The Mechanical Properties of Lightweight Concrete Made with Lightweight Aggregate Volcanic Pumice

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Abstract: Pumice is a type of light-colored rock that contains cavities made from glass-walled bubbles and is usually referred to as volcanic silicate rock glass. These rocks are formed from magma acid through volcanic eruptions that eject material into the air, which then experiences horizontal transport and accumulates as pyroclastic rocks. However, there are also pumice rocks that were formed from dead and weathered sea coral. The pumice stone sea coral species are spread where coastal sea coral reefs grow. In this experiment, volcanic pumice silicate (SP-2) sourced from Gresik is substituted as coarse aggregate in the manufacturing of lightweight aggregate concrete. The result obtained was a lightweight aggregate volume silica volcanic pumice SP-2 at 717 kg/m3. In the testing phase, for a mixture of cement, water, sand and pumice lightweight aggregate concrete, the weight gained per cubic meter of volcanic pumice silicate (SP-2) was 1850 kg/m3. From the test results, pumice stone qualifies as a lightweight aggregate for the manufacturing of lightweight structural concrete. In this study, a testing of the compressive strength of the specimen cylinder (15 x 30cm) was also conducted. Testing results show that concrete compressive strength at age 7, 14 and 28-days obtained values of 15.23 Mpa, 13.86 Mpa and 13.88 Mpa, respectively. Additionally, splitting tensile strength obtained results of 5.16 Mpa, 4.70 Mpa and 4.71 Mpa at the same age.

1 INTRODUCTION

Urban population has increased significantly and is incomparable to the available land that has given rise to the development of cities. This is indicated by the increasing number of high-rise buildings and skyscrapers in the city (Parmo, 2016). The use of external confinement in concrete columns (Parmo, 2012) and concrete beams (Parmo, 2014) can increase strength and ductility. Strength and ductility are very important in designing earthquake-resistant buildings.

As a construction material, concrete has long been used in civil engineering construction, including in Indonesia. This is because concrete is easily molded/casted in accordance to the cross-sectional shape and size desired. In addition, it has easy execution and relatively low maintenance costs. However, concrete has a disadvantage in its ratio of strength to weight volume. To reduce the weight of concrete, several studies have been conducted to produce lightweight concrete with a better *Strength-to-Weight Ratio*.

The need for concrete for construction nowadays continues to increase which has led to the demand of the development of better concrete technology. The use of lightweight concrete as a construction material in earthquake-prone areas serves as a good alternative due to its lightweight characteristics that can reduce the burden if affected by an earthquake.

The advantage of such lightweight concrete is that heavy construction becomes relatively lighter, has good heat propagation properties (Munir et al., 2009), is resistant to fire (G. Batis, 2004), is not harmful to health, is environmentally friendly, and has better sound propagation properties compared to other materials such as bricks. However, lightweight concrete has some drawbacks, such as having low tension, is brittle (Nugraha, P and Antoni, 2007) and has a relatively high content of cement. These weaknesses are continuously being strived to improve, for example with the addition of fibre reinforcement, as well as the partial replacement of cement with other cheaper binder materials (Abdullah, 2007).

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Pumice is a natural lightweight aggregate which is also available for general use, provided it is free of fine volcanic ash and volcanic material. Pumice provide better thermal insulation than other types of lightweight concrete.

This study aims to gain an innovative material utilization of pumice as a lightweight aggregate for use in the manufacturing of lightweight concrete. The burden of building with lightweight concrete is relatively small so it is expected to accommodate vertical urban growth and support comprehensive planning of a city that is healthy, safe and comfortable.

2 CONCEPT OF LIGHTWEIGHT CONCRETE

According to Mulyono (2004), lightweight aggregate is an aggregate with a density of about 300 - 1850 kg/ m3. SNI-03-2641-2002 regulates lightweight concrete criteria limits in the density to be < 1900 kg/m3. The essence of lightweight aggregate is an aggregate with a density that is lightweight and highly porous, which can be made from natural aggregates and fabricating results. Based on this understanding, there are two methods for making lightweight concrete using lightweight aggregate. The first is formed by using a porous lightweight aggregate with a small density. The concrete formed is called lightweight aggregate concrete. The second is to make the mass of mortar highly porous, ie by increasing the air content in it.

There are several methods to reduce the density of concrete or produce lighter concrete, as follows (Tjokrodimuljo, 1996):

a. Creating bubbles of gas/air in the mortar, causing the concrete to have a large number air pores in it.
b. Using lightweight aggregates, such as baked clay, pumice or artificial aggregates so that the concrete made will be lighter than regular concrete.
c. Making concrete without using grains of fine aggregate or sand, which is referred as non-sand concrete.

