

DECAYING EXPONENTIAL MODELS FOR PREDICTING THE SETTING TIME OF CONCRETE AS A FUNCTION OF ITS PENETRATION BY PROCTOR NEEDLE USING SUGAR AS ADMIXTURE

¹Umeonyiagu, I. E. and ²Ikezue, E. N.

¹Dept. of Civil Engineering, Chukwuemeka Odumegwu Ojukwu University, P.M.B.02, Uli, Anambra State, Nigeria.

²Dept. of Chemical Engineering, Chukwuemeka Odumegwu Ojukwu University, P.M.B.02, Uli, Anambra State, Nigeria.

Email: ¹umeonyiaguikuchukwu@yahoo.com, ²eddikezue@yahoo.com

ABSTRACT

This research work set out to develop decaying exponential models for predicting the setting time of concrete as a function of its penetration by proctor needle using common sugar as the admixture. Various percentages of sugar by weight of cement (0.01% —1%) were added to the concrete mix of 1:1:2/0.5 by weight and tested for setting every 15 minutes. It was shown that as the concrete set, the depth of penetration decreased exponentially following decaying models of the form $Y = C_1e^{-C_2X}$ where Y represents the depth of penetration of the proctor needle, x the delay in minutes, C_1 and C_2 are constants. Also, the research showed that increases in the percentage of sugar present resulted in the slowing down of the rate of setting of concrete and increased the average penetration per minute.

Keywords: - Concrete, Sugar, Decaying Exponential Model, Proctor Needle.

INTRODUCTION

Retarders

Retarders are useful in concreting in hot weather, when the normal setting time of concrete is shortened by the higher temperature, and in preventing the formation of cold joints [1]. Retarders do not alter the composition or identity of products of hydration [2]. These admixtures generally slow down also the hardening of the paste. The delay in hardening caused by the retarders can be used to obtain an architectural finish of exposed aggregate: the retarder is applied to the interior surface of the formwork so that the adjacent cement is delayed. This cement can be brushed off after the formwork has been struck so that an exposed aggregate surface is obtained. Retarding action is exhibited by sugar, carbohydrate derivatives, soluble zinc salts, soluble borates, and others. Great care is necessary in using retarders as in incorrect quantities they can totally inhibit the setting and hardening of concrete. The effects of sugar depend greatly on the quantity used, and conflicting results were reported in the past [3]. It is interesting to note that the effectiveness of an admixture depends on the time when it is added to the mix: a delay of even 2 minutes after water has come into contact with cement increases the retardation. Retarders tend to increase the plastic shrinkage because the duration of the plastic stage is extended but drying shrinkage is not affected [4]. The mechanism of action of retarders has not been established with certainty but it is known that they modify the crystal growth or morphology [1].

2. MATERIALS AND METHODS

2.1 Preparation and Testing of Samples

The aggregates were sampled in accordance with the methods prescribed in BS 812: Part 1:1975 [5]. The test sieves were selected according to BS 410:1986 [6] and the sieve analyses of both fine and coarse aggregates were done in accordance with BS 812: Part 103:1983 [7]. The water used for the making of the concrete specimens was subjected to the tests prescribed in BS 3148:1980 [8] and was found satisfactory. The cement used was ordinary Portland cement. The experimental concrete mix of 1:1:2 containing the retarder in varying percentages were produced on a mixer, poured into a cylinder and given maximum compaction. This compacted concrete was then taken to the Vicat apparatus where a proctor needle was used to measure the degree of penetration every 15 minutes.

