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# Optimization of Compressive Strength and Porosity of Normal Concrete Using Fly Ash and Alkaline Activators

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***A B S T R A C T***

*The use of cement in the concrete mix is the most expensive material. In the cement production process, there is $CO_2$ emission into the air, which causes the greenhouse effect and global warming. So we need other materials as an alternative to reduce the use of cement by using by-products such as fly ash which is categorized as a Pozzolan material. In this study, fly ash was used with variations of 0%, 70%, 80%, 90%, 100%, water-cement ratio 0.4. Because fly ash does not have the same binding ability as cement, alkaline activators are needed, namely Sodium Silicate ($Na_2SiO_3$) and Sodium Hydroxide (NaOH) , with molarities of 6M and 8M. To determine the compressive strength of concrete, a compressive test was carried out at the age of 7 days and 28 days and a porosity test at the age of 28 days. The maximum compressive strength of concrete with fly ash content of 90% with a molarity of 6M and 8M. The age compressive strength has the same value. At the age of 7 days is 14.43 MPa. At the age of 28 days, it is 18.39 MPa. The greater the use of fly ash and molarity in concrete, the fewer pores in the concrete because the mixture is more concentrated and round, and the small particle size of fly ash can fill voids in the concrete.*

## 1. Introduction

The need for concrete is increasing yearly in line with the increasing need for facilities and infrastructure because concrete is the most widely used construction material. After all, forming materials are easy to obtain. In addition to its easily available forming material, concrete has high compressive strength and resistance to high temperatures [1][2]. Concrete consists of coarse aggregate, fine aggregate as a filler, water, and cement as a binder [3]. Cement is the most expensive material in the mixture of materials forming concrete [4][5].

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Lately, the demand for cement has been increasing, but $CO_2$ emissions into the air are proportional to the amount of cement produced in the cement production process. This gas is released into the atmosphere freely, which causes the earth's atmosphere to become thinner and then damages our environment, including causing the greenhouse effect and global warming [6]. To overcome the adverse effects that damage the environment and improve durability problems in concrete materials using portland cement, other materials are needed as a substitute for portland cement which is more friendly. To reduce the use of cement by making environmentally friendly concrete, namely by maximizing waste materials [7]. The replacement of some of the amount of cement in making this concrete is with materials that are more environmentally friendly, namely by using fly ash.

Fly ash or fly ash which is the remains of coal combustion, which is flowed from the combustion chamber through the boiler in the form of a burst of smoke, which is in the form of fine particles and is an inorganic material formed from changes in mineral materials due to the combustion process of the coal combustion process in the steam-generating unit (boiler) [8]. Fly ash consists mostly of amorphous and crystalline substances such as mullite, quartz, and CaO. If left alone and not reused, fly ash will cause pollution to the environment because fly ash contains several toxic elements [9]. This material can react chemically with alkaline activators to form mixed materials with cement-like properties.

The activator solution commonly used consists of sodium and/or potassium compounds. These two elements can form highly concentrated aqueous solutions and can dissolve large amounts of silicon [10]. Activator is a compound used for condensation polymerization reaction in a mortar [11]. Alkali hydroxide as an activator is a strong base compound that will react with fly ash because silica is a strong acid [12].

Fly ash is mostly composed of silica and aluminum oxide. Compared to other metal oxides in fly ash, it is possible to use it as an adsorbent [13]. In the mixture, silica will help the binding process between particles, while aluminum oxide will accelerate the polymerization reaction that occurs in the manufacture of geopolymer concrete [14][15]. Fly ash is one of the materials used to make binders. Fly ash is categorized as a "Pozzolan" material, namely siliceous or aluminous material in which there is little or no binding property like portland cement [16]. Fly ash consists of Silica ($SiO_2$), Alumina ($Al_2O_3$), iron oxide ($Fe_2O_3$), calcium (CaO), magnesium oxide (MgO), and the remainder is potassium, sodium, titanium, and sulfur in lower amounts. The addition of fly ash to the concrete mixture fills the existing pores. Having very fine particles to fill the voids (filler) in the concrete can increase the strength of the concrete, increase its resistance to water, and prevent cracks on the concrete surface [17]. The


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pore volume and small surface area for fly ash-based pastes indicate that the paste matrix is dense, which means the permeability is low and the compressive force is high.

