Article

The Effect of Plastocrete® RT6 Plus and Coca-Cola Admixtures on The Concrete Setting Time and Strength

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Abstract: During the casting in a warmer tropical temperature, a setting time delay is required to maintain the workability of the concrete, commonly achieved by the addition of admixtures i.e. silica fume (SF), fly ash (FA), and Plastrocrete®. However, high sugar content Coca-Cola in niche conditions is proposed as an ingredient for delaying concrete setting time in combination with conventional admixtures. This research aims to compare the setting time of admixtures from Coca-Cola and Plastocrete® RT6 plus in concrete mixing with control data of concrete mixed with SF or FA. The second aim is to measure the compression strengths between combinations of Coca-Cola and Plastocrete® RT6 plus. Concretes were produced with admixtures of SF, FA, Plastocrete® RT6plus, or Coca-Cola. The concrete used to control was f'c20 and f'c 25, while other concrete mixes were produced with the addition of Coca-Cola at 0.15% from the weight of cement at variation of moisture treatments. The first method to produce concrete (f'c20+Plas0.23%+Cola0.15% and f'c25+Plas0.23%+Cola0.15%) did not employ water reduction. The second concrete productions (f'c25+Plas0.46%+Cola0.15% and f'c25+Plas0.46%+Cola0.15%) reduced the addition of water at 8.8% (v/w). The first concrete production method had a setting time 44% longer than control. The reduced water concrete in the second productions had a setting time 34% longer than control. Meanwhile, the Plastocrete® RT6 Plus admixture with the reduced water delayed the concrete setting time by 26% longer than control. The delayed setting time of Plastocrete® RT6 Plus admixture with reduction of water was shorter than in the treatment with Coca-Cola. The combination of the addition of Coca-Cola with Plastocrete® RT6 plus by reducing the amount of adding Coca-Cola to 0.10% with Plastocrete® RT6 plus can delay concrete setting time by 51% longer than normal concrete and increase concrete compressive strength by 13% higher than normal concrete. Mixing Coca-Cola with Plastocrete® RT6 plus not only provided an optimal delay effect on setting time but also significantly increase the compressive strength that was desired during the casting in warm tropical weather applied in building construction of Mulawarman University, Samarinda, Indonesia.

Keywords: concrete setting time; Coca-cola; silica fume; fly ash; Plastocrete® RT6 Plus

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1. Introduction

Concrete used in the construction of a building as the main structure. In typical operation, in hot weather conditions, setting time of the concrete may be achieved during the transportation of the mixed concrete to the development site. To reduce the risk of premature setting time, silica fume (SF), fly ash (FA), ground granulated blast-furnace slag (GGBS), and other substances are

 doi:10.20944/preprints202001.0094.v1

added to improve the quality of concrete during construction [l, 6-11]. The addition of silica (SF) affects the setting time [12-14].

The understanding of concrete time setting is essential in the construction field. This understanding can help to make decisions at various implementation stages, such as in transporting a large volume of substances. Subsequently, the challenges associated with concrete mixing need to be adequately analyzed. Referring to a research conducted by the Japan Concrete Institute (JCI) on shrinkage handling [3], concrete measurement in casting need to be commenced at the initial setting and after the final setting [4]. Water ratio, temperature, the concentration of added ingredients, mixing type, and cement composition influenced setting time [5-19].

Plastocrete® RT6 plus is introduced in Indonesia around 2016 as a new type of admixture with the main advantages of increasing setting time, improved workability, and improved concrete quality, which is suitable for tropical countries like Indonesia [25]. This research examines new admixtures (Plastocrete® RT6 plus) on the concrete properties, mainly on setting time, compression strength in comparison to both conventional admixtures of SF or FA [2].

