Civilla : Jurnal Teknik Sipil Universitas Islam Lamongan
Volume 06 Number 2 Year 2021

ISSN (Online) 2620-7222
ISSN (Print) 2503-2399

Available online at
https://jurnalteknik.unisla.ac.id/index.php/CVL

https://doi.org/10.30736/cvl.v2i2

The Effect of Seawater on The Compressive Strength and Split Tensile Strength in Self Compacting Geopolymer Concrete

Herwina Rahayu Putri[1], Firman Paledung[2], Erniati Bachtiar[3*], Popy Indrayani[4], Ritnawati Makbul[5]
Hamayatul Ummah Syarif[6]

[1]Student of Master of Infrastructure and Environmental Engineering, Fajar University, Makassar.
[2]Student of Civil Engineering Study Program, Fajar University, Makassar.
[345]Lecturer of Master of Infrastructure and Environmental Engineering, Fajar University, Makassar.
[6]Lecturer of Engineering Faculty, Fajar University, Makassar
Email : [1] Herwinarahayuputri26@gmail.com. [2] firmanpaledung733@gmail.com.
[3]erni_nurzaman@yahoo.com,[4]poppyindrayani@hotmail.co.jp.[5]ritnawati.nn@gmail.com.[6]humayatulu@yahoo.com.*

ARTICLE INFO

Article History :
Article entry : 2021-10-11
Article revised : 2021-11-04
Article received : 2021-12-09

Keywords :
SCGC, Fly Ash, Compressive Strenght, Split Tensile Strenght, Sea water

IEEE Style in citing this article :
H. R. Putri, F. Paledung, E. Bachtiar, P. Indrayani, R. Makbul dan H. U. Syarif, "The Effect of Seawater on The Compressive Strength and Split Tensile Strength in Self Compacting Geopolymer Concrete," CIVILA, *vol. 6, no. 2, pp. 197-212, 2021.*

ABSTRACT

Fly ash is a kind of trash that may degrade the quality of the air. As a result, it is critical that it be used as an ecologically beneficial material. The aim of this research was to evaluate the strength of self-compacting geopolymer concrete (SCGC) cured in seawater, as well as to compare SCGC with and without saltwater. In this research, a cylindrical specimen with a diameter of 10 cm and a height of 20 cm was utilized as the specimen. Fly ash is used in proportion to fine and coarse aggregates at a ratio of 1: 0.65: 1.5. Using a 0.4 activator to binder ratio. The molarity ranges utilized were 11 M - 15 M. Compressive strength and split tensile strength tests were conducted on 28-day-old concrete. The findings indicated that when the molarity of SCGC treated with seawater increased from 11 to 15 M, the compressive and split tensile strengths increased. Compressive strength values were greatest in SCGC treated at room temperature when an activator of 13 M was used, and compressive strength values dropped in SCGC treated at room temperature when an activator greater than 13 M was used.

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1. Introduction

The United Nations created the Sustainable Development Objectives (SDGs) as a worldwide development program benefiting people and the planet Earth, consisting of 17 goals and 169 quantifiable accomplishments and targets. In 2016, the Sustainable Development Goals (SDGs) for the period 2015–2030 formally superseded the Millennium Development Goals (MDGs) for the period 2000–2015. (MDGs). The SDGs are a collection of universally applicable transformational objectives. Sustaining cities and communities is the SDGs' eleventh objective, with ten targets to be met worldwide. The aim is to create inclusive, safe, resilient, and sustainable cities and settlements. One approach to achieve environmentally friendly sustainable urban development is to minimize the usage of cement in building projects by using renewable resources that may perform the function of cement.

Using X-Ray Fluorescence (XRF) analysis, previous research on fly ash from the Bosowa Ernergi Jeneponto PLTU revealed that the four highest chemical compositions of fly ash are silicate (SiO_2), aluminum (Al_2O_3), iron (Fe_2O_3), and lime (CaO) [1]. According to ASTM C 618-96, PLTU Energi Bosowa Jeneponto's fly ash is classified as a class C type, with a CaO content of 23.52 percent. Apart from being cement, the fly ash from the Bosowa Jeneponto PLTU Energi has pozzolanic properties. This is because the fly ash from the Bosowa Jeneponto PLTU Energi contains a high concentration of CaO. The use of fly ash from the Bosowa Jeneponto PLTU Energi power plant in the manufacture of geopolymer mortar has been investigated, and the results indicate that fly ash can be used in place of cement in mortar due to its high strength for construction. [1]–[4].

