Effect of H₂O₂ as the Foaming Agent on the Geopolymer Mortar using Curing of Room Temperature

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Abstract. Road construction on the peat has been an issue in the world. Yet, due to the reason of topography and alignment through a peat environment, this work remains to be done. The issue in this study was the bearing capacity of soil due to high water content, creep, deformation and high acid, so that was required to find the alternative material to support the base of the road with the light material. This study used fly ash as the alternative material in the foam geopolymer mortar that utilized hydrogen peroxide (H₂O₂) with the percentage of 1%, 2%, and 3% fly ash, respectively, as the blowing foaming agent in fresh geopolymer mortar. The alkaline solution was prepared using the solution of Na₂SiO₃ and NaOH with a ratio of 2.0 and 2.5, respectively. The room temperature was used as the curing for 14 days. The results showed that the optimum compressive strength was obtained about 3.53 MPa with a Na₂SiO₃/NaOH of 2.5 and the percentage of H₂O₂ as 1% fly ash. Furthermore, optimum density was obtained about 0.61 gr/cm³ with a Na₂SiO₃/NaOH of 2.5 and the percentage of H₂O₂ as 3% fly ash.

1. Introduction
Road construction on peaty soil had been an unavoidable issue. It was due to the topography and alignment of the road going through a peat environment so that caused a decline of low soil capacity, high water content, creeping, deformation and a high degree of acidity [1]. The use of material with a low density (1 gr/cm³) and better compressive strength was an alternative material to replace the aggregate which has been used as a foundation material for road pavement. However, the compressive strength of low-density material has to be maintained or better than the compressive strength of normal material [2].

Geopolymer is a material formed by activating alkali and base material that is rich in silica-alumina content. Alkaline activator was a combination of the solution of sodium or potassium [3,4]. Meanwhile, a base material was a by-product material from industry such as fly ash, rice husk ash, metakaolin, and silica fume. Fly ash is a waste material from the combustion residue of coal in the power plants that were rich in content of Si and Al so that was categorized as geopolymer material [5].

Fly ash had been used as an alternative material on lightweight mortar geopolymer. Some investigations had been conducted with the use of H₂O₂ as a foaming agent on geopolymer mortar [6,7]. Described that the use of Hydrogen Peroxide (H₂O₂) on foam geopolymer depend on the alkaline activator/binder ratio and the Na₂SiO₃/NaOH ratio. The lowest density was reached by the mixture with an activator/binder ratio of 0.6 and 3% hydrogen peroxide content. The ratio of Na₂SiO₃ to NaOH of 4.5 resulted in a density of 734 kg/m³, whereas the ratio of Na₂SiO₃ to NaOH of 2.5 resulted in a density of 0.61 gr/cm³.
749 kg/m³. The addition of aluminum powder in the range of 0.07 to 0.2% showed the density of 0.64-0.74 gr/cm³. Furthermore, the use of H₂O₂ in the aluminum mixture provided the density of 0.61-1 gr/cm³. Finally, the use of low density with the better compressive strength was still an issue in the previous study so that it is expected to be solved in the current study.

2. Methodology

2.1. Material
This study used the material of fly ash Nagan Raya that was derived from nagan raya, Acheh, Indonesia. The solution of NaOH and Na₂SiO₃ was bought from the market in Medan, Indonesia. The liquid of hydrogen peroxide (H₂O₂) and calcium stearate were bought from the chemical online market.

2.2. Mix proportion
The maximum compressive strength was obtained from the trial experimentation of foam geopolymer mortar. The alkaline activator was a combination of NaOH and Na₂SiO₃ solution with a ratio of 2.0 and 2.5. The solution of NaOH was used about 12M which was produced from 400 gr NaOH in 1000 ml H₂O. Furthermore, the use of the foaming agent in this study was 1.0%, 2.0%, dan 3.0% of fly ash Nagan raya as seen in Table 1. The mix procedure of the geopolymer mortar is illustrated in Figure 1.

| The Ratio of Alkaline Activator | Foaming Agent of H₂O₂ | Calcium stearate | Tel is of test (Compressive strength and density) |
|--------------------------------|-----------------------|------------------|-----------------------------------------------|
|                                | 1.0%                  | 0.1%             | 3 hari | 3 hari | 3 hari | 3 hari | 3 hari | 3 hari |
| 2,0                            | 2.0%                  | 0.2%             | 3      | 3      | 3      | 3      | 3      | 3      |
|                                | 3.0%                  | 0.3%             | 3      | 3      | 3      | 3      | 3      | 3      |
| 2,5                            | 1.0%                  | 0.1%             | 3      | 3      | 3      | 3      | 3      | 3      |
|                                | 2.0%                  | 0.2%             | 3      | 3      | 3      | 3      | 3      | 3      |
|                                | 3.0%                  | 0.3%             | 3      | 3      | 3      | 3      | 3      | 3      |

![Figure 1. Mix procedure of geopolymer mortar](image)

