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The Effect of Fly Ash Composition on The Hydrophobic Absorption, and Strength Properties of Concrete

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ABSTRACT

The use of concrete in buildings that indicate direct contact with water such as concrete preparation and roof requires waterproof concrete. The air entering the concrete through the capillary tubes formed during the formation process can be reduced by reducing the diameter of the microcapillary. Fly Ash is an additive that has seeds that are smaller than cement. After the fly ash in the concrete mixture reacts with cement and water, the diameter of the microcapillary formed will be smaller. The purpose of this study is to determine the effects of variations in the composition of flying ash on the hydrophobic, absorption, and concrete strength. Variations in the composition of flying ash are 0%, 5%, 10%, 15%, and 20%. Based on the test, the percentage of absorption in concrete aged 7 reached an optimal value at 5% percentage of flying ash with a value of 0.363%, whereas in concrete aged 14 days optimal value is obtained at the percentage of flying ash 5% with a value of a 0.5%. The biggest contact angle for the variation of 0% flying ash at the age of 7 days is 128.79º and the lowest value for the variation in flying 15% is 100.41º. The highest compressive strength value occurs in the percentage of flying ash at 0% is 30,945 in 7 days of concrete age, and the lowest concrete compressive strength value is the percentage of fly ash at 15%, namely 16.05 MPa for concrete age 14 days.

Keywords : *Hydrophobic; Contact Angle; Absorption; Compressive Strenght; Fly Ash*

I. INTRODUCTION

The was 22,308 bridges in indonesia around 2020 and as many as 2,086 pieces (9.35% of the total bridges) were damaged, which was caused by corrosion of reinforcement in reinforced concrete[1]. Concrete structures that are prone to corrosion are bridge and highway structures. This structure is always associated with the open environment and rainwater. Due to these conditions, the concrete can be damaged before the end of its service life. This occurs due to the corrosion of concrete reinforcement, especially in environments contaminated with chloride ions (Cl-) such as coastal areas. Chloride ion penetration will occur through the pores of the concrete and cause corrosion of the concrete reinforcement[2].

In some circumstances, reinforced concrete can experience damage such as corrosion of the reinforcing steel in the concrete, especially in concrete that is in an environment contaminated with chloride ions (Cl-) such as coastal areas. This corrosion can cause expansion stress that can cause cracks on the concrete surface. The cracks that occur can facilitate the penetration of chloride ions by the reinforcement and accelerate the occurrence of corrosion so that the concrete cover (spalling) will peel off. Furthermore, the age of concrete and its strength will decrease drastically[3].

Concrete is the result of mixing cement, water, and aggregate. The composition of making concrete can also be added with other ingredients according to the desired ratio. Some additives consist of chemical additives, fiber, or non-chemical waste materials. The nature of concrete in general is influenced by the quality of the materials used, the way it is worked, and how treated [4]. Additives are materials other than the main

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constituents of concrete which are added to the concrete mix, before, immediately, or safely, the mixing of fresh concrete to change one or more properties of the concrete while it is still fresh or after hardening, for example; accelerating hardening, increasing dilute mortar, increasing compressive strength, increasing functionality, and reducing repeat hardening [5]. According to tests, there is a temperature for concrete throughout its early life that is deemed ideal in terms of strength at later ages. The effect of calcium chloride on strength is investigated at various temperatures for mixing, putting, and curing. Except for the fact that it altered concrete temperature after mixing, the effect of cement temperature was determined to be insignificant[6].

Fly ash, often known as coal ash, is the byproduct of coal combustion that is commonly produced by PLTU (Steam—Electric Power Station). Fly ash is an excellent pozzolanic substance. Fly ash is composed primarily of silica (SiO2), aluminum (Al2O3), iron (Fe2O3), and calcium (CaO), with minor amounts of potassium, sodium, titanium, and sulfur[7]. Fly ash, which has a fineness of 400-700 m3/kg compared to cement's fineness of 300-400 m3/kg, also acts as a filler, closing the pores of the concrete and therefore lowering the number of pores, which affects the concrete's porosity [8].

The higher the percentage of fly ash in the mixture, the higher the compressive strength [9]. This is because the addition of fly ash to cement as an additive without reducing the proportion of cement will increase the binder in cement, namely silica (SiO2) to produce a higher compressive strength [10]. Concrete pressure using 0% fly ash does not cause the strength of the concrete to decrease and even tends to increase. The maximum compressive strength occurs in concrete with the addition of 3 kg of calcium stearate and 40% fly ash content, the increase is 5.67%. The process of forming concrete with the addition of calcium stearate can cause a decrease in the absorption and penetration value of the minimum, namely a dose of 2 kg of calcium stearate which is 1.35% and 1 cm in the tested concrete [2].

