# THE EFFECT OF VARIATION OF PYROPHYLLITE ADDITION TO COMPRESSIVE STRENGTH, POROSITY, AND DIAGRAM OF STRESS STRAIN IN BURNT LIGHTWEIGHT CONCRETE BRICK

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## ABSTRACT

Lightweight brick is a material widely used in civil engineering as a substitute alternative material and brick walls of the building material. The aim of this study is to determine the behavior of burnt light brick, and behavior of piropilit additions in the mix proportion of the light brick. Specimens were tested by compressive strength, porosity, and modulus of elasticity. To test the compressive strength, plates were set at the top and bottom of the test specimen; a dial gauge was used to determine the deformation. To test the porosity, the specimen was cut into a size of 15 x 20 x 10 $cm^3$ and tested in accordance with porosity testing procedures. Data for the elastic modulus was obtained from stress and strain testing in conjunction with the compressive strength test. After the age of 28 days, specimens undergo combustion process before tested in the laboratory. Results of this study show that the addition of amount of piropilit as filler as much as 10-25% by weight of cement will increase the strength of brick light post-combustion at $800^oC$ temperature along with the increasing number of additional piropilit in it, however the addition of 5% would reduce the value of compressive strength. The addition of piropilit in the burnt lightweight brick will decrease the value of the strength. Porosity and modulus of elasticity values indicate that the addition of a filler piropilit as much as 5-15% by weight of cement on the burnt brick would increase the value of its porosity, however the addition of 20% and 25% would reduce the value of porosity. The modulus of elasticity values obtained from the stress and strain diagram, an increase of 5% -25% variation pyrophyllite additions. However there are some fluctuation trends on a variation of 5% -20% due to piropilit characteristics that do not fit to undergo the process of combustion or due to the setting position of the specimen in the furnace when the combustion process which allows the specimen exposed to direct flame or not.

**Keywords:** burnt light brick, compressive strength, stress-strain curve, porosity, elastic modulus

## INTRODUCTION

Green construction is currently being promoted so that the materials will be used as efficient as possible and provide convenience for the construction's future users. In Indonesia, especially in densely populated areas in the big cities, which has very high potential of fire disaster. Some cases have occurred primarily in big cities like Jakarta and buildings that have been affected by fire would be abandoned and caused eyesore on the city. This is not a good environment friendly construction because the presence of waste materials and the processing of waste are not good. In addition, the need of materials that have a lighter weight is also very necessary in the construction of buildings, especially at high level, because heavy material will affect on the resulting magnitude earthquake loads that will be accepted by the building. Nowadays, Indonesia uses red bricks in the construction of the wall, however when compared to the red brick production that consumes very large energy, it is a material that less friendly to the environment.

Lightweight brick is the solution for the problem, because not only ease the building construction but also hold the fire heat. In addressing this issue, refractory lightweight bricks in general are still imported from abroad, especially the type of refractory magnesite materials. The increasing of lightweight brick needs in the future force the writers to conduct research about this refractory lightweight bricks. This refractory lightweight brick will be environmental friendly because of its dense form and made from cement that will not become animal's nesting site.

Pyrophyllite rocks have been long time used in some researches as materials that can be isolator or refractory materials. Pyrophyllite is a combination of aluminum silicate, which has chemical formula $Al_2O_3.4SiO_2H_2O$. Minerals that concluded as pyrophyllite are kianit, andalusit, and diaspor. Piropilit crystal form is monoclinic and has the physical and chemical properties similar to talc. Piropilit formed generally associated with the formation of old andesite, which has control of the structure and intensity of strong hydrothermal alteration. Pyrophyllite was formed in advanced argilic alteration zone (hipogen), such as kaolin, however formed at high temperatures and acidic pH (http://bumi-is-earth.blogspot.com). Piropilit is a type of metamorphic rock that has the properties can be activated by the effect of acid and heat. In East Java, this material is widely available in Southern dictrict of Malang residency, precisely Sumbermanjing district. Seeing the opportunities for the local, metamorphic rock types can be performed piropilit rock material processing development in more detail especially be done for fire-resistant materials.

