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Effects of Using Pumice Sand as A Partial Replacement of Fine Aggregate in Lightweight Concrete Mixtures

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ABSTRACT

Purpose: The advantage of lightweight concrete is to reduce the weight, which is considered the dead load on the structure. This study aims to determine the effect of replacing sand with pumice sand as fine aggregate in lightweight concrete. The substitution affects the compressive strength, split tensile strength, and weight.

Design/methodology/approach: The research method is through testing in the laboratory, where the test specimens are cylindrical following SNI with a height of 30 cm and a diameter of 15 cm totaling 50 pieces. The composition ratio between regular and pumice sand is 75%:25%, 50%:50%, 25%:75%, and 0%:100%, respectively. Control of the test object using 100% regular sand.

Findings: This research shows that adding pumice sand into the mixture decreases the volume weight. The weight of the volume of concrete produced is < 1,900 kg/m3, which is classified as a lightweight one.

Research limitations/implications: The resulting compressive strength of 56.63 kg/cm2 decreased against the control test object by 81.10%. At the same time, the split tensile strength is 1.13 kg/cm2, or a decline of 52.05% from the control test object.

Originality/value: This paper is an original work.

Paper type: Research paper

Keyword: *Compressive Strength, Lightweight Concrete, Pumice Sand, Volume Weight*

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I. INTRODUCTION

Concrete is a combination of several materials that work in a composite manner and is widely used in construction work (Kwek & Awang, 2018). The volume of natural aggregate used in the concrete production process is around 8 to 12 million tons per year, or about 60-70% (Dash et al., 2016) The large volume will affect the concrete's weight, ranging from 2,300 – to 2,500 kg/m3 (SNI 03-2847, 2002). The relatively large weight will have an impact on the weight and the loading of the structure. The solution uses lightweight aggregates to produce lightweight concrete with a volume weight of < 1,900 kg/m3 (SNI 03-2461, 2002).

Innovations in obtaining lightweight concrete include using organic waste as a substitute for coarse aggregate (Jumiati & Masthura, 2018) and the agricultural waste from oil palm (Maghfouri et al., 2021), rice mill waste as ashes, and husk as aggregate in the concrete mix. It produces concrete with a weight of 1,383 kg/m3 with a compressive strength of 11.34 MPa, so it is categorized as non-structural lightweight concrete (Hossain & Morshed, 2020).

Silica sand is a by-product of the cement manufacturing process to produce lightweight concrete, which delivers a compressive strength of 32% better than concrete with ordinary sand at a concentration of 60% (Durga & Indira, 2016). Styrofoam is also used as a substitute for coarse aggregate in making lightweight concrete. Unfortunately, its compressive strength tends to decrease when compared to average aggregate, so it is recommended to use it on non-structural parts, such as partition walls and canopies (Ala & Arruan, 2017; Ginting, 2019; Miswar, 2018; Wibowo & Setiawan, 2019).

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Another lightweight aggregate that can be used is pumice. Its use as an essential material in the manufacture of walls can reduce the weight of the walls (M. A. Sultan et al., 2019; M. amir Sultan et al., 2018). It can reduce weight by up to 14.40% compared to regular coarse aggregated concrete, but there is a decrease in the compressive strength (Gaus et al., 2019, 2020; Indrayani et al., 2020). It is coated with polymer on its surface to improve the characteristics of lightweight concrete with coarse aggregates (Nainggolan et al., 2017; Wijatmiko et al., 2017). In addition to pumice, pumice sand is also found in the Rum region, Tidore Island (M. A. Sultan et al., 2021). Based on the above, this research uses pumice sand as fine aggregate in producing lightweight concrete.

II. METHODOLOGY

A. Research Design

This research uses testing methods or experiments in the laboratory. It aims to investigate the possibility of a relationship between variables by treating the test object under study compared to the untreated or regular test object.

B. Research Tools

The equipment includes sieves, scales, ovens, measuring instruments, concrete mixers, and fresh and hard concrete testing equipment.

C. Research Material

The materials used are two types of fine aggregate, namely normal sand and pumice sand, and coarse aggregate, using pumice, portland cement, and water.

The fine aggregate is < 2 mm. Normal sand was taken from the Kalumata quarry on Ternate Island, while pumice sand and pumice were taken from the Rum quarry on Tidore Island. The cement used is Portland cement type I based on SNI 03-2847 (2002)

Inspection of aggregate properties based on SNI includes:

a. Specific gravity (SNI, 1969; SNI 1970, 2008)
b. Volume weight (SNI 03-4804, 1998)
c. Absorption (SNI 03-1971, 1990)
d. Filter analysis (SNI 03-1968, 1990)

D. Test Object

The test object is cylindrical with pumice as coarse aggregate. Fine aggregate uses composition variations as in table 1, where each variation uses 10 test objects.

