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Towards Eco Green Construction With Pumice Fine Aggregate Concrete

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***Abstract*—Concrete production in construction work is one of the causes of damage to the environment. the use of local materials as aggregates in concrete mixes is expected to be more eco green in construction. With the uniqueness of the pumice it is tried to serve as a fine aggregate for concrete mixing with 3(three) different FAS variations which is 0.4; 0.35 and 0.3. Average compression strength test result of concrete cylinder with Pumice fine aggregate with FAS = 0.4 was = 240 kg/cm2 and for concrete cylinder with pumice fine aggregate with FAS = 0,35, the average compressive strength was = 305 kg/cm2 and concrete cylinder with pumice fine aggregate with FAS = 0,3 obtained average compressive strength = 306 kg/cm2. Furthermore, we tested load on a reinforced concrete beam sample with a pumice fine aggregate. The beam set up with two simply supported and loaded on the 1/3 outer of span. The average load at the initial crack was 19.16 kN and the mean value of the maximum load is 45.33 kN. when it compared to reinforced concrete beam that using normal aggregate with the same concrete mortar composition with pumice fine aggregate beam, obtained results that did not different so much, that is the average load at the initial crack was 23.33 kN and the highest average load was 46.16 kN. Pumice fine aggregate can be used as material for normal concrete mixtures with a small FAS and the use of pumice fine aggregate as a material for concrete will reduce the impact of environmental damage due to construction work activities**

Keywords—concrete; pumice; aggregate

I. INTRODUCTION

Concrete is the most used material in the construction industry and it is also a huge consumer of natural resources. Use of waste in concrete mix is beneficial for the environment protection [1]. The production of one ton of cement emits approximately one ton of carbon dioxide to the atmosphere which leads to global warming conditions [2]. A need of present status is how to build additional cement manufacturing plants or find alternative binder system to make concrete [3]. The global warming gas is released when limestone and clays are crushed and heated to high temperatures [4].

Major forces that were responsible for economic and social transformation in society are population growth, industrialization and urbanization, globalization of market economy and consumerism, and environmental pollution. The forces are interconnected. Their combine impact has triggered another force which is threatening to cause serious damage to human civilization [4]. Global warming is the most important sustainability issue today in public mind [5]. Since the world earth summit 1997 in Kyoto, Japan, which initiated the need to reduce CO2 emission on large scale to avoid catastrophic global world, so many industrial countries around the world agreed to formulate regulations that dreams related to the mission of the protection and preservation of the environment become a reality [6]

Green concrete is defined as a concrete which uses waste as at least one of its components, or its production process does not lead to environmental destruction [7]. Foamed concrete is a type of lightweight aerated concrete which consist principally of a cement paste or mortar with at least 20% of its volume as air [8]. In a content of sustainable development, green buildings aim at reducing the environmental impacts of buildings while also ensuring high quality in comfortable and healthy. Bio-based or recycled raw material can be used to reach this objective [9]

II. METHODOLOGY

This study was carried out by taking a fine aggregate sample from pumice deposit located in Rumbune village of Tidore city. first of all, the pumice are sieved with No.4 sieve (size 4.75 mm) to separate coarse and fine aggregates. Pumice material that passes No.4 sieve then collected and tested its physical properties with aggregate testing standards according to SNI-03. After physical properties known, the concrete mix design is then made for normal concrete with K-250 in compressive strength with 3(three) different FAS variations, which is 0.3; 0.35 and 0.4. Those composition of normal concrete was also applied to mix concrete that using pumice fine aggregate in order to compare the effect on the performance of concrete compressive strength resulted. The concrete compressive strength test carried out according to SNI-03 standards using a compression strength test machine with concrete cylindrical sample with diameter (d) = 15 cm and height (h) = 30 cm. the Testing of concrete cylinder compressive strength was carried out at concrete age 3 days, 7 days and 28 days after curing.

Furthermore, a load test to reinforced concrete beams was carried out with a cross section of 10 cm x 15 cm and a length of 60 cm to observe the mechanical behavior of the use of pumice fine aggregates on the concrete structure. The beam set up with two simply supported at each of the end of beam and loaded on the 1/3 outer of span. Observation is carried out on loads, deflections and cracks that occur. The beam testing setup are shown in Figure -1. The beam specimen is reinforced for tensile and shear with 8 mm steel for longitudinal reinforcement and 6 mm steel for shear reinforcement with 5 cm interval in the support section. The load applied until it reaches the maximum capacity of the beam specimen.

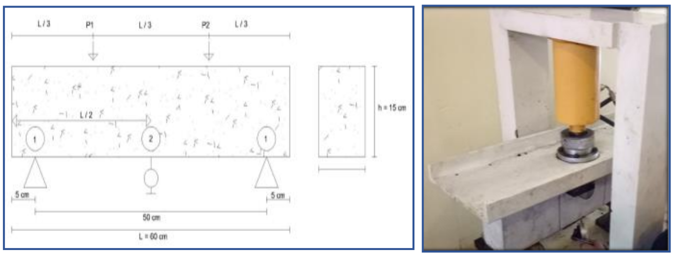

Fig. 1. *Beam test setup*

Research at the microstructure level was done with Scanning Electron Microscope (SEM) on concrete sample pieces from the previous compressive strength test. The sample was also tested with an X-Ray Fluorosence (XRF) tool to analyze the chemical composition along with the concentration of the elements contained therein.

