THE PERFORMANCE OF LOW DOSAGE OF SUCROSE AS 'GREEN' ADMIXTURE FOR CONCRETE

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ABSTRACT

The sustainability in civil engineering is supported by ecological awareness. Several efforts have been done to achieve sustainability of civil engineering, such as introducing 'green' admixture for concrete. The research tries to deliver a low dosage of sucrose as admixture, 0.03% of cement weight that is becomes ingredient of concrete mixture. The research conducts experiment methods and uses specimens consists of some mortar cubes and concrete cylinders specimens with compressive strength design f'_c = 30 MPa. The variant of specimens is divided into plain and added by sucrose 0.03% of cement weight. All specimens are cured for 7, 14, and 28 days, and then tested for its compressive strength. The experiment also conducts an observation of mortar surface hardening by trinoculer electronic microscope. This research meets conclusions as follow: (1) Sucrose with low dosage of 0.03% of cement weight can prohibit the hardening of cement paste; (2) The sucrose admixture with dosage of 0.03% by weight of cement for mortar specimens performs as accelerator because its values of compressive strength at days-14 and 28 are 7-17% higher than plain mortar; (3) The sucrose admixture with dosage of 0.03% by weight of cement for concrete specimens perform as retarder because its values of compressive strength at days-7 and 14 are 11-27% lower compared to plain concrete; (4) The sucrose admixture with dosage of 0.03% by weight of cement for concrete specimens increases the compressive strength, 26% higher than plain concrete; (5) In the first 6 hours of mortar hardening, the presence of sucrose with low dosage of 0.03% of cement weight is giving retardation effect that the surface of mortar specimens is wetter and softer compared to the plain mortar; and (6) The performance of sucrose as retarder and accelerator 'green' admixture will fulfil the need of sustainability of civil engineering.

Keywords: sucrose, 'green' admixture, concrete

1. INTRODUCTION

The sustainability in civil engineering is supported by ecological awareness. There is no doubt that civil engineering field should keep the 'eco-balance' and ecological awareness for better life. Several significant efforts have been done to achieve sustainability of civil engineering, such as introducing 'green' admixture for concrete. The admixture will increase.

The concrete admixture is defined by ASTM C125 (Mehta and Monteiro, 1993) as "a material other than water, aggregates, hydraulic cements, and fiber reinforcement, used as an ingredient of concrete or mortar and added to batch immediately before or during mixing". Several important purposes are also noted by ACI Committee 212, for examples to retard or acclerate the time of set and to accelerate the rates of strength development at early ages. Hence, some admixtures can be used as retarder (to delay cement setting) and accelerator (to accelerate cement setting). Sugar is believed as good retarder in concrete mixing (Etmawati, D. and Yuwono, A., 2008; Nikodemus and Setiawan, B., 2008; Susilorini, Retno, et. al, 2008). For retarding effect, the dosage of sugar as retarder is ranged between 0.03%-0.15% by weight of cement. The accelerating effect will be given by the dosage above 0.25% will a of cement (Jayakumaran, 2005). It should be noticed that certain dosage of sugar can perform as retarder (Jayakumaran, 2005; Suranto, 2008; Etmawati, D. and Yuwono, A., 2008; Susilorini, Retno, et. al, 2008) or accelerator (Jayakumaran, 2005; Nikodemus and Setiawan, B., 2008; Susilorini, Retno, et. al, 2008). Another researches of sugar using in concrete have been reported (Deutschen Bauchemie, 2006; Frias, et.al., 2006; Jayakumaran, 2005; Collepardi, 2005; Chandler, Cristophe, et.al., 2002; Medjo Eko, dan Riwoski, 2001), but there is no exact dosage determined to retard or accelerate the cement setting or concrete hardening.