The larger the pore volume in the concrete, the lower the strength of the concrete[2]. The addition of C-SH, the main compound responsible for the development of cement properties, resulted in a stronger bond between cement and aggregates, and the empty spaces that were previously filled with water and soluble cement particles were replaced with C-S-H, reducing the porosity of the concrete[11]. As the permeability of concrete decreases with hydration age, this occurrence eventually contributes to an increase in compressive strength [12].

Fly ash, a byproduct of the manufacturing process, may be used to make geopolymer concrete. The use of fly ash instead of cement in geopolymer concrete decreases energy consumption and limits carbon dioxide emissions into the atmosphere during manufacturing[13].The finer fly ash grains cause less surface area to be wetted with water so that the free water in the concrete increases at the same water-cement factor value that will facilitate the process of mixing, pouring, and compacting[14]. Compressive strength testing can be done by applying a compressive load to a cylindrical object with a constant diameter. For ductile materials, it is very difficult to obtain a stress-strain curve from this compressive strength test, because ductile materials cannot break when pressed.

The compressive strength of concrete refers to its ability to withstand compressive forces per unit area. Even if there is only a small amount of stress in the concrete, it is sufficient to withstand all compressive stresses. Strength tests are usually carried out on cylindrical and cube-shaped specimens. Water is required to provide chemical activity in the hardening of concrete; However, too much water can increase the ability of concrete as well as reduce its strength[15].

A high absorption number indicates that the concrete is less durable or has poor durability because it quickly absorbs water, causing the concrete's strength to deteriorate. The low absorption value in concrete using fly ash as cementitious because it has smaller pores, and the cracking properties between the aggregates are getting better due to the influence of amorphous silica elements which are more reactive[16].

On a hydrophobic surface, the roughness of the surface will result increase in the contact angle, so that the surface will increasingly repel water. The contact angle is the angle formed between the droplet and the solid surface in contact when the droplet is dropped. Testing the hydrophobic properties of concrete is done by measuring the contact angle using ImageJ Software which is taken first using a camera. The contact angle is determined directly with ImageJ Software.

The contact angles at the front and rear of the drop correspond to the forward and backward contact angles when the drop is on an inclined surface, as shown in figure 1. The contact angle hysteresis will occur if the forward angle is greater than the reverse angle. Due to the roughness of the surface of the object, the contact angle hysteresis develops.

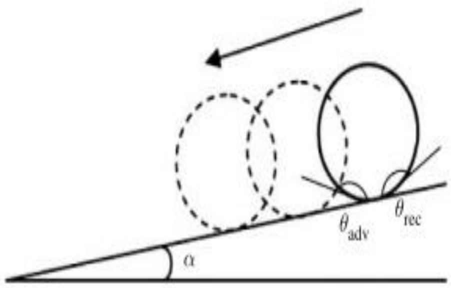


Fig. 1. Tilted surface profile (tilted angel, α) with a liquid droplet; advancing and receding contact angles are θ_{adv} and θ_{rec}, respectively [17].

Water-resistant materials have the effect of preventing air from entering the concrete through the capillaries. the form material comes from soap, butyl stearate, and materials from petroleum products. This barrier is considered to be absorbent to air and damaging compounds[18].

The compressive strength of concrete increases with age. The argument is that, when concrete is cast, the initial compressive strength growth rate is fast, but the rate of increase slows down over time. Consequently, the standard compressive strength of concrete is defined as the compressive strength of concrete at 14 days. The following equation can be used to calculate the compressive strength of concrete:

$$f'c = \frac{P}{A} \qquad (1)$$

where :

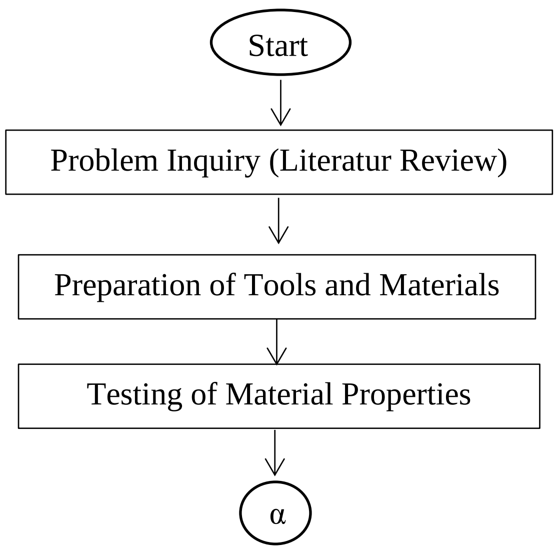
f'c = Concrete compressive strength (Mpa)

A = Cross-sectional area of the test object (mm2)

P = Compressive load (N)[19].

