method of compaction and other controls during placing, curing etc. All concretes made with lightweight aggregate exhibit a higher moisture movement than is the case with normal weight concrete (Neville et al, 2004).

In many parts of the world, a combination of high temperatures, low relative humidity and hot wind that blows across the environment result in rapid evaporation of water from fresh concrete surface. As a result, concrete sets earlier, leaving little or no time for concreting operation, especially where the batching plant is a considerable distance from the actual work location.

For example, it has been reported that, when the temperature of cement mortar with a water/cement (w/c) ratio of 0.6 is increased from 27.8^0C to 45.5^0C, both initial and final setting times are nearly halved (Fattui, 1998).

In order to provide proper time for concreting operation, especially when unavoidable delays between mixing and placing occur, and to save concrete from other detrimental effects of adverse climatic conditions, cement set retardation or use of retarding admixtures is necessary (Bazid et al, 2002).

Admixtures are materials other than water, aggregates, hydraulic cement and any other reinforcement materials, used as ingredients of concrete or mortar and added to a batch before or during concrete mixing. A retarding admixture/retarder is an admixture that retards the setting time of cement concrete, mortar or grout (ASTM, 1982).

(Bazid et al, 2002) investigated the effect of pure sugar on setting time of various types of

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cement. The investigation concluded that setting time of cement was retarded by incorporation of sugar in cement under all conditions of curing. The extension in setting time was increasing with an increase in sugar content up to a certain limit (approximately 0.15%) and then started to drop with further increase in sugar content, accelerated the cement-setting when a higher sugar content (>0.3%) was used. Relatively low retarding tendency was shown by sugar under the second and third curing condition. 0.15% sugar-content acted as optimum sugar content for retarding the setting time.

(Thomas et al, 1983), carried out an investigation on retarding action of sugars on cement hydration. It has been proven that sugar interferes, with the cement binding process in the concrete. A theory suggests that when concrete mixture contains sugar, the sugar molecules attach themselves to the hydrating cement and inhibit the chemical reactions involved in stiffening the material.

Another theory, called the “precipitation theory”, suggests that the addition of sugar increases the concentration of calcium, aluminium and iron in concrete. The sugar molecules combine with these metals to form insoluble chemical complexes that coat the cement grains. Several key chemical processes that harden the concrete are then impeded. Hydration slows down the process and concrete takes longer to set. For this reason, sugar is known as a retarder. Retarders normally increase the setting time of concrete.

It is important to note that all sugars do not retard cement hydration equally. Lactose, which is the sugar found in milk is a moderate retarder (Thomas et al, 1983).

(Bazid et al, 2002) also observed that a retarding admixture causes cement set retardation by the following mechanisms.

1) Adsorption of the retarding compound on the surface of cement particles, forming a protective skin, which slows down hydrolysis.
2) Adsorption of the retarding compound onto nuclei of calcium hydroxide, poisoning their growth, which is essential for continued hydration of cement after the end of induction period.
3) Formation of complexes with calcium ions in solution, increasing their solubility and discouraging the formation of the nuclei of calcium hydroxide.
4) Precipitation around cement particles of insoluble derivatives of the retarding compounds formed by reaction with highly alkaline aqueous solution, forming a protective skin.

(Erdogan, 1997) reported that retarding admixtures are mainly based on materials having ligsulfonic acids and their salts, hydroxyl-carboxylic acids and their salts, sugar and their derivatives and inorganic salts such as borates, phosphates, zinc and lead salts.

Previous studies investigated the use of pure sugar as a retarding admixture, on various types of cements.

(Otunyo et al, 2015) carried out an exploratory study on the effect of sugar cane juice on concrete properties such as bulk density, setting time, workability and compressive strength. The study established that setting time was delayed by the partial replacement of water with SCJ. Slump values decreased as the content of SCJ increased in the mix. Compressive strength of the concrete decreased from 39.0 N/mm^2 at 0% SCJ:100% water to 13.08 N/mm^2 at 100% SCJ : 0% water.

The study also established that at 25% SCJ: 75% water replacement, setting time was as much as 42 hours (almost 2 days.

This current study was therefore undertaken with smaller content of SCJ replacing water to explore the possibility of reducing the delay in setting time with also a possibility of improved compressive strength as the SCJ content increased.

Sugar cane is abundantly grown in some Northern States in Nigeria, notably Sokoto, Taraba, Niger, Kogi and Kwara and some other Northern States as well. SCJ is of preferred economic advantage in the region to the importation of admixtures with hard earned foreign exchange.

2. MATERIALS AND METHOD

As with the exploratory study, the sugar cane used for the study, were obtained from the fruit market in D/Line area of Port Harcourt. The original source of the sugar cane is Northern Nigeria. They were cleaned, peeled, washed and cut into smaller pieces before the juice was extracted by putting the cut pieces into bags. The bags were then subjected to pressure by the use of four iron rods with fixed rebars to compress and extract the sugar cane juice.