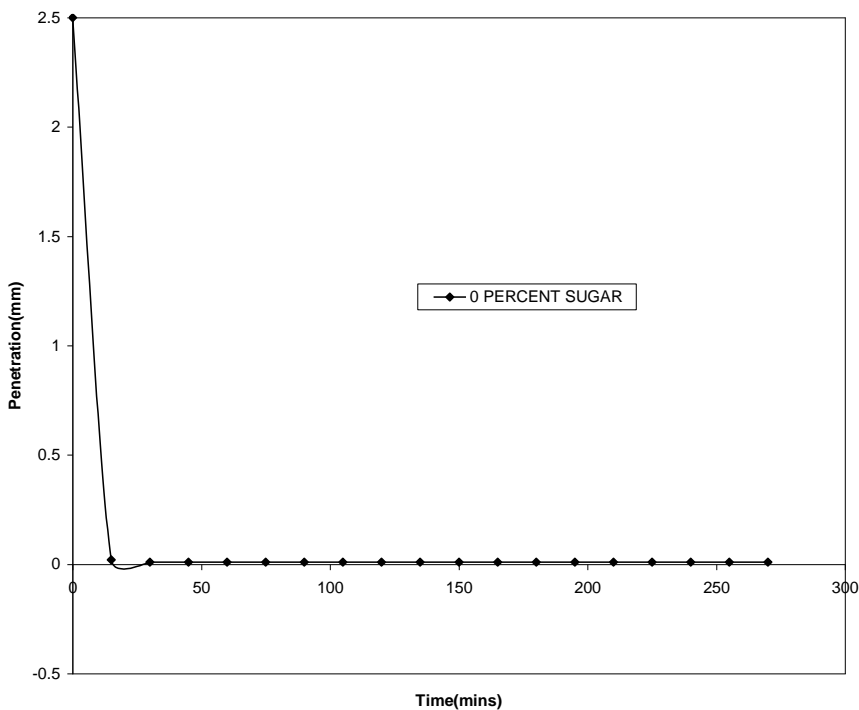


FIGURE 1: Penetration vs Time for 0% Sugar Content

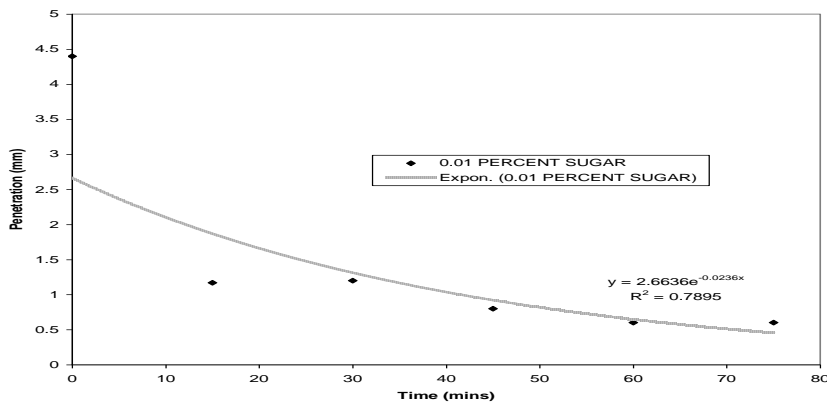


FIGURE 2: Penetration vs Time for 0.01% Sugar Content

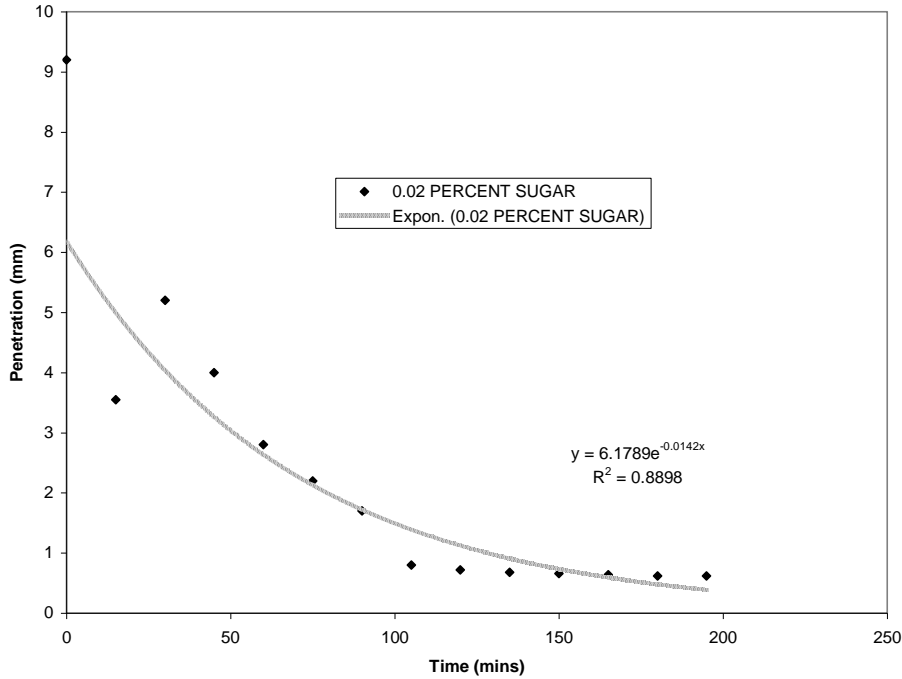


Figure 3: Penetration vs Time for 0.02% Sugar Content

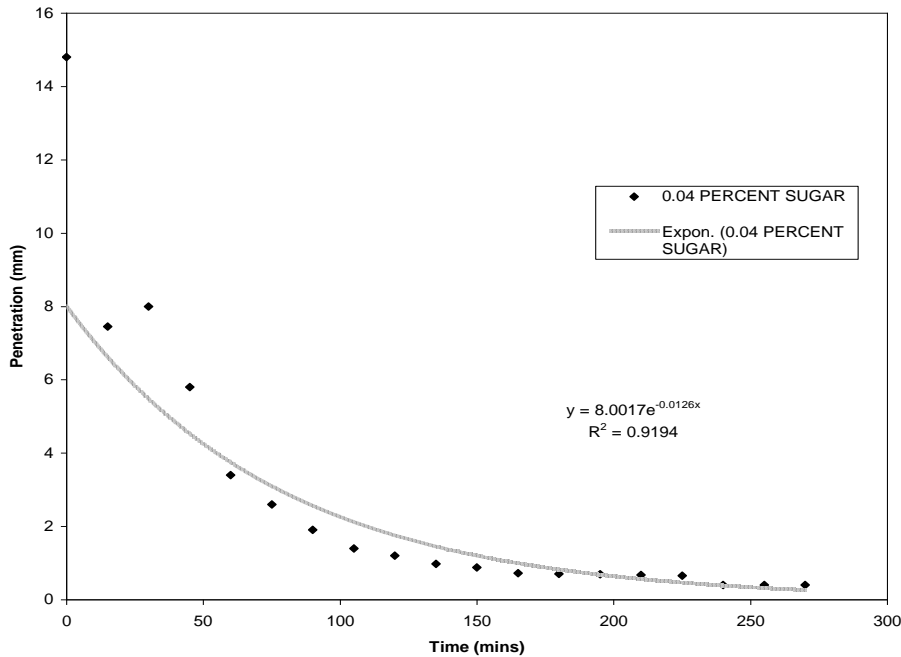


FIGURE 4: Penetration vs Time for 0.04% Sugar Content

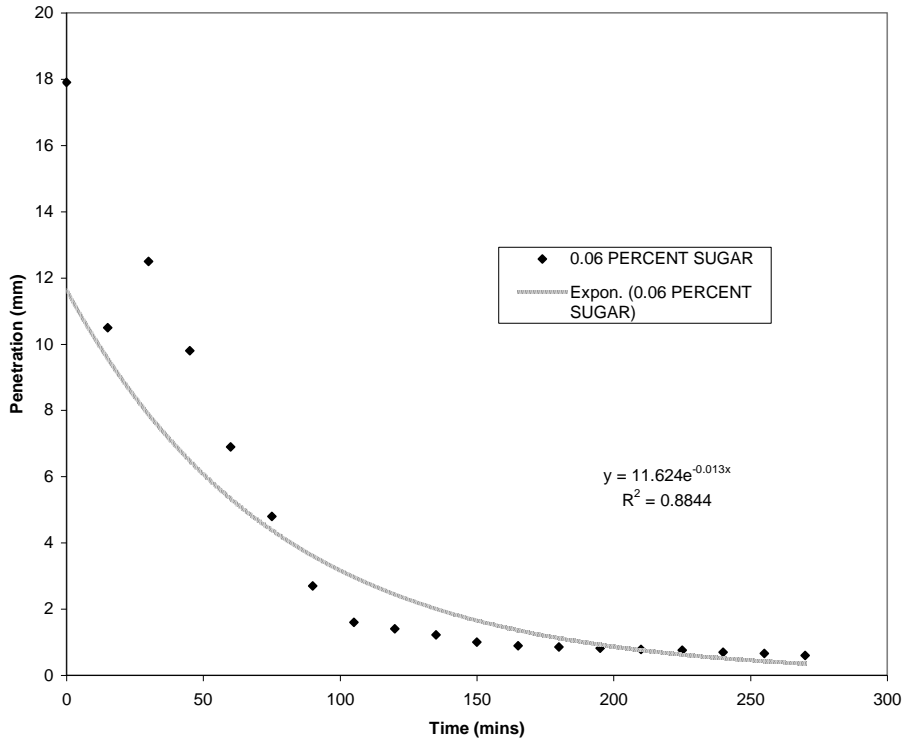


FIGURE 5: Penetration vs Time for 0.06% Sugar Content

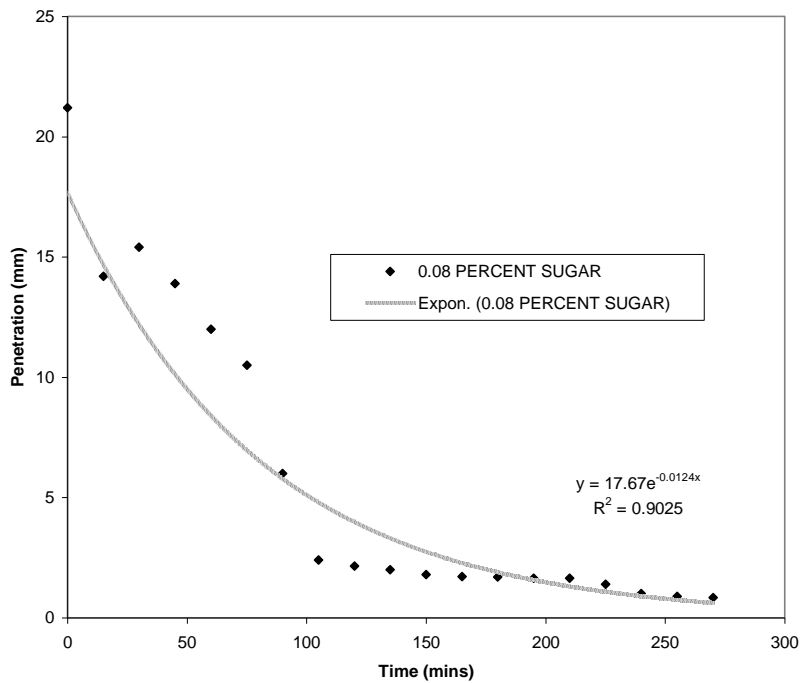


FIGURE 6: Penetration vs Time for 0.08% Sugar Content

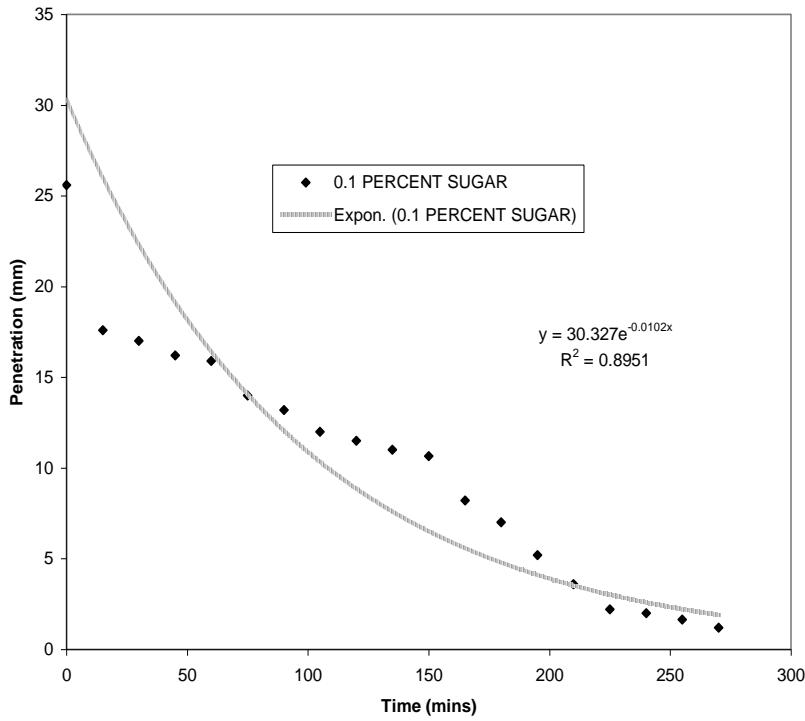


FIGURE 7: Penetration vs Time for 0.1% Sugar Content

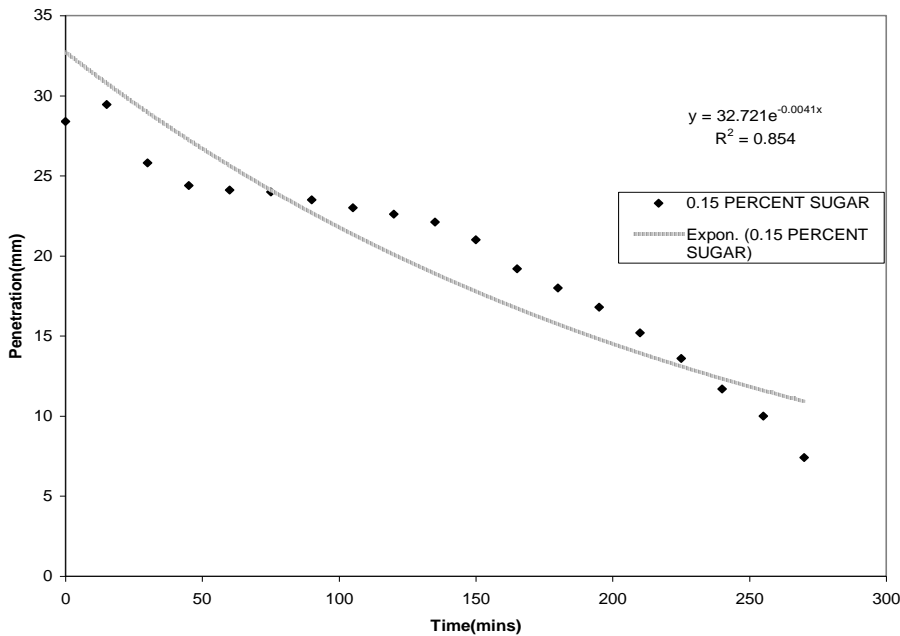


FIGURE 8: Penetration vs Time for 0.15% Sugar Content

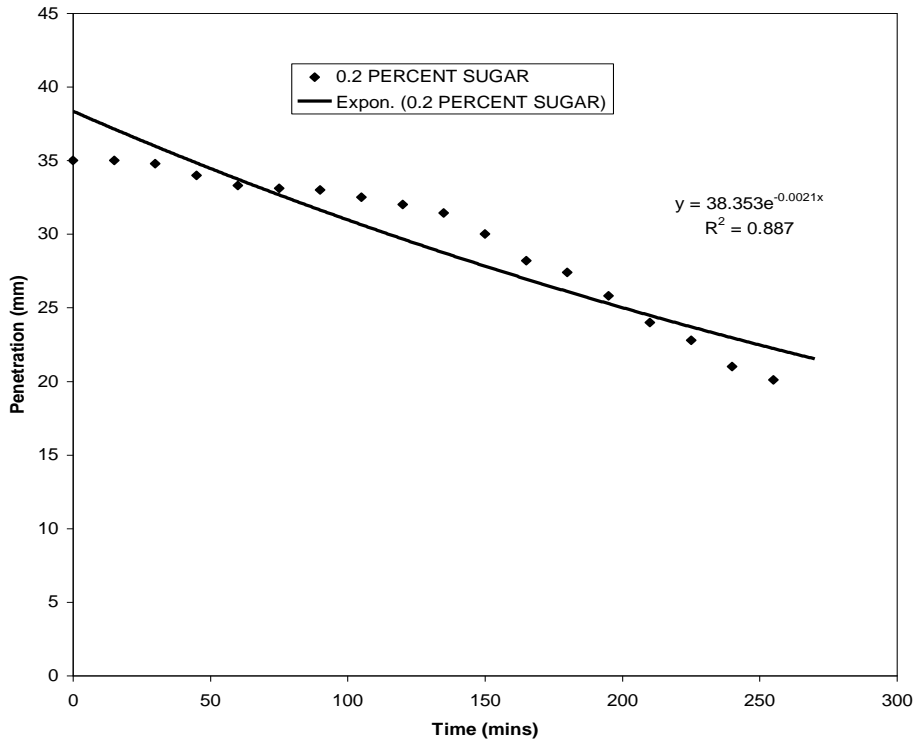


FIGURE 9: Penetration vs Time for 0.2% Sugar Content