The problem is how to influence the compressive strength and porosity of concrete using fly ash with an alkaline activator and how much effect it is compared to normal concrete. It can be seen how effective fly ash and alkaline Activator are for the concrete mixture.

## 2. Research Methodology

### 2.1 Research Design

The method used in this research is a comparative experimental method by conducting tests in the laboratory. To determine the optimization of fly ash and alkaline activator use in normal concrete mixtures, a concrete test object with a w/c of 0.4 was made as a comparison for concrete without using fly ash and alkaline Activator.

### 2.2 Material Preparation

The concrete material in this study used fly ash as the base material and a mixture of sodium hydroxide (NaOH) and sodium silicate ($Na_2SiO_3$) as an activator. The fly ash used in this study came from the waste of the steam generator unit (boiler) PT. Tjiwi Kimia Mojokerto. Meanwhile, a sodium silicate and sodium hydroxide solution is obtained by buying at a chemical store.

1. Fly Ash

   Fly-ash has a fairly fine grain, which passes through the No sieve. 325 (45 milli microns) 5-27%, with a specific gravity between 2.15-2.8 and blackish gray [18].


*Source: Research Documentation*

**Figure 1.** Cement and Fly Ash.

Fly ash used in this research is type F waste from PT. Tjiwi Kimia Mojokerto. The chemical elements of fly ash can be seen in **Table 1.**


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**Table 1.** Chemical Elements of Fly Ash

| No | Ingredients | % Mass |
|---|---|---|
| 1 | $SiO_2$ | 73,21 |
| 2 | $Al_2O_3$ | 2,15 |
| 3 | $Fe_2O_3$ | 5,20 |
| 4 | CaO | 6,72 |
| 5 | MgO | 4,66 |
| 6 | $Na_2O$ | 0,75 |
| 7 | $K_2O$ | 0,27 |
| 8 | $SO_3$ | 0,26 |
| 9 | $H_2O$ | 1,54 |
| 10 | Lol | 4,69 |

*Source: ITS Environmental Engineering Laboratory*

2. Alkaline Activator

Activator is a compound used for condensation polymerization reaction in mortar [19][20]. To be used in mortar mixtures, the Activator in the form of a solid must be dissolved in water according to the desired molarity of the activator solution. The activators used in this concrete mixture are Sodium Silicate ($NaSiO_3$) and Sodium Hydroxide (NaOH). Sodium hydroxide (NaOH) serves to react with the elements Al and Si contained in fly ash so that it can produce strong polymer bonds. In contrast, Sodium silicate ($NaSiO_3$) accelerates the polymerization reaction [21].

(a) Sodium Hidroksida NaOH

(b) Sodium Silikat ($NaSiO_3$)

*Source: Research Documentation*

**Figure 2.** Alkaline Activator (a) Sodium Hydroxide NaOH (b) Sodium Silicate ($NaSiO_3$)

Sodium hydroxide solution (NaOH) used is NaOH solution with a molarity of 6M and 8M. Molarity (mol) is a quantity that states the number of moles / solute dissolved in each unit volume of solution. The unit of molarity is the molar (M) equal to moles/liter.

$n = M \times V$

n = number of moles of solute (mol)

M = molar solution (mol/liter)

V= volume of solution (liter)


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Mr NaOH = 40 (the sum of the elements that make up the compound, namely Na = 23, O = 16, H = 1)

Mass of NaOH = n moles x Mr

= 6 moles x 40 grams/mol

= 240 grams

How to make 1 liter of 8M NaOH solution is as follows:

Mass of NaOH = n moles x Mr

= 8 moles x 40 grams/mol

= 320 grams

Weigh the NaOH weighing 240 grams and 320 grams, put NaOH into a volumetric flask with 1000cc /1 liter, add distilled water to the volumetric flask solution until the volume is 1 liter, then stir until dissolved.


*Source: Research Documentation*

**Figure 3.** Alkaline Activator

3. Material Test

Conducted to determine the characteristic properties of fine aggregates, including sieve analysis, specific gravity, infiltration water, humidity, volume weight, and cleanliness of the mud. Likewise, testing of coarse aggregate will later be needed for the mix design.