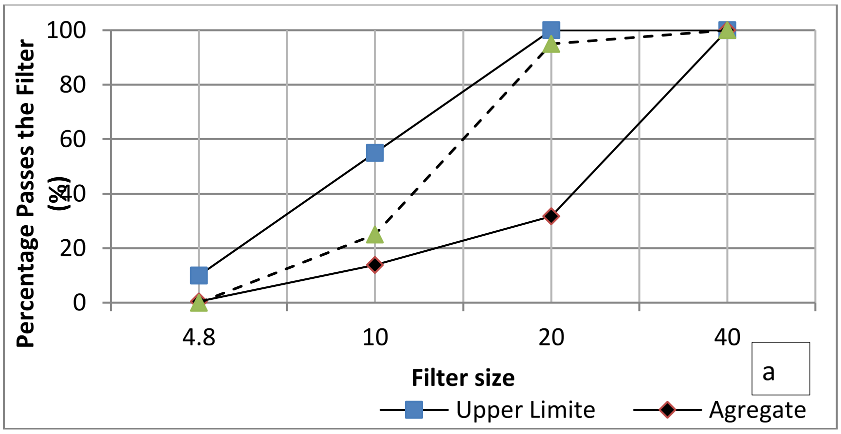
Previous research argued that sugar might increase the setting time [26]. Coca-Cola or Coke, a popular drink, is widely available and in unique condition may be used as an ingredient for delaying concrete setting time [31] due to its high sugar content at 10.6 g per 100 mL [27]. An increase in setting time with the addition of SF, FA, and Plastrocrete® is already suitable in the construction to ensure the quality of concrete. However, during the casting in a particular warm weather as a result of climate change or prolonged drought, i.e., in the construction of buildings in Mulawarman University, further delay on setting time is required to maintain workability of the concrete while at the same time maintaining the required quality of the concrete.

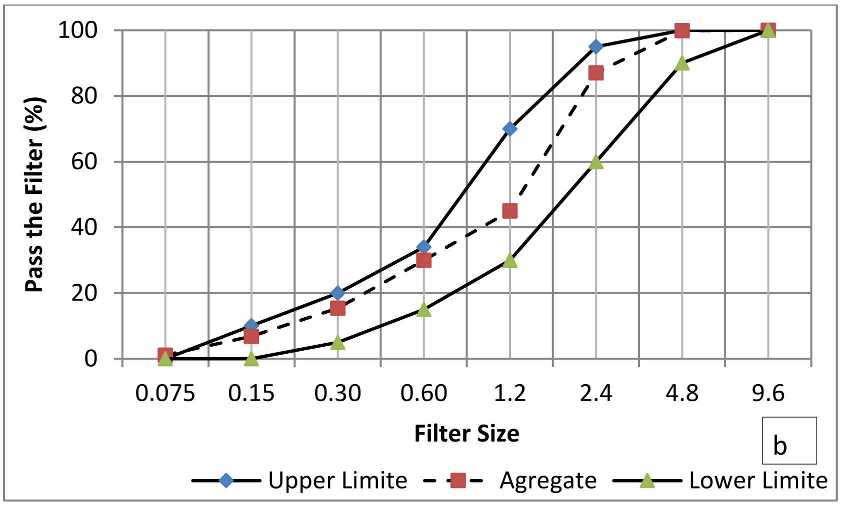
This research aims to compare a combination of admixtures from Coca-Cola and Plastocrete® RT6 plus in concrete mixing in terms of setting time with control data of concrete mixed with SF or FA. The compression strengths were compared between combinations of Coca-Cola and Plastocrete® RT6 plus.

2. Methodology

a) Material

Fine and coarse from Palu, Central Sulawesi, Indonesia tested based on ASTM C 33-92 [23] and should be in the range stated in Figure 1. Figure 1 was supplied as a controlled material for the making of concrete. Therefore concrete can be produced in similar quality during the construction time of Mulawarman University building in Samarinda, Indonesia. The fine and coarse samples were taken during job mixed design in April 2019.





a.Sand Size. b. Aggregate Size.

Figure 1. Aggregate size

The cement was supplied according to the specification provided by Ordinary Portland Cement (OPC) with chemical composition and physical properties presented in Table 1. Furthermore, the details associated with the proportion of cement, aggregate, and the amounts of water in a concrete mixture were also given in Table 1.

Table 1 Chemical and Physical Composition of Cementations Materials

Chemical	OPC	SF	FA
SiO_2	20,9	91,2	47,8
Al_2O_3	5,1	0,71	25,01
Fe_2O_3	2,4	1,25	8,8
MgO	4,0	1,73	1,9
TiO_2	-	-	0,98
CaO	64,01	0,45	8,7
Na_2O	0,5%	0.42	8,7
K_2O	-	1,19	1,2
SO_3	2,4	-	0,85
LOI	2,4	1,18	5,15

LOI = loss on ignition

b) Job Mix Design

Job mix design are produced for the concrete quality of f'c 20 and f'c 25 by mixing the fine and coarse aggregates stated in figure 1 and cement stated in table 1, to obtain the material composition given in table 2.