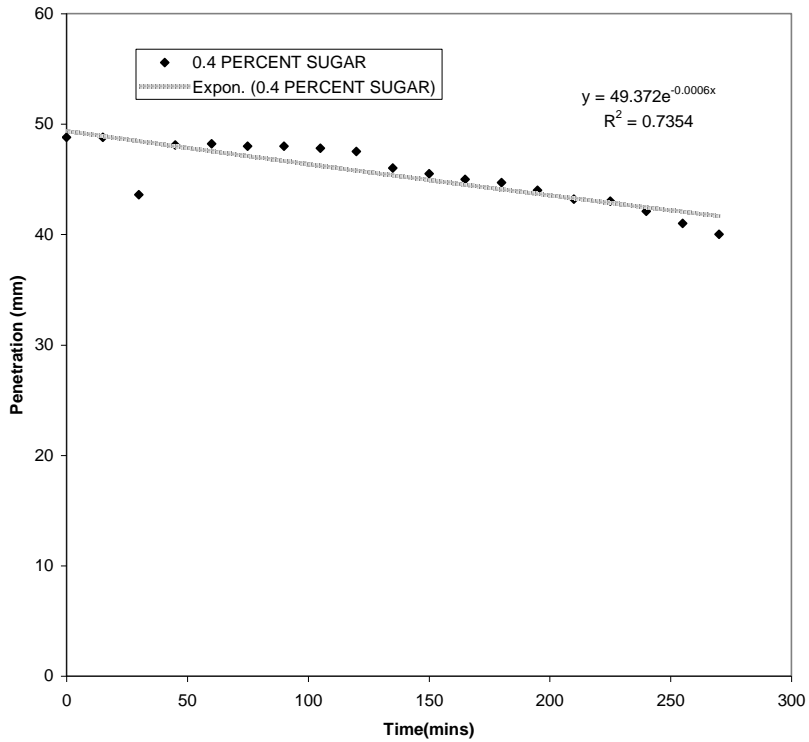


FIGURE 10: Penetration vs Time for 0.4% Sugar Content

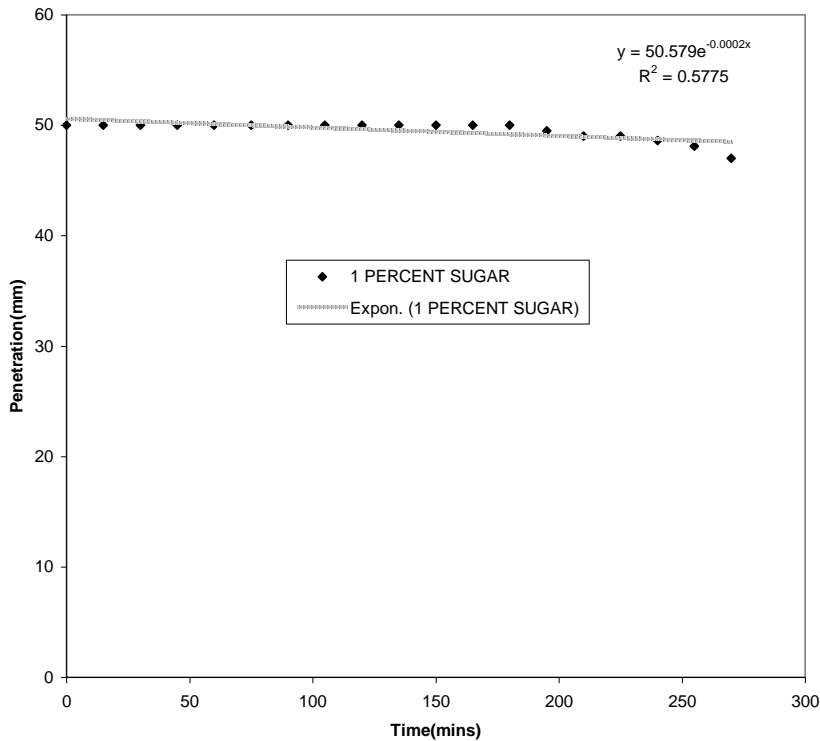


FIGURE 11: Penetration vs Time for 1% Sugar Content

RESULTS AND DISCUSSION

Figure 1 shows the graph of penetration against time for a concrete mix with zero concentration of sugar. The mix was able to set after about 30minutes and had an average rate of penetration of 0.00996mm/min. Figure 2 shows an exponential graph of $Y = 2.6636e^{-0.0236 X}$ for the concrete mix having a sugar percent of 0.01. The coefficient of determination, R^2 of the graph was 0.7895. It had an average rate of penetration of 0.0614mm/min. 0.02 percent sugar content fits the graph of the exponential function, $Y = 6.1789e^{-0.0142X}$ in figure 3 with $R^2 = 0.8898$. The average rate of penetration was 0.1352mm/min. Figure 4 shows the graph of the function $Y = 8.0017e^{-0.0126X}$ for 0.04 percent sugar content. R^2 for this graph was 0.9194 and an average penetration value rate of 0.1966mm/min. Figure 5 shows a decaying exponential graph of $Y = 11.624e^{-0.013X}$ with $R^2 = 0.8844$ for a 0.06 percent sugar content. It had an average penetration rate of 0.2831mm/min. 0.08 percent sugar content fits the exponential graph of $y = 17.67e^{-0.0124X}$ in figure 6. The R^2 for the model was 0.9025 and the average increase in penetration was 0.4166mm/min. Figure 7 shows an exponential decaying graph of $Y = 30.327e^{-0.0102X}$ for 0.1 sugar content with $R^2 = 0.8951$. It had an average penetration value of 0.7251mm/min. Figure 8 shows the graph of 0.15 percent sugar content. It is the exponential function $Y = 32.721e^{-0.0041X}$ and had $R^2 = 0.854$ and 1.408mm/min as the average rate of penetration. 0.2 percent sugar content was the graph of $Y = 38.353e^{-0.0021X}$ in figure 9 with $R^2 = 0.887$ and the average penetration value of 2.0454mm/min. The graph of $Y = 49.372e^{-0.0006X}$ with $R^2 = 0.7354$ in figure 10 represents 0.4 percent sugar. It had average rate of penetration as 3.199mm/min. Figure 11 represents the graph of 1 percent sugar content. It is

the function $Y = 50.579e^{-0.0002X}$ with $R^2 = 0.5775$. It had an average rate of penetration of 3.490mm/min. The coefficients of determination for figs.2 – 11 were relatively high indicating a strong relationship between penetrations and time. As the percentage of sugar increased, the average needle penetration/minute increased signifying increased delays in the setting of the concrete. 0.01% sugar produced a delay of about 25 minutes; 0.02% sugar set at about 225minutes; 0.04% sugar produced a setting time of about 290 minutes; 