II. METHOD

At this stage is planned that the test objects to be made are normal concrete and concrete with the use 5%, 10%, 15%, and 20% fly ash. Each concrete variety will be examined at the age of 7 and 14 days, with a total sample of 30 samples. The Flow Chart in Figure 2. depicts rhe research procedure to be caaried out.



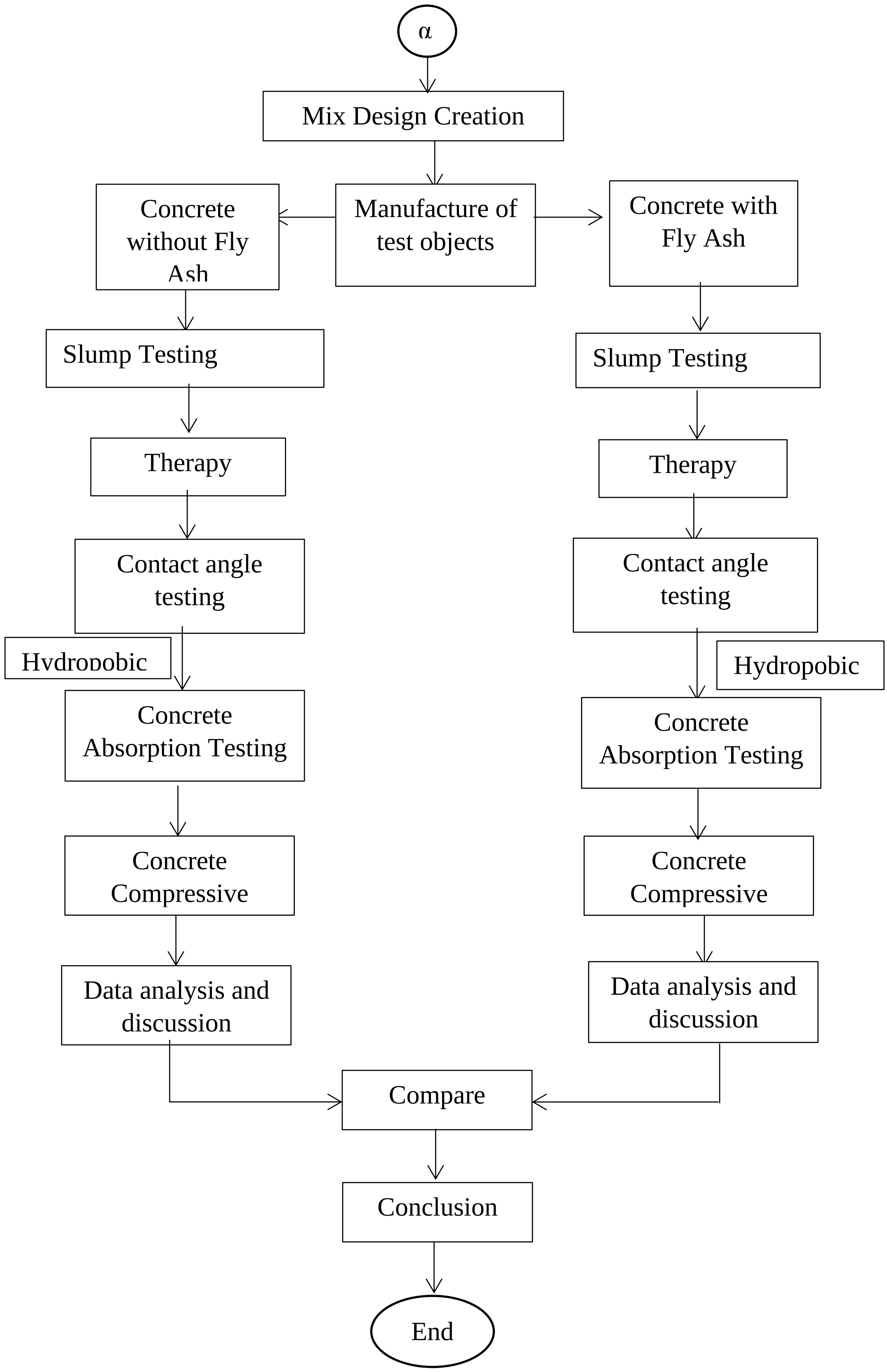


Fig. 2. Flowchart for research

Testing the hydrophobic properties of concrete is done by measuring the contact angle using ImageJ Software which is taken first using a camera. The contact angle is determined directly with ImageJ Software. This is done by selecting the image to measure the contact angle in the "File Tool" section, then selecting the "Angle Tool" and drawing a straight line between the sample surface and the water droplet. As in Figure 2 below.

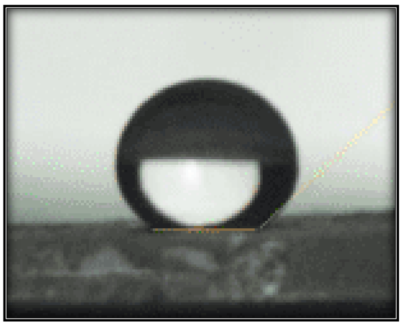


Fig. 3. Measuring the contact angle on the droplet.

When the droplet is placed on a rough surface, the water drop fills the surface roughness, the droplet adheres effectively to the surface, and Wenzel adds the roughness factor (rs) [20].

The concrete absorption test was carried out when the concrete was 7 days and 14 days old. The absorption test was carried out by weighing the test object after being in the oven for 3 days at a temperature of 100±5℃ (a) and then soaking it for 10 minutes in water. Then removed and cleaned water until saturated dry face and weighed (b). Based on SNI 03-6433-2000, the calculation of the amount of water absorption uses equation (2).

$$absorption = \frac{b-a}{a} \times 10 \qquad (2)$$

Several methods can be used to determine the compressive strength of concrete, one of which is a compression test using a Compression Testing Machine (CTM). The compressive strength test of concrete is carried out to measure the strength of concrete by applying pressure to the concrete sample until the concrete is destroyed. The advantage of using this Compression Testing Machine is that it can analyze the thickness of the material or object being tested, know the standards of the material to be used, and can analyze the properties of the material being tested.