Table 2 Job Mix Design f'c 25 and f'c 20

Description	f'c = 20 Mpa	f'c = 25 Mpa
Standard Deviation (s)	7 Mpa	7 Mpa
Compressive Strength	f'c = 20 Mpa	f'c = 20 Mpa
Cement Water Factor	0,5	0,5
Slump Value	110 mm	110 mm
Free water content	170 kg/m3	170 kg/m3
Amount of Cement	327 Kg/m3	427 Kg/m3
Coarse aggregate amount	1232 kg/m3	1232 kg/m3
Cement	370 kg	420 kg

Setting time only sampled on the concrete quality of f'c25. The control was given a symbol f'c25-Normal. To measure the variations of increased setting time on f'c25, concretes are produced with admixtures of SF, FA, Plastocrete® RT6plus, or Coca-Cola. Table 3 stated water, admixture, and slump values produced in the job mix design stage. Concrete variations are given a symbol f'c25-SF5% for concrete added with SF 5%, f'c25+SF10%% for concrete added with SF 10%, f'c25+SF15% for concrete added with SF 15%, f'c25+FA10% for concrete added with FA 10%, f'c25+FA10% for concrete added with FA 10%, f'c25+FA15% for concrete added with FA 15%, f'c25+Cola0.15% for concrete added with Coca-Cola 15%, f'c25+Cola0.20% for concrete added with Coca-Cola 20%, f'c25+Cola0.20% for concrete added with Coca-Cola 25% and f'c25+Plasto6% for concrete added with Plastocrete® RT6plus 0.6%.

Table 3 Mixing proportions of concrete containing mineral

Concrete Mixes	Water Kg/m³	Admixture Kg/m³	Slump Mm
f'c25-Normal (control)	170	0	110
f'c25+SF5%	170	16	185
f'c25+SF10%	170	32	135
f'c25+SF15%	170	48	100
f'c25+FA10%	170	32	130
f'c25+FA15%	170	48	125
f'c25+FA20%	170	64	96
F'c25+Cola0.1%	170	0,32	120
F'c25+Cola0.15%	170	0,48	132
F'c25+Cola0.2%	170	0,64	135
F'c25+Plas0.6%	170	1,92	140

The concrete used to control is f'c20 and f'c 25, while other mixes were conducted with the addition of Coca-Cola at 0.15% from the weight of cement and different water addition treatments, as shown in Table 4. where Concrete variations are given a symbol f'c20-Normal and f'c25-Normal means that the concrete mixture does not use admixture materials, f'c20-Cola0.20% for concrete just added with cola 0.20% without Plastocrete® RT6plus, the others are named f'c20+0.23% for concrete added with 0.23% Plastocrete®RT6plus, f'c20+0.46% for concrete added with 0.46% Plastocrete®RT6plus, f'c25+Plasto0.6% only added Plastocrete® RT6plus without the addition of Coca-Cola, f'c25+ 0.23% for concrete added with 0.23% of Plastocrete® RT6plus, f'c25 + 0.46% for concrete added with 0.46% of Plastocrete® RT6plus and f'c25 + M % for concrete added with 0.10% of Coca-Cola and 0.5% of Plastocrete® RT6plus. To maintain the slump value, the reduction of water carried out on the addition of Plastocrete® RT6 plus at 0.46%, as well as the addition of Plastocrete® RT6 plus at 0.5% and Coca-Cola at 0.1%, as shown in table 4.

Table 4 Mix Proportions for concrete containing Coca-Cola

Concrete Mixes	Water Kg/m³	Plastocrete@ RT6plus Kg/m³	Coca-Cola Kg/m³
f'c20-Normal (control)	170	0	0
f'c20+Cola0.2%	155	0	0,740
f'c20+Plas0.23%+Cola0.15%	170	0,667	0,555
f'c20+ Plas0.46%+Cola0.15%	155	1,334	0,555
f'c25-Normal (control)	170	0	0
f'c25+Plas0.6%	155	1,92	0
f'c25+Plas0.23%+Cola0.15%	170	0,736	0,630
f'c25+Plas0.23%+Cola0.15%	155	1,472	0,630