## 2.3 Experimental Design

The experimental design is a research plan for manufacturing test objects using a ratio between the weight of cement and fly ash, 6M and 8M activator molarity. Each variation made 3 test objects. Mix design was carried out to determine the proportion of crushed stone material needs, fine aggregate (sand), cement, fly ash, alkaline, water in a concrete mixture, with a cement water factor of 0.4 using the DOE method. Details and composition of the test specimen mixture as shown in **Table 2.**


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**Table 2.** Variations of Concrete Mix

| Code | Cement (Kg) | Fly Ash (Kg) | Water (Kg) | Fine Aggregate (Kg) | Coarse Aggregate (Kg) | Alkaline (Kg) |
|---|---|---|---|---|---|---|
| BN Cement 100% | 30,25 | 0 | 8,6 | 39,06 | 54,49 | - |
| BF-6 FA 100% | 0 | 30,25 | 6,94 | 36,96 | 54,39 | 4,84 |
| BF-8 FA 100% | 0 | 30,25 | 6,94 | 37,02 | 54,47 | 4,84 |
| BC1-6 FA 90% PC 10% | 3,02 | 27,22 | 7,54 | 34,92 | 51,18 | 4,84 |
| BC1-8 FA 90% PC 10% | 3,02 | 27,22 | 7,54 | 34,97 | 51,25 | 4,84 |
| BC2-6 FA 90% PC 10% | 6,05 | 24,20 | 7,55 | 34,61 | 51,79 | 4,84 |
| BC2-8 FA 90% PC 10% | 6,05 | 24,20 | 7,26 | 37,88 | 52,09 | 4,84 |
| BC3-6 FA 90% PC 10% | 9,07 | 21,17 | 7,26 | 34,80 | 52,20 | 4,84 |
| BC3-8 FA 90% PC 10% | 9,07 | 21,17 | 7,26 | 35,37 | 53,05 | 4,84 |

*Source: Research Analysis*

## 2.4 Compressive Strength Test

Testing the compressive strength of concrete using cylinders measuring 15 cm x 30 cm at the age of 7 and 28 days aims to test and determine the compressive strength of concrete with fly ash as a cement mixture according to SNI 1974:2011 [22].

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

σ = compressive strength of concrete (MPa)

P = maximum load (Newton)

A = area of compression (mm2).

*Source: Research Documentation*

**Figure 4.** Compressive Strength Test of Concrete


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### 2.4 Porosity Test

Concrete porosity is a level that describes the density of concrete construction, which is closely related to the permeability of concrete [23]. Porosity is the percentage of pores or space in the concrete to the object's volume (total volume of concrete) [24]. This porosity test uses a cylinder measuring 10 cm x 20 cm by immersing the concrete that has just been removed from the mold for a period of time according to the age of the concrete to be tested, which is 28 days [25].

$$P = \left(\frac{A-B}{B}\right) X100\%$$

P = porosity

A = SSD condition sample weight (grams)

B = Oven dry sample weight (grams).

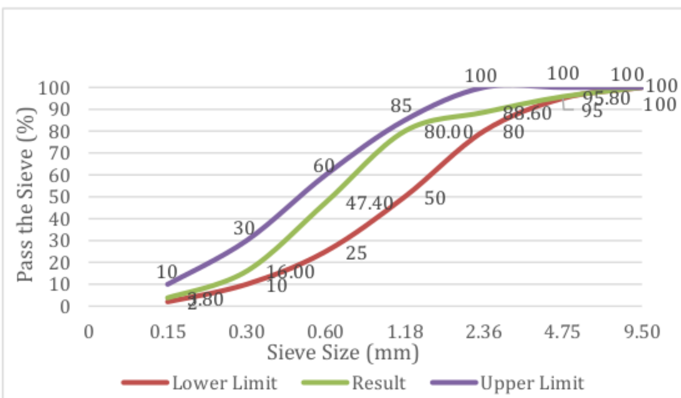
## 3. Results And Discussion

In the following, the research results will be analyzed to obtain the parameters as a material for discussion regarding the effectiveness of using fly ash in normal concrete mixtures with an alkaline activator on concrete compressive strength and porosity.

