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THE EFFECT OF CALCIUM STEARATE USAGE IN SELF COMPACTING CONCRETE 20 MPA WITH PCC AND FLY ASH AS BINDERS TOWARD ON PULL OUT CAPACITY OF REINFORCEMENT

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ABSTRACT

Concrete is widely used for buildings because of its high compressive strength. Reinforced concrete must be able to withstand water infiltration into the concrete. This is to prevent the infiltration of corrosive ions with water that cause corrosion attacks on the reinforcement. One type of concrete that can reduce the infiltration of water into the concrete is Self Compacting Concrete (SCC). SCC generally uses a very small water cement ratio, so it can reduce water infiltration into the concrete. SCC is not enough to cover with corrosion attack significantly. The use of added calcium stearate has been shown to significantly reduce corrosion attack on concrete reinforcement. Unfortunately, the effect of calcium stearate usage on the bond strength of reinforcement and concrete has not been well studied. This study aims to determine the effect of calcium stearate on 20 MPa concrete with doses of 0, 1, 5 and 10 kg/m3 on the pull out capcity and failure pattern of the concrete. The tests carried out include the compressive strength test and the pull out capacity. The results showed that the average pull out capacity with the addition of calcium stearate 0, 1, 5, and 10 kg/m3 were 5.78, 4.08, 3.83, and 3.45 MPa, respectively. The type of failure that occurs when the maximum load is reached is a splitting failure.

Key word: calcium stearate; pull out; Self Compacting Concrete, corrosion attack.

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INTRODUCTION

Developments in the construction sector are currently very fast, both in the development of new materials and working methods. The building material that is widely used for civil construction is generally in the form of concrete. Concrete is a mixture of portland cement or other hydraulic cement, fine aggregate, coarse aggregate, and water, with or without admixture (SNI 2847; 2013). Concrete was chosen as one of the materials that make up the construction structure because it has high compressive strength properties, and its strength can be adjusted to the needs of the building structure. Concrete is also very easy to form or mold so that it can be in accordance with what is planned. Concrete is generally more durable and less expensive than steel. The weakness of concrete is its low tensile strength, so that the contribution of the tensile strength of concrete tends to be neglected in structural design. To cover this weakness, reinforcing steel must be inserted in the tension zone to withstand the tensile force. The tensile stress that occurs in the concrete will be transmitted to the reinforcement by a bond mechanism, so that the concrete and reinforcement become a monolithic composite material. This bond stress occurs because of the shear interlock between the reinforcement and the concrete which is influenced by other factors (Sendow, et al, 2018). Factors that affect the bond strength between reinforcing steel and concrete include adhesion, gripping effect, effect of concrete quality, mechanical effect and diameter of reinforcement (Nawy, 1986).

Concrete combined with reinforcing steel must have good water-resistant properties. Concrete that does not have water-resistant properties, then the reinforcing steel in the concrete will experience corrosion attack due to chloride ion infiltration into the concrete. Corrosion of the concrete reinforcement will cause the structure to collapse. The use of concrete for structures today is not only applied in normal environments, but in extreme corrosive environments. For concrete structures located in corrosive areas, Portland Composite Cement (PCC) can be used to improve its watertight properties. The added material contained in this PCC is not only to increase resistance in aggressive environments, but also to increase quality, accelerate hardening, make work easier and reduce porosity because it contains fly ash which has very fine grains (Putra, et al. 2020).

The many uses of concrete for various types of structures have created several types of concrete innovations that are categorized according to their characteristics. One of these types of concrete is self compacting concrete (SCC). In general, SCC is a concrete variant that has a high degree of workability and also has a large initial strength, thus requiring a low water cement factor (Rusyandi et al., 2012). This type of concrete is easier to apply because it does not need to be compacted and can flow more easily through the gaps in the reinforcement in the formwork (Maryoto, et al., 2019). In making this SCC, additional materials are needed, one of which is a superplasticizer (Shi, et al., 2016, Ibragimov and Fediuk, 2019). The addition of superplasticizer has an effect on the water-cement ratio of the plan, but the recommended dose must still be taken into account. Excessive doses will make the concrete experience a long setting time and can reduce strength at the beginning of the concrete age (Dzikri, M. et al., 2018).