 doi:10.20944/preprints202001.0094.v1

f'c25+Plas0.5%+Cola0.1%	143	1,6	0,420

c) Testing Procedure

The design and implementation of concrete casting were determined by following ASTM C 403 [19]. Its setting time was conducted on mortars obtained by sifting fresh concrete through a 5 mm sieve and determined by testing the needle's strength capable of penetrating the mortar by 25 mm. In this experiment, the variation of casting temperature was conducted in an environment with a controlled temperature of around 27±5 °C. Furthermore, the initial and final set was defined as the penetration time with provisions of ASTM C 403/C 403M and at 3.5 MPa (500 Psi) for the initial setting time and at 27.6 MPa (4000Psi) for the final setting time [18,29]. Compressive Strength test employed ASTM C39-86 Standard Test Method [30].

3. Results and discussion

Before the measurement of setting time, slump value was measured to understand the moisture content of the job mixtures produced from the mixed proportion stated in table 4.

Table 5. Concrete Slump Value

Concrete Mixes	Water (Kg/m³)	Water Reduced (%)	Plastocrte@RT6plus (Kg/m³)	Coca-Cola (Kg/m³)	Slump (mm)
f'c20-Normal (control)	170	0	0	0	110
f'c20+Cola0.2%	155	12	0	0,740	110
f'c20+Plas0.23%+Cola0.15%	170	0	0,67	0,555	135
f'c20+ Plas0.46%+Cola0.15%	155	12	1,3	0,555	125
f'c25-Normal (control)	170	0	0	0	110
f'c25+Plas0.6%	155	12	1,74	0	137
f'c25+Plas0.23%+Cola0.15%	170	0	0,67	0,63	133
f'c25+Plas0.23%+Cola0.15%	155	12	1,3	0,63	125
f'c25+Plas0.5%+Cola0.1%	143	21	1,45	0,42	132

The addition of SF and FA added to the concrete mixture, apparently reduced the value of the concrete slump. SF and FA absorbed the water and formed slumps with lesser slump value than concrete produced with admixture of Plastocrete® RT6 and Coca-Cola. The addition of Coca-Cola and Plastocrete® RT6 plus increased the value of the concrete slump as a result of the initial liquefied form of Coca-Cola and Plastocrete®, therefore increasing the total amount of water in the concrete (Tables 5).

Figure 2 shows the setting time of the concretes plotted to penetration resistance measured for 16 hours. The initial and final sets were graphed by dotted lines at 3.5 MPa (500 Psi) for the initial setting time and at 27.6 MPa (4000Psi) for the final setting time.

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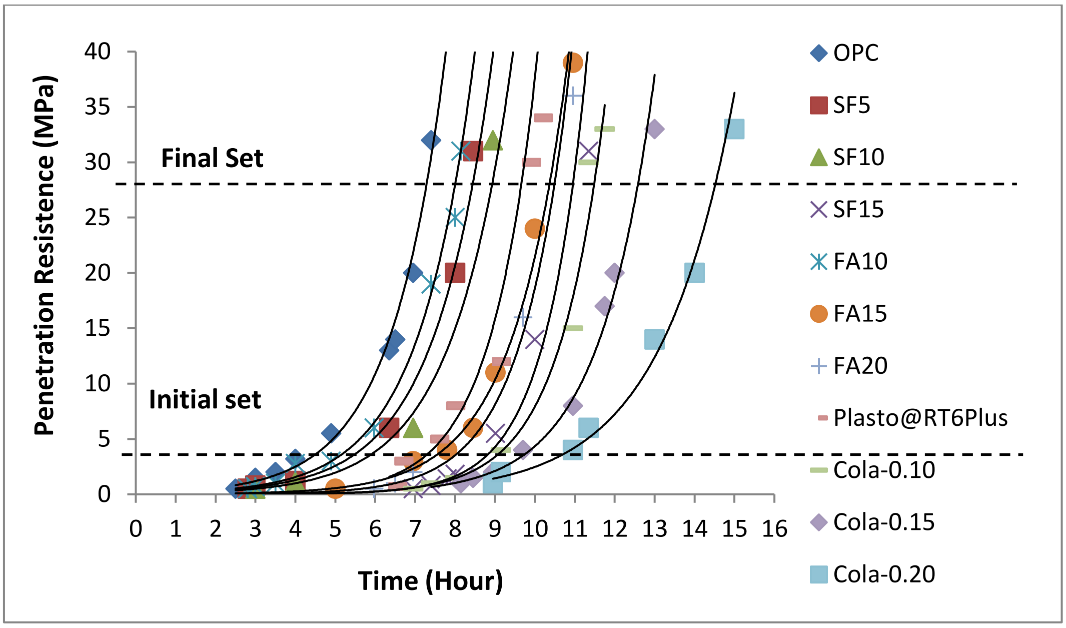

