THE APPLICATION OF LOCAL CANE SUGAR AS A RETARDING ADMIXTURE

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ABSTRACT

Retarding admixtures or retardes are used in the mixing concrete to prolong the setting time or the plasticity of fresh concrete. This is normally done to avoid complications when unavoidable delay may occur between mixing and placing. Moreover, prolonging the setting time or the plasticity of fresh concrete is benefit in placing mass concrete or when the weather is quite hot that normally occurs in Indonesia. A retarder is also used to avoid a cold joint between previously poured concrete that is already hardened and new fresh concrete. This paper reports the effect of cane sugar on the setting time of cement paste using the standard Vicat apparatus to see how effective is the sugar cane can be used as a retarding admixure. In the experiment cement paste was blended with various amount of cane sugar produced by Madukismo, Yogyakarta, Indonesia. The amount of cane sugar varies from 0 % to 0.20 % of the used cement in weight. The test results showed that cane sugar can be used as a retarding admixture. This is because the use of the cane sugar caused the delay of the setting time. For the various amount of sugar ranging from 0 % to 0.20 %, the setting time was increased from 2 hours to almost 18 hours.

INTRODUCTION

Retarding admixtures are known to delay hydration of cement without affecting the long-term mechanical properties. They are commonly used in concrete to offset the effect of high temperatures, which decrease setting times, or to avoid complication when unavoidable delays between mixing and placing occur [Mindess and Young (1981)]. Moreover, the uses of retarding admixtures have the following objectives [ACPA (1975)]:

1. allows more time for texturing or plastic grooving of concrete pavements,
2. allows more time for hand finishing around the headers at the start and at the end of the production day,
3. helps to eliminate cold joints in two-course paving and in the event of equipment breakdown,
4. resists cracking due to form deflection that can occur when horizontal slabs are placed in sections. This is because concrete that has set but acquires little strength is liable to micro crack when subsequent pouring alters the amount of form deflection. If the plastic period is prolonged, the concrete can adjust to form deflection without cracking.

There are a lot of kind of retarders can be found in the market from variety of companies. Basically retarders can be divided into several categories, based on their chemical composition as follows:

1. lignosulfonic acids and their salts,
2. hydroxy-carboxylic acids and their salts,
3. sugars and their derivatives,
4. inorganic salts.

This research is aimed to investigate the possibility of local cane sugar from Madukismo Yogyakarta to be used as a retarding admixture by conducting setting time test using Vicat apparatus. It is hoped that the result of this research can be considered by practical engineers as an alternative of retarding admixture.

THEORY

Process of Hydration in Portland Cement

Chemical reaction of cement powder and water to become a hardened material called cement paste is very complicated. This process is known as a process of hydration in which it is assumed that the hydration of each compound takes place independently of the others that are present in portland cement. Although this assumption is not really valid as the interaction between each compound is not independently, this is the only way how to describe the reaction or what is happening during the hydration process.

Chemical compounds of portland cement can be divided into four major groups which is known as the "Bogue composition". The four compounds can be listed as follows.

1. Tricalcium silicate, where the chemical oxide composition is $3CaO.SiO_2$ or abbreviated as C_3S.

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2. Dicalcium silicate, where the chemical oxide composition is $2CaO.Si.O_2$ or abbreviated as C_2S.
3. Tricalcium aluminate, where the chemical oxide composition is $3CaO.Al_2O_3$ or abbreviated as C_3A.
4. Tricalcium aluminoferrite, where the chemical oxide is $4CaO.Al_2O_3.Fe_2O_3$ or abbreviated as C_4AF.

The reactions of hydration of the above two major compounds after the portland cement is mixed with water can be written as follows.

For C_3S:

$$2C_3S + 6H \rightarrow C_3S_2H_3 + 3\ Ca(OH)_2 \qquad (1)$$

For C_2S:

$$2C_2S + 4H \rightarrow C_3S_2H_3 + Ca(OH)_2 \qquad (2)$$

The rate of hydration depends of the amount of these four major compounds. C_3A and C_3S are the most reactive compounds, whereas C_2S reacts much slower. The presence of gypsum slows the early rate of hydration of C_3A. Quantitative data is not available for C_4AF, but the reaction of C_4AF-gypsum-water is believed to be somewhat slower than C_3S, whereas the hydration of C_4AF without gypsum is faster.