The need for concrete as a building structure material will have an impact on the environment. Some of the materials that make up concrete come from nature that cannot be renewed, so over time nature will be damaged in line with the increasing waste from industry. One of these wastes is coal-fired power plant waste. The reason some countries use coal fuel is because of its abundant availability and affordable price so that it can make cheap electrical energy. But on the other hand the use of coal produces particle pollution and chemical waste, namely fly ash and bottom ash. According to the Minister of Environment and Forestry Regulation No. 26 of 2020 explains the definitions of fly ash and bottom ash. Fly ash is ash particles that float from the results of thermal waste processing. While bottom ash is ash particles that fall from thermal waste processing. According to the Regulation of the Minister of Environment and Forestry No. 18 of 2020, this coal waste is considered as B3 waste (hazardous and toxic materials) from the coal combustion process from power plants with waste codes B409 (fly ash) and B410 (buttom ash).

Currently, many uses and processing of fly ash have been carried out, one of which is by using it as a construction material. There are several researchers who have conducted experiments on the use of fly ash as a cement substitute. Cement substitution with fly ash achieves optimum compressive strength with fly ash content not more than 30% (Umboh, et al., 2014) and increase the abrasion resistance (Yen, et al., 2007).

Based on the above discussion, it is necessary to innovate and conduct further research to overcome some of the problems that arise. Experiments on the concrete constituent materials were carried out using fly ash and calcium stearate. Some researchers (Chari, et al., 2019; Quraishi, et al., 2011) were studied calcium stearate usage as a green inhibitor in conrete. The result shows that it can protect the concrete from corrosion attack. Calcium stearate is also able to increase the water-resistant properties of concrete (Maryoto, et. al., 2020). Furthermore, it is necessary to investigate its effect on the bond strength of reinforcement and concrete through pull out testing. This study aims to determine the effect of using calcium stearate on SCC with PCC and fly ash as a binder on the bond strength capacity of reinforcement in concrete and its failure pattern.

RESEARCH METHODS

This research was conducted using experimental methods with direct manufacturing and testing to obtain the relationship that occurs between variables. In this study, the independent variable was calcium stearate with a percentage variation of 0, 1, 5 and 10 Kg/m3. While the dependent variables are cement content, coarse aggregate, fine aggregate, water, PCC binder, superplasticizer and fly ash.

Materials and equipments

The equipments used in this study included: compression testing machine, pull out tools, scales, oven, concrete mixer, sieve shaker, slump tool, concrete cylinder mold with a diameter of 15 cm

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and a height of 30 cm. While the materials used consist of cement, crushed stone, sand, fly ash, calcium stearate water and steel reinforcement with a diameter of 19 mm. Figures 1, 2, and 3 show the concrete compression testing machine, loading frame and hydraulic jack. The loading frame and hydraulic jack are used for pull out testing. The pull out test scheme can be seen in Figure 4.

