

THE EFFECT OF PYROPHYLLITE USE AS ADMIXTURE IN LIGHT CONCRETE BRICKS'S MECHANICAL PROPERTIES

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ABSTRACT

Pyrophyllite was extracted from Greek Language, in which *pyt* means fire and *phyllon* means leaf or sheet. Otherwise, *phylit* was found not long after *phyllon* word, in which the meaning was crack's sheet. Pyrophyllite is combination of silica alumunium that has chemical formula $Al_2O_3 \cdot 4SiO_2 \cdot 2H_2O$. In this research, testing was conducted for mechanical properties of light concrete brick provided by additional material "Pyrophyllite stone" as additive. The mechanical properties of light concrete brick consist of compressive strength, porosity, stress and strain curve, and elastic modulus. Testing resultsof the light concrete brick will be compared with that without mix of Pyrophyllite additive.

Keywords: Pyrophyllite, concrete, light concrete brick, mechanical properties, admixtures

INTRODUCTION

In the field of building construction, we as engineers are often only considering about building's strength and costumer's convenience. We should start to consider the environment because environmental-friendly construction needs a lot of cost than common construction. Currently, environmentally friendly construction materials are being pursued in order to be used as efficient as possible and provide convenience construction for future users. We should be able to better utilize materials that are environmentally friendly and can cope with various problems in the construction world.

With the construction of which is currently being developed, lightweight brick is a solution that is right and appropriate for the resolution of problems in the field of building construction, because in addition to ease in building construction, light brick can also be designed according to the needs of the

construction's development process. In addressing these issues, generally light brick is still imported from abroad. The increasing demand for lightweight brick in the future spurs writers to do research on this lightweight brick.

Pyrophyllite is a type of metamorphic rock that has the properties can be activated by the effect of acid and heat. In East Java Province, this material is widely available in south Malang area, precisely in Sumbermanjing sub district, Malang District. Seeing this local potential opportunity, then these pyrophyllite metamorphic rocks can be performed rocks material processing development in detail.

This research aims to find mechanical properties of lightweight concrete brick's mechanical property by adding *Pyrophyllite* ($Al_2O_3 \cdot 4SiO_2 \cdot H_2O$) including analyze compressive strength, porosity, stress-strain diagram and elasticity modulus of the lightweight concrete bricks. Pyrophyllite rock with its

ability was blended into the constituent materials of lightweight brick. In the manufacture of lightweight brick which is composed of sand, cement, water, foaming agent as a developer (air filler chemically) mixed into a dough and rise for 7-8 hours. The research was conducted by making test specimens with variations Pyrophyllite amount to be added to the dough of the lightweight brick (additive material) with the addition of other variables such as the type of cement which will be used. Then the specimens were press-tested of lightweight bricks of the bricks which have been designed. Then the result of lightweight bricks mechanical properties will be compared to lightweight bricks mechanical property without any pyrophyllite addition.

REVIEW OF RELATED LITERATURE

1. Stress

Stress is defined as the force per unit area (Dieter, 1996), which is a force and moment that acts on a point of cross-section pieces and produce stress distribution which acts on the cross section. This stress usually is given with Greek letter σ (sigma). By assuming that stress is distributed evenly on a cross-section and the meaning of stress is mentioned as force per unit area, then the formulation of stress can be written as follows:

$$\sigma = \frac{P}{A}$$

2. Strain

When a force acts on an object, the force will tend to change shape, whether these changes lead to addition or reduction in the number of the total volume. Elastic deformation of an object is not only lead to changes in the length of a linear element in the object, but can also lead to changes in the angle between

any two lines (Dieter, 1996). Strain described as a deformation that occurs on length and angle between two points. Normal strain can be defined as the increased length of unity length which is expressed in the Greek letter ε (epsilon) and given the equation:

$$\varepsilon = \frac{\delta}{L}$$

If a material experiencing such materials appeal to experience tensile strain, that the reduction of the length of its original length, whereas if the material is in compression the strain called compressive strain.

3. Stress-strain

Based on the formula that has been written above regarding normal stress and normal strain, it can be made to a diagram of the interaction between the stress strain that occurs in a material. This diagram is obtained after conducting test on a specific material such as tensile and press test, and determine the value of the stress and strain in a variety of different values. Stress strain diagram is a characteristic ingredient and contain important information about mechanical properties and types of behavior.