Chemical Composition of Sugar

Sugar in general term applied to any of a number of chemical compounds in the carbohydrate group that are readily soluble in water which are odorless, colourless, crystallizable and are more or less sweet in taste. Many term of sugar such as disaccharide sugars, maltose, lactose, and sucrose, have the empirical formula $C_{12}H_{22}O_{11}$.

Among the commercially important sugars are glucose, lactose, maltose, and sucrose. Sucrose is generally known as saccharose or cane sugar, which is extracted from sugarcane and was used in this research as a retarding admixture.

Effect of Sugar on the Process of Hydration

The effect of sugar on the process of hydration was unintentionally found in the first time by Thomas (1921). He noticed that, after being laid a very short time, the concrete in a refinery began to disintegrate. The quality of the cement was good, fulfilling satisfactorily the requirements of the British Standard specification, and the aggregate was clean and above suspicion. From the investigation it was found that the water, which had been used in the mixing, though appearing quite clean to the eyes, had contained a small percentage of sugar waste. He assumed that this small percentage of sugar was the cause of the problem because the application of new clear water solved the problem.

Gonnerman (1938-1939) noted that it has been generally accepted in civil engineering and building industries that the presence of a small amount of sugar in a concrete mix has a harmful effect on the setting properties of the concrete. This attitude was originated from the accidental inclusion of sugar in concrete mixes on a number of occasions as mentioned above.

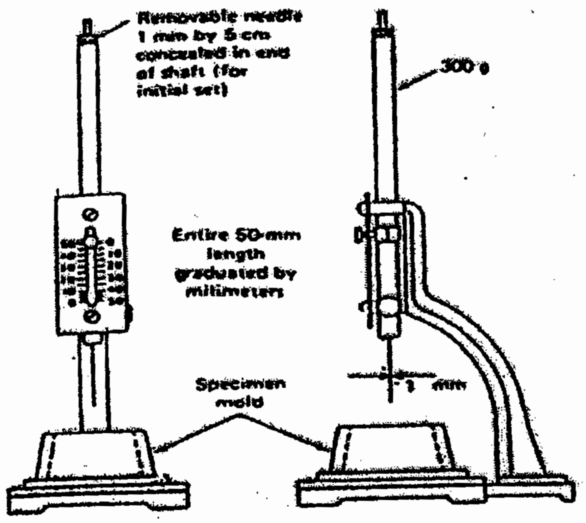
Ashworth (1965) stated in his paper that the chemical reactions giving rise to this retardation effect are very complex and not fully understood in addition to the complex chemical reaction of the process of hydration of the cement itself. Hansen (1952), however, suggested that admixture such as sugar containing the group HO-C-H acts by forming a layer on the grains of the cement compounds that prevents the process of hydration taking place rapidly. The theory of set-retardation mechanism in portland cement pastes containing organic admixture in general was reviewed by Young (1972). He concluded that the role or retarding admixtures can be explained in a simple way that the admixture forms a film around the cement compound, thereby preventing or slowing the reaction with water. The thickness of this film will dictate how much the rate of hydration is retarded. If after a while this film breaks down, normal hydration then proceeds. In some cases when the dosage of admixtures exceeds a certain critical point, hydration of cement compounds will never proceed beyond a certain stage, and the cement will never set. Therefore, it is recommended to limit the dosage of this admixture.

EXPERIMENTAL WORKS

To see the possibility of local cane sugar to be used as a retarding admixture, a series of experiment were carried out at the Building Material Laboratory, Department of Civil Engineering, Gadjah Mada University, Yogyakarta, Indonesia. The first series of experiment is the examination of the effect of cane sugar on the setting time of cement paste using Vicat apparatus, which is reported in this paper. The other series such as the effect of cane sugar on the concrete workability and compressive strength will be presented elsewhere. It is important to note here that the setting time measured in the experiment was the initial setting time.