The extracted SCJ was filtered in order to remove some residual particles of the sugar cane fibre.

A total of thirty (30) cubes were cast from one mix proportion (1:2:4) but with varying percentages of unfermented sugar cane juice and at water/cement (w/c) ratio of 0.50. Water was partially replaced by SCJ in the following proportions: 0%, 3%, 5%, 10%, and 15%. Setting time, slump and compressive test was carried out. The concrete cube was crushed after 14 and 28 days and the various compressive strength values recorded.

2.1. Setting times of water/SCJ concrete:

The setting time of the concrete made with replacement of water by 3%, 5%, 10% and 15% SCJ were obtained (BS.EN.196-3, 1995)..

2.2. Slump Values of water/SCJ Concrete:

The slump values of the concrete made with replacement of water by 3%, 5%, 10% and 15% SCJ were obtained using (BS 1881 Part 102,1996).

2.3. Compressive Strength Test:

Metal moulds measuring 150mm x150mm x 150mm were used to cast the concrete cubes. A total of 30 cubes were prepared for the mix ratios of 1:2:4 and proportions of (water:SCJ), 87:13, 95:5, 90:10, and 85: 15. The samples were left to cure for 14 and 28 days, respectively.

The concrete cubes were loaded to failure using compression machine in the laboratory. The tests were performed in a room with 90% humidity and room temperature of between 25^{o}C and 29^{o}C.

The weight of each cube of concrete for the compressive strength test was 2.5kg. All the tests were in accordance with (BS 1881, Part 114, 1983).

3. RESULT AND DISCUSSIONS

3.1. Chemical Analysis of Sugar Cane Juice

Table 1 is the result of the physiochemical analysis of the sugar cane juice used for this study. It has a pH of 5.67 which is acidic. 67.6% of its constituent is solids, the sugar content is 15.1% while the water content is 20.44%. The decrease in the compressive strength of the concrete cubes with increase in the quantity of SCJ is due to the fact that the components of concrete break down during contact with acid (Otunyo et al, 2015)..

Table 1: Physiochemical Analysis of sugar cane Juice (NIS 235, 1987)

S/N	PARAMETR	TEST METHOD	RESULT	STANDARD
1	pH	(NIS 235., 1987)	5.670	>5
2	Specific Gravity	NIS 235	0.986	0.9 -0.99
3	Sugar Content (%)	NIS 235	15.100	-
4	Total Solid	NIS 235	67.600	<83
5	Water Content (%)	NIS 235	20.440	<25
6	Sulphur (mg/kg)	NIS 235	0.080	1
7	Lead (mg/kg)	NIS 235	0.040	0.3
8	Copper (mg/kg)	NIS 235	0.020	0.5
9	Acidity (mg/koH/g)	NIS 235	0.700	1.5
10	Arsenic (mg/kg)	NIS 235	<0.01	0.2
11	Salinity (ppm)	NIS 235	0.560	1
12	Conductivity (us/cm)	NIS 235	5.060	-
13	Iron (mg/kg)	NIS 235	2.800	5

3.2. Effect of SCJ on Setting Time

Figure 1 shows a plot of the setting time versus (SCJ:water) replacement proportions. The setting time was delayed as the content of the SCJ in the concrete was increased. A final setting time of 6 hours was achieved at 15% SCJ replacement, compared to 3 1/2 hours at 0% SCJ (normal concrete).

