




Effect of Treatment Age on Mechanical Properties of Geopolymer Concrete

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Abstract

There are the same compound content, fly ash does not have the ability to bind, so it requires an alkaline activator for the polymerization reaction or binding reaction to occur. The alkali activators commonly used are sodium hydroxide and sodium silicate. The use of these materials makes concrete with fly ash known as geopolymer concrete. Geopolymer concrete is an alternative to conventional concrete, so it must have optimal strength like conventional concrete, therefore researchers are interested in testing the value of compressive strength, split tensile strength and modulus of elasticity of geopolymer concrete using 10 molar alkali activator with a ratio of 3:2. for variations in the age of concrete 7, 14, 21, and 28 days; and the conversion value of geopolymer concrete using 10 molar alkali activator with a ratio of 3:2 for variations in the age of concrete 7, 14, 21, and 28 days. This research is an experimental study using variations in the age of concrete 7, 14, 21, and 28 days for geopolymer concrete using 10 molar alkali activator with a ratio of 3:2. The results of this study indicate that there is an effect of variations in the age of concrete on the value of compressive strength, split tensile strength, and modulus of elasticity of geopolymer concrete. Where the compressive strength, split tensile strength, and modulus of elasticity of geopolymer concrete at the age of 7 days are 31.40%; 35.44%; and 23.32% which at the age variation of 28 days increased by 100%. In addition, in this study, it is known that the conversion value at the age of 28 days for variations in the age of 7 days, 14 days, 21 days, and 28 days, respectively, is 0.31; 0.73; 0.97; 1.00

Keywords: Geopolymer Concrete, Compressive Strength, Modulus of Elasticity

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INTRODUCTION

The cement industry in Indonesia is experiencing rapid development in line with the high demand for cement in the market. However, this apparently causes an increase in CO₂ gas emissions resulting from the cement manufacturing process. It is estimated that the cement industry contributes 5-7% CO₂ emissions [1]. So if this situation lasts a long time it can have an impact on environmental damage and fatal health problems. Therefore there is a need for a solution to reduce the increase in CO₂ (carbon dioxide) emissions, one of which is to replace

cement in the concrete mix by using materials that contain lots of silica and alumina such as fly ash. By reducing the use of cement in the concrete mixture, it is expected to reduce CO₂ (carbon dioxide) emissions. The choice of fly ash as a substitute for cement is because fly ash contains silica and alumina which can be used as a binder [2]. Silica and alumina found in fly ash require an alkaline activator solution for the polymerization or bonding process to occur. In geopolymer concrete, the right composition is needed so that when mixing alumina which is reacted with an alkaline solution as an activator, it can form geopolymer paste [3]. Of the four known alkaline activator solutions, two of these solutions are sodium hydroxide and sodium silicate alkaline activator solutions which have a maximum compressive strength of more than 60 MPa [4]. The study used a solution of 3.5% alkaline sodium silicate, 20% water, and 4% sodium silicate which produced the highest compressive strength reaching 75 MPa[5]. However, in the end, the commonly used activator is sodium silicate (Na₂SiO₃) and sodium hydroxide (NaOH) with a concentration of 8M to 14M with a ratio of sodium silicate (Na₂SiO₃) and sodium hydroxide (NaOH) between 0.4 to 2.5 [6]. Using 8 and 10 molar sodium hydroxide (NaOH) solutions with a ratio of sodium silicate and sodium hydroxide of 0.5; 1.0; 1.5; 2.0; 2.5. The results obtained are a 10 molar solution of sodium hydroxide (NaOH) with a ratio of sodium silicate and sodium hydroxide of 1.5 which produces the most optimum compressive strength and tensile strength [7]. So in this study the researchers used the results of previous studies as a reference.

The higher use of cement as a material in the manufacture of concrete certainly makes the cement production process increase so that it also has an impact on increasing CO₂ gas emissions (carbon dioxide). strength equal to that of concrete with cement admixtures. The concrete used in this study is geopolymer concrete. To determine the strength of geopolymer concrete, the mechanical properties of geopolymer concrete were tested which included testing the compressive strength, split tensile strength and modulus of elasticity of geopolymer concrete. The mechanical properties of geopolymer concrete are affected by curing time [8], thus this study uses treatment times of 7, 14, 21, and 28 days in order to see differences in the strength of the mechanical properties of geopolymer concrete produced based on age variations.