Materials

The materials used in the experiment are water, Type I Portland Cement of Nusantara, and cane sugar from Madukismo, Yogyakarta, Indonesia, which was ground to become powder.



front view side view

Figure 1. Vicat apparatus (Mindess et.al., 1981)

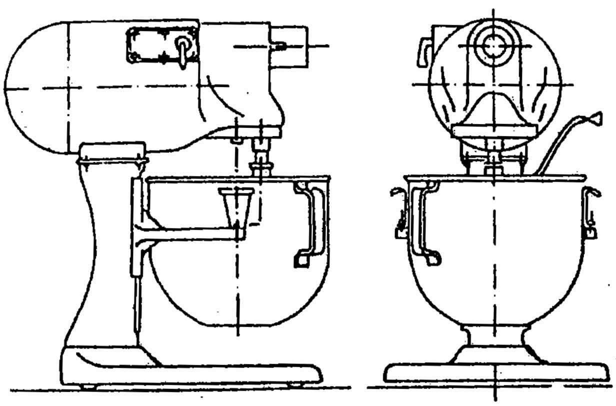


Figure 2. HOBART cement paste mixer

Apparatus

The main apparatus used to study the setting time of cement paste are Vicat apparatus as shown in Figure 1, HOBART cement paste mixer shown in Figure 2, and the other supporting apparatus such as caliper, weighing, stopwatch and spoon.

Procedure

To see the effect of cane sugar on the setting time of cement paste, various percentages of cane sugar to the weight of portland cement in making the cement paste were used. In this experiment the following percentage of cane sugar to the weight of portland cement were used; 0%, 0.01%, 0.02%,0.05%, 0.15%, 0.20%. Three sets of Vicat test were conducted for each cane sugar content, and in each set the Vicat reading was carried out three times.

The following procedure was taken to determine the setting time of each percentage of cane sugar using Vicat apparatus.

1. The required water cement ratio in the Vicat test is between 0.24 to 0.33 [Mindess and Young (1981)]. In this research the water cement ratio of 0.30 was adopted.
2. The required water, portland cement and powdered cane sugar for each sugar cotent mentioned above are shown in Table 1.

Table 1. The amount of material used in the Vicat tests.

Code	Sugar Content (%)	Portland Cement (gr)	Water (ml)	Sugar (gr)
SC-0.00	0.00	500	150	0.00
SC-0.01	0.01	500	150	0.05
SC-0.02	0.02	500	150	0.10
SC-0.05	0.05	500	150	0.25
SC-0.15	0.15	500	150	0.75
SC-0.20	0.20	500	150	1.00

3. Water and sugar were mixed in a glass container.
4. Water with sugar and portland cement were blended in the mixer shown in Figure 2 for about ½ to 1 minute.
5. The Vicat test was carried out by reading how far the needle could penetrate the cement paste, which was measured from the bottom. The reading was conducted every hour and was up to twenty four hours or when the needle could not penetrate the cement paste any more. This reading was taken three times for each set.
6. The readings were then drawn in a graph that shows the relationship between time in hour and the distance of the Vicat apparatus needles from the bottom.
7. The setting time from the graphics above is the hour when the paste stiffens sufficiently for the needle to penetrate only to a point about 5 mm from the bottom [Neville (1975)].

EXPERIMENTAL RESULT AND DISCUSSION

Table 2 and Figure 3 show the relationship between time in hour and the average distance of the Vicat apparatus needles from the bottom for each percentage of sugar. From this figure the setting time for each cane sugar content is then estimated as mentioned above, that is the hour when the paste stiffens sufficiently for the needle to penetrate only to a point about 5 mm from the bottom. Using this procedure the correlation between cane sugar content and setting time can be drawn as can be seen in Figure 4. It is apparent that cane sugar increases the setting time very significant compare to the one without sugar cane. If the ordinary portland cement has normally setting time of about 2 hours, the application of cane sugar content of 0.20% increases the setting time to become almost 18 hours.