While refined sugar as admixture in concrete (Etmawati, D. and Yuwono, A., 2008; Nikodemus and Setiawan, B., 2008; Susilorini, Retno, et. al, 2008), sucrose has become an alternative of concrete admixture in this research. Sucrose is abundant pure organic chemical (Harrison, 2009) that are categorized as disaccharides. Some carbohydrates are disaccharides. Basically, Complex Carbohydrates are made up of two or more simple sugars that are linked together. It is noted that sucrose is made from glucose and fructose units. The glucose and fructose units are joined by an acetal oxygen bridge in the alpha orientation (Figure 1). The structure contains six member ring of glucose and the five member ring of fructose.

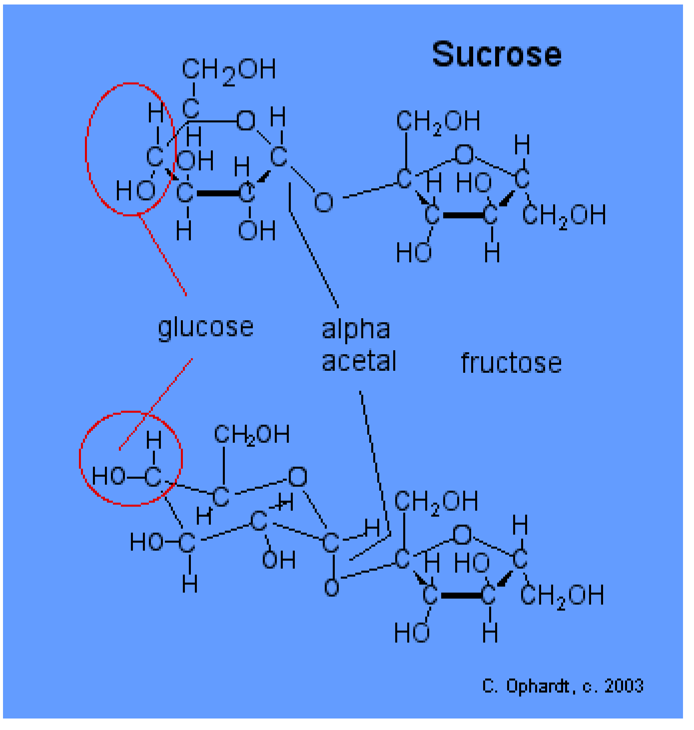

Figure 1. Structure of sucrose
(Ophardt, 2003)

It is interesting that there is significant difference between mortar and concrete stress-strain relations during loading history. The concrete stress-strain relation is non-linear while the mortar one is linear (Neville, 1999). This distinction performs because of the interface existence between cement paste and aggregate in concrete. The interface suffers bond micro cracks that reduce the effective area resisting the applied load. Hence, the setting of cement gives great influence in concrete performance. The admixture will take important role in how the concrete is hardening.

According to the importance of the use of sugar as concrete admixture, sucrose becomes an alternative to perform as 'green admixture'. The research tries to deliver a low dosage of sucrose admixture, it is 0.03% of cement weight that is becomes ingredient of concrete mixture.

2. METHOD OF RESEARCH

The research conducts experiment methods and uses specimens consists of some mortar cubes and concrete cylinders specimens with compressive strength design f'_c = 30 MPa. The variant of specimens is divided into plain and added by sucrose 0.03% of cement weight. All specimens are cured for 7, 14, and 28 days, and then tested for its compressive strength. The experiment also conducts an observation of mortar surface hardening by trinoculer electronic microscope.

(a) (b) (c)

Figure 2. Specimens and equipment
(a) Mortar cubes specimen in casting
(b) Concrete cylinders in curing container
(c) Trinoculer electronic microscope and computer system
(Nikodemus and Setiawan, B., 2008)

3. RESULTS AND DISCUSSION

Result

The Vicat test (Figure 3) shows that the final set time of cement paste with sucrose 0.03% of cement weight is longer (225 minutes) compared to the plain cement (60 minutes). The higher penetration (23 mm) is also achieved by cement paste with sucrose 0.03% of cement weight at final set compared to the plain one (19 mm).