Numerous studies on fly ash-based concrete have been conducted, one of which examined the Utilization of Coal Fly Ash as a Partial Substitute for Cement in Concrete Mixtures by varying the amount of coal fly ash added to PLTU Jeneponto as a substitute for PCC cement by 15%, 30%, and 45 percent. At 28 days, the compressive strength of 15% fly ash concrete increased by 1.2 percent, while at 90 days, the compressive strength of 15% and 30% fly ash concrete increased by 1.28 percent and 3.8 percent, respectively [5].

Geopolymer binders emit carbon dioxide at a rate of 5-6 times that of Portland cement [6]. Through industrial usage of geopolymer concrete and its by-products, hazardous materials are converted into necessary building materials. Alkaline activation of alumino-silicate minerals derived from geological sources or by-products such as metakaline, fly ash, husk ash, and silica fumes results in the formation of geopolymer concrete. Although the mechanism of alkali activation is unknown, the chemical composition of the source material and alkaline activator has a significant influence in the formation of geopolymer products.

Geopolymer is mostly composed of industrial waste fly ash, which is rich in the elements alumina (Al) and silica (Si). The silica and alumina components in fly ash are dissolved in an alkaline solution. The alkaline solution is composed of sodium hydroxide (NaOH), sodium silicate (Na_2SiO_3), and distilled water (H_2O), all of which are necessary components of the synthesis. Geopolymer concrete synthesis is extremely reliant on the state of the raw materials, namely the type and content of the fly ash, the concentration of alkaline solution, and the geopolymerization process [7].

SCC is a self-compacting concrete with a rather high slump. SCC does not need vibration throughout the volume placement and compaction processes, like conventional concrete does. SCC has a high flow capacity, which enables it to flow, fill the formwork, and achieve its maximum density on its own [3]. The impact of superplasticizer (SP) and active sodium hydroxide (NaOH) molarity on the workability, compressive strength, and microstructural characteristics of self-compacting geopolymer concrete was investigated [8]. After 48 hours of treatment, specimens were examined to determine the optimal SP dosage and necessary SCGC molarity. Because 6% was chosen as the optimum concentration, the SP dosage of 6% and the concentration of 12 M NaOH provided acceptable performance. The compressive strength rises as the concentration of NaOH solution increases from 8 M to 12 M. At the age of 28 days, a dosage of 6% SP and a concentration of NaOH 12 was able to generate a concrete compressive strength of up to 51.52 MPa [8].

The strength of structures in a maritime environment will be lowered due to the weight on the structure and an aggressive environment that contains chloride ions in seawater that enters the concrete [9]. The high salt concentration of seawater can have an impact on the strength and durability of concrete. This is because seawater contains chloride, which has an aggressive effect on concrete. Fresh water is used to make concrete mixtures, however seawater will invariably infiltrate the concrete mixture when buildings are cast in a harsh environment. Because casting in building projects takes place in an aggressive environment, such as on the edge/top/on the sea, seawater will invariably infiltrate the formwork before the concrete sets. The chlorides have a complicated history in cement; on the one hand, they have long been employed to speed up cement hydration and strength, while on the other hand, they deprive embedded steel of the corrosion protection that occurs in chloride-free cement environments [9]. Because of the problem of corroded concrete caused by chloride in seawater, it is required to add additives to the concrete mixture to reduce chloride entrance and ensure the safety of the concrete reinforcement. Chloride can be prevented from infiltrating concrete by using fly ash. As shown in previous studies, the addition of fly ash reduces chloride ion precipitation and decreases the chloride ion diffusion coefficient as fly ash replacement increases, and fly ash encourages chloride binding in concrete [10].

This research is very useful in utilizing waste to be used as environmentally friendly materials. It is hoped that this research can be used as a construction material, especially in construction buildings in an aggressive environment (sea area).

The compressive strength and split tensile strength of seawater-cured SCGC concrete and air-cured SCGC are discussed in this research. SCGC was synthesized utilizing NaOH and Na_2SiO_3 as activators, an alkali modulus of 2, and molarity fluctuations between 11 and 15 M.