### 3.1 Material Analysis

1. Sieve Analysis

The aggregate fineness test is carried out according to ASTM C 136 – 06.




*Source: Research Result*

**Figure 6.** Sieve Analysis of Fine Aggregate

From **Figure 6.**, the analysis results are between the upper and lower limits of the fine aggregate sieve analysis requirements with a fineness modulus of 2.68. While the sieve analysis graph for coarse aggregate can be seen in **Figure 7.** below.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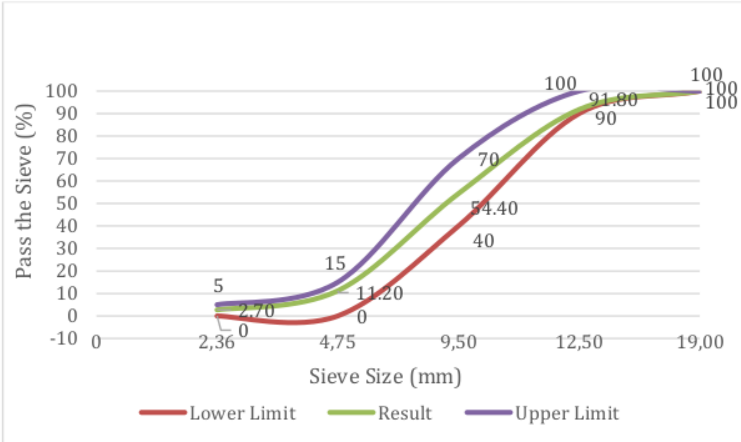


*Source: Research Result*

**Figure 7.** Sieve Analysis of Coarse Aggregate

The sieve analysis results for coarse aggregate correspond to the maximum size of the aggregate from 4.75 to 12.5 with a fineness modulus of 6.29.

2. Analysis of aggregate characteristics according to ASTM C127-88 and ASTM C128-15.

The results of the aggregate characteristics test carried out in the laboratory are in table 3 below.

**Table 3.** Analysis of Aggregate Characteristics

| Description | Fine Aggregate | Coarse Aggregate |
|---|---|---|
| Specific gravity | 2,75 | 2,75 |
| Infiltration | 2,67% | 2,46% |
| Humidity | 4,54% | 1,90% |
| Sludge levels | 2,00% | 1,10% |
| Organic matter content | light yellow | - |
| Fine modulus | 2,68 | 6,29 |

*Source: Research Result*

The characteristics of the fine aggregate tend to be wet. The mud content is < 10% of the requirements, so it can be said that the fine aggregate is clean, and there are no significant organic substances, with the light yellow color test results being less than the standard color. While the characteristics of coarse aggregate, mud content <5% of the requirements means that the coarse aggregate is clean of mud and tends to be dry.

For cement and water, no characteristic analysis was carried out. In this study, Portland Cement type I cement was used, which was considered to have complied with ASTM 150-95, while the water used was PDAM water.


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3. Analysis of Concrete Testing

The results of testing the compressive strength of concrete on cylindrical specimens measuring 15 cm x 30 cm for the age of 7 days and 28 days are shown in table 4.