Figure 2. Influence of SF and FA on the resistance of concrete

In general, the model of initial and final setting times from each concrete treatment were fit with the exponential graph pattern. This model is in line with previous findings from Polivka and Klein[20]. From Palivka and Klein research [20], the R^2 value is used to state the coefficient of multiple comparisons on the fitness of the graph adhering to in exponential pattern. From Figure 2, all concrete mixtures had R^2 of more than 0.9 (R^2 data not presented). The influence of SF, FA, Coca-Cola, and Plastocrete®RT6 plus on concrete setting time as well as on Coca-Cola and Plastocrete® RT6 plus were shown in Tables 6 and 7.

Table 6 Initial and Final sets of concrete containing single admixture

Concrete Mixes	Initial Set (SA)(h)	Final set (FS)(h)
f'c25-Normal	4,9	7,6
f'c25+SF5%	6,35	8,45
f'c25+SF10%	6,95	8,95
f'c25+SF15%	9,01	11,35
f'c25+FA10%	5,97	8,15
f'c25+FA15%	6,25	9,15
f'c25+FA20%	7,1	9,75
F'c25+cola0.1%	9,7	11,8
F'c25+cola0.15%	10,7	13,1
F'c25+cola0.2%	12,2	14,9
F'c25+Plas0.6%	7,8	9,7

Coca-Cola as an admixture in concrete increased setting time to 14.8 in comparison to f'c20 control, regardless that the use of water in the Coca-Cola admixture was already less than the f'c20 control.

Table 7 Setting time of Concrete Containing of Coca-Cola and Plastocrite@RT6 Plus

Concrete Mixes	Initial Set (SA)(h)	Final set (FS)(h)
f'c20-Normal (control)	4'9	7,6
f'c20+Cola0.2%	12,1	14,8

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f'c20+Plas0.23%+Cola0.15%	6,65	10,8
f'c20+ Plas0.46%+Cola0.15%	6,93	10,21
f'c25-Normal (control)	4,9	7,5
f'c25+Plas0.6%	6,25	9,5
f'c25+Plas0.23%+Cola0.15%	6,63	10,65
f'c25+Plas0.23%+Cola0.15%	6,87	10,19
f'c25+Plas0.5%+Cola0.1%	7,52	11,75

a) The general effect of SF and FA admixture

From Table 6 and Figure 2, the admixtures may delay the time setting of concrete. Different admixtures may give different results. Therefore, added materials capable of delaying setting time and enhancing the compressive strength of concrete need to be further studied to reduce the amount of cement used [19]. In general, retarding materials for delaying the setting time of concrete contain C3A compounds, which react with tricalcium silicate (C3S). The covered surface of cement particles prevents the inhibitory layer and cement from bounding [19,22]. Accordingly, the concrete mixture that added with a balanced concentration delayed setting time without affecting the compressive strength concrete. This cement paste reacted optimally and formed concrete particles [24].

b) The general Effect of Coca-Cola and Plastocrete®RT6plus admixture

The effect of Plastocrete® RT6 plus tended to delay setting time, which was dependent on the type of cement and the temperature [25]. Furthermore, Table 7 and Figure 2 above shown that reducing water in f'c20+0.46% and f'c25+0.46%. The reduction of water at a concentration of 12% does not affect the concrete setting time. The setting time of the two mixes is higher than the average concrete setting time of f'c20-N and f'c25-N. The longer setting time showed that the ability of Plastocrete® RT6 plus and Coca-Cola to replace the water/cement ratio in the concrete mixture, in similar fashion to the research conducted by Sri Umniati et al. [21].

