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Workability and Mechanical Properties Self Compacting Geopolimer Concrete

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A B S T R A C T

Building Construction Requires durability of Concrete for longer Use. Workability and SCGC research to determine the relationship between molarity and workability in Self-Compacting Geopolymer Concrete (SCGC), as well as mechanical properties. Compressive strength and tensile strength tests were used to characterize the mechanical characteristics in this study. In addition, this study is the optimal molarity for compaction geopolymer concrete itself. Fly ah is used as a substitute for cement in this study. In compaction of new concrete geopolymers, workability is determined using the EFNARC standard, which includes the Slump Flow, V-Funnel and L-Box tests. The ASTM 39/C 39M-99 standard is used to determine the compressive strength of self-compacting concrete geopolymers. In new concrete, workability is determined using the EFNARC standard, which consists of Slump Flow Test, V-funnel, and L-Box. The compressive strength of the concrete sample was determined according to the ASTM 39/C 39M – 99 standard. The SNI 03-2491-2002 standard was used to determine the split tensile strength of the concrete. At the age of 7, 14, and 28 days tested. The findings indicate that the new concrete at 11M-13M meets the SCGC workability criteria. The compressive strength and split tensile strength of SCGC increase with the age of the concrete. In self-compacting geopolymer concrete, the optimal molarity is 13 M.

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1. Introduction

The development of infrastructure that is increasing day by day results in the demand for the amount of cement which is also greatly increasing. The increase in the use of cement in concrete mixtures causes enormous environmental problems, both in terms of damage caused by the manufacture of concrete mixtures (cement) which causes CO_2 emissions, in other words producing 1 tons of cement is the same as producing 1 ton of carbon dioxide into the air [1]. This is what causes a reduction or substitute for cement for the concrete mixture itself in the construction industry. The thing that is being tried to reduce CO_2 into the air is developing concrete geopolymer.

The mixed fresh geopolymer has rigid viscosity properties, so that the condition is not workability in the casting process. Workability of concrete is very necessary to facilitate implementation in the field. To overcome the problem of workability, in previous research there has been the discovery of one concrete innovation, namely Self Compacting Concrete (SCC). Concrete mixture that can be compacted without using a compactor (vibrator) is called SCC. The method commonly applied to obtain SCC concrete properties is by using admixture (viscocrete) materials [2].

Geopolymer concrete is a type of concrete that does not use cement at all [3]. Fly ash which is the result of burning coal is one of the materials that can be used as a substitute for cement or as a binder in a concrete mixture [4]. The properties and characteristics that are very dominant in geopolymer concrete are that it has high compressive strength and bonding time [3].

In geopolymerization alkaline solution activator has a very important role. The activators that are generally used are sodium hydroxide and sodium silicate. The function of sodium silicate is to accelerate the polymerization reaction, while sodium hydroxide has the function of activating the Al and Si elements contained in the binder so that it can produce strong polymer bonds [5] Combination of sodium hydroxide and sodium silicate produces geopolymer concrete almost without pores and has a strong bond between the aggregate and the binder [6].

In self-compacting concrete, geopolymer fresh concrete properties and compressive strength based on fly ash shows that sodium hydroxide concentration has the least effect on SCGC workability [7]. Superplastisizer yang paling efektif untuk meningkatkan workabilitas dan kuat tekan beton geopolymer adalah SP yang berbasis naphthalene [8]. A higher concentration of sodium hydroxide solution causes a better dissolving ability and produces a more reactive bond, as a result, it can increase the bond between the mixture of geopolymers,

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the mechanical properties of geopolymer concrete are highly dependent on the concentration of the activator solution used. The physical properties of fly ash are closely related to the combustion process, both technical conditions of combustion, while the chemical properties and composition of fly ash depend on the source of coal and the temperature at the time of combustion [9].

Self Compacting Geopolymer Concrete is a relatively new research and it can be said that SCGC is one of the revolutionary innovations in the construction field. Self-compacting geopolymer concrete is self-compacting concrete without the need for vibration assistance for its designation and in self-compacting geopolymer concrete it can eliminate the use of cement which results in carbon dioxide emissions into the air [10]. This study aims to determine the workability of fresh self-compacting geopolymer and mechanical properties of SCGC made using fly ash as a cement substitute, 11M, 12M, 13M, 14M and 15M molarity and alkali modulus 2.

2. Literature Review

Geopolymers are synthesized inorganic polymers that form three-dimensional polymer chains, usually during chemical reactions under alkaline conditions. The chemical mixing of the starting material and alkaline liquid leads to the development of the microstructure (microstructure) and mechanical properties of the final geopolymerization product. Fly ash geopolymer is an alternative binder material that is produced to reduce damage to nature and increase the potential for durability in the construction world [11].