2. Literature Review

Geopolymer is a green substance that may be used in place of Portland cement in construction as a concrete repair material or as a structural element in overall building. SCGC is a relatively new idea and may be regarded the most significant advancement in the area of concrete technology. SCGC is a novel kind of material that does not need vibration to be placed and can be created by eliminating regular Portland from the mix [11].

The binder is the primary factor that distinguishes geopolymers from conventional concrete. When producing conventional concrete, coarse and fine particles are bound together using Portland cement and water [12]. In geopolymer concrete, the silica and alumina in fly ash react with an alkaline liquid to create a geopolymer paste capable of bonding coarse aggregate, fine aggregate, and other components. The glue will harden as a result of the polymerization process. One of the distinctions between geopolymer and ordinary concrete is the way the concrete is treated [12].

Geopolymer is an ecologically friendly substance that may be used in place of Portland cement in construction as a concrete repair material or as a structural element in the overall structure. Geopolymers are inorganic synthetic polymers that generate three-dimensional polymer chains during alkaline chemical processes. The chemical composition of the raw materials and alkaline fluids controls the formation of the final geological polymerization product's microstructure and mechanical characteristics. Fly ash-based polymers are a new kind of binder that has a reduced environmental effect and increases the sustainability potential of concrete buildings [13].

According to the SCC EFNARC standard [3], if the following criteria are fulfilled, the workability or fatigue of a new concrete mix may be referred to as SCC concrete:

a) Filling capacity: The capacity of SCC concrete to support its own weight and completely fill the mold. The Abrams cone slump test may be used to evaluate the workability of concrete by comparing it to the workability of new concrete with a diameter of 60–75 cm.

b) Passing ability: L-shaped Box refers to the capacity of SCC concrete to flow freely through gaps between steel bars or small holes in the mold. The rate value will be determined, which is determined by the H2 / H1 ratio. The greater the blocking rate, the more fluid new concrete is at a given viscosity. The block rate value for SCC-specific standards is between 0.8 and 1.0.

c) Resistance to segregation: The V-Funnel Test determines the capacity of SCC concrete to retain a consistent composition from transport through casting. The V-shaped funnel test is used to determine the viscosity of new concrete, which runs straight into the mouth of the V-shaped funnel's bottom end. The measurement duration is between 3 and 15 seconds.

d) In previous research, fly ash from PLTU Jenneponto was utilized in mortars [1], [2], [4], [14]. This resulted in a very significant connection between the effect of sodium hydroxide and alkali modulus on mortar strength. All variants have the greatest compressive strength at 14 M. The connection between activator composition and compressive strength is represented by a second-order polynomial equation, with the optimal composition occurring between 14 and 15 M NaOH [2]. The compressive strength of geopolymer mortar is significantly related to the temperature and time of the curing oven [4]. Duration and compressive strength are related by a positive non-linear polynomial relationship. Curing at 105°C and for 8 hours is the optimum temperature and time for type C geopolymer mortar foundation [4].

Previous study has examined the impact of sodium hydroxide concentration on the workability (slump flow, V-Funnel, L-box, and J-ring) and compressive strength of SCGC. Where sodium hydroxide concentrations ranging from 8M to 14M are used in the study. The findings of the tests indicate that changes in the sodium hydroxide concentration have the least impact on the freshness of SCGC. The highest compressive strength value is obtained at a sodium hydroxide concentration of 12 M [15].

Many non-Indonesian authors have conducted studies on geopolymer concrete [12] [16] and self-compacting geopolymer concrete (SCGC) [11] [17] [18] [19] [20], however research on SCGC submerged/cured in saltwater is still lacking/non-existent in Indonesia. This research looks at the strength of concrete at 28 days if it has been polluted with saltwater and is continuing in the hydration process.

3. Research Method

The technique employed in this study is the laboratory experiment. The stages in this study are as follows:

a) A literature review collects secondary data from a range of sources, such as books, research journals, scientific papers, and testing standards.
b) Laboratory examination and testing of samples with the goal of obtaining primary data that will be utilized to analyze the findings of the study conducted.
c) Using an excel program, the sample's experimental data will be evaluated to identify the difference between SCGC curing saltwater and SCGC curing fresh water.
d) The data analysis technique utilized in this research is descriptive analysis, which gives an overview of the data collected from the results of utilizing fly ash as a geopolymer concrete material with seawater and air curing procedures.