Literature Review

Geopolymer Concrete

Geopolymer is defined as a material used as an alternative to cement to make it more environmentally friendly, because the material used is composed of the synthesis of non-organic natural materials through a polymerization process. serves as a binder with environmentally friendly materials. [9] stated that geopolymer concrete is an inorganic alumino silicate compound synthesized from

by-product materials such as fly ash, rice husk ash and others, which contain lots of silica and aluminum.

Materials for Making Geopolymer Concrete

To get good quality concrete is determined by the quality of the material used in making the concrete. The basic materials for forming geopolymer concrete are as follows:

Aggregate

Aggregate is a natural mineral grain that functions as a filler in mortar or concrete mixtures. Aggregate occupies as much as 70% by volume of concrete. According to [10], aggregates are grains of crushed stone, gravel, sand or other minerals, both natural and artificial in the form of solid minerals in the form of large or small sizes or fragments. Aggregate is divided into 2 groups, namely fine aggregate and coarse aggregate. Aggregate for building materials is divided into 2 types, namely fine aggregate and coarse aggregate. According to ASTM C-33 2002 it states that fine aggregate is aggregate with a maximum grain size of 4.75 mm while coarse aggregate is aggregate that has a grain size of more than 4.75 mm.

Fly ash

The main materials for the formation of geopolymers having aluminosilicate bonds must be rich in silica and aluminum. Artificial materials such as fly ash and slag are the most potential materials for geopolymer concrete [11]. Fly ash, which is the residue from burning coal, is widely used as a mixture in concrete. Fly ash itself does not have the ability to bind like cement but requires the help of an activator.

Activators and Catalysts

Sodium silicate and sodium hydroxide are used as alkaline activators [12]. Activator is a substance or element that causes other elements to react. In the study of geopolymer concrete activator used is sodium hydroxide which contains silica which is a strong acid so it will react with a strong base. Sodium silicate has a function to accelerate the polymerization reaction. Meanwhile, sodium hydroxide functions to react the elements Al and Si contained in fly ash so that it can produce strong polymer bonds.

Environmental Conditions

Environmental conditions have an influence on the durability of concrete which functions as the main material in infrastructure. In environmental conditions such as seas or rivers it is very susceptible to chemical contamination which can affect the resistance of concrete. Susceptible chemicals mix with sea or river water in high percentages.

Sulfuric Acid (H₂SO₄)

Sulfuric acid is a strong and aggressive mineral (inorganic) acid. This acid can damage the paste structure in concrete and may cause cracks to occur on the surface of the concrete but will also result in a reduction in the volume and strength

of the concrete. Substances that are able to dissolve in water with all these ratios also have uses including as main products in the chemical industry [13]. The basis of sulfate attack is the formation of gypsum (calcium sulfate) and ettringite (calcium sulfoaluminate). The result of these two molecules is to increase the volume so that swelling occurs which eventually damages the concrete.

Hydrochloric Acid (HCl)

Hydrochloric acid is a solution that can cause corrosion and porous in concrete because chloride can attack the calcium silicate binder system. Hydrochloric acid solution is a very corrosive liquid, especially in concrete. In general, it can be said that the durability of concrete against chloride penetration is strongly influenced by the pore structure of concrete, the pore structure of concrete is influenced by factors related to concrete, for example the material and the concreting process. [14] said that the pore structure is influenced by various factors, one of which is mineral additives that affect the development of the pore structure of concrete. Another effect on the porous structure is temperature, high temperatures in the curing process of fresh concrete will make the concrete more mature and have better concrete resistance to chloride penetration than ordinary curing.

