The utilization of gypsum board and fly ash waste on brick in terms of compressive strength to reduce environmental pollution

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Abstract. The utilization of gypsum board and fly ash waste as alternative materials in making bricks is one of the efforts to reduce the amount of industrial waste in the construction sector, namely gypsum board and fly ash waste. The use of gypsum board and fly ash waste cannot be separated from relatively large amount and the potential to pollute the environment. The pozzolanic properties contained in fly ash combined with gypsum board waste are expected to improve the quality of the bricks. The purpose of this study was to determine the value of the compressive strength of bricks. The method used is an experimental research method in which variations in the composition of gypsum board and fly ash waste are 0% and 0%, 5% and 25%, 7.5%, and 27.5%, and 10% and 30% of the weight, respectively. cement using a sample size of 37 x 10 x 15 cm. Based on the results of the study, it showed that the compressive strength test of the gypsum board and fly ash waste bricks had met the quality requirements according to SNI 03-0349-1989 with the average compressive strength value for each composition of 42.37 Kg/cm², 73.04 Kg/cm², 49.30 Kg/cm², and 43.59 Kg/cm².

1. Introduction
Brick is a building material for masonry walls whose manufacture uses a mixture of Portland cement, aggregate, and water with the addition of other materials (additives), shaped like bricks so that they meet the requirements as wall pairs (SNI 03-0349-1989). In the process of making cement bricks, cement is the main raw material because it has a function as a binder with other materials. However, one of the causes of the increase in global temperature is the process of making cement in Indonesia which seems to use a lot of energy and produces CO2 [1]. The recorded demand for cement in 2017 reached more than 65 million. In connection with this, it is necessary to innovate to find other materials that can be used as alternative materials to replace cement to support the concept of green material. These alternative materials can be in the form of utilization of industrial waste that has been disposed of and reused. Some of the industrial waste materials that can be reused are gypsum board waste and coal (fly ash).

Data from the Directorate General of Electricity (KESDM) shows that the potential for fly ash and bottom ash waste from 2018 to 2027 is 16.2 million tons with the assumption that 10% of coal use is the result of 162 million coal needs. Fly ash produced from coal combustion is a fine and light powder containing pozzolans, namely silica and alumina. Fly ash granules can be a filler material between the
cement granules in the brick. So that the brick becomes denser which then affects the compressive strength and water absorption. The addition of fly ash at a certain percentage of the weight of cement can increase the compressive strength of the bricks [2].

Meanwhile, gypsum board waste is an easy industrial waste and is only readily available. Budiono [3] stated that the use of gypsum board in Indonesia is influenced by the number of uses, which is around 100 million m² of a population of about 270 million people, which can cause a waste of gypsum board as much as 450,000 tons/year which may pollute the climate. The content of chemical compounds in gypsum board, such as cement, consists of 0.07% Fe₂O₃, 2.4% SiO₂ and 52.39% CaO. According to [4], the addition of 25% of gypsum board substitution by weight of cement can increase the compressive strength of bricks by 5,729 kg/cm².

Because the use of industrial waste in the form of gypsum board and fly ash is less than optimal, it is also to reduce environmental pollution generated from these wastes. So, in this study, gypsum board and fly ash waste will be used as a mixture for bricks as a substitute for cement. The hope is that besides improving the quality of the bricks themselves, it also reduces the amount of waste in Indonesia.

2. Methods

2.1 Material

Portland cement type 1, fine aggregate (sand), water free from chemical content, gypsum board waste and fly ash. With variations in the percentage of Gypsum board and Fly ash waste as much as 5% and 25%, 7.5% and 27.5%, 10% and 30% of the cement weight. Table 1 is the need for test objects based on mechanical testing used in this study.