Figure 1. Compression machine

Figure 2. Loading frame

Figure 3. Hydraulic *jack*

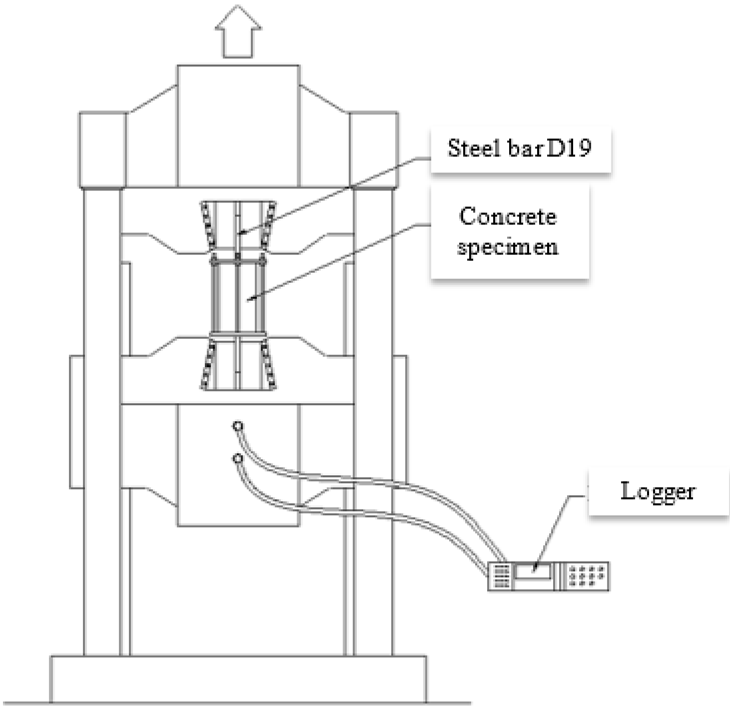

Figure 1. Scheme of pull out testing

The compressive strength test specimens used were 2 and 3 for the pull out test for each specimen code. A total of 12 specimens for the pull out test. Figure of compressive strength and pull out specimens are shown in Figure 5.

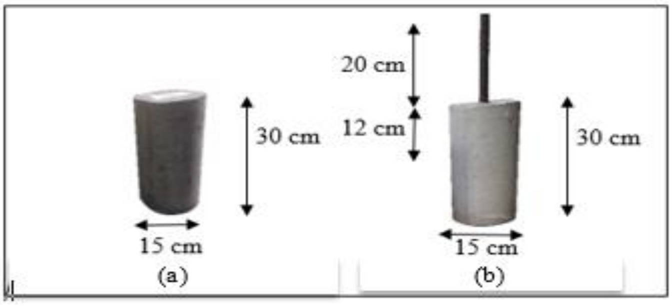

Figure 2. Spesimen of compressive strength (a) and pull out (b)

Compressive strength and bond strength equation

Compressive strength can be obtained using Equation 1.

$$\sigma = \frac{P}{A} \tag{1}$$

where σ is compressive strength (MPa), P is maximum load (Newton) dan A is area under compression (mm^2).

Bond strength capacity can be calculated using Equation 2.

$$\mu = \frac{P}{\pi . d . L} \tag{2}$$

where, μ is bond strength capacity (MPa), P is maximum tensile load (Newton), d is diameter of steel bar (mm), and L is the lengh of steel bar inserted in the concrete (mm)

RESULT AND DISCUSSION
Material Preliminary Test

Preliminary testing was conducted to determine the physical and mechanical properties of the concrete constituent materials, namely crushed stone and sand. The test results of crushed stone and sand used are shown in Table 1.

Table 1. The test result of crushed stone and sand

Type of testing	Crushed stone	Sand
Water content	0.96%	2.97 %
Clay content	0.12%	4.55%
Spesific gravity	2.70	2.59
Absorption	0.51%	6.12%
Sieve analysis	Max. 10 mm	Group 2

Based on Indonesian national standards, the maximum clay content of crushed stone is 1% and sand is 5%. The results of testing the clay content of crushed stone and sand are 0.12% and 4.55% so that the aggregate has met the minimum requirements for the aggregate to be used for the manufacture of concrete.

Mix design

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Referring to the results of the crushed stone and sand testing in Table 1, a concrete mix design was prepared using the SNI method so that a concrete mix design was obtained as shown in Table 2.

Table 2. Mix proportion of concrete

Materials	Weight (Kg)
Cement	315
Crushed stone	895
Sand	915
Water	175
Superplasticizer	0.88
Fly ash	35
Calcium stearate	0; 1; 5; 10

RESULT AND DISCUSSION

Compressive strength

Table 3 shows the results of testing the compressive strength of concrete. The results show that the self-compacting concrete without the addition of calcium stearate on average is 22.49. Furthermore, after the addition of 1, 5 and 10 kg of calcium stearate per m^3 of concrete, the compressive strength decreased to 20.65, 20.09, and 19.95 MPa. The addition of calcium stearate to self-compacting concrete (SCC) causes a decrease in compressive strength. This is because calcium stearate added to concrete will react with cement to form a compound that resembles wax. The bond of this compound is weaker when compared to the C-S-H bond or calcium silicate hydrate which is formed due to the reaction between cement minerals such as C3S, C2S, C3A and C4AF with water, resulting in a lower compressive strength of concrete.