Sea Water

Corrosive seawater conditions make normal concrete that uses cement not have good resistance to chemicals, durability or the age of the concrete itself doesn't last long. The percentage of seawater content is 96.5% pure water, 3.5% salts, while 3.5% of the main salts contained in seawater are chloride (55%), sodium (31%), sulfate. (8%), magnesium (4%), calcium (1%), potassium (1%) and the remainder is less than 1% [15].

METHODS

This research is based on research guidebooks, and some journal literature so that this research requires a certain amount of time which consists of the preparation process, material testing, casting, curing, compressive strength testing, split tensile strength, and concrete elastic modulus. So that in this study research and testing was carried out at the civil engineering laboratory, tribhuwana tunggadewi university, malang and the central mineral and advanced materials laboratory, faculty of mathematics and natural sciences, state university of malang. The method used in this study was an experimental method by making several test objects with ages of 7, 14, 21, and 28 days of geopolymers concrete so that the number of test objects used was 24 cylindrical test objects with a diameter of 150 mm and a height of 300 mm. The research design consists of testing the compressive strength, split tensile strength, and modulus of elasticity of geopolymers concrete. Research on geopolymers concrete does not yet have a

definite mix design, so the mix design used in previous studies. Here's a chart of the composition of the mix:

Figure 1. Composition Chart of Geopolymer Concrete Mix [16]

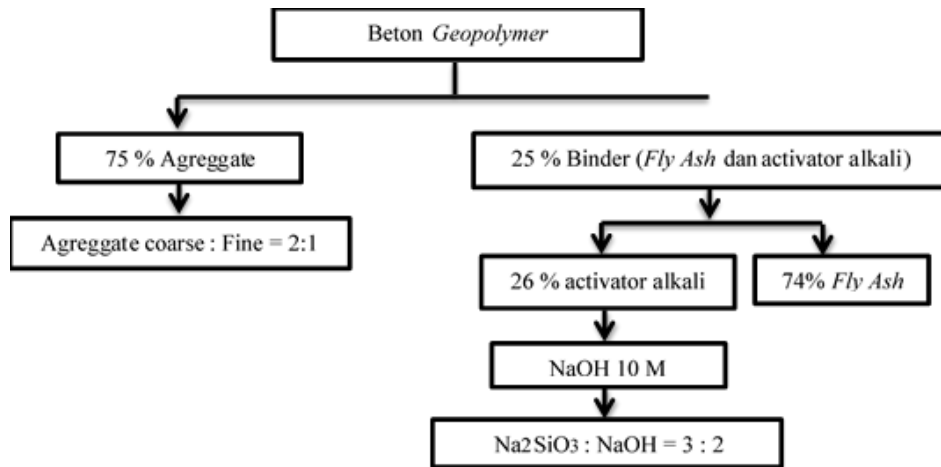
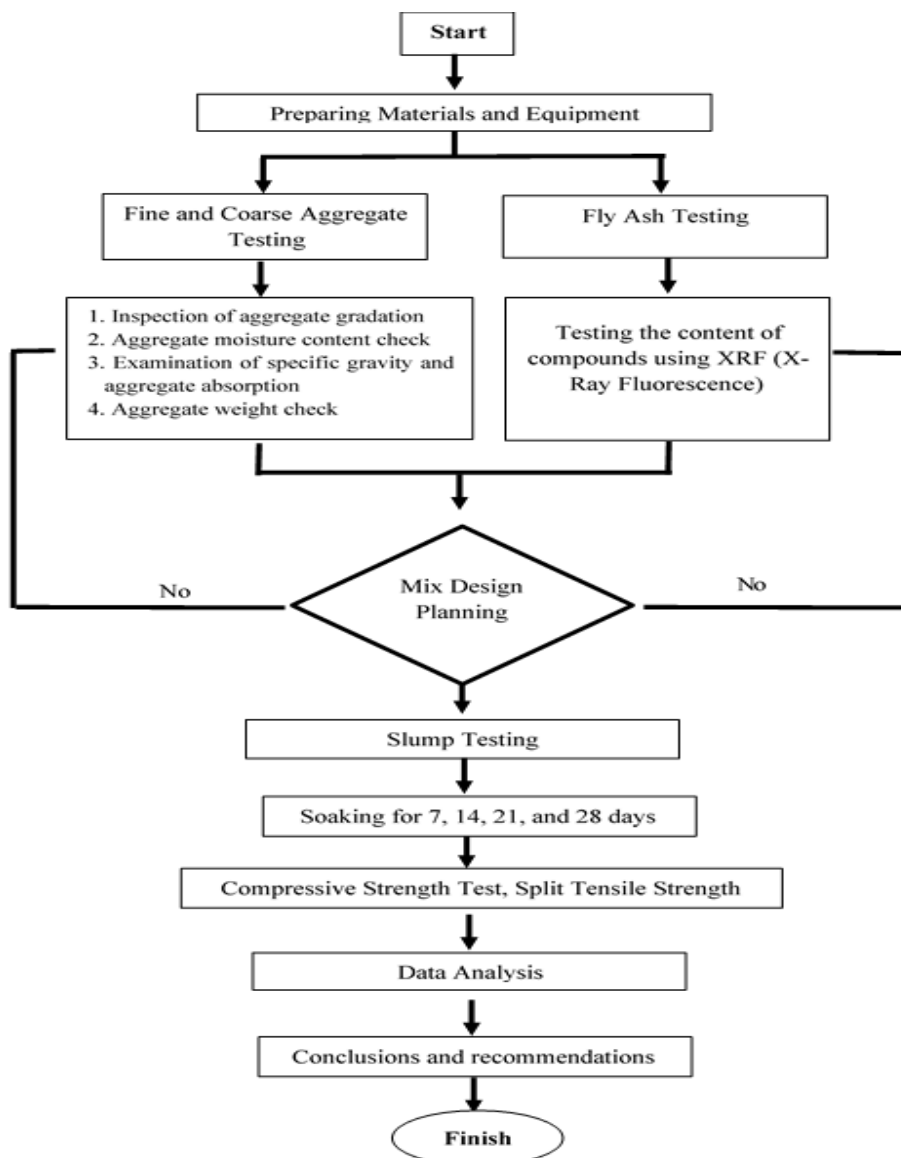