Table 1. The material composition of the test object with the coarse aggregate of pumice

Test Object	*Fine Aggregate*	
	Sand (%)	*Pumice Sand (%)*
$B\text{-}_{100}$	*100*	*0*
$B\text{-}_{75}$	*75*	*25*
$B\text{-}_{50}$	*50*	*50*
$B\text{-}_{25}$	*25*	*75*
$B\text{-}_{0}$	*0*	*100*

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E. Compressive Strength Test

Following SNI 03-1974 (2011), the test object used is a cylinder with a diameter of 15 cm and a height of 30 cm, as shown in Figure 1.

The test was at the age of 28 days. The testing stages are as follows:

a. Prepare the test object;
b. Put the test object on the test equipment;
c. Start the engine, and give the load until the manometer needle on the tool does not rise again, which indicates the maximum load;
d. Record test results;
e. The process is on each test object.

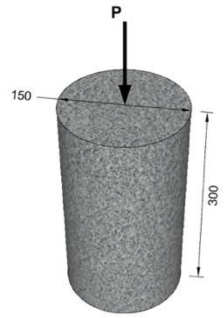

Figure 1. The test object model for compressive strength testing

F. Split Tensile Test

Based on SNI 03-2491 (2002), the object's position is crosswise, as shown in Figure 2.

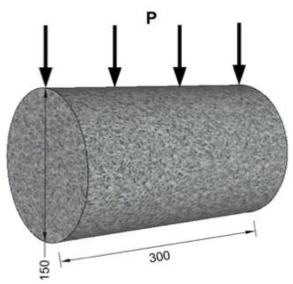

Figure 2. Model benda uji pengujian kuat tarik

Split tensile testing was at the age of 28 days with the following stages:

a. Prepare the test object;
b. Place it on the test apparatus in a transverse position;
c. Start the test machine and apply the load until the manometer needle no longer rises, which indicates the maximum load;
d. Record test results;
e. The process is on each test object.

III. RESULTS AND DISCUSSIONS

A. Volume Weight

Using pumice as coarse aggregate and pumice sand as a partial substitution for fine aggregate aims to reduce the weight of the concrete volume. Pumice sand replaces fine aggregate at 25%, 50%, 75%, and 100% of the fine aggregate volume.

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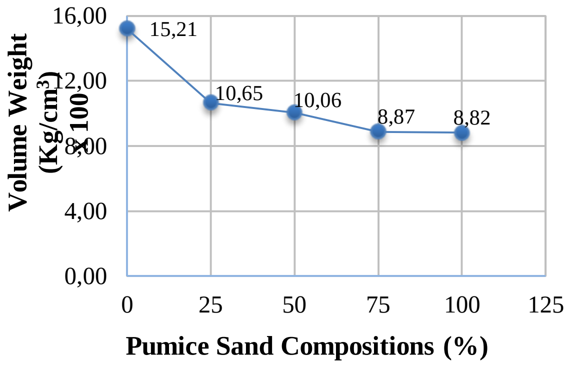

Figure 3. The relationship between volume weight with the composition of pumice sand as a partial substitution of fine aggregates

The decrease in volume weight was obtained after the examination, as shown in Figure 3. The object using a fine aggregate of normal sand was used as a comparison test object (B_0) with a volume weight of 1,520.97 kg/m^3. The volume weight decreased to 1,065.11 kg/m^3 after replacing 25% of normal sand with pumice sand (B_{25}). In the same way, it dropped to 1,006.02 kg/m^3 after replacing it with 50% pumice sand (B_{50}). Then, it became 887.18 kg/m^3 after using 75% pumice aggregate sand (B_{75}). Finally, it was 881.52 kg/m^3 after pumice sand reached 100% (B_{100}). The decrease in volume weight is caused because it is smaller than regular sand. Since it is less than 1,900 kg/cm3, it is categorized as lightweight concrete.

B. Compressive and Split Tensile Strength

The use of pumice sand causes a decrease in the compressive strength of the concrete, as shown in Figure 4.