A reduction of water at 12% concentration in the f'c20-0.46% concrete mixture and f'c25-0.46% had similar setting time delay. This shows the similarity of admixture effects on two different concrete qualities, so there is no effect of the concrete quality on the length of the setting time delay, which influences the amount of water and the type of ingredients added. When a mixture was combined with the addition of Coca-Cola 0.10% and Plastocrete® RT6 plus 0.5% with a water reduction of 12%, it increased the setting time and compressive strength to 54% and 13% respectively as shown in Table 6 and Figure 2.

c) Effect of Coca-Cola and Plastocrete® RT6 plus on Concrete Compressive Strength

Results on concrete compressive strength testing conducted based on the ASTM C39-86 standard [30] were shown in Table 8, Figure 3, and Figure 4.

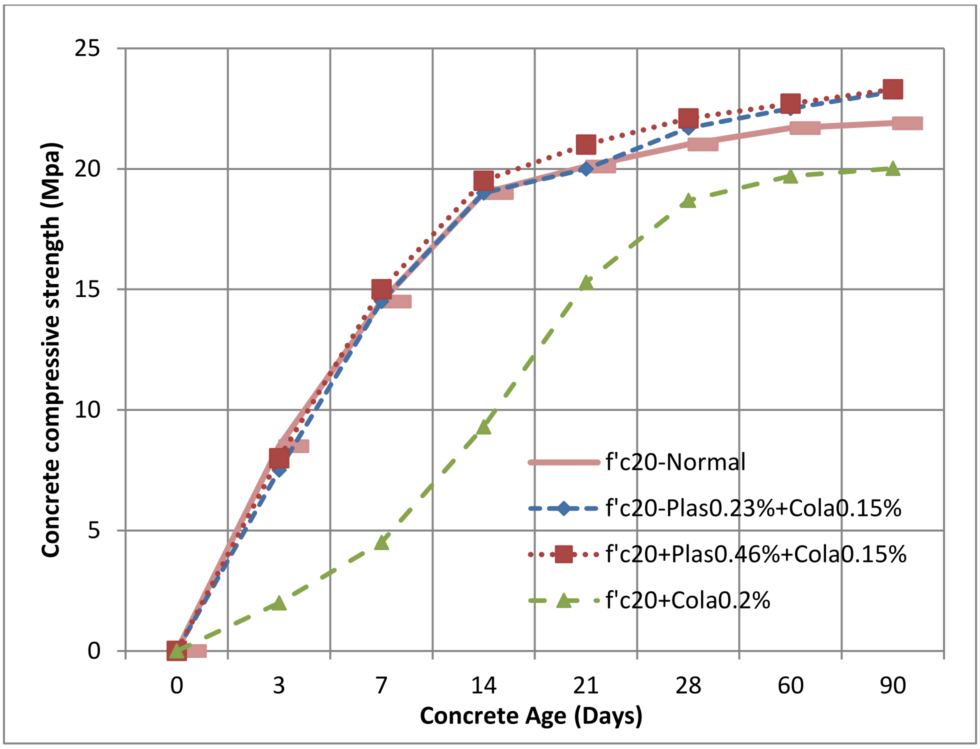

Figure 3 Relationship of concrete age and compressive strength of f'c 20

Figure 3 showed the addition of admixtures in excess concrete sometimes provides an unfavorable effect. Therefore, manufacturers tend to provide a maximum limit to its usage [25]. In the case of added Coca-Cola at 0.2%, the compressive strength of the concrete was less than average at the observed 28 days because of the effect of sugar working in the concrete. This result is similar to research on the research conducted by Usman [26]. In the case of added Coca-Cola 0.15% and PlactocreteRT@6 plus, the variations of compression strength were at 0.23% and 0.25%. It was shown that the compressive strength of the concrete compressive strength could be supplied above the strength design at the age of 28 days of concrete.

