THE USE OF SUGAR, SUCROSE AND SUGAR CANE LIQUID MIX AS SUGAR BASED ADMIXTURE FOR MORTAR

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Abstract
Admixture takes an important role to improve physical and economic benefits with respect to concrete and mortar. Previous researches concluded that sugar based admixture such as sugar, sucrose, sugar cane liquid, perform as accelerator and retarder with dosages of 0.03% and 0.3% by weight of cement. The composition of those three component (sugar, sucrose, sugar cane liquid) in one mix then being investigated to improve the compressive strength of mortar. There are 16 compositions to be investigated with designed compressive strength of mortar f'_c = 30 MPa.The specimens are tested for ages of 7 days, 14 days, and 28 days. The research meets conclusions : (1) Chemical test of ingridients of sugar based admixture gives result that all ingridients contain lignin of about 0.175%-0.186% while the highest glucose content found in sugar cane liquid, 76.933%, followed by sugar 76.738%. It means that sugar and sugar cane liquid will affect the performance of mortar hardening, (2) There are 6 optimum compositions. Five composition then perform accelerating action that increase the compressive strength in early ages and one composition performs retarding action which slowing the compressive strength growth in early ages; (3) The low content of sugar and sugar cane liquid will contribute rapid growth of calcium silicate hydrates and enrich bond mechanisme of hardening mortar while high content of sucrose, sugar and sugar cane liquid, will make growth of calcium silicate hydrates slower and then retard the bond mechanisme of hardening mortar; (4) The optimum compositions of sugar based admixture consists of sucrose, sugar and sugar cane liquid mix could become reference for designing concrete that also have high performance of compressive strength.

Keywords: sugar, admixture, mortar, compressive strength

1. INTRODUCTION

Recent development of concrete technology has improved the innovation of admixture to get best performance of concrete. Admixture takes an important role to improve physical and economic benefits with respect to concrete and mortar. Sugar based admixture proves that this type of admixture has ability to accelerate or retard the hardening of mortar and concrete, and also improve the strength of concrete and concrete. It should be noted that by investigating the mortar performance, the concrete can be designed to achieve its best performance [1]. It can be explained as follow. 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 [2]. The distinction exists because of the interface lays between cement paste and aggregate in concrete. The bond micro cracks are initiated in the interface and reduce the effective area resisting the applied load. Therefore, the setting of cement takes important role in concrete performance.

Previous researches of sugar based admixture have emphasized that strength of concrete and mortar can be improve, beside the benefit of accelerating and also retarding action of this admixture when applied in concrete and mortar mix ([3]-[21]). Some investigators found that sugar, sucrose, sugar cane liquid, can be used as sugar based admixture which performed as accelerator and retarder with dosages of 0.03% and 0.3% by weight of cement ([11]-[21]). Those researches have shown that sugar based admixture (sugar, sucrose, sugar cane liquid) increase the strength of mortar and concrete, from age 7 days until 84 days. When the sugar based admixture consists of only one ingridient (sugar only, or sucrose only, or sugar cane liquid only), then this research wants to study deeply about the performance of sugar, sucrose, sugar cane liquid mix applied into mortar.

Firstly, recall the hydration process of cement. Cement consists of some compounds such as C_3S (tricalcium silicate), C_2S (dicalcium silicate), C_3A (tricalcium aluminate), and C_4AF (tetracalcium aluminoferrite) and also gypsum as setting additive regulator ([2], [21]). The beginning of hydration process is when cement mixed with water. The reaction of C_3A and C_4AF predominates at the initial stage of hydration and gives ettringite as the product of hydration. The reaction of C_3S and - C_2S predominates at the time of initial set onwards forming calcium silicate hydrates and $Ca(OH)_2$.

Secondly, the admixture performs retarding or accelerating action in mortar and concrete hardening, or in other words, it modify the hydration process. The retarder admixture will modify the crystal growth and morphology and then being absorbed in the membrane of hydrated cement which is formed rapidly [4]. It is also slowing the growth of calcium hydroxide nuclei. In opposite, the accelerator admixture will accelerate the hydration of calcium silicates, mainly C_3S.

Sugar based admixture affects the hydration process. Sugar contains sucrose. Sucrose is abundant pure organic chemical [23] that are categorized as disaccharides. Some carbohydrates are disaccharides. Basically, complex carbohydrates (as well as sucrose) 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 [24]. The structure contains six member ring of glucose and the five member ring of fructose. The chemical structure of sugar will interact with calsium-silicate-hydrate in hardening process. Hence, in this research, the composition of each ingridient of mix of sugar-sucrose-sugar cane liquid will determine the mortar performance as well.