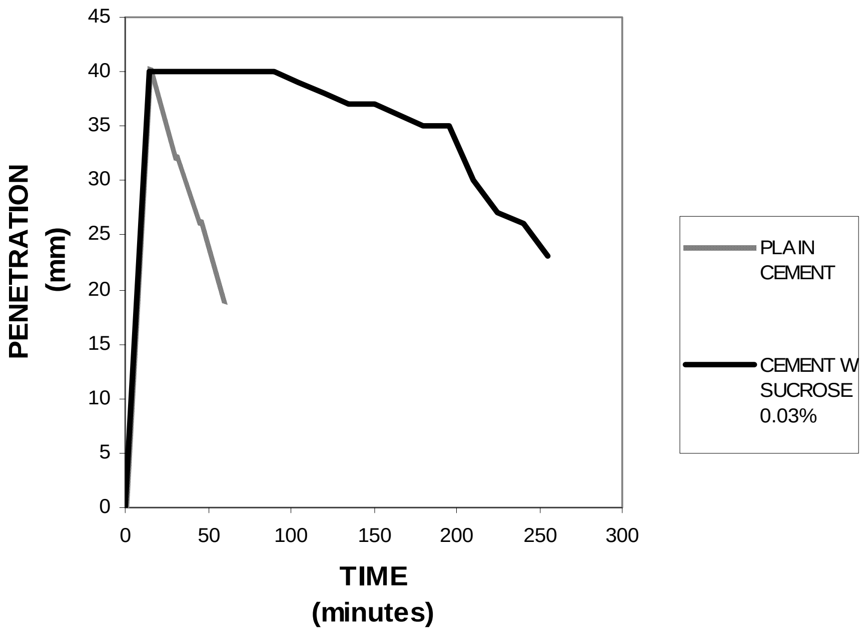

Figure 3. Vicat test of cement paste with and without sucrose 0.03% of cement weight
(Modified from Nikodemus and Setiawan, B., 2008)

The compressive test of mortar specimens shows (Figure 4) a very slightly higher compressive strength of mortar specimens with sucrose 0.03% of cement weight (33 MPa) compared to plain mortar specimens (32.533 MPa) at days-7. A clear increasing of compressive strength of mortar specimens with sucrose 0.03% of cement weight is found at older ages, 38.267 MPa at days-14 (while for plain mortar is 32.7 MPa) and 40 MPa at days-28 (while for plain mortar is 37.333 MPa). The gradual compressive strength of mortar specimens with sucrose 0.03% of cement weight increases about 7-17% at days-14 and older compared to plain mortar ones.

Another phenomenon happened in concrete compressive test result (Figure 5). It is found that compressive strength of concrete specimens (22.535 MPa and 26.37 MPa) with sucrose 0.03% of cement weight are 11-27% lower compared to plain concrete specimens (28.746 MPa and 29.313 MPa) at days-7 and days-14. A progressive increasing of compressive strength of concrete specimens with sucrose 0.03% of cement weight are found at the oldest ages, 40.036 MPa at days-28 (while for plain mortar is 31.69 MPa). The compressive strength of concrete specimens with 0.03% of cement weight increases about 26% at days-28 compared to concrete mortar ones.