According to ASTM C.330, lightweight aggregates can be divided into two: natural and artificial aggregates. Natural lightweight aggregates includes types of diatomite, pumice, *scoria, volcanic tuff Dinder* and everything including original volcanic rocks. Artificial lightweight aggregates can be made from the process of heating and cooling industry *cinder.* Artificial lightweight aggregates include *expanded clay, shale, slate,* perlite, vermiculite, and fly ash (Mulyono, T., 2004).

According to the heavy volume and minimum compressive strength that must be met, and also retain earnings, lightweight concrete can be divided into three categories (Dobrowolski, 1998):

a. For non-structures, a density of 240 kg/m^3 to 800 kg/m ^{3} and a compressive strength of 0.35 MPa to 7 MPa is generally used for dividing walls or walls for insulation.
b. For lightweight structures, a density of 800 kg/m^3 to 1400 kg/m^3 and a compressive strength of 7 MPa to 17 MPa is generally used for walls that also bear burdens.
c. For other structures, a density between 1400 kg/m^3 to 1800 kg/m^3 and a compressive strength of more than 17 MPa can be used as normal concrete.

3 CONCEPT OF PUMICE

Pumice is a light-coloured rock that usually resembles a layer of glass, with a unit weight of 500 to 900 kg/m^3 (Mulyono, 2004: 286). According to Murdock and Brook (1999: 396), pumice is a natural lightweight aggregate and that is suitable for general use as well. Provided it is free of fine volcanic ash and volcanic material that is not native such as clays, pumice can be made into a satisfactory lightweight concrete with a density of 720 kg/m^3 to 1440 kg/m^3. Pumice provides better thermal insulation than other lightweight concrete.

Pumice is a type of light-coloured rock that contains cavities made of glass-walled bubbles and is usually referred to as volcanic silicate rock glass. These rocks are formed from magma acid through volcanic eruptions that eject material into the air, which then experiences horizontal transport and accumulates as pyroclastic rocks. Pumice has high *vesicular* properties and contains a number of cells and plenty of cellular structured foam due to the expansion of natural gas contained therein and in general as a freelance or fragments in a volcanic reaction. While the minerals contained in pumice include *feldspar,* quartz, obsidian, cristobalite, and tridymite. The existence of pumice is always associated with a series of volcanoes, from old quarter to tertiary.

The existence of pumice is always associated with a series of volcanoes. The chemical and physical properties of pumice include: oxides SiO_2, Al_2O_3, Fe_2O_3, Na_2O, K_2O, MgO, CaO, TiO_2, SO_3, and Cl, lost incandescent (*loss of ignition)* of 6%, pH 5, bulk density 480 to 960 kg/cm^3, water absorption of 16.67%, a specific gravity of 0.8 g / cm ^{3}, a low sound conduction *(sound transmission)* , the ratio of compressive strength to high loads, low thermal conductivity, and resistant to fire for up to 6 hours (*http://www.tekmira.esdm.go.id*).

4 EXPERIMENTAL SECTION

In this research, the materials used include: a). Type I cement with a unit weight of 1310 kg/m3; b). Fine aggregate from Lumajang, East Java with the physical properties of: unit weight of 1571 kg/m3, water content of 10.12%, bulk density of 2.410 gr/cm3, specific gravity of SSD at 2.430 gr/m3, absorption of 0,801 %, and sludge levels of 1.12%; and c). coarse aggregate of pumice (100%) with a volume weight of 717 kg/m3. Figure 1 shows the shape of pumice, while Figure 2 shows the pumice after it was processed as a coarse aggregate sized 2/3 cm.

Figure 1: The shape of pumice.

Figure 2: Lightweight aggregate pumice.

To obtain the level of concrete viscosity, the slump is tested (Figure 3) which describes concrete workability and obtained an average slump value of 11.45 cm. A lightweight concrete specimen made from lightweight pumice aggregate was obtained, after casting the volcanic pumice silicate (SP-2) was of 1850 kg/m3.

Figure 3: Slump testing.

In this research, a specimen cylinder was prepared with a diameter of 15 cm and height of 30 cm. Three test specimens were taken for compressive strength testing, while another three specimens were taken for testing tensile strength, with a total of six specimens. The details of the research plan can be viewed on the table below.

Table 1: Testing of Objects Made From Pumice Aggregates For Lightweight Concrete Compressive Strength.

Specimen	*Specification of Gravity*	*Age of Specimen*	*% Pumice*	*Amount*
Cylinder (SP 2)	1.6	7 days	100	1
Cylinder (SP 2)	1.6	14 days	100	1
Cylinder (SP 2)	1.6	28 days	100	1

Table 2: Testing the Splitting Tensile Strength of Lightweight Concrete Aggregate Pumice Stone.