Concrete is a composite material (mixture) of several materials whose main ingredients consist of a mixture of cement, sand, water gravel and or without other additives with a certain composition ratio. Because concrete is a composite, the quality of concrete is very influential with the concrete-forming materials used. One of the parameters used as a benchmark in the polymerization process is the adhesive used, namely SiO_2, H_2O and NaOH [12]. Previous studies have shown that geopolymerization can convert various aluminum silicate wastes into building materials with excellent chemical and physical properties such as fire resistance and acidic environments [13].

Research on the combination of GGBS and Fly ash with air binder factor (W/B) on the workability and properties of GRAC hard concrete using the alkali modulus, GGBT and fly ash showed interrelated results on the performance of GRAC, the fly ash ratio had a very significant effect on the performance of GRAC. The workability and hardness of GRAC concrete and the effect of the W/B ratio on GRAC are highly dependent on the GGBT/fly ash ratio [14] .

The addition of additives in improving the quality of concrete, among others, the

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addition of waste (B3) is an effort to increase the calcium element needed in the Pozzolan reaction when used in a mixture of SiO2 in fly ash [15].

Geopolymer materials are composed of silica (Si) and alumina (Al) containing substances. As previously established, fly ash is a source of silica and alumina, that there are four dominant elements found in fly ash namely silica (SiO_2), aluminum (Al_2O_3), ferum (Fe_2O_3) and lime (CaO) [16] . The silica and alumina components found in fly ash are melted in an alkaline solution known as alkaline solution. The alkali solution is composed of Sodium Silicate (Na_2SiO_3), Sodium Hydroxide (NaOH), and Distilled Water (H_2O), each of which plays a significant part in the synthesis. Geopolymer synthesis is highly dependent on the beginning material conditions, particularly the characteristics of fly ash, the concentration of the geopolymer process, and alkaline solutions [17]. Previous studies have shown that 100% fly ash can be used as a binder by activating it with alkaline components such as alkaline caustic, silicate salts and weak acid non-silicate salts [18].

Geopolymer synthesis technology relies on the activation of relatively simple bases from starting materials rich in silica (Si) and aluminum (Al) in amorphous form at relatively low temperatures [5]. In the geopolymer process, a chemical reaction occurs between silicate aluminum oxide ($Si2O_5$, Al_2O_2) and polyslic alkali metal, resulting in a Si-O-Al polymer bond. SCC is a fresh plastic concrete that flows easily because its own weight fills the entire mold, because the concrete can solidify itself without using a vibrator to compact.

According to Okamura and Ouchi (2003), One solution for strong concrete structures, depending on the possibility of construction work, is the capacity of self-compacting concrete, which can flow into every corner of the mold under its own weight and without the need for a vibrator, with a coarse-grained layer mix composition of 50% concrete, 40% fine aggregate by volume of solution and water-cement factor 0.25-0.40.

The advantages of SCC are that it is very runny, has a high slump for a long time (sludge retention additive), does not require manual compaction, is smoother and more stable, the compressive strength of concrete can be increased/very high quality, more water resistant, with less porosity and more shrinkage. less, more durable (stronger), smoother concrete surface, low noise pollution and more energy consuming.

3. Research Method

The method used in this research is a laboratory experimental method. The experimental method is a research that tests a hypothesis in order to find the effect, relationship, or difference of change. This research was conducted by looking for the effect of molarity on workability and compressive strength of self-compacting geopolymer concrete by performing

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workability tests which included slump flow, L-Box and V-Funnel tests.

The materials used in this research are

a. Fly Ash

The fly ash used is obtained from the PLTU Jeneponto in South Sulawesi. The fly ash used can be seen in Figure 1, the color and appearance of the PLTU Jeneponto fly ash

Figure 1. Fly Ash (PLTU Jeneponto 2021)

b. Activator

Activator is an additive used in the binding process of a mixture of NaOh, Na_2SiO_3 and water

Figure 2 Aktivator (NaOh,Na_2SiO_3 and water 2021)

c. Water

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The water used is PDAM water. Water is used to make activator

d. Aggregate

Coarse aggregate and fine aggregate are obtained from different sources, namely coarse aggregate obtained from the Jeneberang/Bili-bili river while fine aggregate is obtained from the Pinrang river. These aggregates are widely available in general aggregate sales places in the city of Makassar.

e. Admixture

The retarder used is the RTR-100 Retarder type and the Viscocrete used is the 43am Plastiumen type.

Mix Design use EFNARC [19]. The composition of the mixture for making Self compacting geopolymer concrete with a binder water factor of 0.4 using Fly ash from PLTU Jeneponto with a molarity variation of 11M, 12M, 13M, 14M and 15M with an alkaline modulus 2. Aggregate requirement 1: 0.65: 1.5 (fly ash: sand: gravel) The viscocrete used is 2% of cemented rice and 3% retarder by weight of cement. The test object is cylindrical with an area of 100 mm x 200 mm. From the mix design calculation, it is obtained that the material requirements for 6 samples per 1 time of mixing are obtained.