The following are the requirements for equipment, materials, the needs of the test object, the size of the test object, and the stage of research implementation. The equipment includes: scales, sieves, buckets, measuring cups, concrete mixers, concrete cylinder molds, slump test equipment, and concrete compressive strength test equipment. while the materials used for the research include cement, sand, crushed stone, fly ash, and water[21].

The compressive strength test of concrete was carried out on a concrete cylinder with a height of 30 cm and a diameter of 15 cm [22]. The concrete cylinder can be seen in Figure 3.

Fig. 4. The Concrete compressive strength test object

III. RESULTS AND DISCUSSION

The findings of this study include the identification of contact angle data collected from concrete surface measurements and analyzed with ImageJ software. Additional research was conducted to determine the absorption value of each fly ash variant on the test object, then the compressive strength was tested using a Compression Testing Machine. The contact angle is defined as the angle formed by two lines, with the first line forming the boundary between the air and the liquid being dropped and the second line forming the boundary between the liquid and the solid being dropped. The picture below shows the measurement of the contact angle.

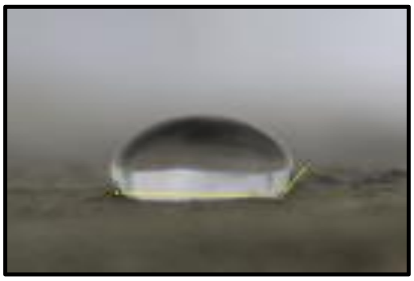


Fig. 5. Contact angle measurement

This contact angle measurement is important to determine whether the concrete surface layer is hydrophobic. The hydrophobic surface has a large contact angle of 90°. Data on the effect of variations in the composition of fly ash on the contact angle can be seen in Table 2.