3.1 Tools

The following tools were utilized in this study:

1. Weighing scales with a 0.1 gram sensitivity
2. Universal Testing Machine offers a collection of compressive strength testing equipment (UTM).
3. A mixer, also referred to as a concrete mixing machine.
4. Oven or dryer with a temperature control
5. Sieve
6. The mold of the test object, the mold of the test object used is a mold measuring 10 cm x 20 cm.
7. Other tools
    1) Cement mold for mixing and inserting fly ash geopolymer concrete.
    2) Water is measured using measuring cups with capacities of 2000 ml and 50 ml.
    3) Stirrer for mixing an alkaline activator solution.
    4) A stainless steel cup or tray is required to store the components and alkaline activator solution.
    5) A brush is used to remove any leftover debris from the utilized equipment.
    6) The time spent stirring was recorded using a timer.
    7) Bucket for storing the remainder of the mixture and water.
    8) Purpose: material movement from one place to another.

ISSN (Online) 2620-7222
ISSN (Print) 2503-2399

9) A soaking tub for soaking concrete.

3.2 Materials

Fly ash, coarse aggregate (gravel), fine aggregate (sand), sodium silicate (NaOH), and sodium hydroxide (Na_2SiO_3) were utilized in this study. The inspection of fine and coarse aggregate is governed by the Indonesian National Standard, which is summarized in Tables 1 and Table 2.

Table 1. Assessment of Fine Aggregates

No.	Assessment	Standard
1	Mud Content	SNI 03-4141-1996
2	Organic concentrations	SNI 03-2816-1992
3	Water Content	SNI 03-1971-1990
4	Weight in volume	SNI 03-4804-1998
5	Specific gravity and absorption	SNI 03-1970-1990
6	Fineness Modulus	SNI 03-1968-1990

Table 2. Assessment of Coarse Aggregate

No.	Assessment	Standard
1	Mud Content	SNI 03-4141-1996
2	Abration	SNI 03-2417-1991
3	Water Content	SNI 03-1971-1990
4	Weight in volume	SNI 03-4804-1998
5	Specific gravity and absorption	SNI 03-1969-1990
6	Fineness Modulus	SNI 03-1968-1990

3.3 Fabrication and Curing of Sample

The production of test items is based on the findings of mixed design, and this study is divided into the following stages:

1) Prepare a solution of alkaline activator (leave it for 24 hours)
2) Preparation of a SCGC fly ash concrete mix.
3) Prior to placing the mixture in the cylinder, SCC new concrete is tested for slump flow, V-Tunnel, and L-Shape Box properties.
4) Fill a cylindrical mold halfway with the mixture (10 cm x 20 cm).
5) Remove the test item from the mold after one day (24 hours).
6) For 28 days, the test item is submerged in a bath of seawater.

3.4 Mix Design of SCGC

Prior to sampling, a mix design was performed utilizing the EFNARC technique. The specimens were produced with varying molarities (11M, 12M, 13M, 14M, and 15M) and alkaline modulus 2, the water used to cure seawater and air-cured specimens, respectively. Prior to placing the mixture in the cylinder, SCC fresh concrete is evaluated using The Europan Guidelines for SCC (2005) technique, namely Slump flow, V-Tunnel,

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and L-Shape Box. The material requirements for six samples per mix are determined using the mix design calculation. Table 3 details the composition of the SCGC concrete mixture.

The cylindrical test item has a diameter of 10 cm and a height of 20 cm. For each variation of three samples, samples were taken. Three samples were taken for seawater curing compressive strength, three samples for air curing compressive strength, three samples for seawater curing tensile strength, and three samples for air curing splitting strength for each molar variation. Table 4 shows the total number of test items.

Table 3 Composition of the SCGC Concrete (6 samples)

	Materials							Viscocrete	Retarder
Molaritas	Fly Ash	Fine aggregate	Coarse Aggregate	Activator	Water	NaOH	Na_2SiO3		
11	7074	4457	10399	2830	1220	537	1073	226	142
12	7074	4457	10399	2830	1160	557	1113	226	142
13	7074	4457	10399	2830	1105	575	1150	226	142
14	7074	4457	10399	2830	1056	591	1183	226	142
15	7074	4457	10399	2830	1011	606	1213	226	142

Table 4. Number of SCGC Samples

Molarity	Test Type	Curing	Number of SCGC
11M	Compressive Strength, Split Tensile Strength	Water-Cured, Air-Cured	12
12M			12
13M			12
14M			12
15M			12

3.5 Testing of Concrete

Compressive strength (ASTM-C39) [21] and split tensile strength (ASTM-C496/C496M) [22] tests have been performed. Mechanical characteristics were determined at 28 days of age (compressive strength and split tensile strength).