For the compressive strength test, the test object is cylindrical with a size of 10 mm x 20 mm. The compressive strength test was carried out at the age of 7, 14 and 28 days. The compressive strength test method follows the standard ASTM C 39/ C 39M – 05 [20] and The split tensile strength test method follows the standard ASTM 39/C 39M – 99 [21]. The Universal Testing Machine (UTM) is used for testing the compressive strength by providing a uniaxial static monotonic compressive load with an average speed of 0.14 – 0.34 MPa/second. The compressive strength can be calculated by equation 1.

$$f'c = P/A \tag{1}$$

Where f'c = concrete compressive strength (MPa), P = maximum load (N), A = surface area (mm)

For the tensile strength test, the test object is in the form of a cylinder with a size of 10mm x 20mm. The split tensile strength test was carried out at the age of 7, 14 and 28 days. The test object used was a cylindrical test object which was worked evenly along the diameter direction along the test object. The test object will split in half when the tensile strength is reached. Split tensile strength can be calculated in equation 2.

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$$f'_{ct} = 2P/(\pi.d.L) \quad (2)$$

Where f_{ct} = Split tensile strength of concrete, P = Load at Split Time (N), d = Diameter of test object [mm], L = Length of Cylindrical Test Piece, π = Phi (22/7) Previous Research on Geopolymer Concrete.

4. Results and Discussions

Test Workability SCGC

In this study, the workability of SCGC using air curing met the requirements at 11M-13M in the slump flow and L-Box tests, but none of the V-Funnel tests met the requirements, while at Molarity 14-15 the workability test results did not qualify as SCC. The results of the workability test of fresh concrete are shown in Table 1.

Table 1. Workability test results on SCGC (Labority Data 2021)

Molarity (M)	Slump Flow (mm)	V-Funnel (dtk)	L-Box (H2/H1) Ratio
11	750	29,15	0,91
12	710	31,66	0,88
13	693	36,53	0,85
14	610	37,93	0,49
15	577	40,11	0,52
Criteria SCC by EFNARC 2005			
min	650 mm	6 sec	0,8
max	800 mm	12 sec	1

In the table it can be seen that the slump flow that meets the requirements is at molarity 11-13 while at molarity 14-15 does not meet the requirements, the highest slump flow value is at molarity 11. In the V-Funnel self compacting geoolimer concrete test, none of the EFNARC requirements met. In the L-Box test, only 11-13 molarity met the requirements, while 14-15 molarity did not meet the requirements.

Compressive Strength At SCGC.

Testing the compressive strength of self compacting geopolymer concrete aged 7, 14 and 28 days with variations in Molarity 11M, 12m, 13M, 14M and 15M Alkali 2 modulus can be seen in the table 2. The value of the compressive strength rises with the age of the concrete, as shown in Table 3. the compressive strength increases with age in a variety of ways. Furthermore, the use of 13 molars yields the greatest compressive strength value.

Table 2. Results of SCGC Compressive Strengh (Processing Data 2021)

Age	Compressive Strength (Mpa)

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(Days)	11M	12M	13M	14M	15M
7	11,03	12,81	15,23	14,04	13,66
14	22,06	22,91	30,41	29,28	22,28
28	34,15	38,82	44,12	36,74	31,01

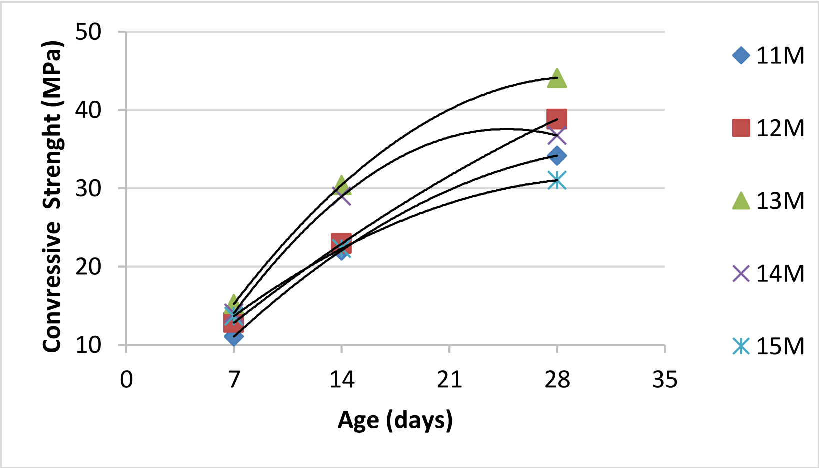

Figure 3 Compressive Strength Relation to Age Of Concrete (Processing Data 2021)