**Table 4.** Compressive Strength Test Results of 7 and 28 Days of Concrete

| Concrete Code | Concrete Age | | | | | |
|---|---|---|---|---|---|---|
| | 7 days | | | 28 days | | |
| | Pmax KN | f'c MPa | Average MPa | Pmax KN | f'c MPa | Average MPa |
| BN | 480 | 27,16 | 27,45 | 615 | 34,80 | 34,24 |
| | 495 | 28,01 | | 570 | 32,26 | |
| | 480 | 27,16 | | 630 | 35,65 | |
| BF-6 100% | 120 | 6,79 | 6,79 | 165 | 9,34 | 9,34 |
| | 120 | 6,79 | | 150 | 8,49 | |
| | 120 | 6,79 | | 180 | 10,19 | |
| BF-8 100% | 135 | 7,64 | 8,21 | 195 | 11,04 | 10,47 |
| | 150 | 8,49 | | 195 | 11,04 | |
| | 150 | 8,49 | | 165 | 9,34 | |
| BC1-6 90% | 255 | 14,43 | 14,43 | 330 | 18,67 | 18,39 |
| | 270 | 15,28 | | 345 | 19,52 | |
| | 240 | 13,58 | | 300 | 16,98 | |
| BC1-8 90% | 240 | 13,58 | 14,43 | 315 | 17,83 | 18,39 |
| | 255 | 14,43 | | 345 | 19,52 | |
| | 270 | 15,28 | | 315 | 17,83 | |
| BC2-6 80% | 195 | 11,04 | 11,04 | 240 | 13,58 | 13,58 |
| | 195 | 11,04 | | 240 | 13,58 | |
| | 195 | 11,04 | | 240 | 13,58 | |
| BC2-8 80% | 240 | 13,58 | 14,15 | 315 | 17,83 | 17,54 |
| | 240 | 13,58 | | 315 | 17,83 | |
| | 270 | 15,28 | | 300 | 16,98 | |
| BC3-6 70% | 195 | 11,04 | 10,47 | 210 | 11,88 | 12,45 |
| | 180 | 10,19 | | 225 | 12,73 | |
| | 180 | 10,19 | | 225 | 12,73 | |
| BC3-8 70% | 225 | 12,73 | 11,32 | 285 | 16,13 | 15,00 |
| | 180 | 10,19 | | 240 | 13,58 | |
| | 195 | 11,04 | | 270 | 15,28 | |

*Source: Research Result*

(a) FA Concrete with 6M Activator

(b) FA Concrete with 8M . Activator

*Source: Research Documentation*

**Figure 8**. Fly Ash Concrete Specimen with 6M and 8M Activator


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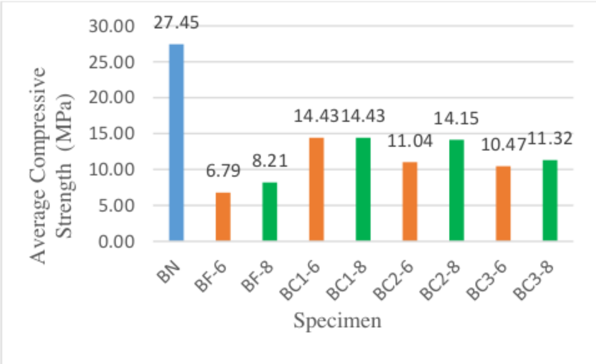
(a) Normal Concrete (b) Concrete with 100% Fly Ash

*Source: Research Result*

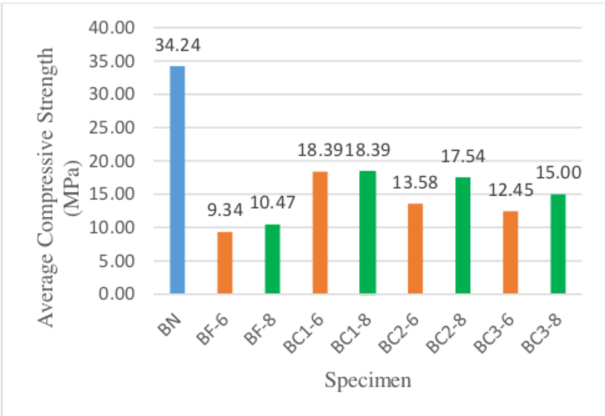
**Figure 9.** Compression Test on Normal Concrete and Fly Ash Concrete

The concrete test object is made according to the variation determined with a w/c ratio of 0,4. In Figure 9 the 100% fly ash concrete looks more brittle than normal concrete. This is due to differences in binding materials, where fly ash has little or no binding properties.




*Source: Research Result*

**Figure 10.** Average Compressive Strength of Concrete with 6M and 8M Molarity at 7 Days




*Source: Research Result*

**Figure 11.** Average Compressive Strength of Concrete with 6M and 8M Molarity at 28 Days


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**Figure 10** and **Figure 11** show that concrete using fly ash has a lower compressive strength than normal concrete using 100% cement. From the results of this study, the effect of using fly ash with variations in the mixture of fly ash and cement with a ratio of 90%: 10%, 80%: 20%, and 70%: 30%, and the addition of alkaline Activator has a relatively low compressive strength when compared to normal concrete. Meanwhile, the proportion of the mixed variant with fly ash as a partial substitute for portland cement for class F fly ash is 15% - 25% (SNI 03-6468-2000). And the most effective use of fly ash on the compressive strength of concrete is 10% of the weight of the binder, while those with fly ash content of 20% or more will experience a decrease in compressive strength.