3.6 Data Analysis

The test data collection was completed and the compressive strength and split tensile strength of SCGC concrete were computed. Compressive and split tensile strengths are calculated using Equations 1 and 2. The slump flow characteristics, compressive strength, and split tensile strength of seawater and air cured SCGC concrete are next analyzed.

$$f'c = P/A \quad \text{..} (1)$$

$$T = \frac{2P}{\pi L D} \quad \text{..} (2)$$

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where f 'c = Compressive Strength (MPa), P = Ultimated Load (kg), A = area of test section (mm^2), T = kuat tarik belah (MPa), L = length of test object (mm), D = diameter of sample (mm).

4. Results and Discussions

4.1 Characteristic of Aggregate

Aggregate testing for both fine and coarse aggregates was conducted in accordance with SNI standards at Fajar Makassar University's Civil Engineering Laboratory. The results of testing the aggregate material produced indicate that the properties of fine aggregate and coarse aggregate meet the requirements for self-compacting geopolymer concrete component materials. Table 5 and Table 6 provide the test results for fine and coarse aggregate, respectively.

Table 5. Properties of Fine aggregate

No	Test Item	Result	Interval
1	Mud Content	2,60%	0,2% - 5%
2	Water Content	4,71	3% - 5%
3	Volume Weight		
	a. Lose Condition	1,44	1,4 - 1,9 kg/liter
	b. Compacted Condition	1,54	1,4 - 1,9 kg/liter
4	Absorption	1,96	0,2 - 2%
5	Specific gravity		
	a. Bulk Specific gravity	2,61	1,60 - 3,30
	b. Apparent specific gravity	2,48	1,60 - 3,31
	c. Surface specific gravity	2,53	1,60 - 3,32
6	Fineness Modulus	3,09	2,5 - 3,8
7	Organic content	No.2	<No.3

Table 6. Properties of Course Aggregate

No	Jenis pengujian	Result	Interval
1	Mud Content	1%	Maks 1%
2	Water Content	1,52	0,5% - 2%
3	Volume Weight		
	a. Lose Condition	1,66	1,6 - 1,9 kg/liter
	b. Compacted Condition	1,84	1,6 - 1,9 kg/liter
4	Absorption	1,11	Maks 4%
5	Specific gravity		
	a. Bulk Specific gravity	2,98	1,60 - 3,33
	b. Apparent specific gravity	2,88	1,60 - 3,33

	c. Surface specific gravity	2,92	1,60 - 3,33
6	Fineness Modulus	7,43	5,5 - 8,5
7	Abrasion	31	Maks 50%

Table 5 demonstrates that all kinds of testing for fine aggregate's properties satisfy the criteria for usage as a concrete component material, as they conform to Indonesian national regulations. Similarly, Table 6 demonstrates that coarse aggregate meets all required testing criteria as a concrete component material. Both coarse and fine aggregates have features that, if they do not satisfy the criteria for standard construction materials, they may have an adverse effect on the quality of the concrete.

4.2 Slump Flow

To evaluate the workability of the SCC concrete mix, a Slump Flow test is performed. Workability refers to the ease with which the SCC concrete mix may be mixed, carried, poured, and compacted without producing segregation of the concrete components. The degree of workability is determined by the mixture's composition, physical properties, and the kind of mixing medium used. As shown in Figure 1, the slump flow test at a molarity of 11-15 fulfilled the EFNARC criteria but did not satisfy them at a molarity of 13-15 because the self-compacting geopolymer concrete underwent fast bonding throughout the flow and therefore did not achieve the diameter limit. The EFNARC requirement is between 650 and 800.