Table 3. Compressive strength

Calcium stearate content (kg/m^3)	Specimen	Compressive strength (MPa)	Average (MPa)
0	MD1-CS0	22.64	22.49
	MD2-CS0	22.35	
1	MD1-CS1	20.94	20.65
	MD2-CS1	20.37	
5	MD1-CS5	20.37	20.09
	MD2-CS5	19.81	
10	MD1-CS10	19.81	19.95
	MD2-CS10	20.09	

Pull Out Testing

The bond strength capacity of concrete reinforcement is shown in Table 4. The slip length (1) is the data obtained from LVDT 1 and the slip length (2) is the slip length data obtained from LVDT 2.

Table 4. Result of pull out test

Specimen	Length of slip LVDT 1(mm)	Length of slip LVDT 2(mm)	Maximum load (kN)	Bond strength (MPa)	
				Individual result	Average

MD2-CS0	11.1	0.0	44.3	6.18	5.73
MD3-CS0	9.4	5.2	38.5	5.38	
MD1-CS1	7.4	3.9	30.2	4.22	4.08
MD2-CS1	10.8	8.0	28.5	3.98	
MD3-CS1	7.3	2.7	29.0	4.05	
MD1-CS5	6.4	6.5	27.3	3.81	3.83
MD2-CS5	8.9	5.6	28.0	3.91	
MD3-CS5	9.2	10.8	26.9	3.76	
MD1-CS10	7.8	1.9	25.1	3.50	3.45
MD2-CS10	7.0	9.5	24.9	3.48	
MD3-CS10	10.1	8.3	24.2	3.37	

The test results show that the bond strength capacity of concrete with calcium stearate 0 Kg/m3 has an average bond strength of 5.78 MPa and the highest slip value is 11.1 mm. For the value of the bond strength of concrete with calcium stearate 1 Kg/m3 obtained an average value of 4.08 MPa and the highest slip value at 10.8 mm. For the bond strength of 5 kg/cm3 calcium stearate concrete, the average value is 3.83 MPa and the highest slip value is 9.2 mm. Meanwhile, for concrete with calcium stearate content of 10 Kg/m3 the average bond strength value is 3.45 MPa with the highest slip value of 10.1 mm. The results of the bond strength analysis are also presented in graphical form as shown in Figure 6. The relationship between tensile load and slip on LVDT 1 and 2 is presented in Figures 7 and 8.

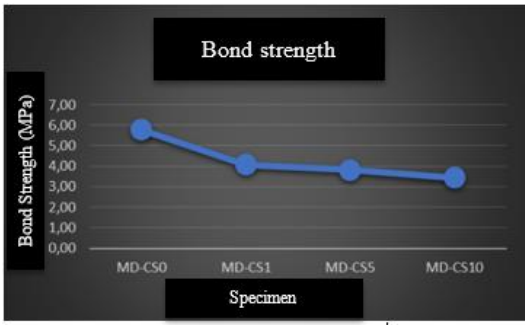

Figure 3. Bond strength

Figure 6 shows that the higher the calcium stearate content in the concrete, the lower the pull out capacity between the reinforcement and the concrete will be. This is in line with the tendency that occurs in the compressive strength. This decrease in concrete strength can be caused by the reaction between calcium stearate, water and cement which forms a wax-like compound. This compound is hydrophobic so that the surface of the concrete with the addition of calcium stearate becomes more slippery. This causes the bonding capacity of the reinforcement and the concrete to be easily removed.

