Compressive Strength Analysis On Geopolymer Paving By Using Waste Substitution Of Carbide Waste And Fly Ash

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Abstract. The method to make paving sample in this research was done by mixing fly ash, carbide waste, sand, and alkali activator in the form of sodium silicate (Na₂SiO₃), 8M and 12M sodium hydroxide (NaOH) with ratio 1 : 2 as the binder, then it was pressed by using hydraulic press machine. The paving was made in the size of 20 cm x 10 cm x 6 cm with mix composition of 70% fine aggregate, 30% binder and activator from paving weight. The percentage of binder and activator was 65% and 35%, respectively. The curing was done by using wet burlap sack for about 28 days. After that, the compressive strength test was done. From the result of the compressive strength test of geopolymer paving sample can be concluded that the mixed test of carbide waste and fly ash (10 %: 90%) produced 34.6 MPa, and 39.8 MPa for its compressive strength.

1. Introduction
This Paving is one of the building material product that is often used for road pavement construction. The use of paving supports green construction because rain water falling on the paving surface will enter the soil, so it can maintain the ground water balance. In general, conventional paving blocks made of fine aggregate, cement and water are then molded in a solid state [1]. Past research suggests that portland cement material is not environmentally friendly, because the portland cement production process generates carbon dioxide gas that causes global warming. This carbon dioxide gas (CO₂) is generated during the process of calcination, fuel combustion and electricity consumption during chemical reactions. In the calcination process produced 0.407 tons CO₂ / ton clinker. The amount of carbon dioxide emissions is proportional to the average yield of cement produced by 0.77 tons CO₂ per ton of cement [2]. Carbide wastes include toxic and hazardous materials, if they are large in the soil surface, then rain splashing will soak into the soil, causing groundwater pollution. To reduce waste of carbide and fly ash wastes, as well as maintain environmental balance, both materials are used as raw material for paving polymer. Paving polymer is made of fly ash as an alternative to cement and sodium silicate (Na₂SiO₃) and sodium hydroxide (NaOH) instead of water, serves as activator[3,4].
2. Materials and Methods

2.1. Fly Ash

Fly ash used in this research is from unit 3 and 4 of Electric Steam Power Plant (ESPP) Tanjung Jati B Jepara categorized as fly ash type F. Before being used, EDX analysis test is done to know the chemical characteristic of fly ash.

Table 1. The Chemical Composition Result of Fly Ash

| No | Parameter       | Unit | Test Result |
|----|----------------|------|-------------|
| 1  | SiO₂           | % Wt | 46.70       |
| 2  | Al₂O₃          | % Wt | 25.01       |
| 3  | Fe₂O₃          | % Wt | 9.43        |
| 4  | TiO₂           | % Wt | 0.98        |
| 5  | CaO            | % Wt | 6.26        |
| 6  | MgO            | % Wt | 3.65        |
| 7  | K₂O            | % Wt | 2.19        |
| 8  | Na₂O           | % Wt | 2.96        |
| 9  | SO₃            | % Wt | 0.81        |
| 10 | MnO₂           | % Wt | 0.07        |
| 11 | P₂O₅           | % Wt | 0.41        |
| 12 | Moisturecontent| % Wt | Nd          |
| 13 | L O I          | % Wt | 1.05        |
| 14 | Oil Content    | % Wt | 0.05        |
| 15 | Unburned Carbon| % Wt | 0.65        |

Figure 1. Fly Ash  

2.2. The Carbide Waste

The carbide waste used in this research is originally from weld-shop in Jepara regency, Indonesia. Before being used, the carbide waste is dried first, because it still wet and the chemical composition of carbide waste by using Scanning Electron Microscopy-Energy Dispersive X-Ray (SEM-EDX) is analyzed which is aim to know the content in it. The chemical composition of carbide waste can be seen in table 2.

Table 2. The Chemical Analysis Result of Carbide Waste

| Component                  | Composition (% weight) |
|----------------------------|------------------------|
| Carbon, (C)                | 23.06                  |
| Alumina, (Al₂O₃)           | 4.83                   |
| SilicaDioxide, (SiO₂)      | 1.97                   |
| Sulfite, (SO₃)             | 5.15                   |
| CalciumOxyde, (CaO)        | 63.95                  |
| Zinc (II) Oxyde, (CuO)     | 1.03                   |
2.3. Fine Aggregate

The sand that is used in this research, for example, Muntilan sand. The aggregate passes through 4.76 mm sieve. Before being used, the inspection of material characteristics test is done which consists of: The specific weight of sand based on ASTM C128-01, from the experiment was obtained that the specific weight of sand was 2.43 gr/cm² so that the sand condition has fulfill the needed requirement[5,6,7,8]. The testing of mud content based on PBI 1971(Concrete Regulation Indonesia) N.1-2 analysis on the sand mud content, the result was good which has a maximum limit of 5% in the experimental sample. From the above conclusion, it is found that the sand meets the requirements due to the mud content of 5%.

2.4. The Alkali Activator

This study uses alkali activator in the form of sodium hydroxyde (8M and 12M) derived from white crystals dissolved with clean water and sodium silicate in the form of liquid and viscous. Sodium silicate functioned as a catalyst or mixer of sodium hydroxyde[9,10].