## REVIEW OF RELATED LITERATURE

### 1. Stress-strain

Stress is defined as the force per unit area (Dieter, 1996), which is a force and moment acting on a point of cross-section pieces that produce stress distrihoweverion acting on the cross section. By assuming that the stress was distribute evenly in a cross-section and the meaning of stress is force per-unit area then the formula of stress can be written as follows:

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

Strain described as a deformation that occurs on length and angle between two points. Normal strain can be defined as the length of the length of unity expressed in Greek letters ε (epsilon) and given equation:

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

If a material is experiencing tensile, then the material is experiencing tensile strain, which means the reduction of length from its original length, were as the material is experiencing compression, then the strain is called as compressive strain.

Based on the formula that has been written above about the 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 testing on a specific material such as tensile test or press test and determine the value of the stress and strain in a variety of different values. Stress strain diagram show the characteristic of material and contain important information about the mechanical properties and types of behavior.

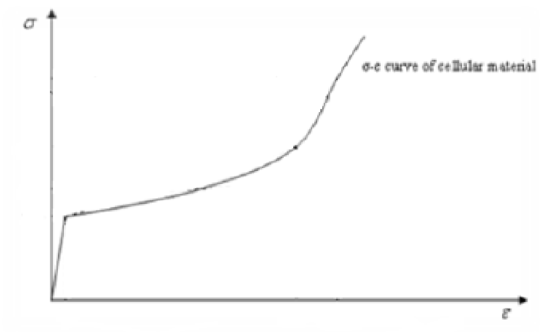


**Figure 1**. Stress-strain diagram of porous material (cellular material), (Abdul Rachman, et. al., 2008)

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 Properties *(Elastic Region)*
   The elastic behavior of porous materials is very different from the elastic behavior of the steel.
b. Strength Increasing *(Yield Region)*
   Stress that occurs increased along with increasing values of strain that occurs in a material.
c. Plastic *(Plastic Region)*
   Curve that shows the ability of a material to resist forces that it receives until it reaches the ultimate stress (maximum).

Robert Hooke performed the relationship between stress and strain of a material, which is experiencing tensile in a research in 1676 and commonly known as Hooke law.

$$\sigma = \boldsymbol{E}.\boldsymbol{\varepsilon}$$

Where:
$\boldsymbol{E}$ = Modulus Young
$\boldsymbol{\varepsilon}$ = Strain
$\boldsymbol{\sigma}$ = Stress

## 2. 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):

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

Where:
Wa = mass of water saturated samples were weighed in water (gram)
Wb = mass of water saturated samples were weighed in air (gram)
Wk = 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).

## 3. 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 that is MPa or kg/cm2.

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

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

Analysis flowchart will be presented in **Figure 2.**

In this research, variaton of pyrophyllite : 0%, 5%, 10%, 15%, 20%, 25% of specimen's mixture weight.

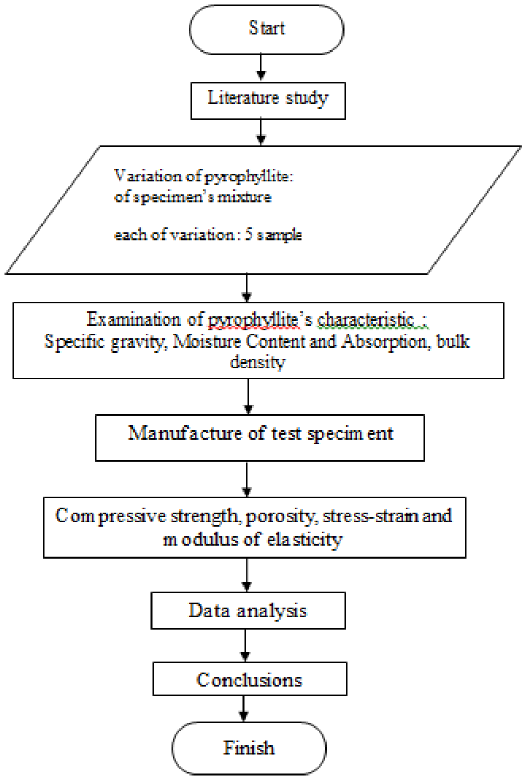


**Figure 2.** Research flowchart

## RESULT AND DISCUSSION

### 1. Pyrophillite

- Examination of pyrophyllite's Specific Gravity, Moisture Content and Absorption.

  Pyrophyllite which is used in this rearch is from southern Malang, and the size of pyrophyllite grain used is as *filler*, which means material which passed filter number 200. From the results of research, the data obtained in **Table 1**.