Some of the stress strain characteristics of the porous material can be seen by the graph above, which is divided into three zones (Abdul Rahman, et al., 2008)

a. Elastic Property (*Elastic Regime*).

The elastic behavior of porous materials is very different from the elastic behavior of the steel.

b. Strength Increasing (*Plateau Regime*).

Stress that occurs increases with increasing values of strain that occurs in a material.

c. Densification (*Densification Regime*)

Curve that shows the ability of a material to resist forces that it receives until it reaches the ultimate stress (maximum).

The relationship between strain and stress for a material experienced drag or press is being researched by Robert Hooke in 1676, better known as Hooke's law.

$$\sigma = E \cdot \varepsilon$$

With:

E = Young Modulus

ε = Strain

σ = Stress

4. Porosity

The porosity of a material is the ratio of the volume of empty cavities to the total volume of material. This comparison is usually expressed in percent and is called porosity. The magnitude of the porosity of a material varies from 0% to 90% depending on the type and application of these materials. There are two types of porosity are open porosity and closed porosity. Closed porosity is generally difficult to determine because the pores are trapped in a cavity in the form of solids and there is no access and exit the outer surface, while the open porosity is still no access off the surface, although the cavities in the midst of solids. The porosity of a material is generally expressed as an open porosity with the formula (Van Vlack, Lawrence H., 1989):

$$\text{Porosity} = \frac{wb-wk}{wb-wa} \times 100\%$$

With :

W_a = mass of water saturated samples were weighed in water (gram)

W_b = mass of water saturated samples were weighed in air (gram)

W_k = The mass of the sample after oven (gram)

Lightweight concrete brick is a porous concrete bricks have air cavities generated by air flow, mixing foam and also a combination of both. Porosity lightweight concrete brick Cellular Lightweight Concrete types can reach 80% with a pore size of 50-500 μm , while modern brick lightweight concrete (AAC) has a porosity of 60-90% of the total volume of material (Narayan, Ramamurthy, 2000).

5. Elasticity Modulus

Elasticity Modulus is comparison of stress and strain in elastic area. The standard of a material's elastic character is elasticity modulus which is comparison of stress that given with the transformation per length as the result of the stress given. The higher material's compressive strength is, the higher its elasticity modulus. Modulus of elasticity of the material varies according to the strength and depending on the age of the material, the properties of aggregates and cement, speed of loading, type of cement and the size of the test specimen (Wang and Salmon, 1985). Strain is the rate of relative change to the length obtained from the magnitude of the change in length divided by original length. The ratio of stress to strain is called the modulus of elasticity. Because strain did not have the unit value, then the modulus of elasticity is expressed in the same units as stress which is MPa or kg/cm^2 .

$$\varepsilon = \frac{\Delta L}{L}$$

Static modulus of elasticity can be defined as the ratio between stresses with unity length deformation due to the applied voltage. In general the equation of static elasticity modulus of concrete is given as follows:

$$E_s = \frac{\sigma}{\varepsilon}$$

Where:

- E_s = Static Elasticity Modulus (MPa)
- σ = Stress (MPa)
- ε = Strain
- ΔL = Change in Length (mm)
- L = Initial Length (mm)

RESEARCH METHOD

Research method can be seen at **Figure 1**.

RESULT AND DISCUSSION

1. Diagram of Stress-Strain

In the trial stress strain diagram is connected with compressive strength test. At the time of compressive strength testing takes place, any increase in the maximum load of 4 kN the decline in lightweight concrete brick was recorded. By using a dial mounted on the plate so the reduction in gain that occurred in each specimen, it can be calculated strain that occurs in the specimen using the following formula:

$$Strain (\tau) = \frac{\Delta L}{L}$$

Where:

- ΔL = Occurred Decline (cm)
- L = Length before decline (cm)

After processing the data of the relationship of stress and strain variations that occur from each specimen, the average data obtained for each specimen can be seen at **Figure 2**.