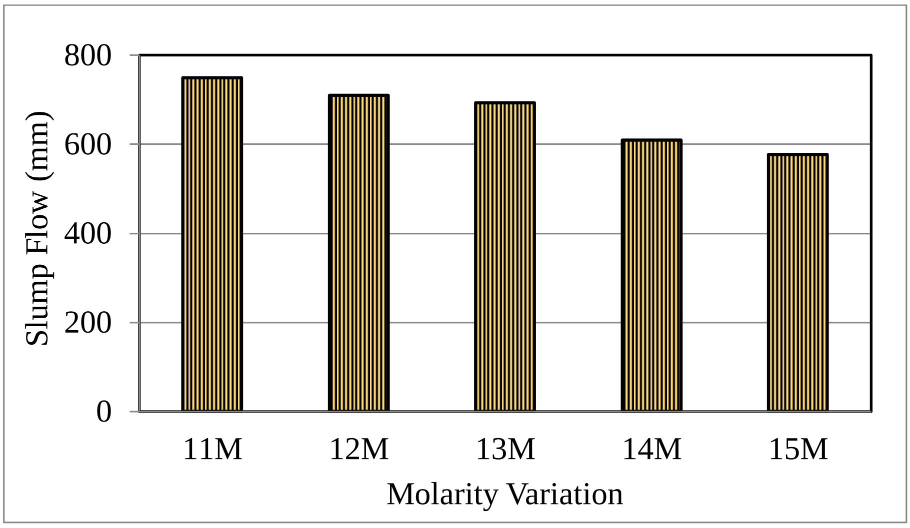

Figure 1. Slump Flow in SCGC concrete

4.3 The Compressive Strenght

At the age of 28 days, the compressive strength test was performed. The load is applied until the test item cracks or the load is no longer able to be applied. It is shown on the UTM tool by a pointer. For comparison, Figure 2 displays the compressive strength of seawater-cured SCGC and air-cured SCGC.

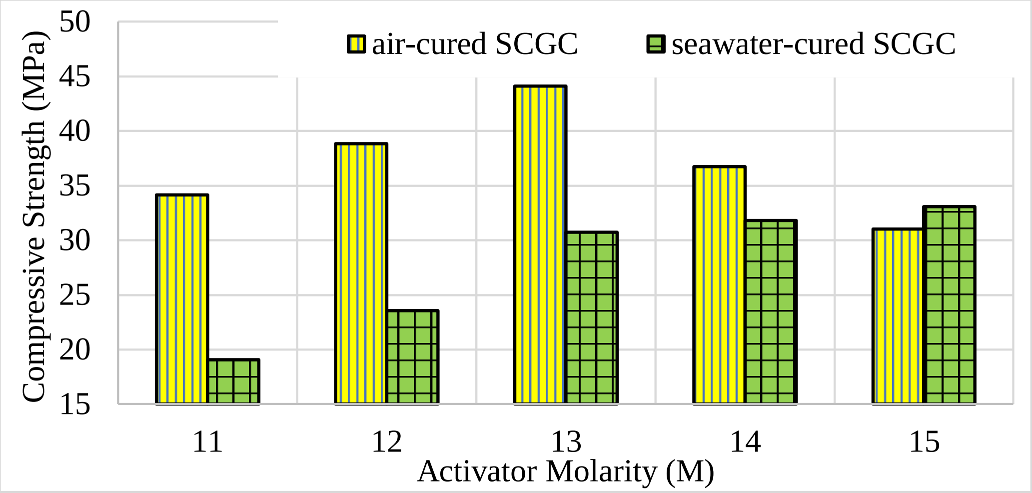

Figure 2. The Compresive Strength of air-cured SCGC and seawater-cured SCGC

The compressive strength of seawater-cured SCGC is compared to that of air-cured SCGC in Figure 2. Seawater curing has a significant impact on the compressive strength of SCGC concrete. This is shown in Figure 2, where nearly all of the compressive strength was lost owing to saltwater curing. However, a rise in the compressive strength of the seawater-cured SCGC was associated with an increase in the activator's molarity. Compressive strength of seawater-cured SCGC is lower than that of air-cured SCGC when the molarity is between 11 and 14. Sea water has a detrimental impact on the compressive strength of seawater-cured SCGC, reducing it by 44.10 percent, 39.34 percent, 30.39 percent, and 13.39 percent, respectively, compared to air-cured SCGC. When 15 M was used, the compressive strength of seawater-cured SCGC was greater than that of water-cured SCGC, with a 6.71 percent increase.

4.4 The Split Tensile Strength

The split tensile strength of split concrete is determined when it is subjected to the maximum load. Split tensile strength is then computed using the resultant data in accordance with Indonesian National Standard (SNI 2491-2014). The split tensile strength test results are shown in Figure 3.