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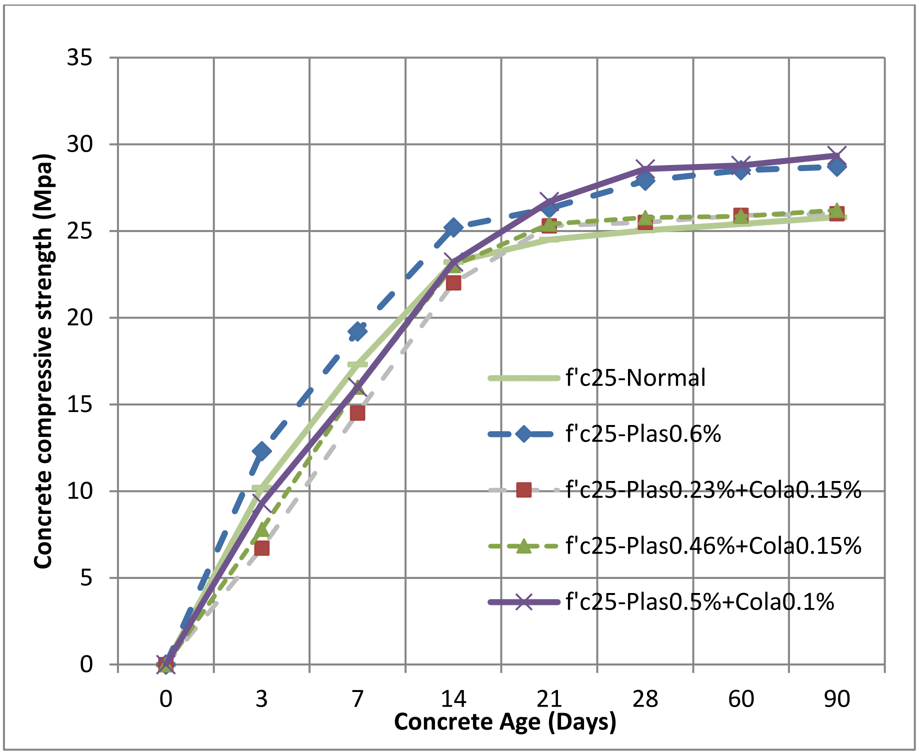

Figure 4 Concrete age relationship with compressive strength f'c 25

Figure 4 showed that the mixture concrete, added with Coca-Cola, had a low compressive strength in the first two weeks. In contrast to concrete added by Plastocrete® RT6 plus without Coca-Cola, the compressive strength starts above the regular concrete since the third day [21]. In the case of reducing the amount of Coca-Cola in the concrete mixture to 0.10% with the addition of Plastocrete® RT6 plus at 0.5%, the strength of the concrete at 28 days of concrete was higher than the condition of the concrete with Plastocrete®RT6 plus without Coca-Cola. However, the amount of cement used was lesser than regular concrete.

Table 8 Compressive Strength Concrete Contain Coca-Cola and Plastocrete®RT6 Plus

Concrete Mixes	Cement Kg/m³	Strength MPa (28D)	Relative Strength
f'c20-N (control)	370	21,02	1
f'c20+Cola0.2%	370	18,7	0,95
f'c20+Plas0.23%+Cola0.15%	365	21,7	1,1
f'c20+ Plas0.46%+Cola0.15%	360	22,1	1,11
f'c25-N (control)	420	25,03	1,22
f'c25+Plas0.6%	415	27,9	1,37
f'c25+Plas0.23%+Cola0.15%	415	25,5	1,24
f'c25+Plas0.23%+Cola0.15%	410	25,78	1,25
f'c25+Plas0.5%+Cola0.1%	415	28,58	1,4

Table 8 showed the case of concrete with Coca-Cola as admixtures. The concrete was not fulfilled compressive strength design, although the amount of cement used is the same as normal concrete, so the coefficient for prediction strength test concrete, which is commonly used to calculate the compressive strength before 28 days, cannot be used [30]. The strength of concrete that added with Coca-Cola exhibited a prolonged setting time to achieve the right quality. This phenomenon was caused by sugar content that was too high, therefore delaying concrete setting time even further. This result was similar to research on the research conducted by Usman [26].

 doi:10.20944/preprints202001.0094.v1

4. Conclusion

The strength of concrete can withstand penetration during the test setting time, which tends to follow the exponential function in the mixture with/without added material. The addition of Coca-Cola in the concrete mix can increase the concrete setting time, and it does not have a significant impact on increasing the compressive strength. The addition of Plastocrete® RT6 plus, besides being able to delay setting time, also increased the compressive strength of concrete. Mixing Coca-Cola with Plastocrete® RT6 plus may provide an optimal delay effect and a significant increase in compressive strength and optimally reduce the use of cement.

Acknowledgments: This research is fully supported by the Project Implementation Unit (PIU) 4 In One, IDB Mulawarman University-Indonesia.

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