III. Result and Discussion

The result of physical examination obtained that the specific gravity of pumice fine aggregate is smaller than the specific gravity of normal fine aggregates that ranging between 1.6 to 3.2. This condition will also have an effect on measuring the mass-volume of pumice fine aggregate. When compared to water mass-volume = 1, the specific gravity of pumice fine aggregate is still smaller which causes pumice fine aggregate will float when put into water. the complete result of physical examination of pumice fine aggregate showed in the following Table I.

From table-1 above can be seen the physical texture of pumice fine aggregates that have cavities of air, so that with the same volume the weight of pumice fine aggregate is smaller than normal fine aggregates. However, after a long period of immersion, the water can enter and fill the air space which results the weight of pumice fine aggregate increase up to 15% when water-saturated condition reached and the pumice fine aggregate grains also begin to sink. The comparison of physical texture of pumice fine aggregate with normal fine aggregates as shown in Figure 2.

Figure-2 shows the SEM results of both fine aggregates, ca be seen that both of shapes and textures are different, the constituent and forming elements of pumice fine aggregates are smaller than the elements in ex-Tubo fine aggregates as normal fine aggregate according to SNI-03 specification. The following table is a comparison of the chemical composition and concentration of the elements contained in the two fine aggregates.

TABLE I. PHYSICAL EXAMINATION RESULT

No	Examination	Specification (SNI-03)	Test result
1	Sand equivalent	0,2% - 5%	0,53%
2	Specific gravity		
	Bulk Specific Gravity on Dry Basic	1,6 - 3,2	0,76
	Bulk Specific Gravity on SSD Basic	1,6 - 3,2	0,63
	Apparent Specific Gravity	1,6 - 3,2	0,82
	Water Absorption	0,2% - 2%	14,98%
3	Mass Volume		
	Solid state	1,4 kg/ltr - 1,9 kg/ltr	0,71 kg/ltr
	Loose state	1,4 kg/ltr - 1,9 kg/ltr	0,66 kg/ltr
4	Fine Modulus	1,5% - 3,8%	2,75%

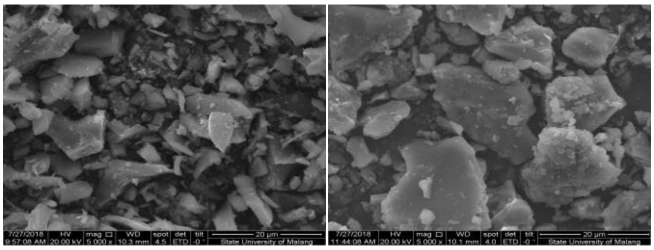

Fig. 2. *SEM of pumice fine aggregate (left) and SEM of ex-Tubo fine aggregate (right)*

TABLE II. COMPARISON OF CHEMICAL ELEMENTS

Fine Aggregate	Al	Si	K	Ca	Fe	Ti
Pumice	10%	58,9%	9,78%	8,82%	10,1%	
Ex-Tubo		28,7%	2,96%	17,1%	44,5%	2,18%

Table II shows the composition of the dominant chemical elements in 2 (two) types of fine aggregates from XRF testing. Pumice fine aggregates contain the chemical elements of silica (Si) which are more dominant than other elements, and even almost 6 (six) times more than the chemical elements of iron (Fe) which in ex-tubo fine aggregates are the most contained chemical elements. In addition, fine pumice aggregates contain elements of aluminum (Al) which are quite a lot and are not contained in fine ex-tubo aggregates, whereas pumice fine aggregates do not contain titanium (Ti) elements in ex-tubo fine aggregates. The contradiction between pumice and ex-tubo fine aggregates in the chemical elements contained causes the physical properties of the two fine aggregates to be different.

The test results of the compressive strength of concrete cylinders that using pumice fine aggregate material with normal concrete mix K-250 can be seen in the following Table III.

Compressive strength test results for FAS = 0.3 obtained average compressive strength value was = 306,052 kg/cm2 with a standard of deviation was = 48,495 kg/cm2 so that the percentage of number of the sample that exceed the K-250 is 87,1% under the normal distribution curve. For concrete mix with FAS = 0.35 the average compressive strength value was

= 304.778 kg/cm2 with a standard of deviation was = 71.101 kg/cm2 so that the percentage of number of the sample that exceed the K-250 is also 87.1% under the normal distribution curve. Quite different results were obtained in concrete mix with FAS = 0.4. The value of the average concrete compressive strength obtained under the concrete of the K-250 which is 240,078 kg/cm2 with a standard of deviation was = 61,916 kg/cm2 so that the percentage of number of the sample that exceed K-250 is only 48.4% under the normal distribution curve. The variation of compressive strength produced by concrete mix with pumice fine aggregate at 3 (three) different FAS can be seen in the following pie chart.