The compressive strength of seawater-cured SCGC is compared to that of air-cured SCGC in Figure 3. Seawater curing has a significant impact on the split tensile strength of SCGC concrete. As shown in Figure 3, almost all of the tensile strength diminishes as a result of saltwater curing. However, SCGC treated with sea water demonstrated a rise in splitting strength concurrent with an increase in activator molarity. Compressive strength of seawater-cured SCGC is lower than that of air-cured SCGC when the molarity is between 11 and 13. Split tensile strength was reduced by 35.14 percent, 18.99 percent, and 8.88 percent in seawater-cured SCGC, respectively. The split tensile strength of SCGC seawater-cured concrete was greater than the split tensile strength of SCGC air-cured concrete when activators 14 M and 15 M were used, increasing by 2.49 percent and 12.61 percent, respectively.

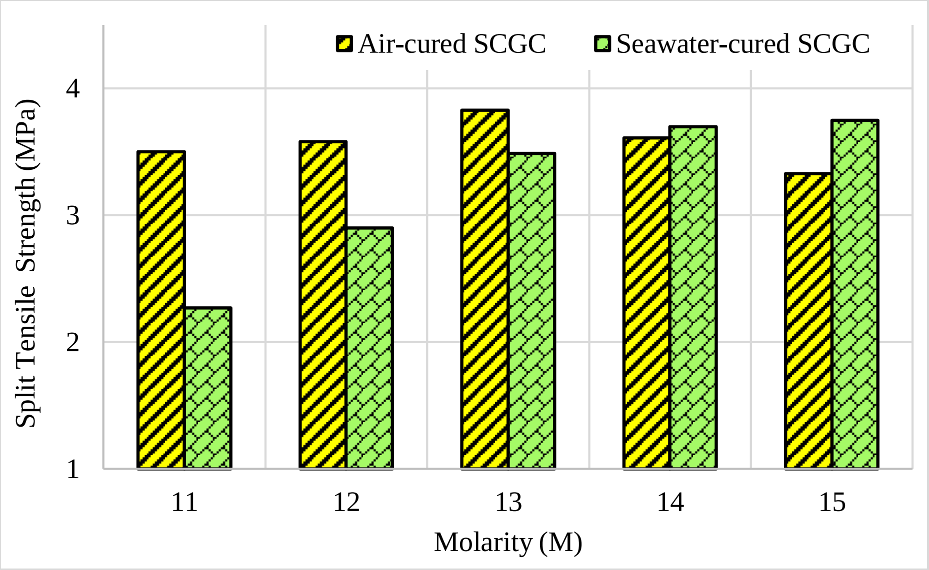

Figure 3. The Split Tensile Strength of air-cured SCGC and seawater-cured SCGC

5. Conclusion and Suggestion

5.1 Conclusion

The following conclusions are drawn from the study's findings:

1. As the activator molarity rises, the slump value of SCGC concrete falls. It does not qualify as SCGC concrete in the 14 M and 15 M variants.
2. Compressive and split tensile strengths of sewater-cured SCGC rise in proportion to the activator's molarity.
3. When using an activator concentration of 11-14 M, the compressive and split tensile strengths of sewater-cured SCGC are lower than those of air-cured SCGC, while when using a concentration of 15 M, the reverse is true.
4. With a molarity of 11 to 14, sewater-cured SCGC has a lower compressive strength than air-cured SCGC. Compressive strength decreased by 44.10 percent, 39.34 percent, 30.39 percent, and 13.39 percent in the sewater-cured SCGC, respectively. While the compressive strength of the sewater-cured SCGC was greater than the compressive

strength of the air-cured SCGC, there was a 6.71 percent improvement in compressive strength when 15 M was used.

5. When an 11-13 M activator was used, the split tensile strength of jointed sewater-cured SCGC decreased by 35.14, 18.99, and 8.88 percent, respectively. While activators 14 and 15 M were used, the split tensile strength of sewater-cured SCGC was greater than that of water-cured SCGC, increasing by 2.49 and 12.61 percent, respectively.

5.1 Suggestion

1. A similar investigation of the mechanical characteristics of SCGC concrete immersed in saltwater for an extended period of time is required.
2. It is essential to investigate the optimum value of the alkaline modulus in self-compacting geopolymer concrete immersed in saltwater, as well as the variation of additional materials (viscocrete and retarder).

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