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High strength lightweight concrete with expandable perlite as the aggregate

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Abstract. Lightweight concrete has been an interest due to its advantages compared to normal concrete. Lightweight concrete can be produced by the use of lightweight aggregates. In this study lightweight concretes were made with the composition of expandable perlite combined natural sand with each volume is 50% and concrete with 100% expandable perlite as the aggregates. The volume of the aggregates was varied from 80% up to 89%. The concretes were measured for their density and tested for the mechanical and absorption properties. As the results, expandable perlite obviously has the effect in reducing the concrete density. Nevertheless, the strength decrease as the expanded perlite aggregate increase. The optimum lightweight concrete that acceptable as the international standard is with the aggregates of expandable perlite combined natural sand having the 50% of each volume with the aggregates composition is 80%.

1. Introduction

Indonesia is endowed with abundant of both renewable and non-renewable natural resources. Considering the renewable natural resources such agricultural products, Indonesia is one of the world's major producers of palm oil and cocoa. Likewise, the non-renewable natural resources such mining products, Indonesia is one of the world's largest reserves.

Based on regulation concerning mineral and coal mining in Indonesia, mining efforts are grouped as mineral mining and coal mining. Mineral mining is categorized as radioactive mineral mining, metal mining, non-metal mineral mining and ore mining. One example that included in non-metal mineral mining and ore mining is perlite as one of the volcanic glass.

It is known that volcanic glass, in this case perlite is formed from the volcanic eruption, and the lava flows cooled rapidly. The rapid cooling of the lava trapped the water within the rock. Thus, perlite has relatively higher water content than obsidian due to hydration of volcanic glass. Perlite has water content ranged from 2% to 5%. While, the water content in obsidian is less than 2%. The characteristic feature which puts perlite unlike other volcanic glasses due to its water content is that, it can expand to four to twenty times its original volume when heated to its softening range between 900-1200 °C. Expanded perlite has porous structure, high water absorption and low density [1-3].

Expanded perlite can be utilized in building construction as a mixture of insulating medium, as a medium hydroponic planting, and as filler in paint making [2,3]. Mainly, the conventional applications of perlite are in construction field with the productions such as acoustic ceiling tiles, pipe insulation,



roof insulation board, etc. Nevertheless, the utilization of perlite in concrete has not been widely industrialized [4].

Concrete is a composite material contained of aggregates and cement that bonded together and hardens over time. Recently, lightweight concrete has been an interest due to its superiority in lower density, thermal conductivity, environmental friendly and presents many economic advantages [5,6]. Lightweight concrete can be produced by the use of lightweight aggregates. Considering expanded perlite has low density, it is a suitable aggregate for lightweight concrete [7,8]. Moreover, expanded perlite can produce water for the hydration of cement due to its high water absorption properties. However, the properties of the lightweight concrete and normal concrete are generally different. This study is aimed to provide more information on the density, mechanical properties, and absorption properties of the concrete with different variable of expanded perlite aggregates.

2. Experiments

2.1. Materials

The expanded perlite was provided by Indonesia's Mineral and Coal Technology Research and Development Centre. The composition of the expanded perlite was analysed with X-ray fluorescence spectroscopy (XRF) and the result is showed in table 1. The density of the expanded perlite is measured and the result is 150 Kg/m³. The cement used was Portland Cement.

2.2. Mixtures

The mixtures of the concrete were prepared using expanded perlite and natural sand. The mixtures were prepared and divided by unit volumes. The experimental proportions and the compositions arrangement are shown in table 1.

Table 1. Expanded perlite composition obtained by XRF.

Composition	Percentage (%)
SiO ₂	74,33
Al ₂ O ₃	12,75
Fe ₂ O ₃	0,95
K ₂ O	4,14
Na ₂ O	4,68
CaO	2,10
MgO	0,88
TiO ₂	0,15

3. Test methods

The specimens were tested for their density, compressive strength, and absorption. The water absorption test was done with the comparison of the weight between the wet and dry concrete after immersion.

4. Results and discussion

4.1. Results

Figure 1 shows the results of the concrete density measurements. It is clearly seen that the concrete with the 100% expendable perlite as the aggregate has the lowest density.

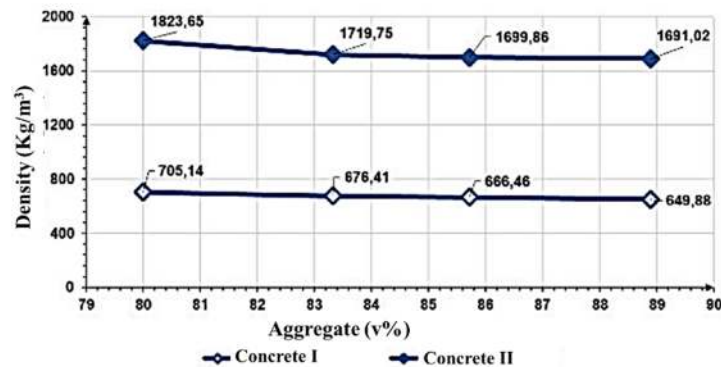


Figure 1. Density measurement results of the concrete with different types of aggregates.