Table 2. Testing the effect of variation of fly ash composition on concrete contact angle

Fly Ash composition variations	Concrete Age	Contact Angle θ°
Fly Ash 0% + Nanocrys	7 days	128,79°
Fly Ash 5% + Nanocrys	7 days	106,04°
Fly Ash 10% + Nanocrys	7 days	102,13°
Fly Ash 15% + Nanocrys	7 days	100,46°
Fly Ash 20% + Nanocrys	7 days	103,90°
Fly Ash 0% + Nanocrys	14 days	114,53°
Fly Ash 5% + Nanocrys	14 days	105,451°
Fly Ash 10% + Nanocrys	14 days	114,341°
Fly Ash 15% + Nanocrys	14 days	100,58°
Fly Ash 20% + Nanocrys	14 days	112,84°

A comparison of contact angle data for concrete aged 7 days and 14 days can be seen in Figure 6.

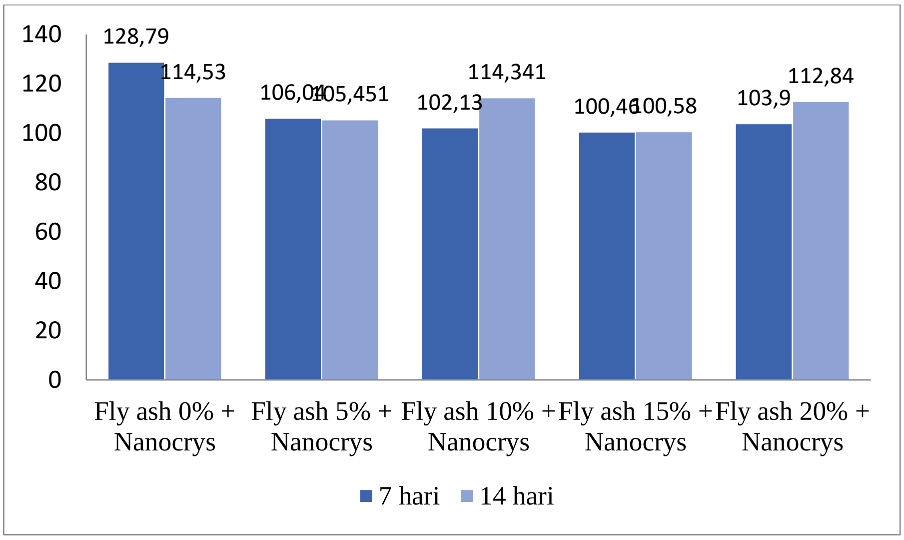


Fig. 6. Comparison of contact angle data for concrete aged 7 days and 14 days

From the data that has been analyzed, it can be seen that the contact angle test did not experience a significant change. Testing the highest contact angle on 7 days old concrete with a 0% fly ash variation of 128.79°. While the concrete aged 14 days tested the highest contact angle on concrete with 0% fly ash variation of 114.53°. The lowest contact angle of 7-day-old concrete with at 15% fly ash variation of 100.41°, while for 14-day-old concrete the lowest contact angle of 100.58° is found with a 15% fly ash variation. In this study, Nanocrys waterproofing liquid was used which can close small pores on the concrete surface, so that the concrete is watertight or impermeable to water. From the contact angle data, it is found that variations in the composition of fly ash used in concrete affect the resulting contact angle. The more fly ash used, the lower the contact angle value or the hydrophobic nature of the concrete.The amount of water absorbed by the concrete is affected by the amount of fly ash added. This is because the fly ash used does not fill the pores of the concrete surface perfectly. The average absorption test results for 7-day and 14-day-old concrete can be obtained from Table 3.

Table 3. The Average absorption test results for 7-days and 14-days-old concrete

No	Mixed Variety	Absorbs	
		Days	
		7 Days	14 Days
1.	Normal Concrete + Fly Ash 0% + Nanocrys	0.365 %	0.5%
2.	Normal Concrete + Fly Ash 5 % + Nanocrys	0.363%	0.91%
3.	Normal Concrete + Fly Ash 10 % + Nanocrys	0.56%	0.59%
4.	Normal Concrete + Fly Ash 15 % + Nanocrys	0.59%	0.8%
5.	Normal Concrete + Fly Ash 20 % + Nanocrys	0.63%	0.81%

Testing the value of absorbing concrete to see how much concrete absorbs air. The results of the comparison of absorption of concrete aged 7 days and 14 days can be seen in Figure 7.