Table 2. Average Vicat readings for each sugar content.

Hour	Vicat readings (mm)					
	0.00%	0.01%	0.02%	0.05%	0.15%	0.20%
0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.00	0.33	0.00	0.00	0.17	0.00	0.00
1.50	1.72	0.11	0.19	0.00	0.00	0.02
2.00	18.00	0.38	0.18	0.00	0.00	0.00
2.50	33.00	10.44	2.40	0.22	0.00	0.00
3.00	37.56	26.97	9.26	0.33	0.06	0.17
4.00	39.11	36.56	29.44	0.41	0.11	0.17
5.00	39.56	38.72	36.52	2.61	0.28	0.00
6.00	39.61	39.00	38.00	11.33	0.49	0.08
7.00	40.00	39.33	38.69	21.22	1.07	0.39
8.00		40.00	39.72	24.72	0.78	0.72
9.00			40.00	29.28	1.06	0.80
10.00				34.44	2.88	1.17
11.00				36.00	6.11	1.89
12.00				37.89	8.24	3.22
13.00				38.11	11.53	2.11
14.00				38.28	19.06	2.89
15.00				39.17	25.17	3.17
16.00				39.00	29.13	3.72
17.00				40.00	31.39	4.39
18.00					31.34	5.06
19.00					31.40	4.72
20.00					32.38	6.00
21.00					33.10	2.56
22.00					34.08	5.22
23.00					34.06	5.39
24.00					34.46	5.00

Note: maximum reading is 40 mm, where the final set has taken place

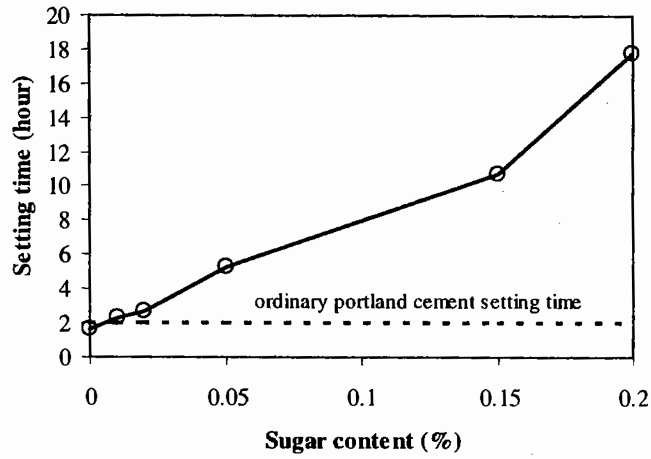


Figure 3. Effect of cane sugar content on the initial setting time.

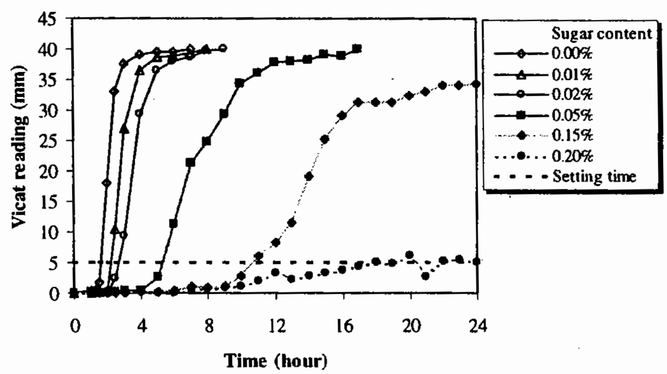


Figure 4. Effect of cane sugar content on the Vicat test.

CONCLUSION

From the experimental result and discussion mentioned above it is concluded that the application of cane sugar increases significantly the setting time to about 18 hours for the sugar content of 0.20%. Therefore cane sugar may be used as a retarding admixure.

RECOMMENDATION

It is important to note that the results of Vicat readings reported here are limited up to 24 hours and the maximum sugar content is 0.20%. Further Vicat tests until the final test of cement paste for all sugar content is reached need to be studied. It is also required to carry out further Vicat tests for sugar content of more than 0.20%.

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