Figure 2. Research Flowchart



RESULTS AND DISCUSSION

Before using the material in geopolymer concrete, several tests were carried out including: fine and coarse aggregate test results

Table 1. Results of fine aggregate quality testing

Fine Aggregate Testing		
Test Type	Magnitude	Unit
Gradation Analysis	zona 1	
Fineness Modulus	3,28	
Water content	4,72	%
Surface Dry Saturated		
Specific Gravity	2,78	
Water Absorption	2,04	%
Fill Weight (Rodded)	1,39	gr/cc
Fill Weight (Shoveled)	1,15	gr/cc

Table 2. Results of coarse aggregate quality testing

Coarse Aggregate Testing		
Test Type	Magnitude	Unit
Gradation Analysis	zona 3	
Fineness Modulus	3,52	
Water content	2,01	%
Surface Dry		
Saturated Specific		
Gravity	2,67	
Water Absorption	2,02	%
Fill Weight (Rodded)	1,61	gr/cc
Fill Weight		
(Shoveled)	1,41	gr/cc

Based on SNI 03-2834-2000 [17] the test results have met the requirements for aggregate characteristics, so they can be used in the manufacture of concrete mixtures.

Test Results For Fly Ash Content

Figure 3. Fly Ash Test Results

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Sample results

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Sample ident
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Application	<Standardless>
Sequence	1 of 1
Measurement time	03-mrt-2021 09:02:54
Position	9

