Infiltration of chloride ion in the self compacting concrete with calcium stearate

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Abstract. Corrosion rates in reinforced concrete can be detected by the amount of chloride ions present in concrete. This study aims to determine the effect of calcium stearate use on self compacting concrete on the infiltration of chloride ions. The calcium stearate content used is 0, 1, 5 and 10 kg per 1 m³ of self-compacting concrete (SCC). The concrete quality tested includes 20, 30 and 40 MPa. The parameters tested in this study were compressive strength and infiltration of chloride ions. Compressive strength specimen is in the form of cylinder 15 mm in diameter and 150 mm in height, while chloride ion infiltration specimen is in the form of cubes with sides of 150 mm. The results show that calcium stearate concrete with 10 kg/m³ of concrete when compared to normal concrete, the compressive strength decreases by -6.69%, 16.16% and 18.74% for concrete 20, 30 and 40 MPa respectively. Whereas the infiltration of chloride ions in concrete on 10 mm depth from the concrete surface was 0.153, 0.061 and 0.012% in the concrete of 20, 30 and 40 MPa. These infiltration of chloride ion in concrete 20, 30 and 40 MPa are lower around 287, 252, and 626% compared to concrete without calcium stearate.

1. Introduction
Self-compacting concrete (SCC) is concrete that is capable of compacting itself without the help of external compaction. This type of concrete can flow only by relying on its own weight [1]. SCC is able to fill even the narrowest space between even tight concrete reinforcements [2]. This capability is not possessed by conventional concrete, consequently SCC is generally denser and has a higher compressive strength [3,4]. The high compressive strength of SCC is also due to the use of a low water cement ratio of around 30%. Because the usage of a low water cement ratio, SCC has the small number of capillaries and concrete pores. These capillaries and pores are formed during a hydration reaction process where the water needed to react with cement is only about 25% of the weight of cement. This means that only 25% of the total weight of water used evaporates and leaves pores and capillaries. Another advantage of SCC concrete compared to conventional concrete is that it is more waterproof, lower shrinkage and creep, more resistant to corrosion attack [5], lower permeability, better flexural strength and durability.

Reinforced and pre-stressed concrete can be used for building structures located in free and un-free from corrosion attacks and corrosive locations [6,7]. The concrete structure located in the corrosive environment has a shorter service life. Bridge structures of reinforced or pre-stressed concrete located in coastal areas generally have a service life that is shorter than the design. This is caused by corrosion attacks on concrete reinforcement by chloride ions. It can be infiltrated into concrete due to pressure,
diffusion and absorption. When corrosion starts in concrete reinforcement, the service load of reinforced concrete structures decreases by the time [8]. Although in general, the reduction in service capacity of reinforced concrete can be improved [9], the carrying out of repairs is very complicated and the costs are expensive.

Maryoto et al. [10] have investigated the use of calcium in conventional concrete. The results show that the use of calcium stearate in conventional concrete can reduce the infiltration of chloride ions. The effect of using calcium stearate is to make the concrete more hydrophobic. Finally, the corrosion attack that occurs in concrete contained calcium stearate becomes smaller. On the other hand, SCC is concrete made by adding superplasticizer as a significant additive to increase the workability of fresh concrete. Until now, there are no researchers to investigate whether the use of calcium stearate is safe or unsafe in SCC. Moreover, this study aims to determine the effect of calcium stearate on infiltration of chloride and compressive strength ions in SCC 20, 30 and 40 MPa.

2. Method

2.1. Materials and equipment

The materials used in this study include Portland Composite Cement (PCC), sand, broken stone, water, superplasticizer (Viscocrete 1003), coating material, NaCl and calcium stearate. Meanwhile the main equipment used includes concrete mixer, slump equipment, oven, balance, sieve shaker, molding cylinder diameter 150 mm and 300 mm height, cube molding 150x150x150 mm, compression machine / universal testing machine (UTM), X-ray fluorescence (XRF) and drilling machine.