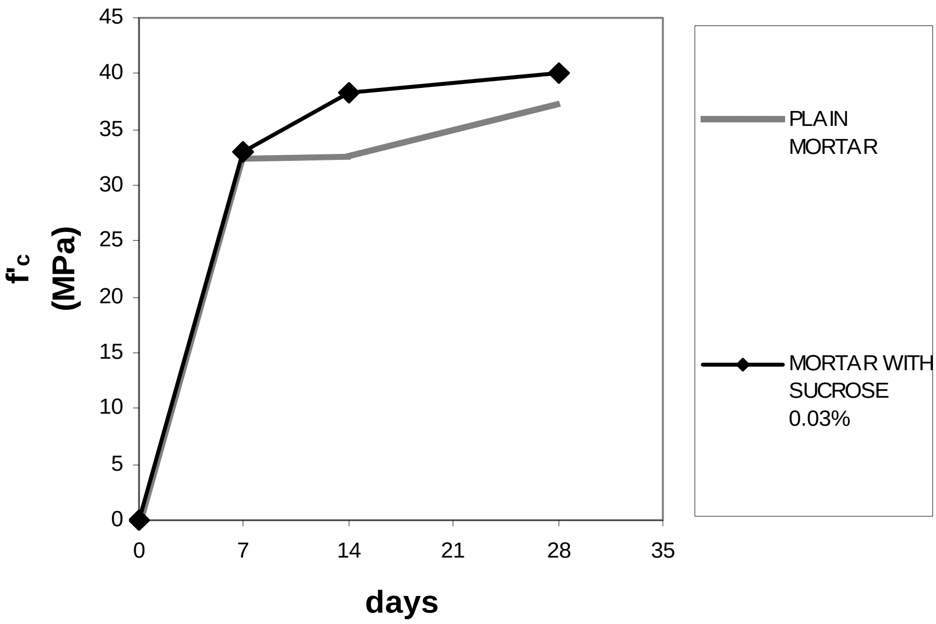

Figure 4. Compressive strength of mortar with and without sucrose 0.03% of cement weight
(Modified from Nikodemus and Setiawan, B., 2008)

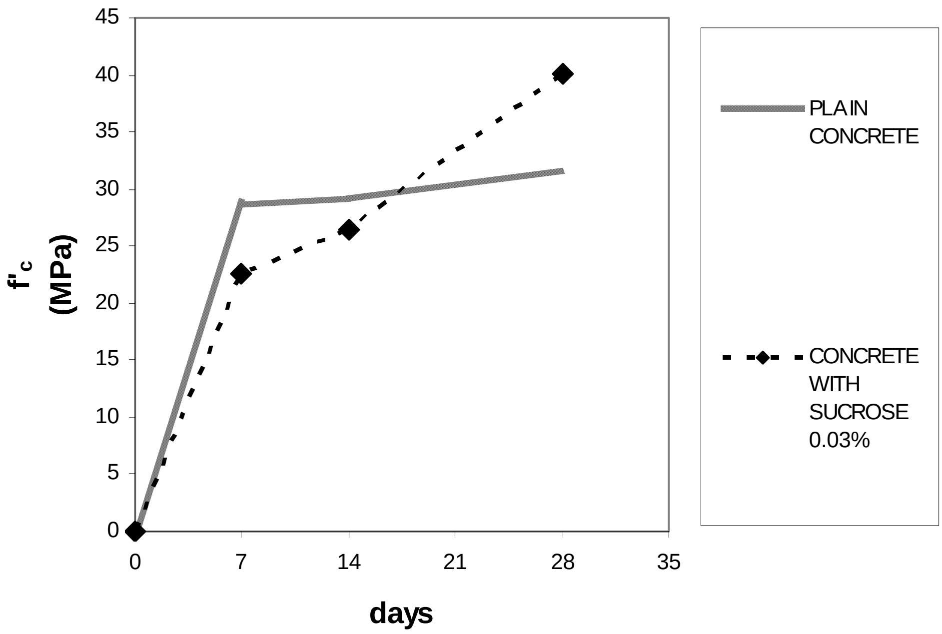

Figure 5. Compressive strength of concrete with and without sucrose 0.03% of cement weight
(Modified from Nikodemus and Setiawan, B., 2008)

The observation of electronic microscope is conducted by trinoculer lens with 10x magnification in first 6 hours setting (Nikodemus and Setiawan, 2008) on Figure 6 and 7. In the hours-1 of observation, it is found that the surface of plain mortar is found rough and porous compared to surface of mortar with sucrose 0.03% of cement weight. The surface of mortar with sucrose 0.03% of cement weight seems more consistent. By hours-3, the surface of plain mortar is getting drier and harder compared to the surface of mortar with sucrose 0.03% of cement weight. At hours-6, both surfaces of specimens are getting harder, but it seems that the surface of plain mortar is harder and also drier compared to the surface of mortar with sucrose 0.03% of cement weight.