2. METHOD OF RESEARCH

The resesearch was conducted experimentally. Several mortar cubes specimens awere produced by designed compressive strength f'_c = 30 MPa and divided into 16 compositions of sucrose, sugar, and sugar cane liquid mix, as described by Table 1. The sugar which used in this research is local sugar with brand “Gulaku”. The sugar cane liquid extracted from local sugar cane plantation from Klaten. All specimens are cured and then getting for compressive test at 7, 14, and 28 days.

Table 1. Composition of sugar based admixture (Modified from [1] and [25])

No.	Specimen Code	% admixture of cement	sucrose content in admixture	sugar content in admixture	sugar cane liquid content in admixture
1	M-I-A-01	0.03%	0	1.5	1.5
2	M-I-A-02	0.03%	0.5	1.5	1
3	M-I-A-03	0.03%	1	0.5	1.5
4	M-I-A-04	0.03%	1.5	1	0.5
5	M-I-B-01	0.03%	0.5	1.5	1
6	M-I-B-02	0.03%	1	1.5	0.5
7	M-I-B-03	0.03%	1.5	0.5	1.5
8	M-I-B-04	0.03%	0	1	0.5
9	M-II-A-01	0.3%	0	1.5	1.5
10	M-II-A-02	0.3%	0.5	1.5	1
11	M-II-A-03	0.3%	1	0.5	1.5
12	M-II-A-04	0.3%	1.5	1	0.5
13	M-II-B-01	0.3%	0.5	1.5	1
14	M-II-B-02	0.3%	1	1.5	0.5
15	M-II-B-03	0.3%	1.5	0.5	1.5
16	M-II-B-04	0.3%	0	1	0.5

3. RESULTS AND DISCUSSION

Experimental result shows that there are 6 optimum compositions (see Table 3 and Figure 1). Five compositions (M-I-A-03, M-I-A-04, M-I-B-04, M-II-B-01, M-II-B-04) give accelerating action, and one composition (M-II-B-02) perfoms retarding action. As mentioned above, sugar contains sucrose, and sucrose (as complex carbohydrates) consists of reducing sugar, in this test is glucose as described by Table 2. The sugar based admixture ingridients also contain lignin that provide bond characteristic. Chemical test of ingridients of sugar based admixture gives result that all ingridients contain lignin of about 0.175%-0.186%. The highest glucose content found in sugar cane liquid, 76.933%, followed by sugar 76.738%. It means that sugar and sugar cane liquid will affect the performance of mortar hardening.

Table 2. Chemical test result of ingridient of sugar based admixture (source: [1])

NO	INGRIDIENT	LIGNIN	REDUCING SUGAR (GLUCOSE)
		(%)	(%)
1	Sucrose	0.181	59.106
2	Sugar	0.175	76.738
3	Sugar cane liquid	0.186	76.933

Table 3. Compressive strength of each composition (Modified from [1] and [25])

AGE (DAYS)	COMPOSITION							
	M-I-A-01	M-I-A-02	M-I-A-03	M-I-A-04	M-I-B-01	M-I-B-02	M-I-B-03	M-I-B-04
	COMPRESSIVE STRENGTH (MPa)							
0	0	0	0	0	0	0	0	0
7	29.2	33.28	35.12	44.4	26.08	34.64	23.68	39.44
14	38.32	38.08	40.32	48.16	33.76	37.12	30.56	42.4
28	39.44	40.3	41.12	50.24	39.2	40.16	33.2	45.68
AGE (DAYS)	COMPOSITION							
	M-II-A-01	M-II-A-02	M-II-A-03	M-II-A-04	M-II-B-01	M-II-B-02	M-II-B-03	M-II-B-04
	COMPRESSIVE STRENGTH (MPa)							
0	0	0	0	0	0	0	0	0
7	36.96	15.2	30.64	1.44	19.04	1.04	23.6	20.72
14	42.56	20.32	39.68	38.72	33.36	2.16	31.92	42.48
28	43.52	26.48	40.96	37.76	41.52	41.92	38.56	49.44

Table 3 and Figure 1 show that the optimum composition have compressive strength of about 40-50 MPa at age 28 days. Most compositions achieve about 67.67% of design compressive strength (30 MPa) at age 7 days, about 19-20 MPa and even more, exceed the design compressive strength, about 35-44 MPa. Those 5 composition then perform accelerating action that increase the compressive strength in early age. One composition performs retarding action that achieve only 1-2 MPa in early ages (7 and 14 days), but extremely increase at age 28 days.