In this study, the activator concentration has an important role in increasing the strength of a concrete binder with a molarity of 8M, which has a higher compressive strength than a concrete binder with a molarity of 6M as shown in Figures 10 to 11. The higher the molarity used in the mixture, the faster the initial setting takes place. The 8M NaOH solution is more concentrated than the 6M NaOH solution, so the higher the concentration of NaOH in the mixture, the more OH- in the mixture, so the binding process will be faster. This also proves that the time for initial binding of each binder composition can be different at the same age, depending on the amount of Na+ ion content contained in the mixture. In addition, the higher the mass ratio of sodium silicate to sodium hydroxide, the faster the final setting time takes place. This is because the amount of $Na_2SiO_3$ present in the binder mixture is more than the amount of NaOH, thus accelerating the polymerization reaction. The polymerization reaction is the binding reaction of the Si-O and Al-O monomer chains contained in fly ash and also $Na_2SiO_3$, which is used in the paste of making concrete which serves to speed up the polymerization reaction so that if the levels are high, the crystallization process will also take place more quickly.

This Activator consists of NaOH dissolved with distilled water and added with $Na_2SiO_3$ with a ratio of $Na_2SiO_3$/NaOH=2,5. It was mixing using a ratio of 40% alkaline and 60% water with a w/c ratio of 0,4. Porosity testing was carried out on 3 cylindrical specimens with a size of 10 cm x 20 cm, previously soaked in the concrete that had just been removed from the mold for a period of time according to the age of the concrete to be tested, which was 28 days.


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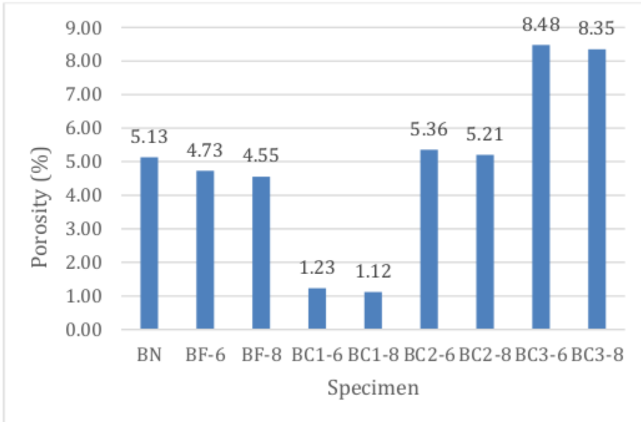


*Source: Research Result*

**Figure 12.** Relationship of the Average Porosity of Concrete with 6M and 8M Molarity 28 Days

**Figure 12** shows that concrete using 100% fly ash has smaller pores than normal concrete using 100% cement. Concrete with a mixture of fly ash which is getting smaller has larger pores when compared to normal concrete. For concrete mixtures with 90% fly ash, the porosity of the concrete decreased by 76% with a molarity of 6M (BC1-6), and 78% with a molarity of 8M (BC1-8) compared to normal concrete porosity. The higher the molarity, the smaller the total pores. This is influenced by the viscosity possessed by NaOH in the mixture of each composition. The mixture using 8M NaOH solution is more concentrated than the 6M solution. Therefore, the amount of water in the mixed cavity with 8M solution is less than the mixture using 6M NaOH solution. Likewise, the spherical shape and small particle size of fly ash can fill voids in the concrete. The pore volume and small surface area for fly ash-based pastes indicate that the paste matrix is dense, which means the permeability is low and the compressive force is high.

*Source: Research Result*

**Figure 13.** Fly Ash Concrete with 6M and 8M Molarity for Porosity Test


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## 4. Conclusion

The use of large fly ash and the addition of an alkaline activator causes the compressive strength of the concrete to decrease significantly both at the age of 7 days and age 28 compared to normal concrete. The optimization of adding fly ash is only 90% with 6M or 8M activator.