(a) (b) (c)

Figure 6. Plain mortar surface under trinoculer microscope eletronic (10x magnification)
(a) Plain mortar surface at day-1 hour-1
(b) Plain mortar surface at day-1 hour-3
(c) Plain mortar surface at day-1 hour-6
(Nikodemus and Setiawan, 2008)

(a) (b) (c)

Figure 7. The surface of mortar with sucrose 0.03% of cement weight under trinoculer microscope eletronic (10x magnification)
(a) Mortar with 0.03% sucrose surface at day-1 hour-1
(b) Mortar with 0.03% sucrose surface at day-1 hour-3
(c) Mortar with 0.03% sucrose surface at day-1 hour-6
(Nikodemus and Setiawan, 2008)

Discussion

The mechanism of retarding effect in concrete mix is basically modify the crystal growth or morphology to be absorbed on the rapdly formed membrane of hydrated cement and slowing down the growth of calcium hydroxide nucle (Neville, 1999). It generates barier to further hydration. The admixture will finally be removed from solution by being incorporated into hydrated material, but it doesn't mean a formation of different complex hydrates. The retarding action of sucrose is caused by the prevention of the formation of C-S-H. In the case of sucrose addition to concrete mix (Tattersall and Banfill, 1983), it makes silicate ion to dissolve from its previous form, anhydrous grain. After dissolving, the concentration aqueous phase will increase by time. The membrane is performed and may incorporate the retarder molecul. If the membrane is permeable to silicate, then the formation and growth of hydrates will be taken placed by a mechanisme that involves the growth of solution.

The Vicat test (Figure 3) emphasizes that the higher value of penetration at final set (29 mm) described by cement paste with sucrose 0.03% of cement weight compared to the plain one (19 mm) is showing an action of retardation of cement setting. It has been proven that low dosage of sucrose 0.03% of cement weight can prohibit the hardening of cement paste. The cement paste with sucrose 0.03% of cement weight takes 225% longer time (225 minutes) to achieve final set compared to the plain one (60 minutes).

It is shown by experimental results that sucrose with low dosage of sucrose 0.03% of cement weight gives accelerating action in mortar specimens at days-14 and days-28 (Figure 4). It means that the hydration calcium silicates has been accelerated (Neville, 1999) by the presence of sucrose. It is also stated by Neville (1999) that an increase of strength, in this case is compressive strength, will happened beyond about 7 days compared to non-retarded mix, and it has been proven. The compressive strength of mortar specimens with sucrose 0.03% of cement weight rise about 7-17% compared to plain mortar ones.

The experimental results also emphasizes that sucrose with low dosage of 0.03% of cement weight gives retarding action in concrete specimens at days-7 and days-14 (Figure 5). It means that the formation of C-S-H is prohibited by the low dosage of sucrose 0.03% of cement weight. As Neville (1999) states, there the compressive strength is slightly reduced about 7 days, but it will be increase in older ages. It has been proven that at days-28, the concrete specimen's compressive strength is about 26% compared to plain concrete.