0.06% sugar produced a setting time of about 310 minutes; 0.08% sugar content was able to set at about 350 minutes after mixing; 0.10% sugar content set at about 410minutes. From 0.15% - 1 % sugar content, the concrete mix virtually refused to set.

CONCLUSIONS

- The relationship between proctor needle penetrations (mm) and time (s) for a concrete mix with sugar as admixture formed decaying exponential models of the form $y = c_1e^{-c_2x}$.
- The average rate of penetration increased with increase in the sugar content as a percentage weight of the cement.
- As the average rate of penetration increased, so did the setting time.
- Above 0.8 percent sugar, the concrete mix virtually refused to set.

REFERENCES

1. Neville, A. M., *Properties of Concrete*, Longman Ltd, England, 1996.
2. Seligmann P. and Greening , N. R., *Studies of early hydration reactions of Portland cement by X-ray diffraction*, Highway Research Record, Highway Research Board, No.62, pp.80– 105,Washington D.C., 1964.
3. Bloem, D. L., *Preliminary Tests Of Effects Of Sugar On Strength Of Mortar*, Nat. Ready-Mixed Concr.Assoc. Publcn.,Washington D.C.,August,1959.
4. Scholer, C.F., *The Influence Of Retarding Admixtures On Volume Changes In Concrete*, Joint Highway Res. Project Report Jhrp-75-21,Pp.30, Purdue University, October, Indianapolis, Indiana, USA,1975.
5. British Standards Institution.BS 812: Part 1: 1975 *Sampling, shape, size and classification*. Methods for sampling and testing of mineral aggregates, sands and fillers.
6. British Standards Institution .BS 410: 1986. *Specification for test sieves*.
7. British Standards Institution. BS 812: Part 103:1983 *Testing aggregates*.
8. British Standards Institution .BS 3148:1980 *Tests for water for making concrete*.