### 2. Burning Test

- **Specimen's Burning**

  After the specimens were mixed, the speciment were settled in open space for 3 days then stored in a locked room for 28 days. After the 28-day-old specimen, then the specimen tested in the furnace of fire burning up to temperatures of 800°C. Temperature was increased gradually ±30° C in every 10 minutes to avoid an explosion in the furnace (Explosion). With reference to ASTM E 119 (Fire Test of Building Construction and Materials), the temperature increase in the combustion diagram is presented at **Figure 3**.

**Table 1**. Pyrophyllite inspection result

| Number of Example | A |
|---|---|
| Bulk Spesific Gravity | 1.756 |
| Bulk Spesific Gravity Saturated Surface Dry | 2.097 |
| Apparent Spesific Gravity | 2.664 |
| Absorption (%) | 19.388 |
| Moisture(%) | 3.050 |

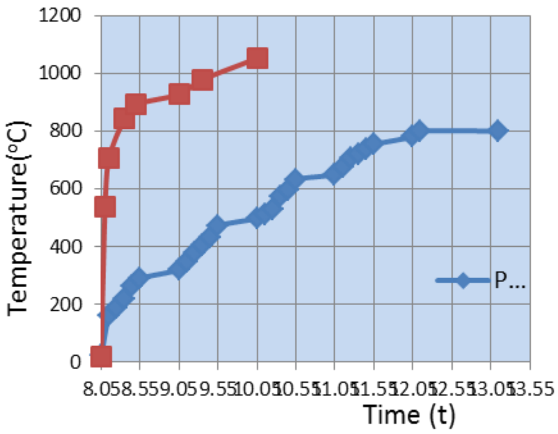


**Figure 3**. Burning graph

**Table 2.** Specimen's bulk density in every variation

| No | Variation | Bulk density (gr/cm3) | | | | | |
|---|---|---|---|---|---|---|---|
| | | Normal | 5% | 10% | 15% | 20% | 25% |
| 1 | specimen 1 | 0.68 | 0.68 | 0.79 | 0.75 | 0.79 | 0.88 |
| 2 | specimen 2 | 0.69 | 0.68 | 0.79 | 0.78 | 0.78 | 0.87 |
| 3 | specimen 3 | 0.66 | 0.69 | 0.78 | 0.77 | 0.76 | 0.87 |

- **Specimen's Cooling**

  The specimen has been experienced burning process to temperature of 800° C the settled for one day until reach room temperature. The decrease in temperature was also carried out in stages, a new furnace can be opened when the temperature inside the furnace reaches 300° C. Then the specimen removed and carried back to the Lab.

## 3. Results

- **Specimen Checking**

  The bulk density checking is done by weighing the specimens in laboratory and the data were divided with the specimen's volume.

$$bulk\ density = \frac{Mass\ (gr)}{Volume\ (cm^3)}$$

Calculation of bulk density of each specimen of each variation in attachment 5, and obtained the results in **Table 2**.

- **Specimen's Compressive Strength Testing**

  Compressive strength test performed to test objects have cracks and no longer able to hold greater loads. Specimen undergone phase combustion and cooling. Loading process is done by means of compression test (Compression testing machine) and a plate placed on the test specimen mounted on the top and bottom. Calculation of compressive strength test specimens with cement-water ratio value was set at 0.415 in attachment 5. The results of the calculation of compressive strength test specimens and diagrams the average compressive strength is presented in **Figure 4**.