The concretes were tested for the compressive strength and the results are presented in figure 2. The concrete that use mix aggregates of 50% expandable perlite and 50% natural sand shows superior compressive strength. However, as the aggregates volume increase the strength tends to decrease significantly and have the value close to the concrete with 100% expandable aggregates. On the other hand, the concrete with 100% expandable perlite aggregate shows relatively stable strength regardless the aggregates volume.

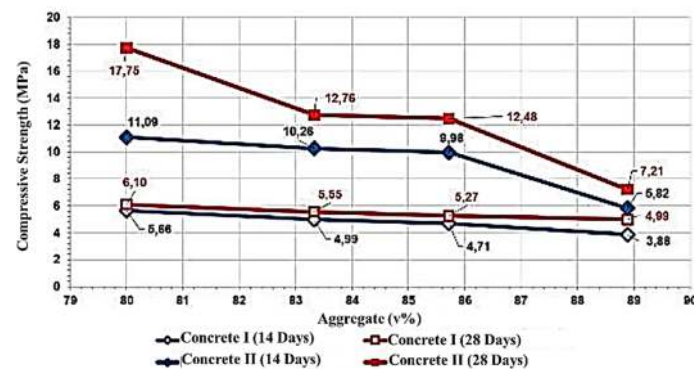


Figure 2. Compressive strength of the concrete with different types of aggregates and curing times.

Table 2. Experimental setup and mixtures arrangement.

Specimens Code	Volume Ratio (Cement : Aggregate)	Cement (v %)	Aggregate (v %)	Aggregate Composition
Concrete I	I.1	1:04	20	80
	I.2	1:05	16.66	83.33
	I.3	1:06	14.28	85.72
	I.4	1:08	11.11	88.89
Concrete II	II.1	1:04	20	80
	II.2	1:05	16.66	83.33
	II.3	1:06	14.28	85.72
	II.4	1:08	11.11	88.89

The absorption test results in figure 3 show that the concrete with 100% expandable perlite has higher absorption properties. The results were expected since the expandable perlite known has high water absorption property.

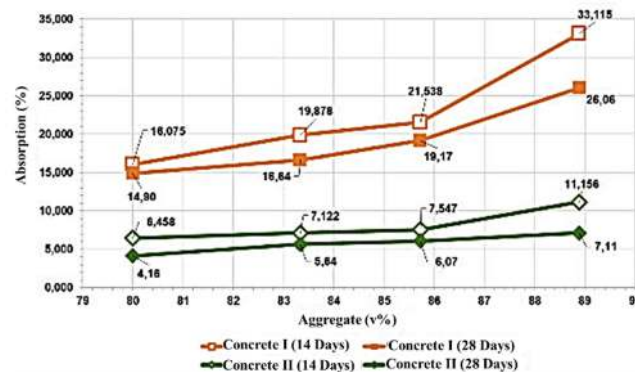


Figure 3. Absorption properties of the concrete with different types of aggregates.

4.2. Discussion

The density of the concrete can be reduced by the use of expanded perlite as aggregate (figure 1). Light weight concrete can provide significance structural advantages. The dead load of a structure can be reduced and the structure earth quake resistant can be increased [9]. The requirement of structural lightweight concrete is with the density of 1350–1920 Kg/m³ [10]. The results in figure 1 show the density of concrete with 100% expandable perlite is in the range of 649,88 – 705,14 Kg/m³. While, the density of concrete with 50% expandable perlite and 50% natural sand is in the range of 1691,02 – 1823,65 Kg/m³. These results suggest that the concrete with mix aggregates is more close to the requirement. In addition, the requirement of structural lightweight concrete also stated the minimum strength 17.0 MPa [10]. Thus, it is clear that the concrete with mix aggregates with 80 v% fulfill the prerequisite density and strength. Figure 4 shows the relationship of density and compressive strength of the concretes.

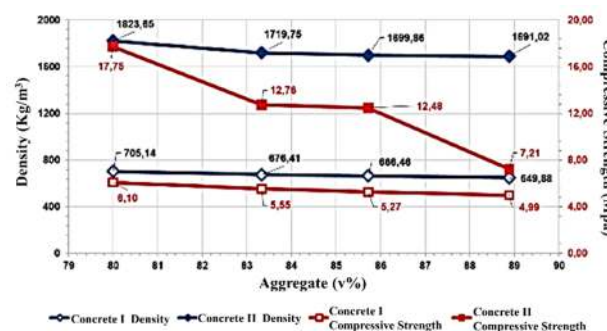


Figure 4. The relationship of density and compressive strength of the concrete with different types of aggregates.

Expanded perlite obviously contributed to the low density of the concrete. Nevertheless, its addition as an aggregate produce lower compressive strength.

Expanded perlite has porous structure and low compressive strength. Hence, the effect of low strength concrete with expandable perlite as aggregates is expected. The porous structure of expanded perlite has also contributed to the high absorption property. As the volume of the expanded perlite increase the water absorption increase (figure 3).

5. Conclusion

Expandable perlite as a concrete aggregate has the effect of reducing the concrete density. The porous structure of the expanded perlite has also contributed to the high water absorption property of the concrete. However, the addition of the expandable perlite as the aggregates has reduce the compressive strength of the concrete. The most optimum composition of the lightweight concrete is 50% expandable perlite and 50% natural sand with the aggregates 80 v%.

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