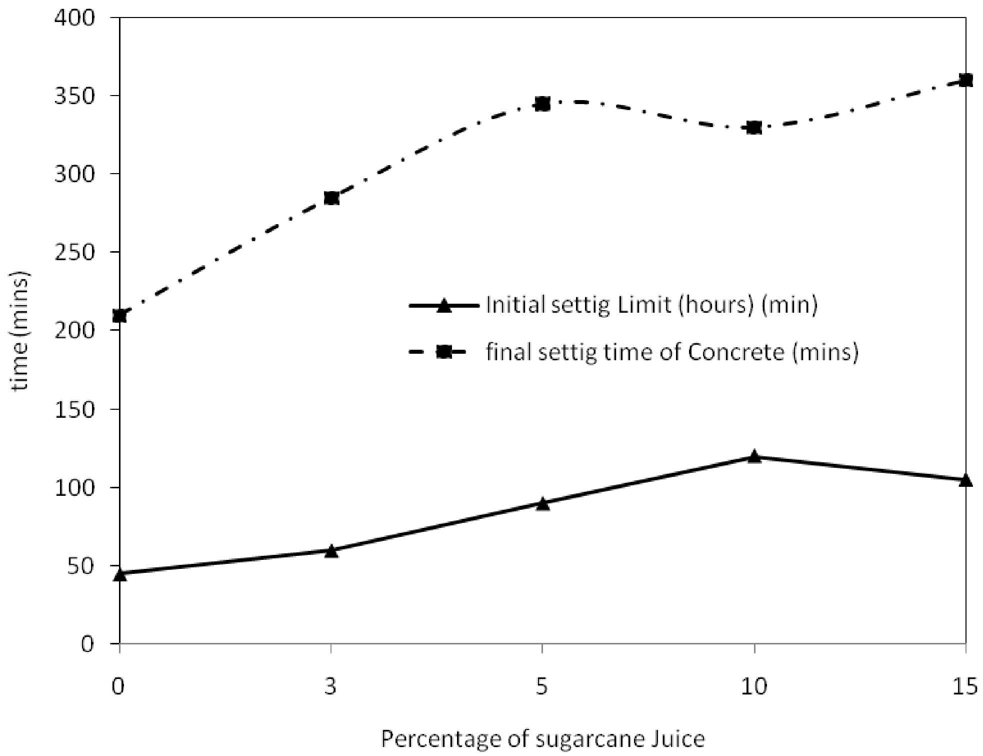

Figure 1. Plot of setting time of Concrete versus pecentage Replacement of water by sugar cane juice)

3.3. Effect of SCJ on Slump Values

Table 2 is the result of the slump test, while Figure 2 is a plot of Table 2 to clearly and graphically show how the slump values decreased as the content of SCJ increased. Slump values of 60mm at 0% SCJ and 10mm at 15% SCJ replacement were obtained. Since the minimum acceptable slump to ensure proper workability and compaction of concrete on site is assumed to be between 60-70mm. It therefore follows that SCJ reduces the workability of concrete.

Table 2: Effect of Sugarcane Juice on Slump of fresh concrete

Sugarcane	% of Water	slump vlues of concrete (mm)
0	100	60
3	97	45
5	95	28
10	90	14
15	85	10

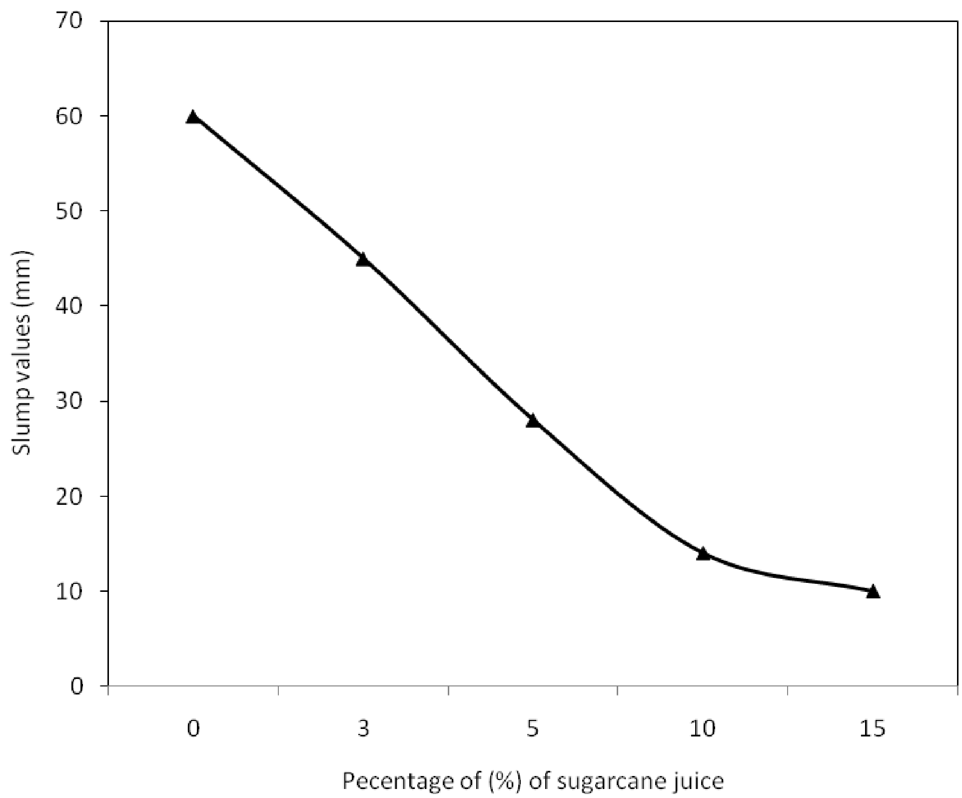

Figure 2 . Plot of Slump values versus Percentage replacement of water with sugarcane juice)

3.4. Compressive Strength

From Figure 3 it can be observed that the compressive strength decreased as the quantity of the SCJ increased up till 10% SCJ replacement. The lowest values of compressive strength, 8.30 N/mm^2 and 5.63 N/mm^2 respectively were obtained at 10% SCJ replacement. Thereafter the compressive strength started to increase as the content of the SCJ increased, attaining a maximum strength of 17.45 N/mm^2 at 14 days and 19.11 N/mm^2 at 28 days for 15% SCJ replacement. These compressive strength values satisfy the strength requirements for light-weight concrete. The compressive strength at 3% SCJ was 24.44 N/mm^2 at 14 days and 31.40 N/mm^2 at 28 days respectively compares very well with the strength at 0 % SCJ.