Beam testing uses 3(three) beams specimen both concrete using pumice fine aggregate and concrete with normal aggregate. Observations on beam testing are shown in the following histogram diagram.

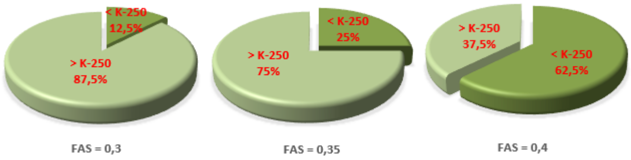

Fig. 3. *SEM of pumice fine aggregate (left) and SEM of ex-Tubo fine aggregate (right)*

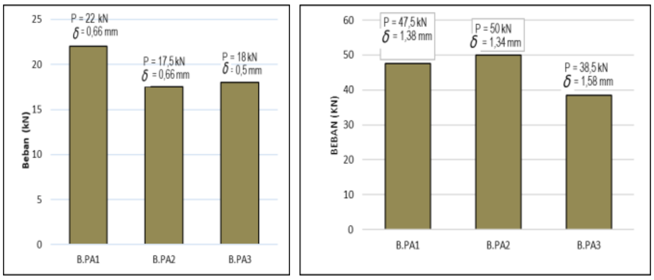

Fig. 4. *Test result of beam with pumice fine aggregate*

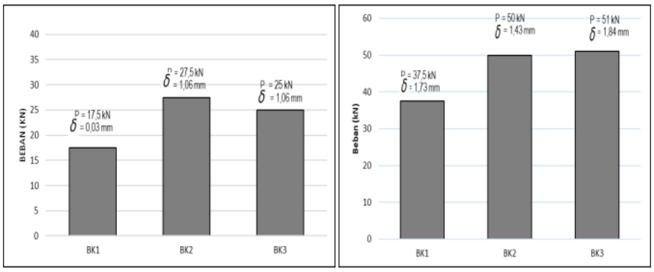

Fig. 5. *Test result of beam with ex-tubo fine aggregate*

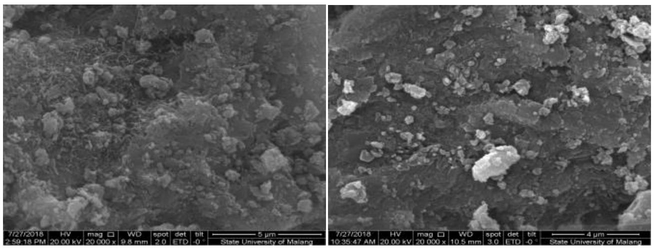

Fig. 6. *SEM on concrete with pumice fine aggregate (left) and concrete with ex-tubo fine aggregate*

The histogram diagram in Figure 4 is the result of load test observations on reinforced concrete beams that use pumice fine aggregate. The first histogram on the left is the magnitude of the load at the initial crack, the average load of the initial crack was = 19.17 kN with the average deflection observed = 0.61 mm. while the second histogram at the right is the highest load that can be held by beams, the highest average load was = 45.33 kN with an average deflection was = 1.43 mm. The average weight of the beam using pumice fine aggregate was = 18.97 kg.

Furthermore, the histogram in Figure-5 is the result of observations of beam samples with ex-tubo fine aggregates. The first histogram on the left is an observation when an initial crack occurs and the second histogram at the right is an observation of the beam maximum capacity. The average load on the initial crack is 23.33 kN with an average deflection = 0.81 mm and the average value of the highest load held by the beam is = 46.17 kN with an average maximum deflection = 1.67 mm. The average weight of the beam sample is 26.87 kg.

From the results of the beam testing, it is seen that the use of pumice fine aggregate as a concrete mixture does not change drastically the mechanical behavior of the beam structure. The biggest decrease in beam capability occurred at the initial crack condition which was 17.86%, but the capability limit between the two types of concrete beam was almost as large. The capability limit of concrete beams that use ex-tubo fine aggregates is 1.81% higher than concrete beams with pumice fine aggregates, but concrete beams using pumice fine aggregates are lighter than ex-tubo fine aggregate concrete beams. Weight reduction of beams using fine pumice aggregate up to 29.42% of the average weight of ex-tubo fine aggregate concrete beams.

The following Figure-6 are the results of SEM on concrete beams using pumice fine aggregates with concrete beams that use ex-tubo fine aggregates for micro structure observation.

The difference seen in the SEM results of the two types of concrete above is the surface texture and chemical composition and the concentration of the elements. Concrete that uses pumice fine aggregate, there appears to be tissue shaped like fine threads, while in concrete using ex-tubo fine aggregates, there is a dominant element in brightly colored grains.

IV. Conclusion

Basically, pumice fine aggregate can be used as material for normal concrete mixtures with a small FAS value. With the unique physical properties possessed by pumice fine aggregates also affect the mechanical properties of concrete beam structures that use pumice fine aggregate i.e. the reduced beams capability but the weight of the beams itself also becomes lighter. The use of pumice fine aggregate as a material for concrete is suitable to be applied for light constructions especially in earthquake prone areas such as in North Maluku. The use of pumice fine aggregate as a material for concrete will reduce the impact of environmental damage due to construction work activities.

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