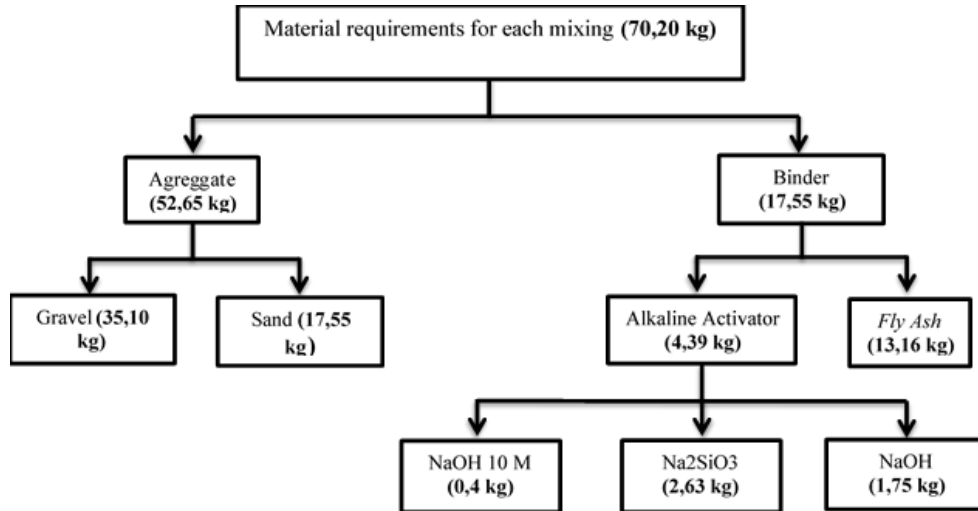
Compound	MgO	Al2O3	SiO2	K2O	CaO	TiO2	V2O5	Cr2O3	MnO	MoO3	BaO
Conc	1,6	11,9	34,8	2,49	33,5	2,2	0,37	0,73	3,4	6,09	2,8
Unit	%	%	%	%	%	%	%	%	%	%	%

Based on the test results it is known that the fly ash is classified as type F fly ash because it contains mineral oxide compounds (SiO₂ + Al₂O₃ + Fe₂O₃) of 71.1% which according to SNI 2460:2014 type F fly ash contains mineral oxides (SiO₂ + Al₂O₃ + Fe₂O₃) minimum 70% [18].

Mix Design Results

In this mix design calculation, the specific gravity of geopolymer concrete is 2400 kg/m³[19]. After calculating the material requirements for the 24 cylindrical test objects, which are as much as 350.99 kg, because the capacity of the mixer machine at the Untri Civil Engineering Laboratory is only 80 kg, the concrete mixing process is carried out five times, with each stirring requiring 70.20 kg of material. The following is a chart of the results of the needs of each material for one mixing.

Figure 4. Material Requirements Chart



Test Results for Compressive Strength, Split Tensile Strength and Modulus of Elasticity of Geopolymer Concrete.

Table 2. Results of Compressive Strength, Split Tensile Strength and Modulus of Elasticity of Geopolymer Concrete

No	Umur Beton (hari)	Kuat Tekan (MPa)	Kuat Tarik Belah (MPa)	Modulus Elastisitas (N/mm ²)
1	7	5,724	0,708	10968,857
2		8,215	0,873	
3		6,970	0,987	
Rata-rata		6,970	0,856	
4	14	15,524	1,100	22605,512
5		13,565	0,899	
6		19,595	1,079	
Rata-rata		16,228	1,026	
7	21	19,465	3,018	32447,935
8		22,120	2,452	
9		22,828	1,093	
Rata-rata		21,471	2,187	
10	28	21,486	2,164	40151,124
11		24,459	2,234	
12		20,637	2,848	
Rata-rata		22,194	2,415	

Based on table 2 above, it can be seen that the results of the compressive strength, split tensile strength and modulus of elasticity of geopolymer concrete have increased every week, which means that the age variation has an effect on the results of the test values. The value of split tensile strength of geopolymer concrete follows the increase in compressive strength because compressive strength and split tensile strength are structural components that are interconnected [20]. Whereas the value of the test results for the modulus of elasticity also follows an increase in the compressive strength value because in general an increase in compressive strength

will be followed by an increase in the modulus of elasticity [21]. The process of increasing the strength that occurs in the test is due to the increasing age of the concrete, the better the hardening process, so that the strength increases. To clarify the table above, below is a chart of the results of testing the compressive strength, split tensile strength, and modulus of elasticity of geopolymer concrete.