2. Porosity Test

Porosity test performed after a 28-day-old specimen with a consideration when aged 28 days then the binding process of cement with aggregate in it have been completed. The data obtained from the results of tests performed in the laboratory of Structural and Construction Materials, Department of Civil

Engineering, UB. Porosity values were calculated and are presented in **Table 1**.

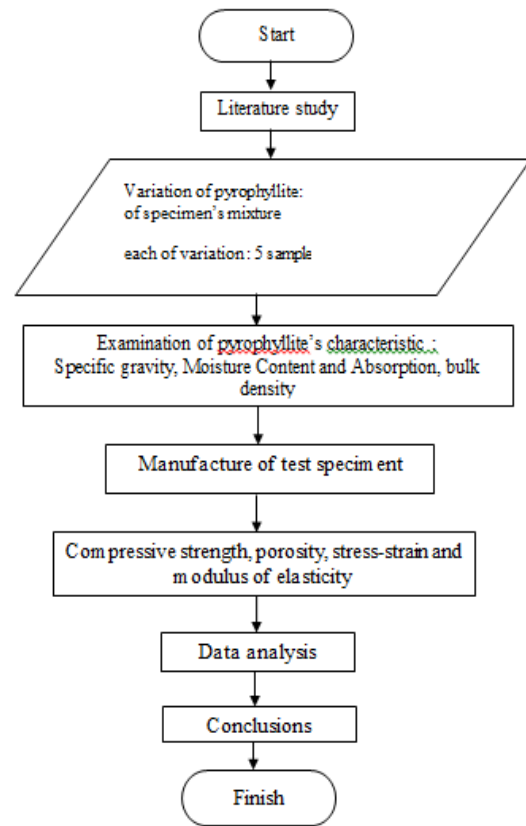


Figure 1. Research flowchart

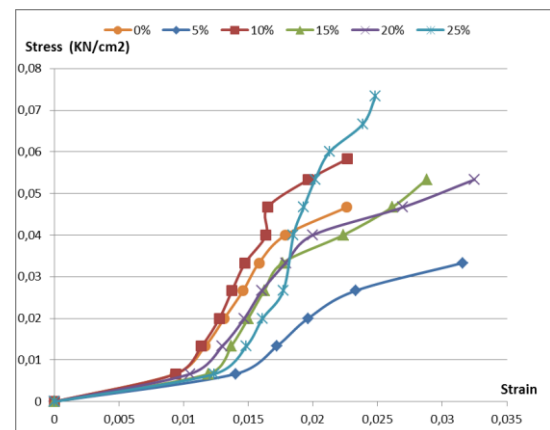


Figure 2. Diagram of average stress strain in every variation of specimens

Table 1. Table of lightweight bricks' porosity calculation result

Sample	Elasticity Modulus (KN/cm ²)				
	Variation of Pyrophyllite Level				
	0%	10%	15%	20%	25%
1	3,604	3,104	5,135	4,004	5,612
2	3,627	4,890	5,815	4,802	6,034
3	4,256	4,963	5,941	5,333	6,914

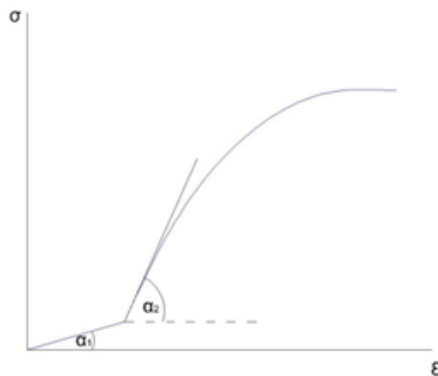


Figure 3. Diagram of stress-strain

Table 2. The result of lightweight bricks elasticity modulus

Sample	Porosity (%)				
	Pyrophyllite Level Variations				
	0%	10%	15%	20%	25%
1	18,96	23,08	18,86	18,29	16,73
2	19,58	23,76	21,10	19,16	17,19
3	20,29	23,90	21,47	19,34	17,99

3. Elasticity Modulus Test

Once the data is owned by that is compressive strength's data, and the reduction of the specimen recorded by a dial mounted on the plate, the strain values obtained where the value of ΔL is data of specimen reducing due to loading in Compression Test, then, the data were divided into initial length to obtain strain value. Diagram-stress obtained in this study can be seen at **Figure 3**.