The Figure 3 shows the relation between compressive strength and age forms a polynomial equation relation as Equation 3.

$$y = ax^2 + bx + c \quad (3)$$

Based on the variation of molarity 11-15 Molarity, the relation between compressive strength and age forms a polynomial equation relationship, namely:

11M: $y = -0{,}0339x^2 + 2{,}2879x - 3{,}3231$; 12M : $y =-0{,}0146x^2 + 1{,}7484x + 1{,}2871$;

13M: $y =-0{,}0566x^2 + 3{,}3584x - 5{,}5028$; 14M; $y =-0{,}0783x^2 + 3{,}8214x - 8{,}8705$; and

15M: $y =-0{,}029x^2 + 1{,}8396x + 2{,}2022$

Split Tensile Strength At SCGC

Testing the split tensile strength of self compacting geopolymer concrete aged 7, 14 and 28 days with variations in Molarity 11M, 12M, 13M, 14M and 15M Alkali 2 modulus can be seen in the table and graph showing the results of the split tensile strength in SCGC having an average value which increases with the age of the concrete in show Table.3. As shown in Table 3, the value of split tensile strength rises with the age of the concrete. Tensile strength increases with age in all variants. Additionally, the greatest compressive strength value is obtained when 13 molars are used.

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Table 3. Split Tensile Strengt SCGC (Labority Data 2021)

Age (Days)	Split Tensile Strength (MPa)				
	11M	12M	13M	14M	15M
7	2,15	2,22	2,37	2,36	2,23
14	2,55	3,27	3,64	3,49	2,94
28	3,5	3,58	3,83	3,61	3,33

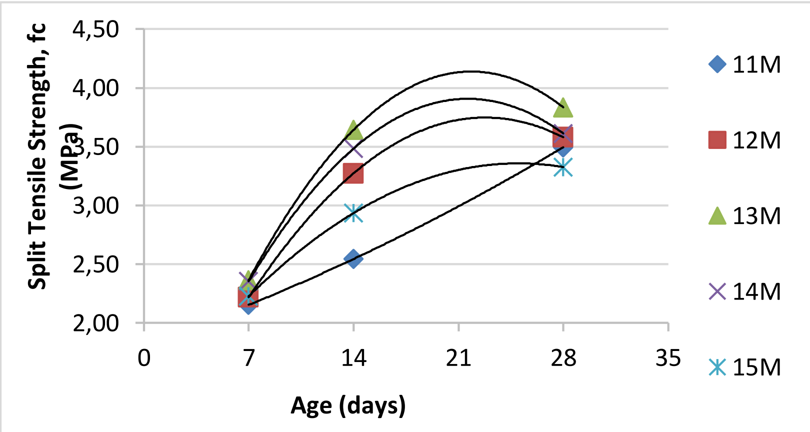

Figure 4. Split Tensile Strength Relation Age of Concrete (Processing Data 2021)

Figure 4 shows the relationship between tensile strength and age forms a polynomial equation relationship as equation relationship as Equation 3. Based on the variation of molarity 11-15 Molarity, the relationship between split tensile Strength and age forms a polynomial equation relationship, namely

11 M: $y = 0{,}0006q^2 + 0{,}0438q + 1{,}8203$; 12 M: $y = -0{,}0061q^2 + 0{,}2799q + 0{,}5598$

13 M: $y = -0{,}008q^2 + 0{,}3516q + 0{,}2993$; 14 M: $y = -0{,}0073q^2 + 0{,}3139q + 0{,}5141$

15 M: $y = -0{,}0035q^2 + 0{,}1743q + 1{,}1795$

5. Conclusion and Suggestion

5.1 Conclusion

From all the data analysis tests and discussions carried out in this study, it was concluded that the workability self-compacting geopolymer concrete at molarity 11-13 met the EFNARC requirements in the slump flow, L-Box and V-Funnel tests but at molarity 14-15 did not meet the requirements. The EFNARC requirements in the slump flow, L-Box and V-

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Funnel tests occur because the activator used accelerates the bonding time of the concrete.

Self-Compacting Geopolymer concrete that uses air curing has increased compressive strength and split tensile strength as the concrete ages. The molarity of 11-15 molars at the age of 7 days to 14 and 28 days experienced a very significant increase in pressure. The effect of Molarity on the mechanical properties of self-compacting geopolymer concrete increased in compression at 11M-13M but at molarity 14 and 15 it decreased.

5.2 Suggestion

It is essential to do research on the optimal quantity of superplasticizer and retarder to ensure that all criteria for self-compacting concrete are met. With the same research, it is necessary to further study the characteristics and microstructure and mechanical properties of SCGC for ages more than 28 days. Further research is needed for the characteristics of self-compacting geopolymer concrete with variations in alkali mode.

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