2.5. Mixed Design

Mixed design used in making 8 M and 12 M geopolymer sample will be explained in figure 3:

![Fig 3 Flow Diagram Mixed Design](attachment:flow_diagram.png)

**Figure 3.** The Flow Diagram about Mixed Design of Geopolymer Paving

3. Result and Discussion

The Compressive Strength Test Result of Geopolymer Paving

![Fig 4 Compressive Strength Graph](attachment:compressive_strength_graph.png)

**Figure 4.** The Compressive Strength Graph of 8M and 12M Geopolymer Paving
From the analysis of the figure 4, the compressive strength of 8M geopolymer paving in the age of 28 days with the variation in mixed design of 100% FA has the higher compressive strength equal to 35 MPa. It is different with the ratio variation of FA : CW (50% : 50%) that has the lower compressive strength result equal to 9.35 MPa. The most increasing tendency of FA variation was the increasing started from 60% to 100% variations of FA and significantly increased in variations of 50% to 60% FA that was equal to 9.35 MPa to 25.2 MPa with difference in the compressive strength of 15.85 MPa. Accompany with the increasing of carbide, it was influence the compressive strength of the geopolymer paving. According to[13] and SNI 03-0691-1996, based on the quality of the compressive strength above, most of them were categorized in type A and B with the compressive strength result equal to 35 MPa to 25.1 MPa which is used for roads and parking lots. Figure 4 shows that when on 12M geopolymer paving was more increasing of FA, it will make the compressive strength produced by the geopolymer paving higher[14]. It was seen from the mix ratio of FA 50% to 60% which increased significantly with the compressive strength equal to 14 MPa and 22.2 MPa with the difference of the compressive strength point equal to 82 MPa. It is different in the variation of FA 70% to 100% which the increasing with an average of compressive strength point was 34.5 MPa. The highest point was the mixture of FA 100% in the absence of carbide waste mixture with the compressive strength point equal to 41.9 MPa. The quality of paving blocks based on SNI 03-0691-1996 were classified into the A quality category with an average of the compressive strength point was 40 MPa with a minimum of 33 MPa which is enabled for the road.

3.1. The Comparison of Geopolymer Paving

The classification of paving usage as the building material has its own quality especially on 8 M and 12 M geopolymer paving. The 12 M geopolymer paving has higher compressive strength point than 8 M geopolymer paving because of its molarity was bigger than 8 M geopolymer paving although both of them used the same fly ash mixture by using carbide waste. There is the classification table about the use of paving based on SNI-03-0691-1996 towards the compressive strength of 8 M and 12 M geopolymer paving.

| The Percentage of Carbide Waste in Each Mix | Compressive Strength (MPa) |
|--------------------------------------------|----------------------------|
| 8 M Paving                                 | 12 M Paving                |
| FA50 %                                     | 9.35                      | 14                        |
| FA60 %                                     | 25.2                      | 22.2                      |
| FA70 %                                     | 25.65                     | 34.5                      |
| FA80 %                                     | 33.3                      | 34.9                      |
| FA90 %                                     | 34.6                      | 39.8                      |
| FA100 %                                    | 35                        | 41.9                      |

- Paving block quality category D, used for gardens, with an average compressive strength of 10 MPa with a minimum of 8.5 MPa.
- Paving block quality category C, used for pedestrians, with an average compressive strength of 15 MPa with a minimum of 12.5 MPa.
- Paving block quality category B, used for parking lots, with an average compressive strength of 20 MPa with a minimum of 17 MPa.
- Paving block quality category A, used for roads, with an average compressive strength of 40 MPa with a minimum of 35 MPa.
From the each mixed design analysis on 8M and 12M geopolymer paving started from the percentage of fly ash (50%, 60%, 70%, 80%, 90%, 100%) with the percentage ratio of carbide waste (50%, 40%, 30%, 20%, 10%, 0%) seen from the graph above, the more increasing of fly ash will make the compressive strength point of geopolymer paving higher and the more increasing of carbide waste will make the compressive strength point decreased. It can be known from these variations that produce a high compressive strength in the 0% variable or do not use weld mixture at all. In the composition of (60% fly ash: 40% carbide waste) and (50% fly ash: 50% carbide waste) on 8M and 12M geopolymer paving produced 22 MPa compressive strength. It can be seen that from the graphic above, the higher percentage of the carbide waste mixture and the greater molarity of the geopolymer paving used was resulted in a very drastic reduction[15].

3.2. The Water Absorption on Paving

The water absorption test aims to be an indicator of water absorption into the soil and the saturation or maximum peak absorption rate in the material itself was the size of water absorption generated depends on the density and the number of cavities contained in the paving block. When water is saturated, it can cause humidity in the paving. In the calculation of water absorption with the reference[16] and SNI 03-0691-1996, the maximum in the A quality is 39%.

![Water Absorption](image)

**Figure 5. Water Absorption**

From the calculation Figure 5 show, the result of the higher absorption was on 12M geopolymer paving that equal to 1.76% and the lower absorption of 8M geopolymer paving was 1.63%. It is known that the geopolymer paving that used a large molarity was more absorbed and the water absorption was less when the paving only used small molarity[14]. The result of both types of paving fulfilled the standard. It is known that when the pressing process has well condensation, the pores on the paving will reduce so that the water absorption will be less.

4. Conclusion

Based on the research that has been conducted in the increasing of carbide waste ash towards the geopolymer paving, the conclusions can be taken as follows:

a. The more increasing ratio of fly ash in the geopolymer paving mixture produces higher compressive strength point.

b. The more increasing ratio of carbide waste variations with the percentage in the geopolymer paving mixture produces lower compressive strength point. So, it can be concluded that the use of carbide waste is only be used as filler.

c. The increasing of carbide waste cannot support the compressive strength towards the geopolymer paving.

d. The higher water absorption was in 12 M geopolymer paving which is equal to 1.76% and the lower water absorption of 8M geopolymer paving was 1.63%.
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