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Investigation Of The Effect Of Sugar On The Hardening Of Dangote Portland Cement

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ABSTRACT

The need to provide an alternative to other set time retarders, preventing cold joints in concreting, eliminating the need for constant vibration which might lead to loss of consistency and also offset the effect of high down hole temperature motivated this research. Therefore, the aim of this work is to investigate the effect of sugar on the set time on ordinary Portland cement (OPC) concrete considering the fact that sugar is readily available and at lower cost compared to other known retarders. The effects of sugar at concentrations of 0, 0.01, 0.02, 0.03, 0.04, 0.05, 0.07, 0.09. 0.25, 0.30, 0.40, 0.45, 0.50 and 1.0 % by weight of cement on cement paste and its strength at 28 days was investigated. The setting time of the cement was found to increase from 121, 154, 220, 262, 282, 309, 342, 328, 128, 78, 68, 53, 40 minutes when the sugar content was varied from 0 % sugar content to 0.5 % sugar content respectively. Peak time was attained at 0.07% sugar content where a time of 342 minutes delay in set was recorded. Steady decline starts at 0.09 % sugar content and flash setting comes in between 0.25 and 0.5 %. The compressive strength test also showed slight strength gains with peaks at 0.02 % and 0.07 % where its load bearing capacity was determined to be 533 and 470 kN respectively. Thus, sugar can be used as a setting time retarder since its action does not amount to a loss in strength of the tested samples.

Key words: Retarders, Ordinary Portland Cement, Setting Time, Compressive Strength, Load bearing capacity.

INTRODUCTION

Concrete is a mixture of sand, water and cement as a binder. It is a valuable material in many aspect of life due to its strength, durability etc. but has its usage limited due to its high likely hood to set easily (Bermudez, 2007). Setting and Hardening are the most critical phases during construction because they have significant influence on final properties of concrete structures. Hence it becomes necessary to monitor setting, hydration and hardening (Abalaka, 2011). When water is mixed with cement to form a paste, reaction starts. In its pure form, the finely ground cement is extremely sensitive to water. According to Khan and Baradan (2002), three of the main compounds, viz. C_3A, C_3S and C_2S, reacts quickly with water to produce a jelly-like compound which starts solidifying. The action of changing from a fluid state to a solid state is **c**alled '**setting**' after which the 'hardening' process sets in. In the first few minutes, the setting action is more predominant and later on the hardening action becomes dominant (Rana, 2014). In practice, such solidifying action or loss of plasticity is required to be delayed, because some time is needed for mixing, transporting and placing of concrete into final position before the mix loses its plasticity due to the setting action (Fial et al. 2012). An admixture that lengthens setting time and workability time is known as set retarder or retarding admixture (Ramachandran, 2002). When these retarders are added to concrete mixtures, some kind of physical and/or chemical reaction takes place in such a way to retard the setting time (Myrdal, 2007a; Myrdal, 2007b). The rates of cement hydration reactions can be influenced by chemicals added to the cement water mix. Chemical admixtures affecting these reactions to produce a delay in the process of cement paste stiffening are termed retarding admixtures or simply retarders. Hence, a retarder is added to a concrete mix in order to lengthen setting time and workability time (Khan and Ullah, 2006;

Khan and Baradan, 2002). As a secondary effect, many retarders reduce the water requirement to produce a concrete of desired workability and produce a concrete of higher strength with equal cement content. Hence, the use of retarders is also beneficial to other properties of concrete such as workability, strength, and durability (Yamamoto, 1972). Sucrose is one of such retarders (Ramachandra, 1993). Sugar is a natural product derived from plants.

Therefore, taking advantages of availability and cost of sugar compared with the other conventional retardant, this research work is aimed at studying the effect of sugar on the setting time of Dangote Portland Cement. Some of the specific objectives include sourcing, formulation of the sugar and cement admixtures and studying its performance tests like peak time, compressive strength, and the load bearing capacity of the formulation for benchmarking purposes.

Figure 1: Curing Tank

MATERIALS AND METHOD

Materials/Apparatus

The major materials used in this work include ordinary Portland cement, sand, water and sugar. The supporting sets of instrument are measuring cylinder (0 – 2000 ml, ±2 ml) and beaker (0 – 100 ml, ±2 ml). The sets of equipment as well and their specifications included Analog weighing balance (0 – 50 kg, ±1 kg) of Wenzhou Times Company Ltd, China, Vicat Apparatus with both the mold and needle (0 – 40 mm) of Equipment Laboratory International, United Kingdom as well as Tamping rod. Others are Compressive Strength Machine (0 – 2500 kN, ±2 kN), Digital weighing Balance (0 – 200 g, ±1 g) of Mettler Instrument, B.U. Arnhem Switzerland, Digital stop watch (0-23:59:59, ±2 secs) obtained from Wenzhou Times Company Ltd, China and water bath. The curing tank is as displayed in Figure 1.