3. Results and discussion

3.1. X-ray fluorescence
The characteristic material was investigated by XRF analysis that provides the indication of chemical content percentage in the material. Table 2 shows that the material of fly ash nagan raya has the chemical content of SiO₂ and Al₂O₃ of 37.16% and 17.61%, respectively. It means that the material of fly ash nagan raya formed the gel of Si-O-Si and Si-O-Al that contributed to the mechanical properties of geopolymer, especially compressive strength. Furthermore, total chemical content of SiO₂ + Al₂O₃ + Fe₂O₃ is 73.52%. It means that the material of fly ash Nagan raya was categorized as class F fly ash.
The Ca content of fly ash is 8.72% that is categorized as moderate Ca content. This category provides a similar final setting time with OPC mixture (5-6 hours)

| Table 2. Chemical composition of fly ash nagan raya |
|----------------------------------------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| SiO₂       | Al₂O₃   | Fe₂O₃   | CaO     | Na₂O    | K₂O     | TiO₂    | MgO     | P₂O₅    | SO₃     |
| 37.16      | 17.61   | 18.75   | 8.72    | 0.468   | 0.788   | 0.747   | 6.43    | 0.139   | 1.96    |

3.2. X-ray diffraction
The measurement of fly ash nagan raya by XRD showed in Figure 2. The spectrum in the particle of fly ash nagan raya refers to the database of XRD. The spectrum in figure 2 indicates that the material consists of quartz (SiO₂), mullite (3Al₂O₃ 2SiO₂ or 2Al₂O₃SiO₂) and hematite (Fe₂O₃). Whereas, the maximum dispersion peak at 20º-30º indicates that the material of fly ash nagan raya was categorized as the amorphous material.

3.3. Scanning Electron Microscopy
Figure 3 shows the spherical shape of FA particle with the misty surface. The surface of FA in this study was in contrast with the surface of common FA that is a spherical shape with a sleek surface. The misty surface was considered absorbing the alkaline solution on fresh geopolymer mortar so that caused the reduction of workability. Also, the spherical shape of FA indicated that it was able to fill the concavity of geopolymer binder.
3.4. Hardened properties

3.4.1. Compressive strength and density of foaming geopolymer mortar
The specimen for compressive strength used a 50mm x 50mm x 50mm cubes. The test of compressive strength was investigated at 1, 3, 7, and 14 days. Figure 4 shows the difference of Na$_2$SiO$_3$ to NaOH ratio of 2.0 and 2.5 on the compressive strength of foaming geopolymer mortar. The figure describes the decrease of compressive strength due to the rise of H$_2$O$_2$ percentage in fresh geopolymer mortar. It is attributed to the increase of H$_2$O$_2$ percentage caused the increase of the air bubble in fresh geopolymer mortar and finally, it is pore in the geopolymer mortar. Both figures show that the percentage of 1% H$_2$O$_2$ in the weight of fly ash provides the optimum compressive strength. However, the ratio of Na$_2$SiO$_3$ to NaOH of 2.5 provides better compressive strength than the ratio of Na$_2$SiO$_3$ to NaOH of 2.0.

![Figure 4. Compressive strength of foaming geopolymer mortar with (a) the ratio of Na$_2$SiO$_3$ to NaOH of 2.0 (b) the ratio of Na$_2$SiO$_3$ to NaOH of 2.5.](image)
Figure 5 shows the relation between the ratio of Na$_2$SiO$_3$ to NaOH on the weight of foaming geopolymer mortar. It indicates that the increase of H$_2$O$_2$ percentage in fresh geopolymer mortar reduces the density of geopolymer mortar. It is attributed to the presence of an air bubble that was formed by the reaction of H$_2$O$_2$ and binder. Both figures show that the use of different Na$_2$SiO$_3$ to NaOH ratio does not impact the density of foaming geopolymer mortar.

![Density of foaming geopolymer mortar with different Alkaline Ratios](image)

**Figure 5.** Density of foaming geopolymer mortar with (a) the ratio of Na$_2$SiO$_3$ to NaOH of 2.0 (b) the ratio of Na$_2$SiO$_3$ to NaOH of 2.5

3.5. Relation of density and compressive strength

Figure 6 shows that the relation of density and compressive strength is linear which the decrease of density provides the reduction of compressive strength. The low density was caused by the presence of more pore in foaming geopolymer mortar so that impacted to the compressive strength. It is consistent with the concept of porous material that mentioned high density provides high compressive strength and vice versa. It similar to studies results of Michal lach et. al.

![Relation of Density and Compressive Strength](image)

**Figure 6.** Relation of Density And Compressive Strength
4. Conclusion
This study concluded that the maximum compressive strength was 3.53 MPa that was obtained with the use of Na$_2$SiO$_3$ to NaOH ratio of 2.5 and 1% H$_2$O$_2$. Whereas, the density was not influenced by the use of Na$_2$SiO$_3$ to NaOH ratio. It means that the use of hydrogen peroxide (H$_2$O$_2$) caused foaming geopolymer mortar had more pore so that impact on the compressive strength density of foaming geopolymer mortar. This research concluded that fly ash nagan raya was suitable to be used as base material on foaming geopolymer mortar. Furthermore, it was able to be used as the application on direct casting the site.

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