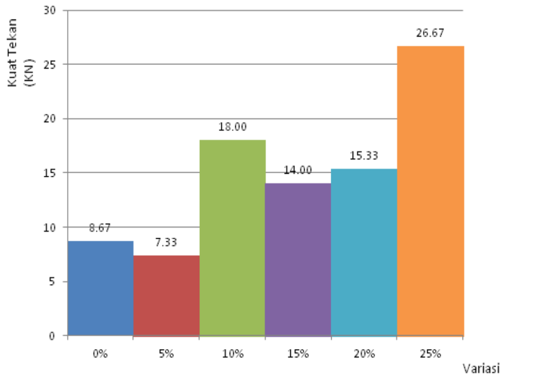


**Figure 4.** Result of specimen's average compressive strength in every variation

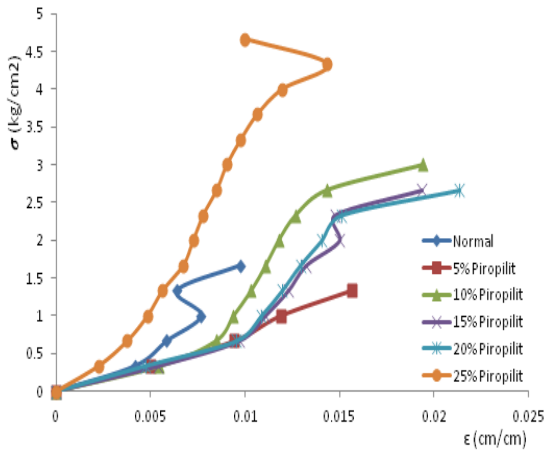


**Figure 5**. Diagram of specimen's average stress-strain

- **Stress-strain Diagram**
  After the data obtained which are compressive strength data and specimen's decreasing data that recorded through dial installed in plate gained the strain value.
  Where the value of **Δ**L is the data of specimen reduction as the result of loading in *Compression Test*, then the data were divided with the initial length ao the strain value can be obtained. The complete result of stress-strain diagram is presented in **Figure 5**.

- **Regression Equation Analysis**
  From the results of experiments testing press, also obtained strain values obtained from the value of the rotating dial plate rested on the test specimen. The dial is mounted on the right and left of the test object, then the value used is the average of the two values of the dial. From the data obtained compressive strength value of stress, and dial test data obtained from the strain of data that is the result of dividing the change in length to the initial length.It should be noted here specimen undergoing a process of change in properties as noted in previous studies, ie:

**1. Elastic Phase (Elastic Region)**

In this phase the specimen is condensed and there is reducing of cavities inside the specimen. This phase used polynomial regression equation (Linier). So the regression used is as follow:

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

Where:

S = Specimen's Stress (kg/cm2)
ε = Specimen's Strain
$a_1,...,a_n$ = Polynomial Coefficient

**2. Strength Increasing Phase (Yield Region)**

In this phase the specimens were experiencing a strong strength so the value of the strength (stress) is high however 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,...,an = Polynomial Coefficient

3. **Plastic Phase (Plastic Region)**
In this phase of the test specimen has reached its peak and has experienced failure in the form, which has been very much fractured and there was no increase in the value of its strength, so that the specimen has reached its peak and the data can not be taken.

## CONCLUSIONS

Based on the research that has been conducted, the conclusion can be taken as follow:

1. The relationship between stress and strain is presented is relationship diagram that is stress-strain diagram. The statistic test shows pyrophyllite addition in lightweight brick will affect the shape of stress-strain diagram. The higher pyrophyllite percentage (%) added to lightweight mixture, the diagram will be shifted to the left. Changes in the form of stress and strain diagram show the mechanical properties the material to be better than ever.
2. The research data show that total percentage (%) of maximum pyrophyllite cannot be concluded yet because the value of strength increasing is getting higher and better along with pyrophyllite addition into the mixture of lightweight bricks, so it has not decided the optimum value for pyrophillite addition.
3. Specific gravity of lightweight bricks were increasing when added pyrophyllite to specimen's mixture, so it is higher than specific gravity of normal specimen without pyrophyllite, however the value is still in the requirements which is 1,681 gram/cm$^3$ ( ASTM C140)
4. Pyrophyllite addition as filler with 5 variations starts from 5%-25% of cement's weight in lightweight concrete bricks and by experiencing burning process it has significant effect to the value of its porosity and elasticity modulus. For lightweight concrete bricks addition in 5%-15% is increasing, however for variantions of 20% and 25% is decreasing if it is compared to lightweight concrete bricks without pyrophyllite. However generally, from 5%-25% is experiencing porosity decreasing. While for the elasticity modulus, pyrophyllite addition is also significantly affects. Based on the data, variations of 5%-25% was having increasing trend, only few up and down trend between 5%-20%. This is due to the location of the test object during the burning process which allows the specimen exposed to direct flame or not, so the condition of the test specimen after the burn there is good and there are less good.
5. For the significant and optimum increasing of porosity and elasticity modulus of burnt lightweight concrete bricks is not happened in the variation of 20%, however the significant increasing for porosity was happened in variation of 5% pyrophyllite addition and elasticity modulus in 25% of pyrophyllite addition. This is not consistent with the initial hypothesis which written by the writters, because the characteristic of pyrophyllite used is pyrophyllite from Sumbermanjing area, Southern Malang is not suitable to experiencing burning process.

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