Based on the physical properties of fine aggregates and coarse aggregates, the mix proportion of SCC 20, 30 and 40 MPa as shown in Table 1. The number of test specimens, type of test and calcium stearate content used in SCC are shown in Table 2.

| Table 1. Mixed proportion of SCC. |
|----------------------------------|
| Material | Quality of concrete (MPa) | 20 | 30 | 40 |
| --- | --- | --- | --- | --- |
| Cement, PCC (kg) | 350 | 425 | 545 |
| Sand (kg) | 910 | 815 | 740 |
| Crushed Stone (kg) | 910 | 920 | 886 |
| Water (kg) | 175 | 186 | 183 |
| Superplasticizer (kg) | 1.8 | 1.9 | 2.7 |

| Table 2. Number of specimen. |
|-------------------------------|
| Code of specimen | Compression test | Infiltration of chloride ion test |
| --- | --- | --- | --- | --- |
| --- | 20 | 30 | 40 | 20 | 30 | 40 |
| C0S0.5 | 3 | 3 | 3 | 3 | 3 | 3 |
| C1S0.5 | 3 | 3 | 3 | 3 | 3 | 3 |
| C5S0.5 | 3 | 3 | 3 | 3 | 3 | 3 |
| C10S0.5 | 3 | 3 | 3 | 3 | 3 | 3 |

In the table: C is representing calcium stearate, one number behind C shows calcium stearate content in each m³ of SCC (in kg), S is representing superplasticizer, and two numbers behind S show superplasticizer content in percentage by the cement weight.
2.2. Infiltration of chloride ion

The infiltration of chloride ions test was carried out to determine the amount of chloride ions that ingress into the SCC. The test object used is a cube measuring 150x150x150 cm. Specimens are removed from the water soaking tub after 28 days of water immersion. The test object is dried by placing it in an open space but not exposed to direct sunlight for 24 hours. Cover the 5 surfaces of the specimen with coating material so that the water cannot infiltrate into the concrete as shown in Figure 1. Soak the specimen cube with 3% NaCl solution for 3 months. The depth of 3% NaCl solution is 3 cm to the surface of the specimen as shown in Figure 2. The position of the uncoated surface is located in the above position. It means that the 3% NaCl solution can infiltrate into the SCC. The next step is to remove the specimen from the immersion of 3% NaCl solution after 3 months and dry it for 24 hours. Drilling specimens is carried out on uncoated surfaces such as Figure 3. The drilling powder is put in a glass baker as shown in Figure 4. A drilling scheme with a distance of 1, 2, 4, 6 and 8 cm is illustrated in Figure 5.

![Figure 1. Coating protection.](image1)
![Figure 2. Soaking under NaCl solution.](image2)

![Figure 3. Taking powder of concrete.](image3)
![Figure 4. Powder of concrete.](image4)
As for powder of concrete shown in the Fig. 4 is then analyzed to identify the chloride content using XRF. The working principle of chloride analysis using XRF is based on the collision of atoms on the surface of specimens by X-rays. Qualitative results are indicated by the peak of the spectrum representing the type of element in accordance with X-ray energy characteristics. Quantitative analysis is obtained by comparing the sample intensity with the standard. The steps for testing specimens with XRF are as follows: Powder of concrete is finely ground by using a portable ball mill. Sieving powder of concrete so that its size is homogeneous at +/- 100 mesh. Enter the powder of concrete in the ring and weigh it to get the weight of the specimen. XRF and computer are turned on and wait for a while so the equipment is ready to be used to analyze the powder of concrete.
Specimens that are ready to be put in in XRF. Measurement variables are filled in accordance with Standard Operating Procedures of XRF. Energy to analyze is regulated. Filters are arranged according to the elements to be analyzed in this case is the element Chloride and Sodium. XRF is closed and runs an analysis program that is on the computer and is related to XRF. Testing of specimen is conducted and the result is a spectrogram. Percentage of each element contained in powder of SCC is obtained. Save the test results data on a computer. The result of elemental analysis is a spectrogram as in Figure 6. Based on the graph, it can be observed the intensity and energy reflected by Cl (chloride). The high intensity shows how much content in the test sample. High energy is a specific characteristic of certain elements. The output of the XRF instrument can be put in a table of mass content of each element in percentage.

2.3. Compressive strength
The concrete compressive strength test is carried out when the concrete is 28 days old and has been placed in an open space to dry the surface of the specimen. Capping concrete surfaces is conducted in order to obtain a good distribution working load on the concrete surface. Put the specimen in the testing position and turn on the compression machine at a speed of 0.19 - 0.39 MPa. The compressive strength of concrete is obtained when the maximum force that causes the specimen fall out. The amount of compressive strength is calculated by dividing the maximum force with the surface area of the cylindrical specimen.

3. Result and Discussions

3.1. Infiltration of chloride ions
Figures 7, 8 and 9 show the results of ion chloride infiltration tests on SCC 20, 30, and 40 MPa contained calcium stearate. Meanwhile, Figure 10 shows the relationship between infiltration of chloride ion in 6 cm depth and calcium stearate content in concrete.
In the figures 7, 8 and 9, C0, C1, C5 and C10 represent calcium stearate content in SCC. It is 0, 1, 5 and 10 kg per 1 m³ of fresh SCC.