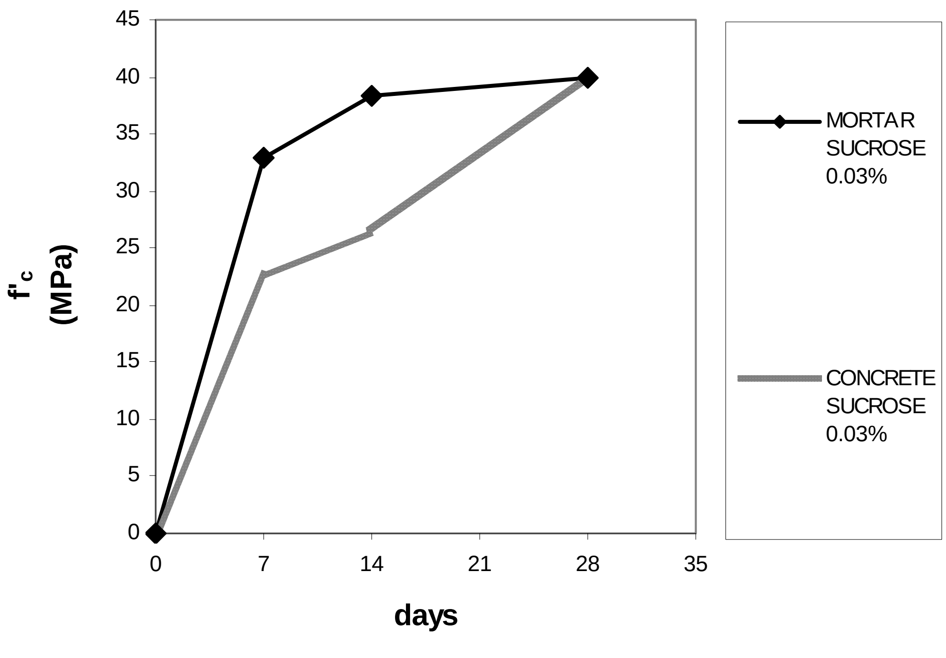

Figure 8. Compressive strength of mortar and concrete with sucrose 0.03% of cement weight
(Modified from Nikodemus and Setiawan, B., 2008)

An interesting phenomenon happened when the compressive strength of mortar specimens with sucrose 0.03% of cement weight are about 45% higher than concrete specimens with sucrose 0.03% of cement weight at days-7 and days-14 (Figure 8). It has been proven that mortar specimens contain no interface between cement paste and fine aggregate that could make bond micro cracks which is reducing the strength during loading. However, at days-28, the compressive strength of both mortar and concrete specimens with sucrose 0.03% of cement weight exceed the plain specimens, and even higher, about 33%, than the design compressive strength of f'_c = 30 MPa.

One important thing should be noted that the observation of electronic microscope of mortar specimens with and without sucrose 0.03% of cement weight obviously described that in the first 6 hours of mortar hardening, the presence of sucrose with low dosage of 0.03% of cement weight is giving retardation effect. It is shown by the observation (Figure 6 and 7) that the surface of mortar specimens is wetter and softer compared to the plain mortar. However, in older ages (after days-7), the bond of C-S-H compound is getting stronger that makes its compressive strength is higher than the plain specimens (Figure 4).

4. CONCLUSIONS

This research meets conclusions as follow:

(1) Sucrose with low dosage of 0.03% of cement weight can prohibit the hardening of cement paste. The cement paste with sucrose 0.03% of cement weight takes 225% longer time to achieve final set compared to the plain one

(2) The sucrose admixture with dosage of 0.03% by weight of cement for mortar specimens performs as accelerator because its values of compressive strength at days-14 and 28 are 7-17% higher than plain mortar

(3) The sucrose admixture with dosage of 0.03% by weight of cement for concrete specimens perform as retarder because its values of compressive strength at days-7 and 14 are 11-27% lower compared to plain concrete

(4) The sucrose admixture with dosage of 0.03% by weight of cement for concrete specimens increases the compressive strength, 26% higher than plain concrete

(5) In the first 6 hours of mortar hardening, the presence of sucrose with low dosage of 0.03% of cement weight is giving retardation effect that the surface of mortar specimens is wetter and softer compared to the plain mortar. However, in older ages its compressive strength is higher than the plain specimens

(6) The performance of sucrose as retarder and accelerator 'green' admixture will fulfil the need of sustainability of civil engineering

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