Figure 5. Chart of Compressive Strength Test Results for Geopolymer Concrete

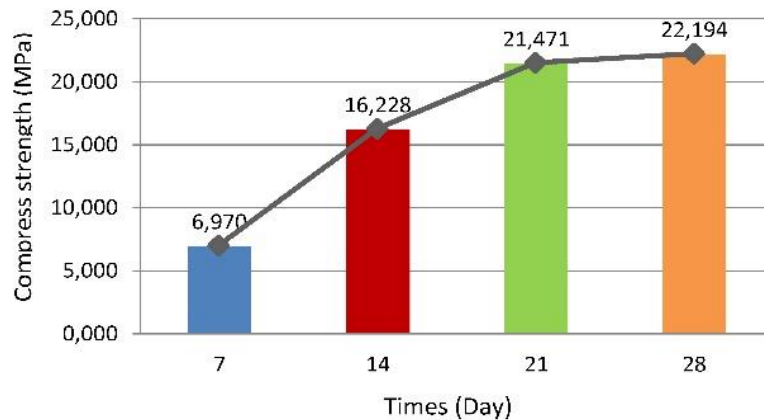


Figure 6. Chart of Split Tensile Strength Test Results for Geopolymer Concrete

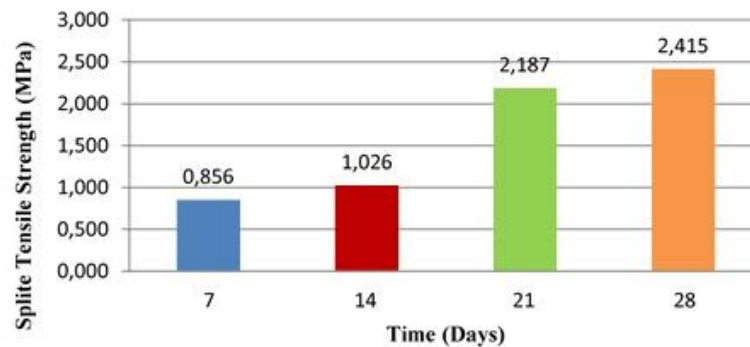
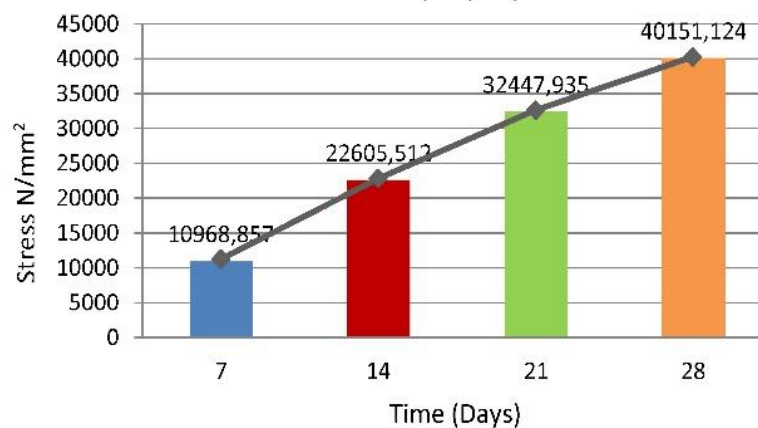


Figure 7. Chart of Geopolymer Concrete Modulus of Elasticity Test Results



CONCLUSION

Based on the results of the research on compressive strength, split tensile strength, and modulus of elasticity of geopolymer concrete, it can be concluded that The compressive strength test results of geopolymer concrete have increased every week, where at the 7-day age variation the geopolymer concrete compressive strength ranged from 31.40%, at 14 days it reached 73.12%, and at 21 days it was around 96.74% of 100% at the age of 28 days. The split tensile strength test results of geopolymer concrete have increased every week, where at the 7-day age variation the geopolymer concrete split tensile strength ranged from 35.44%, at 14 days it reached 42.47%, and at 21 days around 90.56 % of 100% at 28 days of age. The results of the geopolymer concrete modulus of elasticity have increased every week, where at the 7-day age variation the geopolymer concrete elastic modulus ranged from 27.32%, at 14 days it reached 56.30%, and at 21 days around 80.81% than 100% at 28 days.

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