Figure 7 shows the relationship between the depth of the chloride ion infiltration and the percentage of chloride ion in the SCC 20 MPa. The deeper position of taking concrete powder from the surface, the infiltration of chloride ions decreases. The effect of this incident is that corrosion attacks on concrete reinforcement that placed deeper than the concrete surface also decreases. Furthermore, reinforced concrete located in a corrosive area, it would be safer if the size of the concrete cover is greater than 50 mm.

In addition, based on Figure 7, it can be found that SCC with the addition of calcium stearate, infiltration of chloride ion in the SCC is decreased. Higher the content of calcium stearate in SCC, the chloride ion is lower. The infiltration behavior of chloride ions in 30 and 40 MPa concrete was the same behaviour with SCC 20 MPa. Greater the addition of calcium stearate, the smaller the infiltration of chloride ions into concrete (Figures 8 and 9). This is understandable because calcium stearate in the concrete will react with cement to form the wax-like compound [10,11,12,13]. The wax-like have a hydrophobic property. This property cause the contact angle formed between the water and the concrete surface becomes large. Consequently, water will be difficult to ingress into the SCC.

Figure 10 shows the magnitude of chloride ion infiltration in SCC 20, 30 and 40 MPa at a depth of 6 cm from the surface of the SCC. Based on this figure, the interesting thing is that the higher the quality of the concrete used, the infiltration of chloride ions decreases. Infiltration of chloride ions at a depth of 6 cm in SCC 20, 30 and 40 MPa with an additional calcium stearate of 1 kg per 1 m³ of concrete decreased by 8%, 32% and 15% compared to conventional concrete. This phenomenon occurs because the higher the quality of the concrete, the lower the water cement ratio used in the mix proportion of concrete. Based on Table 1, the water cement ratio used is 0.50, 0.44 and 0.34 for concrete grade 20, 30 and 40 MPa. Chemically, the water used by cement so that the hydration reaction can take place is 0.25 of the weight of cement. This means that there is still water left for 0.25, 0.19 and 0.14 of the weight of cement on concrete quality concrete 20, 30 and 40 MPa. The residual water evaporates and comes out of the concrete and the effect is leaving the pore and capillary. The bigger the water evaporates, the bigger the pore and capillaries are formed. This capillary network is used by chloride ions in and seep into the concrete.

3.2. Compressive strength

Compressive strength of SCC can be identified in the Figure 11. It can be observed that calcium stearate applied in SCC reduces the compressive strength. This decline of the compressive strength not only occurs in the SCC 20 MPa, but also in the SCC 30 and 40 MPa. This trend is matched to the usage of calcium stearate in the conventional concrete [10]. The effect of calcium stearate 1 kg per cubic meter in compressive strength of SCC is insignificant. Because of this, Calcium stearate is safe to be applied in the SCC. No negative effects in the SCC due to addition of calcium stearate. According to Maryoto, 2018 the reduction of compressive strength of SCC is caused by the bonding of wax-like constituent. Unlike the bonding of calcium silicate hydrate (C-S-H) in concrete, the bonding of wax-like constituent in SCC is very weak. As the influenced, the compressive strength of SCC containing calcium stearate is descend. The reduces of compressive strength is around -3.7%, 6% and 0.5% for SCC containing calcium stearate 1 kg per 1 m³ of fresh concrete.
4. Conclusions
Infiltration of chloride ion in SCC is affected by containing calcium stearate. Additional of calcium stearate in SCC 20, 30 and 40 MPa reduces infiltration of chloride around 8%, 32% and 15% in 6 cm depth from surface of SCC. Lower infiltration of chloride ion, the resistance of SCC toward the corrosion attack increase. On the other hand, compressive strength of SCC 30 MPa with calcium stearate 1 kg per 1 m³ of SCC is reduced insignificantly. The decreasing of the compressive strength of concrete with calcium stearate is -3.7%, 6.1% and 0.525 for SCC 20, 30 and 40 MPa respectively. Even though the usage of calcium stearate on high content reduced the infiltration of chloride ion in the SCC significantly, it suggested that the safe usage of calcium stearate in SCC is 1 kg per 1 m³ of fresh SCC.

Acknowledgement
Thank you to LPPM Universitas Jenderal Soedirman for funding this research through the 2019 IRC scheme so that this paper can be presented and published.

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Figure 11. The average of compressive strength of SCC with calcium stearate