Table 1. Samples of test objects

| Testing            | Ratio Cement and Aggregate | Dimension (Cm) | Percentage Gypsum board by weight cement | Percentage Fly ash by Weight cement | Sample |
|--------------------|----------------------------|----------------|-----------------------------------------|-----------------------------------|--------|
| Compressive Strength | 1:6                        | 10 x 15 x 37   | 0%                                      | 0%                                | 3      |
|                    |                            |                | 5%                                      | 25%                               | 3      |
|                    |                            |                | 7.5%                                    | 27.5%                             | 3      |
|                    |                            |                | 10%                                     | 30%                               | 3      |
| Total Sample       |                            |                |                                         |                                   | 12     |

From Table 1 above, it is found that the need for bricks in the research is 12 pieces of brick for compressive strength testing.

2.2 Research Flow

Some of the steps taken when conducting this research can be seen in Figure 1.

2.3 Compressive Strength

Compressive strength is the ability of bricks to accept force with a unit area, so that the compressive strength can determine the quality of the bricks produced. To get a high-quality brick, the value of the compressive strength of the brick must also be high. The compressive strength test refers to SNI 03 – 0349 – 1989 concerning Concrete Brick for Wall Pairs, using the equation (1).

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Compressive \text{ Strength} : = \frac{P}{A}
\]  

Description:
Compressive Strength (kg/cm²)
\(P\) = Maximum Compressive Load (kg)
\(A\) = Surface Area (cm²)
3. Results and Discussion

3.1 Compressive Strength

The variations used were 4 types with each variant having 3 samples. The test object in the form of brick has a size of 37 cm x 15 cm x 10 cm with a mixture of 5% G: 25% F, 7.5% G: 27.5% F, 10% G: 30% F. Table 2 are the results of testing the compressive strength of gypsum board and fly ash waste bricks.

From the test results, it was found that the compressive strength of variation 1 brick as a control study after the age of 28 days had a value of 42.37 kg/cm². Thus, the compressive strength value of the control blocks has met the requirements where the minimum standard of SNI 03-0349-1989 for quality III is 40 kg/cm². Figure 2 in the form of a graph of the results of testing the compressive strength of bricks with the addition of gypsum board and fly ash.

In Figure 2, when compared to variation 1 as a control, it has a compressive strength value of 42.4 kg/cm², in variation 2 the compressive strength increases by 30.6 kg/cm² to 73.04 kg/cm², but in variation 3 the compressive strength decreases by 23.74 kg/cm² so that it becomes 49.3 kg/cm², and so on until variation 4 the compressive strength value decreases by 5.71 kg/cm² so that it becomes 43.59 kg/cm². Thus, the optimum condition of the bricks was achieved in variation 2 with a mixture of replacement of gypsum board and fly ash waste of 5% and 25% of cement weight, respectively.
Table 2. Compressive Strength Test Results

| Variant    | code | max load (Kgf) | Maximum Load Average (Kgf) |
|------------|------|----------------|----------------------------|
| 0% G       | 1a   | 15928.3        |                            |
| 0% F       | 1b   | 14371.8        |                            |
|            | 1c   | 16738.5        | 15679.5                    |
| 5% G       | 2a   | 27141.7        |                            |
| 25% F      | 2b   | 28747.9        |                            |
|            | 2c   | 25191.5        | 27027.03                   |
| 7.5% G     | 3a   | 18016          |                            |
| 27.5% F    | 3b   | 18873.8        |                            |
|            | 3c   | 17842          | 18243.9                    |
| 10% G      | 4a   | 17143.7        |                            |
| 30% F      | 4b   | 16196.7        |                            |
|            | 4d   | 15045.7        | 16128.7                    |

Description:
G = Gypsum Board
F = Fly Ash

Figure 2. Compressive Strength Test Results Brick

Description:
Variation 1 = 0% Gypsum Board: 0% Fly Ash (Control)
Variation 2 = 5% Gypsum Board: 25% Fly Ash
Variation 3 = 7.5% Gypsum Board: 27.5% Fly Ash
Variation 4 = 10% Gypsum Board: 30% Fly Ash

3.2 Concrete Quality
Based on SNI 03-0349-1989, the addition of gypsum board and fly ash waste on bricks as a substitute for cement weight in variation 2 with a mixture of 5% gypsum board and 25% fly ash was proven to be able to increase the quality of the original bricks from quality III to quality II, while in variation 3 with
a mixture of 7.5% gypsum board and 27.5% fly ash, then variation 4 with a mixture of 10% gypsum board and 30% fly ash brick remains in the III quality category.