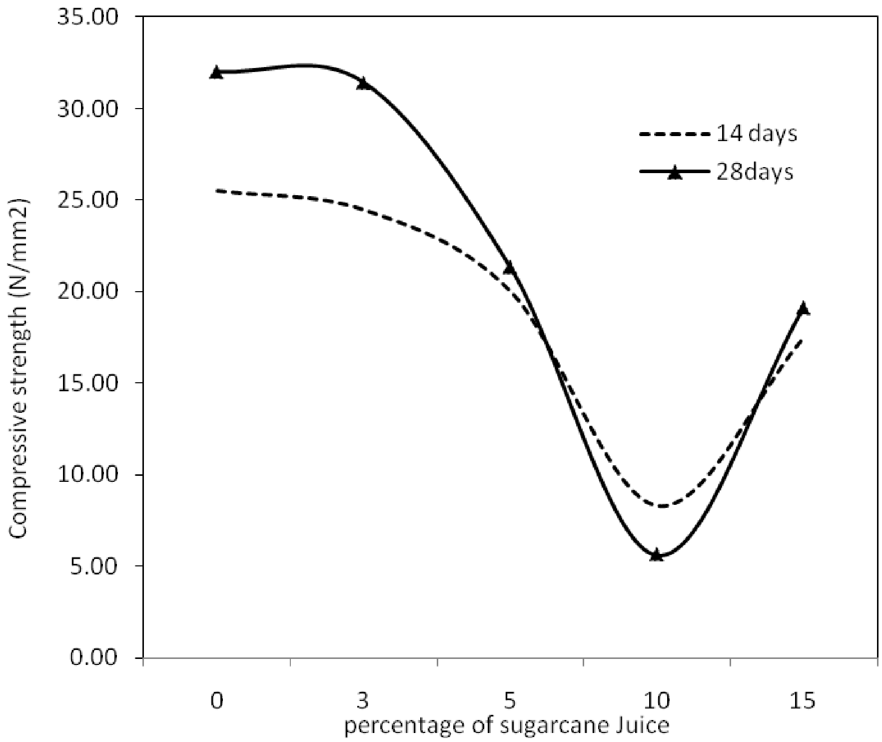

Figure 3 .Plot of Compressive strength versus percentage replacement of water with sugar cane juice

(Neville et al, 2006) observed that sugar when used as a retarder severely reduces early strength of concrete for all ages, thereafter the strength increases at all ages. The early decrease in strength is due to quick-setting. As the quantity of SCJ increases, retardation sets in leading to increase in strength. The result of the current study is in agreement with the above fact.

Also, (Otunyo et al, 2015) established that 25% SCJ as the point where the SCJ:water concrete attains the lowest strength.

In the present study, 10% SCJ is the point where the SCJ:water concrete attained the lowest strength. [(Asma et al, 2014) observed optimum replacement for producing high strength concrete at between 5% to 15% of sugar cane bagase ash. All these could be explained from (Akogu, 2011) that showed an initial decrease in soundness of cement due to the effect of sugar up to 0.06% sugar and increase in soundness thereafter up to 0.08%.

There is a relationship between soundness of cement and strength of concrete produced with such cement. It is believed that retarders modify crystal growth or morphology, becoming absorbed on rapidly formed membrane of hydrated cement and slowing down the growth of calcium hydroxide nuclei thus forming a more efficient barrier to further hydration than is the case without a retarder (Neville, 2006).

CONCLUSION

From this experimental study the following conclusions can be drawn.

Sugar Cane Juice retarded the setting time of concrete.

The workability of concrete was reduced by the addition of sugar cane juice.

Compressive strength of the concrete initially decreased as the content of the sugar cane juice was increased, at an optimum Sugar cane juice content of 10%, the compressive strength started to increase as the sugar juice content was increased. These results compare with results by other works carried out with pure sugar.

Even though the compressive strength of concrete was reduced due to the partial replacement of water with sugar cane juice, the strength obtained at smaller sugar cane juice content compares favourably with the strength for light-weight concrete.

The abundance of sugar cane in Nigeria is of economic advantage in terms of savings in the foreign exchange used to import retarding agents into the country.

NOMENCLATURE

ASTM	American Society for Testing of Materials
BS	British Standards
NIS	Nigerian Industrial Standards
SCJ	Sugar Cane Juice

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