Most accelerator compositions with category “I” have 0.03% sugar based admixture of cement content. It means that the low content of sugar and sugar cane liquid will contribute rapid growth of calcium silicate hydrates and enrich bond mechanisme of hardening mortar. Hence, the mortar will have high compressive strength at its early ages. It should be noted that the compressive strength still increase, slightly, until reaching age 28 days. Accelerator composition with category “II” have 0.3% sugar based admixture of cement content. It has lower compressive strength increasing compared to category “I”, especially at age 7 days, about 19-20 MPa. The retarder admixture has high content of sucrose, sugar and sugar cane liquid, that all of the ingridients contribute slowing growth of calcium silicate hydrates and then retard the bond mechanisme of hardening mortar.

The research emphasizes that sugar based admixture consists of sucrose, sugar and sugar cane liquid mix applied into mortar is proven can improve the compressive strength of mortar significantly. Hence, those optimum compositions of sugar based admixture consists of sucrose, sugar and sugar cane liquid mix could become reference for designing concrete that also have high performance of compressive strength.

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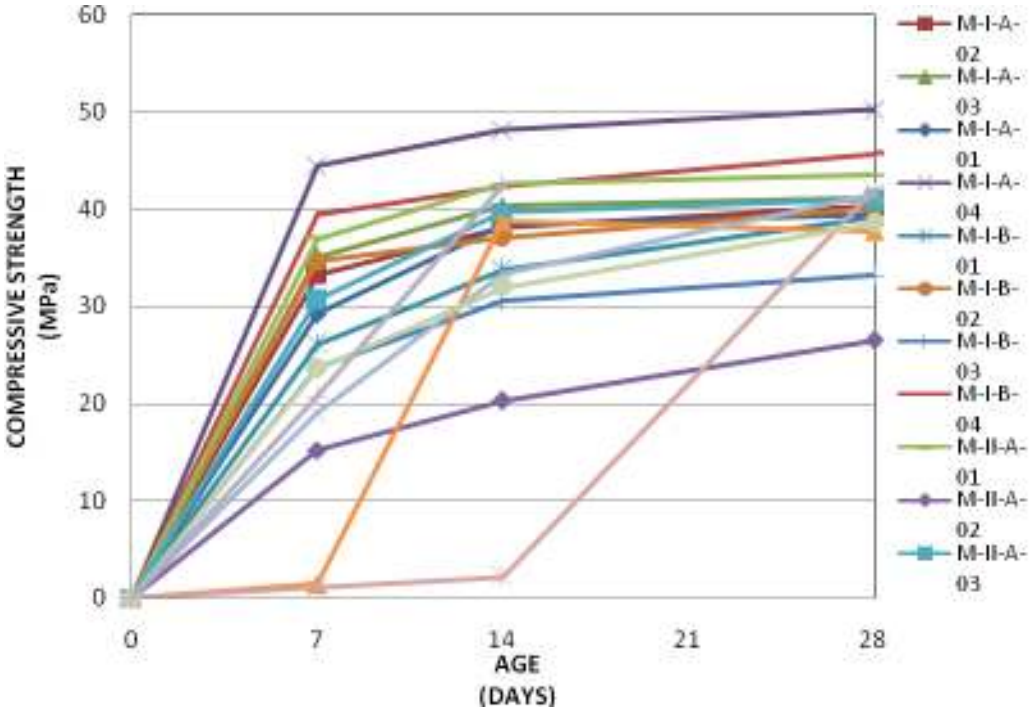

Figure 1. Compressive strength at age 7, 14, and 28 days, of each composition (Modified from [1] and [25])

4. CONCLUSIONS

This research meets conclusions as follow:

(1) Chemical test of ingridients of sugar based admixture gives result that all ingridients contain lignin of about 0.175%-0.186% while the highest glucose content found in sugar cane liquid, 76.933%, followed by sugar 76.738%. It means that sugar and sugar cane liquid will affect the performance of mortar hardening.

(2) There are 6 optimum compositions. Five composition then perform accelerating action that increase the compressive strength in early ages and one composition performs retarding action which slowing the compressive strength growth in early ages.

(3) The low content of sugar and sugar cane liquid will contribute rapid growth of calcium silicate hydrates and enrich bond mechanisme of hardening mortar while high content of sucrose, sugar and sugar cane liquid, will make growth of calcium silicate hydrates slower and then retard the bond mechanisme of hardening mortar.

(4) The optimum compositions of sugar based admixture consists of sucrose, sugar and sugar cane liquid mix could become reference for designing concrete that also have high performance of compressive strength.

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