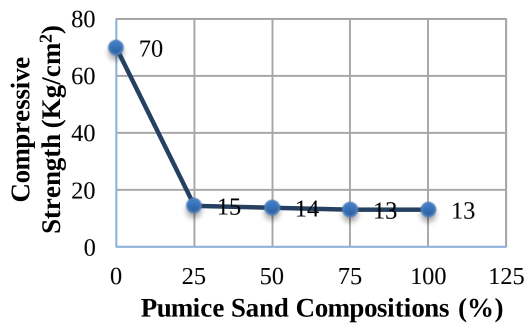

Figure 4. Compressive strength relationship with pumice sand composition as a partial substitution of fine aggregate

The control test object (B_0) has a compressive strength of 69.83 kg/cm^2. After substitution with pumice sand with pumice sand composition of 25%, 50%, 75% and 100%, it shows the compressive strength of 14.53 kg/cm^2, 13.87 kg/cm^2, 13.20 kg/cm^2, and 13.20 kg/cm2, respectively. The decrease in compressive strength of B100 to B0 is 56.63 kg/cm2 or 81.10%.

Using pumice sand reduces the split tensile strength of the concrete, as shown in Figure 5.

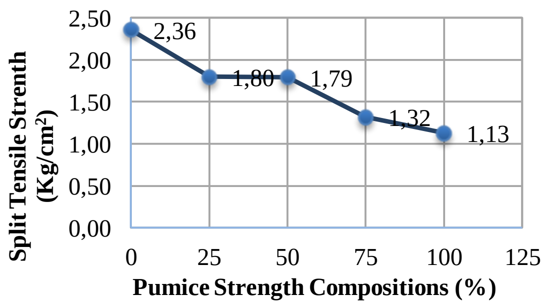

Figure 5. The relationship of split tensile strength with pumice sand composition as a partial substitution of fine aggregate

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The control test object (B_0) has a split tensile strength of 2.36 kg/cm^2. After being replaced with pumice sand at a composition of 25%, 50%, 75% and 100% pumice sand, it exhibits split tensile strength of 1.80 kg/cm^2, 1.79 kg/cm^2, 1.32 kg/cm^2, and 1.13 kg/cm2, respectively. Decrease in compressive strength of B_{100} to B_0 by 1.23 kg/cm^2 or 52.05%.

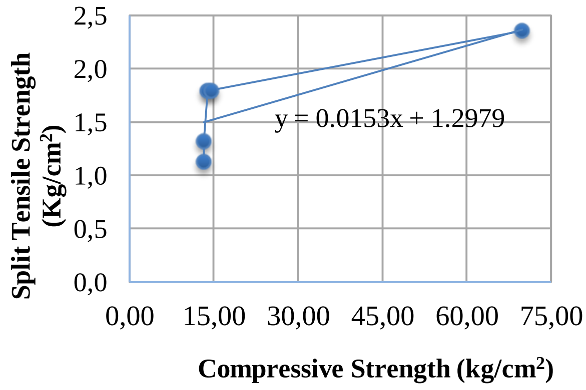

Figure 6. The relationship between split tensile strength and compressive strength with pumice sand composition as a partial substitution of fine aggregate

Figure 6 concludes that the increase in compressive strength is directly proportional to the rise in split tensile strength. Comparison of the compressive strength of lightweight concrete with split tensile strength as shown in Tables 2 and 3 below:

Table 2. Comparison of the value of the split tensile strength to the square root of the compressive strength of concrete

Test Object	*Comparison of fsp to $\sqrt{fc}$*
B-100	*0.3110*
B-75	*0.3633*
B-50	*0.4816*
B-25	*0.4713*
B-0	*0.2820*

Tables 2 and 3 show fsp = 0.28-0.48$\sqrt{fc}$ The values of split tensile strength are 3.37%-12.93% of those of compressive force.

Table 3. Comparison of the value of the split tensile strength to the square root of the compressive strength of concrete

Test Object	*Comparison of fsp to fc (%)*
B-100	*8.56*
B-75	*10.00*

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B-50	*12.93*
B-25	*12.36*
B-0	*3.37*

C. Conclusions

The experimental results and data analysis proves that the volume weight is 881.52 kg/m^3 – 1,520.97 kg/m^3 and is included in the lightweight category. The compressive strength of concrete at 100% regular sand composition is 69.83 kg/cm^2 and 13.20 kg/cm^2 at 100% pumice sand composition, and there is a decrease of 81.10%. Split tensile strength at 100% regular sand composition is 2.36 kg/cm^2 and 1.13 kg/cm^2 at 100% pumice sand composition or a decrease of 52.05%. The value of fsp = 0.28-0.48$\sqrt{fc}$ The values of the tensile strength ratio are 3.37%-12.93% of those of compressive strength.

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