The greater the fly ash and activator use in concrete, the fewer pores in the concrete because the mixture is more concentrated and round, and the small particle size of fly ash can fill voids in the concrete.

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## References

[1] R. Abaeian, H. P. Behbahani, and S. J. Moslem, "Effects of high temperatures on mechanical behavior of high strength concrete reinforced with high performance synthetic macro polypropylene (HPP) fibres," *Constr. Build. Mater.*, vol. 165, pp. 631–638, 2018, doi: 10.1016/j.conbuildmat.2018.01.064.

[2] M. Solikin, "Analisis Pemakaian Kombinasi Fly Ash Tipe F Dan Slag 1: 1 Pada Beton Geopolymer Dengan Na2SiO3 Dan NaOH Sebagai Alkali Aktivator: Sebuah Kajian Literatur," *Din. Tek. Sipil Maj. Ilm. Tek. Sipil*, vol. 14, no. 1, pp. 13–20, 2021, [Online]. Available: https://journals.ums.ac.id/index.php/DTS/article/view/15274.

[3] M. A. Keerio, S. A. Abbasi, A. Kumar, N. Bheel, K. ur Rehaman, and M. Tashfeen, "Effect of Silica Fume as Cementitious Material and Waste Glass as Fine Aggregate Replacement Constituent on Selected Properties of Concrete," *Silicon*, vol. 14, no. 1, pp. 165–176, 2022, doi: 10.1007/s12633-020-00806-6.

[4] A. K. Mishra and E. U. Chaudhary, "Assessment of Cement Handling Behaviour For Selected Construction Sites of Bhatbhateni Supermarket Risk and Safety View project Risk and Safety View project Anjay kumar Mishra," *J. Adv. Res. Constr. Urban Archit.*, vol. 3, no. 3, pp. 1–11, 2018, [Online]. Available: https://www.researchgate.net/publication/327797165.

[5] S. Elavarasan, A. K. Priya, N. Ajai, S. Akash, T. J. Annie, and G. Bhuvana, "Experimental study on partial replacement of cement by metakaolin and GGBS," *Mater. Today Proc.*, vol. 37, no. Part 2, pp. 3527–3530, 2020, doi: 10.1016/j.matpr.2020.09.416.

[6] Esparham, A. B. . Moradikhou, and M. J. Avanaki, "Effect of Various Alkaline Activator Solutions on Compressive Strength of Fly Ash-Based Geopolymer Concrete," *J. Civ. Eng. Mater. Appl.*, vol. 4, no. April, pp. 115–123, 2020, doi: 10.22034/jcema.2020.224071.1018.

[7] Y. Meng, T. C. Ling, and K. H. Mo, "Recycling of wastes for value-added applications in concrete blocks: An overview," *Resour. Conserv. Recycl.*, vol. 138, no. May, pp. 298–312, 2018, doi: 10.1016/j.resconrec.2018.07.029.

[8] T. F. Luan, "Pengaruh Pemakaian Fly Ash Sebagai Cementitious Pada Beton Mutu Tinggi Terhadap Kuat Tekan Beton Umur 28-29 Hari," *J. Sondir*, vol. 4, pp. 78–83, 2020, doi: https://doi.org/10.25077/jrk.v11i2.350.

[9] Y. Yusuf, V. F. Savitri, and H. Aziz, "Pengaruh Penggunaan Fly Ash dari Berbagai Sumber terhadap Sifat Kimia dan Sifat Fisika pada Semen Tipe I (OPC)," *J. Ris. Kim.*, vol. 11, no. 2, pp. 61–71, 2020, doi: 10.25077/jrk.v11i2.350.

[10] N. Nikoloutsopoulos, A. Sotiropoulou, G. Kakali, and S. Tsivilis, "Physical and mechanical properties of fly ash based geopolymer concrete compared to conventional concrete," *Buildings*, vol. 11, no. 5, pp. 1–14, 2021, doi: 10.3390/buildings11050178.

[11] N. Sedira and J. Castro-Gomes, "Effect of activators on hybrid alkaline binder based on tungsten mining waste and ground granulated blast furnace slag," *Constr. Build. Mater.*, vol. 232, p. 117176, 2020, doi: 10.1016/j.conbuildmat.2019.117176.