Sample Collection

It must be stated that all the tests carried out in this research work were consistent with BSI standards for material specifications, testing and procedure.

A 50 kg bag of Ordinary Portland cement and 1 kg of sugar were purchased from the Samaru market in Zaria, Kaduna State, while distilled water was procured from the Department of Chemical Engineering, Ahmadu Bello University, Zaria, Kaduna State. After obtaining the samples, the following tests were carried out.

Determination of Setting Time and Consistency

400 g of the cement was mixed with 124 ml of water, carefully stirred for 4-5 minutes and then placed in a mold where the vicat plunger and needle was used to check for its consistency and setting time respectively. The measurement of setting times of standard cement paste was done using Vicat apparatus in conformity with European Standard 196-3 (EN 196-3) standard. Consistency test was also employed to determine the amount of water required to make the standard cement paste.

Determination of Compressive Strength

1.6033 kg of cement powder was mixed

Table 1: Initial and final setting time of the Portland cement

Sample (% sugar)	Initial Set. (mins)	Final set. (mins)	Consistency (mm)	Water content (mL)
0.00	121	184	5	124
0.01	154	226	7	122
0.02	220	293	7	122
0.03	262	358	5	120
0.04	282	372	6	120
0.05	309	383	5	119
0.07	342	426	5	117
0.09	328	373	6	117
0.25	128	381	5	112
0.30	78	341	6	113
0.40	68	181	6	112
0.45	53	98	5	110
0.50	40	76	5	110

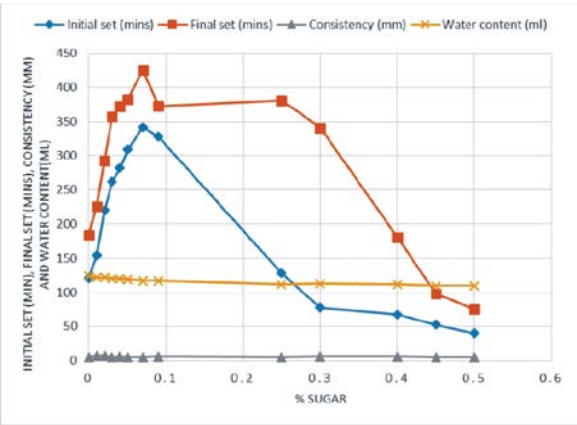

Figure 2: Effect of sugar on setting time of the cement paste

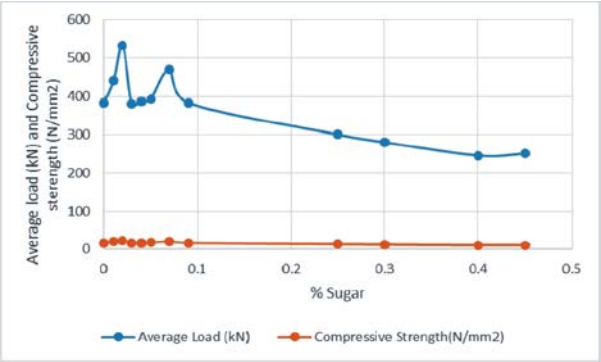

Figure 3: Effect of Sugar on load bearing capacity of concrete and the compressive strength

Table 5.2 Load bearing capacity of the concrete.

Sample (% sugar)	Average Load (kN)	Compressive Strength(N/mm^2)
0.00	383	17.02
0.01	440	19.56
0.02	533	23.67
0.03	380	16.89
0.04	386	17.16
0.05	393	17.47
0.07	470	20.89
0.09	383	17.02
0.25	300	13.33
0.30	280	12.44
0.40	245	10.89
0.45	250	11.11
0.50	233	10.36

with 4.8098 kg of fine aggregate and 641.32 ml of water. To form a paste, it was compounded in a 150 x 150 x 150 mm mold and carefully compacted with about 25 blows per level. A water cement ratio of 0.5 was maintained while varying the amount of sugar additive for all samples. The resulting mortar was cured for 28 days in water at constant relative humidity and room temperature and then crushed to obtain the strength values for each specimen. Sugar crystals were weighed and dissolved in the required weight of water before mixing. The materials were batched by weight and mixed manually. Each mould was filled in three layers, each layer of concrete was compacted by not less than 35 strokes of 25 mm square steel plunger to obtain sufficient compaction and the mould top finished by trowel in accordance with British Standard (BS), British Standard Institutions (BSI), European Standards (EN) and European Standard Pre-standards (ENV). These include BS 1881: Part 108 (BSI 1996) and BS 1881: Part 111 (BSI 1997). Three cubes were cast for each mix parameter and crushed at maturity in accordance with BS EN 12390-2 (BSI 2003). Curing of the cubes was done in compliance with British Standards Institution BS EN 12390-2 (BSI 2003) requirements.