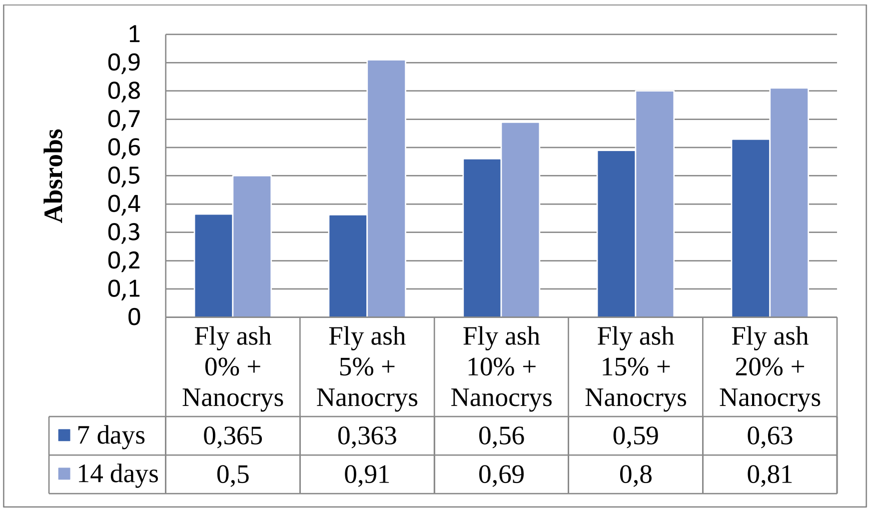


Fig. 7. The results of the comparison of absorption of concrete aged 7-days and 14-days

From Figure 7 it is clear that variations in the addition of fly ash affect the amount of water absorption capacity of the concrete. This is because the fly ash used does not optimally fill the pores formed on the concrete surface. Absorption or absorption of water in 7-day-old concrete, it is known that the optimum value is obtained at the percentage of fly ash of 5% with the addition of nanocrystal additives with total water absorption of 0.363 %. Meanwhile, the minimum water infiltration was obtained at 20% fly ash percentage with the addition of nanocrystal additives of 0.63%.

From the data that has been analyzed the results of the absorption percentage of water absorption at the age of 14 days, it is known that the optimum value is obtained at the percentage of fly ash 0% with the addition of nanocrystal additives with 0.5% water absorption. Meanwhile, the minimum water absorption was obtained at 5% fly ash percentage with the addition of nanocrystal additives of 0.91%.

From the results of measurements and analysis of the absorption of the test object, it can be seen that the greater the percentage of fly ash used, the greater the water absorption value of the concrete, and the longer the life of the concrete treatment, the more water absorption will be. So that the water absorption value is directly proportional to the variation of the fly ash composition and the age of the concrete treatment.

With water cement factors of 0.3, 04, and 0.5, the influence of fly ash on the compressive strength of concrete, the more fly ash, the lower the compressive strength. The influence of the water-cement factor on concrete compressive strength and porosity in terms of variations in fly ash, 0%, 10%, and 20%, essentially the bigger the FAS value, the lower the value of the concrete compressive strength[23].

The goal of compressive strength testing is to determine how much load per unit area causes a test object to disintegrate when a compressive force is applied. When the concrete was seven and fourteen days old, its compressive strength was assessed. Figures 7 and 8 show the impact of differences in fly ash content on the compressive strength of concrete.