[12] D. Adi S, F. Rahman N, H. A. Lie, and Purwanto, "Studi Experimental Pengaruh Perbedaan Molaritas Aktivator Pada Perilaku Beton Geopolimer Berbahan Dasar Fly Ash," *J. Karya Tek. Sipil*, vol. 7, pp. 89–98, 2018, [Online]. Available: https://ejournal3.undip.ac.id/index.php/jkts/article/viewFile/19368/18372.

ISSN (*Online*) 2581-2157
ISSN (*Print*) 2502-9304


[13] J. D. S. Caroles, "Ekstraksi silika yang terkandung dalam limbah abu terbang batu bara," *Fuller. J. Chem.*, vol. 4, no. 1, p. 5, 2019, doi: 10.37033/fjc.v4i1.43.

[14] R. R. Haydar and A. S. Mohammed, "Modeling The Behaviour of Chemical Resistant Concrete Modified with Fly Ash under Different Ph Environments," *Third Int. Conf. Recent Innov. ln Eng. Duhok*, vol. 23, no. 2, pp. 15–30, 2020, doi: https://doi.org/10.26682/csjuod.2020.23.2.2.

[15] M. Ibrahim, M. A. Megat Johari, M. Maslehuddin, M. K. Rahman, B. A. Salami, and H. D. Mohamed, "Influence of composition and concentration of alkaline activator on the properties of natural-pozzolan based green concrete," *Constr. Build. Mater.*, vol. 201, pp. 186–195, 2019, doi: 10.1016/j.conbuildmat.2018.12.117.

[16] A. G. S. Azevedo, K. Strecker, L. A. Barros, L. F. Tonholo, and C. T. Lombardi, "Effect of curing temperature, activator solution composition and particle size in Brazilian fly-ash based geopolymer production," *Mater. Res.*, vol. 22, pp. 1–12, 2019, doi: 10.1590/1980-5373-MR-2018-0842.

[17] E. Siswanto, "Penambahan Fly Ash Dan Serat Serabut Kelapa Sebagai Bahan Pembuatan Beton," *UKaRsT*, vol. 3, no. 1, p. 48, 2019, doi: 10.30737/ukarst.v3i1.352.

[18] W. Kushartomo and Sofianto, "Mechanical properties of powder concrete with a geopolymer bond," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 852, no. 1, 2020, doi: 10.1088/1757-899X/852/1/012003.

[19] Y. A. Priastiwi, Muhrozi, R. Y. Adi, D. Daryanto, and Z. Salamsyah, "The effect of white soil on geopolymer mortar porosity," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 669, no. 1, 2019, doi: 10.1088/1757-899X/669/1/012031.

[20] M. Tumpu and D. S. Mabui, "Effect of hydrated lime (Ca(OH)2) to compressive strength of geopolymer concrete," *Int. Conf. Sci. Appl. Sci. 2021*, vol. 2391, no. March, p. 070011, 2022, doi: 10.1063/5.0086702.

[21] E. E. Sánchez Díaz and V. A. Escobar Barrios, "Development and use of geopolymers for energy conversion: An overview," *Constr. Build. Mater.*, vol. 315, no. November 2021, 2022, doi: 10.1016/j.conbuildmat.2021.125774.

[22] Badan Standardisasi Nasional, "SNI 1974:2011 Cara uji kuat tekan beton dengan benda uji silinder," *BSN*, 2011.

[23] L. Berredjem, N. Arabi, and L. Molez, "Mechanical and durability properties of concrete based on recycled coarse and fine aggregates produced from demolished concrete," *Constr. Build. Mater.*, vol. 246, p. 118421, 2020, doi: 10.1016/j.conbuildmat.2020.118421.

[24] K. Xu *et al.*, "Microstructure and water absorption of ancient concrete from Pompeii: An integrated synchrotron microtomography and neutron radiography characterization," *Cem. Concr. Res.*, vol. 139, no. July 2020, 2021, doi: 10.1016/j.cemconres.2020.106282.

[25] ASTM C 642-06, "Standard Test Method for Density, Absorption, and Voids in Hardened Concrete, ASTM International, United States," *Annu. B. ASTM Stand.*, no. March, pp. 1–3, 1997.

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