However, an excessive amount of gypsum board and fly ash waste in the manufacture of bricks will reduce the compressive strength of the bricks, this is due to the reduced amount of cement in the brick products. According to Munir [5] as a result of decreasing tricalcium silicate and dicalcium silicate, it can reduce the binding power (setting) between aggregates to be imperfect. So that when the bonding strength between materials decreases, the compressive strength of the bricks decreases.

By utilizing gypsum board and fly ash waste as a substitute for cement in the process of making bricks, it has the advantage of avoiding waste pollution due to heavy metal elements in it and the more use of the waste can also reduce CO2 gas emissions into the air.

Although there is a decrease in the value of the compressive strength of the bricks in certain variations, if we look back from the quality aspect, variation 2 with a mixture of 5% gypsum board and 25% fly ash has better quality when compared to variation 1 as control brick. Thus, the addition of gypsum board and fly ash waste at 5% and 25% respectively by weight of cement resulted in a product having a quality above the control brick as shown in Table 3.

| Variant   | composition | compressive strength (kg/cm²) | SNI 03-0349-1989 Status | compressive strength |
|-----------|-------------|-------------------------------|-------------------------|---------------------|
| Variation 1 | 0% G : 0% F | 42.38                         | ok                      | Quality III        |
| Variation 2 | 5% G : 25% F | 73.08                         | ok                      | Quality II         |
| Variation 3 | 7.5% G :27.5% F | 49.31                         | ok                      | Quality III        |
| Variation 4 | 10% G : 30% F | 43.59                         | ok                      | Quality III        |

Study of the American Coal Ash Association [6] found that the use of fly ash in Portland cement concrete (PCC) has many benefits and improves concrete performance in both the fresh and hardened state. Fly ash use in concrete improves the workability of plastic concrete, and the strength and durability of hardened concrete. Rao and Rao [7] revealed the marginal increase of compressive strength for specimens with replacement of cement by 30% fly ash at age of 7, 28, 56 and 91 days. Nath and Sarker [8] found that incorporation of fly ash as partial replacement of cement improved the durability properties of concrete. Fly ash affects the plastic properties of concrete by improving workability, reducing water demand, reducing segregation and bleeding, and lowering heat of hydration. It was found that fly ash also increases strength, reduces permeability, reduces corrosion of reinforcing steel, increases sulphate, resistance, and reduces alkali aggregate reaction [9]. Rovnanik et al. [10] revealed that materials based on the fly ash and brick powder showed lower flexural and compressive strengths than materials based on fly ash alone.

4. Conclusion
Based on the results of the research on the use of gypsum board and fly ash waste for bricks in terms of compressive strength that is beneficial to the environment, it can be concluded as follows:

a. From the results of the research that has been carried out, the optimum compressive strength value of bricks is obtained, namely in variation 2 with a percentage of 5% gypsum board waste and 25% fly ash with an average compressive strength of 70.03 kg/cm².

b. The effect of adding gypsum board and fly ash as a substitute for cement in concrete blocks can reduce the risk of environmental pollution and reduce the amount in Indonesia.

c. Based on the results of research that has been carried out, all variations have met the requirements of SNI 03-0349-1989 regarding concrete bricks for wall pairs with variation 1 having a compressive strength value of 42.4 kg/cm², variation 2 having a compressive strength value of 70.03 kg/cm².
variation 3 has a compressive strength value of 49.3 kg/cm², and variation 4 has a compressive strength value of 43.6 kg/cm².

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