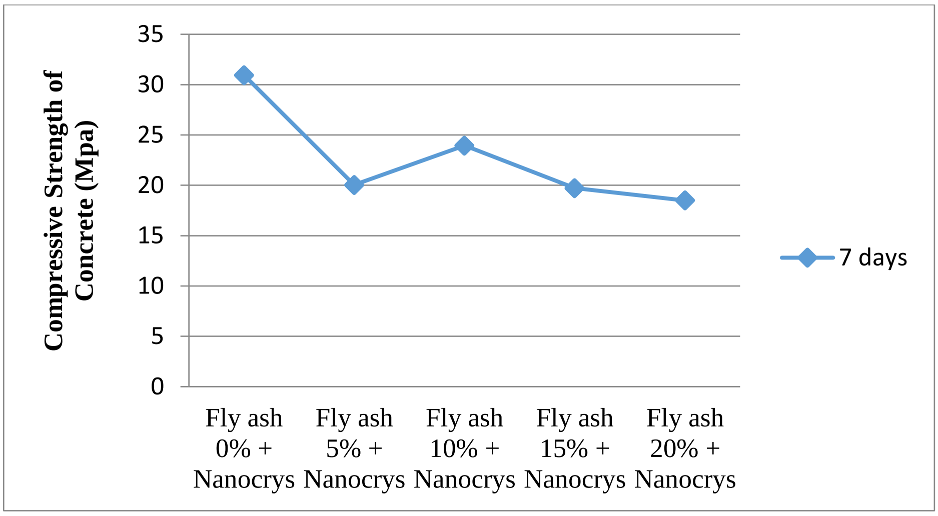


Fig. 8. Compressive strength of 7 day old concrete

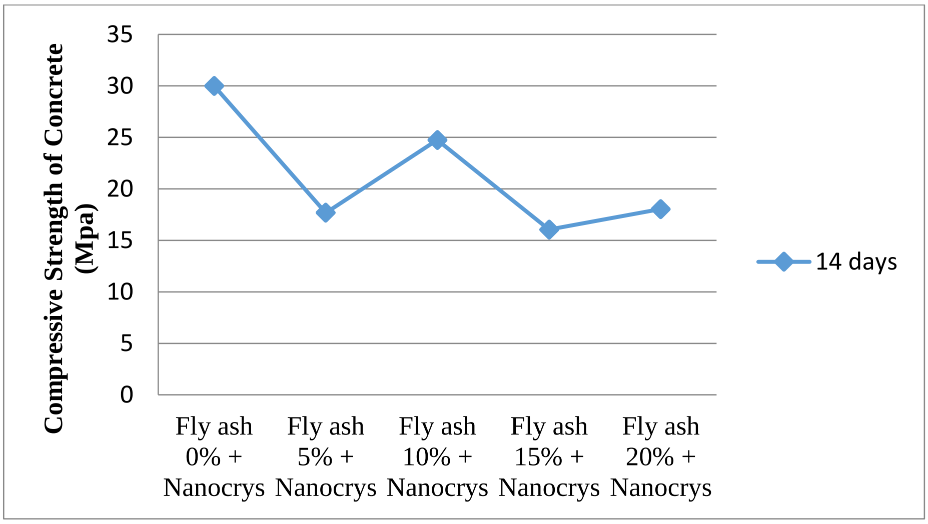


Fig. 9. Compressive strength of 14 day old concrete

From Figure 8 and Figure 9 it can be seen that the compressive strength of 0% fly ash concrete with the addition of Nanocrys is better than concrete with the addition of 5%, 10%, 15%, and 20% fly ash. At the age of 14 days, the lowest concrete compressive strength was found in a mixture of 15% fly ash with the addition of the Nanocrys additive of 16.05 MPa. Meanwhile, at the age of 7 days, the minimum concrete compressive strength occurred in the 20% fly ash variation with the addition of 18.49 Mpa Nanocrys additive. The compressive strength of concrete increases with the use of fly ash [10], but in this study the compressive strength of concrete at the age of 14 days decreased compared to the compressive strength of concrete at the age of 7 days. This result was caused by deficiencies at the time of the study, such as the factor of the material used, the factor of compaction of the concrete when it was printed, and the uneven mixture. And in this study, fly ash was used as a substitute for cement not as an additive. However, the planned compressive strength of the concrete was achieved at variations of 0%, 5%, and 10% fly ash. Research [23] showed the effect of fly ash on the compressive strength of concrete with water cement factors of 0.3, 0.4, and 0.5, the more fly ash, the lower the compressive strength value. The effect of the water-cement factor on the compressive strength and porosity of concrete in terms of variations in fly ash, 0%, 10%, and 20%, namely the greater the water cement factors value, the lower the value of the compressive strength of concrete.

IV. CONCLUSION

The effect of variations in the composition of fly ash on the hydrophobic properties of concrete was found that the contact angle will be lower as the composition of fly ash used in the concrete mix increases. It can be seen from the magnitude of the contact angle obtained. The effect of variations in the composition of fly ash on the absorption value of concrete is that the greater the percentage of fly ash used, the absorption value or water absorption of concrete is directly proportional to the proportion of fly ash used. The effect of variations in the composition of fly ash on the strength of concrete, the use of fly ash in concrete with the addition of nanocrystal additives causes the strength of the concrete to tend to decrease. The strength of concrete with the use of 0% fly ash with the addition of nanocrystal additives achieved the highest concrete strength, followed by the percentage of 15% fly ash mixture which had the second-highest concrete strength. So it must be determined the proportion of fly ash used to get maximum concrete strength.

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