Specimen	*Specification of Gravity*	*Age of Specimen*	*% Pumice*	*Amount*
Cylinder (SP 2)	1.6	7 days	100	1
Cylinder (SP 2)	1.6	14 days	100	1
Cylinder (SP 2)	1.6	28 days	100	1

5 RESULTS AND DISCUSSION

5.1 Compressive Strength Testing Results

In general, the use of volcanic pumice aggregate gave a positive contribution to cylinder compressive strength, f'c. Further details can be viewed on table 3.

Table 3: Results of Lightweight Concrete Compressive Strength Testing of Volcanic Pumice Aggregate.

Speci-men	*SG*	*Age of Speci-men*	*Compressive Strength (Mpa)*	*Average Compressive Strength (Mpa)*
Cylinder (SP2 7)	1.6	7 days	15.23	14.32
Cylinder (SP2 14)		14 days	13.86	
Cylinder (SP2 28)		28 days	13.88	

From the concrete strength test results of the lightweight pumice aggregate, the lightweight concrete obtained can be classified as a *Moderate Strength Concrete* with a compressive strength value of less than 16.35 Mpa.

5.2 Splitting Tensile Strength Testing Results

Splitting tensile strength tests were performed on the cylindrical concrete specimens with diameters of 15 cm and 30 cm. Further details can be seen on table 4.

Table 4: Splitting Tensile Strength Test Results of Lightweight Concrete Made From Volcanic Pumice Aggregate.

Specimen	*Specification of Gravity*	*Age of Speci-men*	*Spliting Tensile Strength (Mpa)*	*Average Splitting Tensile Strength (Mpa)*
Cylinder (SP2 7)	1.6	7 days	5.16	4.86
Cylinder (SP2 14)		14 days	4.70	
Cylinder (SP2 28)		28 days	4.71	

The test results of splitting tensile strength show that lightweight aggregate concrete sides pumice can increase the value of the tensile strength divided by an average of 4.86 Mpa.

5.3 Relationship between Compressive Strength and Splitting Tensile Strength

Data regarding the compressive strength and tensile strength of the lightweight aggregate concrete sides pumice was obtained by testing the compressive strength and tensile strength divided by the specimen cylinder. Compressive strength and splitting tensile strength of the lightweight aggregate concrete sides pumice were interconnected and influenced each other. This data graphed the relationship between the compressive strength and tensile strength of lightweight aggregate concrete sides of pumice. A graph of the relationship between compressive strength and tensile strength with the ages of concrete sides is shown on Figure 4.

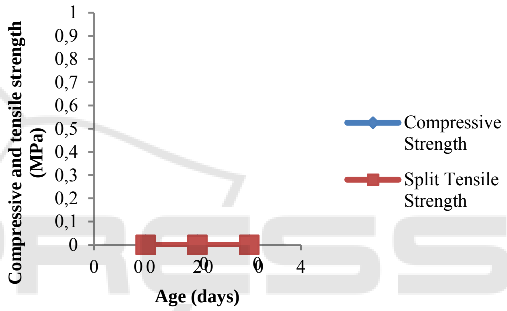

Figure 4: Graph of the Relationship between Compressive Strength and Split Tensile Strength of Lightweight Pumice Concrete at Concrete Age of 7, 14 and 28 days.

Table 5: The Relationship between Splitting Tensile Strength and Compressive Strength of Lightweight Pumice Concrete.

Testing	*Nilson and Winter Testing Result*	*Lightweight Concrete Pumice Testing Results*
Split Tensile Strength of Lightweight Pumice Concrete (ft)	0.333 √f'c to 0.448 √f'c	0.309 √f'c to 0.372 √f'c

Based on Table 5, it can be seen that the tensile strength of lightweight concrete sides pumice obtained average test results that was within the interval of 0.309 √f 'c to 0.372 √f'c (MPa). The value of these approaches provides a smaller interval of restrictions given by Nilson and Winter of 0.333 √ f'c to 0.448 √ f'c (MPa).

6 CONCLUSIONS

The conclusion that can be drawn from the results of this research are as follows :

- Judging from the properties, a feisty, lightweight aggregate pumice can be used as a construction material for lightweight concrete.
- From the compressive strength test results, lightweight concrete pumice can be classified as a lightweight concrete structure *(Moderate Strength Concretes).*
- The greater the value of the compressive strength, the greater the value of the splitting tensile strength .
- The values for the splitting tensile strength of lightweight concrete sides pumice obtained average test results within the interval of 0.309 √f'c to 0.372 √ f'c (Mpa). The value of these approaches provides a smaller interval of restrictions given by Nilson and Winter at 0.333 √f 'c to 0.448 √ f'c (Mpa).

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