RESULTS AND DISCUSSION

The experimental results obtained in the course of this project include setting time tests and the compressive strength test which was carried out within 4 weeks and the results are all presented in this Section.

Estimating Cost of Using Sugar Compared with Calcium lignosulphonate

Cost of 1000 kg of sugar is estimated to be worth 80000 naira (alibaba.com/product-detail/white-sugar-white-refined-crystal).

Cost of 1000 kg of lignosulphonate is estimated to be worth 70000 naira (alibaba.com/product-detail/calcium-lignosulphonate-MG-3).

Hence the cost of usage can be estimated using the relation;

Cost of usage = mass consumed * (price of 1000kg of chemical/ 1000kg) (1)

Sugar

0.07% sugar in 1000kg

0.07kg of sugar costs = $\frac{3 \times 70{,}000}{1000}$ = 56 naira per 1000kg

Lignosulphonate

Calcium lignosulphonate are usually doped 0.25-0.3% of cement.

Hence, 0.3% of 1000kg = $\frac{3 \times 70{,}000}{1000}$ 210 naira per 1000k

The results of effects of sugar on setting times and soundness of cement paste are presented in Table 1. The test showed increase in the setting times for very minute amount of sugar in use and was quite opposite for larger percentages which concurs with Rana, (2014).

Similarly, From Table 1, the sample with sugar content at 0.01% with an initial and final setting times of 154 and 226 minutes respectively is higher compared to the control sample with initial and final setting times of 121 and 184 minutes respectively. The other samples from 0.02% to 0.07% showed continuous and steady increase as stated by Abalaka (2011). From 0.08%, a small drop in setting time commences but becomes more obvious from 0.25% to 0.50% where flash sets since total hardness was not observed but at high dosages, sugar is known to induce flash setting according to Haseeb (2017).

Consistency and Water Content

Consistency of cement paste is a measure of expansion of set cement paste (Khan and Baradan, 2002). It is important that cement should not undergo large volume change, since this could inevitably lead to a disruption of the hardened cement paste (Haseeb, 2017). The maximum value allowed by ENV 197-1 (1992) standard is 10 mm and the acceptable minimum is 5 mm hence varying amount of water was employed for different sample to ensure consistency to this rule. For the control sample, standard amount of water was employed but for subsequent samples with increased sugar content the water content was reduced to ensure

conformity with EN 197-1. The result obtained shows that sugar does not just increase setting time, it could also be a water reducer and this is in agreement with Engelsen et al. (2014).

Compressive Strength Test

Load bearing capacity of the concrete cubes at varying sugar content was evaluated after 28 days as shown in Table 2. From the table, the test showed increasing strength with more addition of sugar. Concrete sample with 0.01% sugar content showed an increase of 14.88% in strength and at 0.07 where a further strength gain was recorded, it rose up to 22.72%. This is validated by Abalaka, (2011). This increment in strength could be attributed to the less water content required when sugar is in use as stated that the water/cement ratio is the largest single factor in the strength of fully compacted concrete (Neville, 2011). Also, when sugar is used as a set retarder, it can severely reduce early strength of concrete, but that beyond about seven days there is an increase in strength of several percent compared with non-retarded mix (Engelsen et al. 2014). Loss in strength begins at 0.09% which is to be expected with increasing sugar content in cement. Significant loss of strength is observed for cement samples between 0.25 -5 percent; this can be attributed to its rapid rate of hardening as deduced from the setting time test.

Cost Effectiveness of Using Sugar as a Retarder

From the calculations, it is obvious that using the sugar concentration where the test sample had its peak strength gain and an initial setting time of 342 minutes, the use of sugar when an increase in setting time is required is way more economical than employing known retardants such as Calcium lignosulphonate MG-3 superplasticizer admixture (Anon, 1988). A saving of 154 naira per 1000 kg of cement was calculated which amounts to a whole lot in the long run.

CONCLUSION

From the results obtained in the investigation into the effect of sugar in the hardening of cement, the following conclusions have been drawn:

1. Sugar when used in minute proportion acts as a retarder but in somewhat excessive amount (from 0.25 % of the cement in use), it acts as an accelerator.
2. The quantity of the sugar and other related quantities such as amount of cement in use, water-cement ratio must be adequately metered in the production process as cement is very sensitive to sugar concentrations.
3. Sugar content in cement does not alter the compressive strength of cement rather certain increment was noticed with 0.07 % of sugar proving to be most promising at 28 days with a compressive strength of 20.89 N/mm^2.
4. Sugar above 0.25 % by weight acts as an accelerator with notable reduction in compressive strength. Excessive volume expansion was also observed with surface cracks.
5. Sugar can also be applied as a water reducer in cases where its setting time increase can be ignored.
6. Compared to other known retarders, sugar serves as a cheap alternative when set. Time delay is desired. A saving of 154 naira per 1000 kg of cement when sugar is employed as against other retarders.

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