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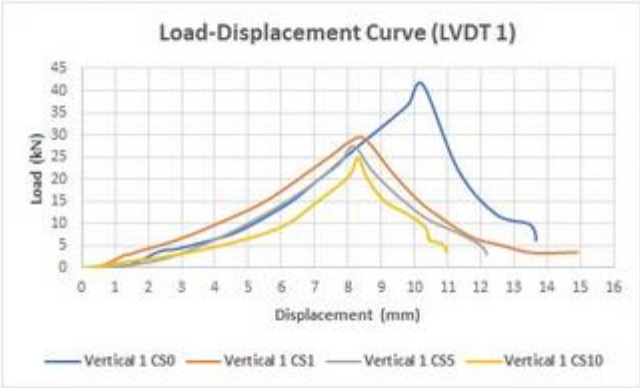

Figure 4. Relationship between load and slip at LVDT 1

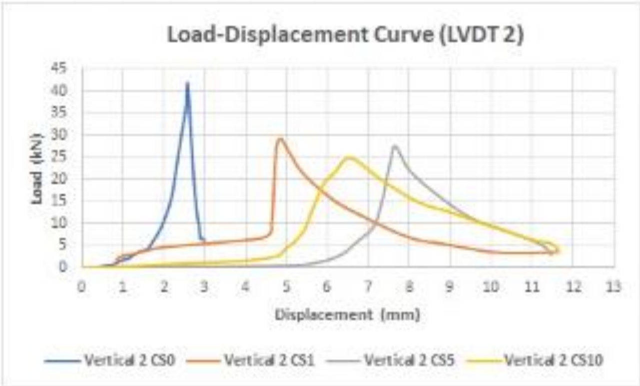

Figure 5. Relationship between load and slip at LVDT 1

Figure 7 shows the relationship between the average load and slip at LVDT per concentration of calcium stearate added to the specimen. The data for this vertical slip at LVDT 1 is obtained from the LVDT reading placed on the frame. From this graph show that the largest average load and slip occurred in the specimen with calcium stearate content of 0 Kg/m3. Then the average load and slip decreased in line with the addition of calcium stearate to the specimen. It can be concluded that the amount of slip that occurs is directly proportional to the tensile load that the specimen can withstand. However, the tensile load retained by the specimen will decrease due to increasing of calcium stearate content to the specimen. The slip that occurs will also decrease.

Figure 8 shows the relationship between the average load and slip (2) per concentration of calcium stearate added to the test object. The vertical slip 2 data is obtained from the LVDT reading which is placed on a thin iron plate connected to the reinforcement of the specimen. It looks out of sync when compared to Figure 7. This is influenced by the instability of the LVDT position, so the results of vertical slip 2 readings obtained have a large error. So the graph of the average load and slip relationship is more accurate using vertical slip data 1 and can be seen in the graph in Figure 7.

Failure pattern

In the pull out test, the failure pattern and the condition of the reinforcement after removal from the specimen were also analyzed. This analysis aims to determine the effect of giving the maximum load that the specimen can withstand. In addition, to determine the effect on the reinforcement whether there is an extension or not. After the results of the tensile strength test, for example the pattern of cracks and the condition of the reinforcement that emerges is shown in Figures 9 and 10.

Figure 6. Crack pattern

Figure 7. Steel bar condition

The pattern of failure in concrete with calcium stearate content of 0, 1, 5 and 10 kg/m3 indicates that the crack pattern extends so that splitting failure occurs. For the condition of the reinforcement after the test, there was no increase in length and there were thread marks on the concrete. This means that the reinforcement is pulled out of the concrete because the concrete has cracked first.

CONCLUSION

Based on the results and discussion in the previous section, it can be concluded as follows: 1) The compressive strength of concrete decreases due to the addition of calcium stearate. The higher the addition of calcium stearate, the lower the compressive strength of the concrete is also higher. 2) The bonding strength between reinforcement and concrete also showed a downward trend due to the addition of calcium stearate to the concrete. 3) The pattern of cracks that occur in all specimen, namely the longitudinal crack pattern. This crack pattern causes splitting failure.

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