The stress diagram shows behavioral changing in linear phase (phase I), wherein that phase the specimens are having compression and

there are cavities inside. In the next phase (phase II) stress diagram was having non-linear behavior which is called as elastic phase (*elastic regime*). While strength increasing phase (*plateau regime*) in this diagram is cannot be seen because in that phase the specimens is already failed so it is difficult to observe the stress-strain. The modulus of elasticity is calculated in this phase by using the initial tangent modulus of the slope of the curve at the origin of elastic phase. The result of Elasticity modulus is presented in **Table 2**.

4. Regression Analysis

In this regression analysis it is used to find correlation equation of stress and strain. Stress and strain were obtained from the results of research that has been done. By using this regression analysis, it will produce a graph of correlation between stress and strain which is more appropriate.

This research of stress and strain on lightweight concrete brick has been through several phases in the suppression of the following conditions

1. Linear Phase :

In this phase the specimens were condensed and there is reducing of cavities inside the specimens. This phase used linear regression equation. So the regression used is as follow:

$$S = g(x) = a_1 \epsilon$$

With the values:

S = Specimen's stress (kg/cm²)

ϵ = specimen's strain

a_1, \dots, a_n = polynomial coefficient

2. Non-Linear Phase

In this phase the specimens were experiencing a strong strength so the value of the strength (stress) is high but the strain is decreased. This continues to happen until there is maximum stress and maximum strain. In this phase used two

degrees polynomial regression equation. So the regression used is as follow:

$$S = g(x) = a_1\varepsilon^2 + a_2\varepsilon + a_3$$

Where:

S = Specimen's stress (kg/cm²)

ε = Specimen's Strain

a₁, ..., a_n = Polynomial Coefficient

After obtaining the regression equation of the two regression lines on each specimen, the regression formula of each specimen was made in one chart and can be seen in **Figure 4**.

To determine the effect or the relationship of the independent variable (x) with the dependent variable (y) in the regression analysis porosity, used polynomial regression analysis as follows:

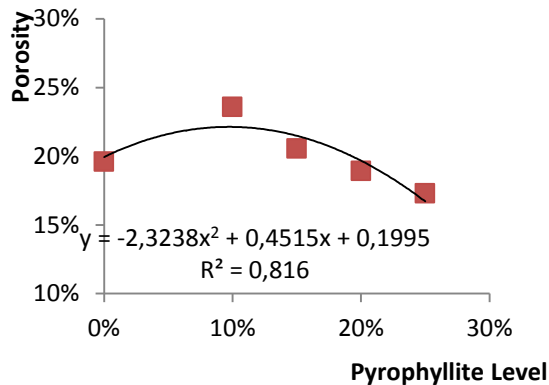


Figure 5. The result of lightweight bricks average porosity regression

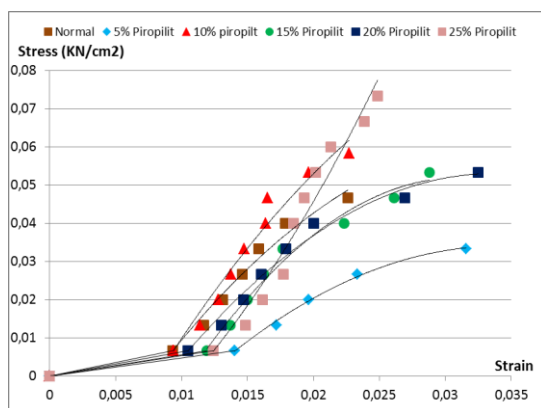


Figure 4. Communal regression stress strain diagram

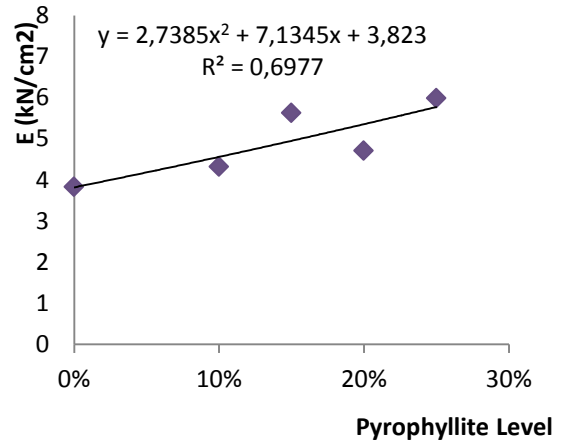


Figure 6. Result of lightweight bricks average elasticity modulus

From the results of the regression analysis for lightweight brick porosity obtained suitable regression equation is $y = -2,323x^2 + 0,451x + 0,199$, with determination coefficient, $r^2 = 0,816$. It can be seen from the regression results in the increased value of the porosity levels of 20% and gradually decreased to levels of 15%, 20% and 25%. The calculation of optimum porosity value is as follows:

$$Y = -2,323x^2 + 0,451x + 0,199$$

$$dy/dx = -4,646x + 0,451$$

$$\text{Optimu Porosity, } dy/dx = 0 \rightarrow x = 10,301\%$$

$$Y = -2,323(10,301\%)^2 + 0,451(10,301\%) + 0,199 = 22,081\%$$

From the results of these calculations porosity values obtained optimum levels of 22.081% on the addition of 10.301% Pyrophyllite.

From the result of regression analysis of lightweight bricks elasticity modulus obtained equation $y = 2,738x^2 + 7,134x + 3,823$, with determination coefficient, $r^2 = 0,697$. The minimum point of the regression results is contained in the boundary curve at levels

of 0% addition of Pyrophyllite. From the regression results can be seen in the light brick Pyrophyllite additions tend to increase the modulus of elasticity of the lightweight brick.

5. Compressive Strength Comparison

It is expected from this research there is increasing of lightweight concrete brick strength as the result of Pyrophyllite addition of 5%, 10%, 15%, 20%, and 25%. Thus the comparison is presented in table of comparison of compressive strength from without Pyrophyllite addition to with Pyrophyllite addition.

For the variation of Pyrophyllite addition 5% is experiencing strength decreased, it is because the data is invalid with the statistic trial attached in attachment 8. So the variation of 5% Pyrophyllite can be ignored.

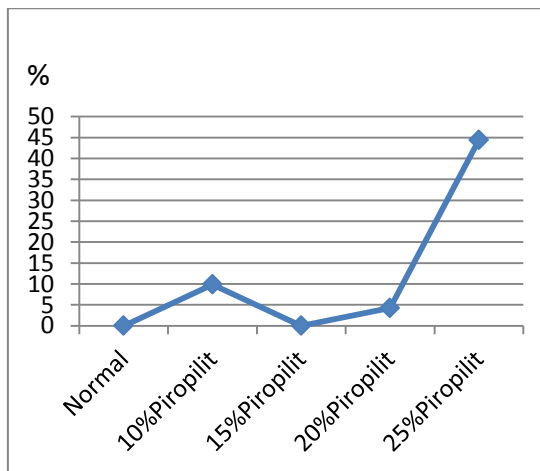


Figure 7. Graph of specimen's strength changes

CONCLUSIONS

Some conclusion regarding lightweight concrete brick test with pyrophyllite addition are as follow:

- 1) With the addition of pyrophyllite influence on the compressive strength will certainly affect the stress and stress. It can be concluded that the stresses and strains that occur

in each variation differs according to the level of addition of Pyrophyllite on lightweight concrete brick. Which is the greater the level of addition of Pyrophyllite on lightweight concrete brick, then the stress is getting bigger and decreasing strain occurs.

- 2) Specimen porosity value with different variation which are normal, addition of 10%, 15%, 20%, dan 25% Pyrophyllite give porosity values as follow 23,581%, 20,548%, 18,930% and 17,299%. From the results of statistical analysis is known that addition of the amount Pyrophyllite into lightweight bricks will have a significant effect on the porosity of light brick with the lowest porosity at the 25% level.
- 3) Modulus of elasticity obtained in the test object get from a normal variation, addition of 10% Pyrophyllite, addition of 15% Pyrophyllite, addition of 20% Pyrophyllite, and addition of 25% are as follows 3,829 KN/cm², 4,319 KN/cm², 5,620 KN/cm², 4,713 KN/cm², and 5,987 KN/cm². From the analysis of the differences significantly influence the variation of the modulus of elasticity of lightweight brick.

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