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Experimental Study of Lightweight Geopolymer by Synthesis of Fly Ash, Waste Powder Coating and PU Foam

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ABSTRACT

This research paper presents the report on the study of polyurethane foam (PU foam) to produce lightweight geopolymer composite. In this study, fly ash (FA) for 70% and powdered coating sludge (PCS) for 30 % used as source were activated by alkaline activator NaOH 14 M and Na_2SiO_3 mixture with the ratio Na_2SiO_3/NaOH of 2.0 and samples were cured at 80°C for 4 hours, stored at room temperature for 7, 14 and 28 days. The impact of adding PU foam particles, ranging in size from 2 to 4 mm, to FA/PCS-based geopolymers with a solid content of 0 to 50% has been studied. It was discovered that the amount of PU foam particles added caused the compressive strength and density of the lightweight geopolymer composite to decrease. Although the compressive strength was decreased when the amount of PU foam was increased but it is still be the standard of block lightweight concrete. Therefore, it is indicated that PU foam is one of the viable alternatives for reinforcement in the creation of lightweight geopolymer composites.

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1. Introduction

Due to environmental pollution problems, the current climate has a higher temperature. It causes the need for more insulation materials for building houses, which makes the temperature inside the building lower. Nowadays, many types of insulating materials for wall construction in houses and buildings have been developed to meet the needs of consumers. Most insulation materials are lightweight. It consists of many tiny air bubbles that have the property of blocking heat in the bubbles and do not let the heat move to other parts, as well as the principle of sound insulation materials that rely on the principle of open pores (open cell) and absorb sound, as well as the principle of sound insulation materials that rely on the principle of open pores (open cell). The thicker the wall, the greater the sound transmission class (STC) of the system. Geopolymers can now be used as one of the greener alternative materials since the production process produces relatively few carbon dioxide emissions and environmental damage. Compared to other materials, geopolymers are synthesized from materials mainly composed of silica (SiO_2) and alumina ($Al2O_3$) and reacted with alkaline solutions and catalyzed by heat so that they harden and gain compressive strength. In Thailand, most of the lignite fly ash is used to generate electricity in the power plant in Mae Moh District, Lampang Province. Fly ash geopolymers are commonly used as a substitute for concrete blocks used for load support. Due to its relatively large weight and relatively high thermal conductivity, it is considered a limitation that will lead to the replacement of insulating materials used for walls or roofs of houses. In the past, weight and thermal insulation properties were developed by studying the mechanical properties of geopolymer materials containing waste and fly ash [1]. The study revealed that the ratio of geopolymer preparation from fly ash to powder residue was 70:30, the solid to liquid ratio (S/L) was 1.6, and the concentration of sodium hydroxide solution (NaOH) was 14 molars. The ratio of sodium silicate to sodium hydroxide (Na_2SiO_3/NaOH) in the second cure for 28 days showed that the compressive strength was 186.8 kg/cm^2, the water absorption rate was 3.42%, the density was 1,576 kg/m^3, and the thermal conductivity coefficient (k) was 0.274 W/(m-K). Moreover, the other study found that the compressive strength after adding powder coating wastes to the geopolymer material decreased when compared to fly ash, but it was still within the C16 lightweight concrete block standard. In addition, compressive strength of geopolymer foam made from fly ash and aluminum powder was studied [2]. The study revealed that the interior consists of air cavities obtained from a combination of geopolymer and foam bubbles or between the geopolymer and aluminum powder for gas formation. For the foaming method, it can be done by adding the foam before mixing it into the fresh geopolymer, as in the production of foam concrete called the "pre-formed foam method," by using a mixer to stir well. Then insert the foam into the geopolymer. When the geopolymer hardens, it forms evenly distributed small air voids, or air pores. The walls of the pores, or air cells, are disconnected from each other. This gives geopolymer foams a lighter unit and better thermal insulation than regular geopolymers. For structural and non-load-bearing applications, there is relatively little information available on the usage of foam particles as aggregates in lightweight geopolymer concrete. The effects of various mixes of foam particles on the characteristics of lightweight geopolymer foam composite and the viability of using foam particles as reinforcement aggregates in geopolymer concrete were therefore studied for this research using fly ash, powder residue geopolymer, and foam particles. The outcome is crucial for understanding and the potential future development of this composite. Fly ash, powder residue, and foam will be used to create lightweight concrete foam composites. In samples containing different percentages of foam particles (0–50 vol%), important properties such as density and compressive strength were determined.

2. Materials and Methods

2.1. Materials

Fly ash (Fig.1(a)), industrial waste collected from the Mae Moh power plant in Lampang province, northern Thailand, powder coating sludge (Fig. 1(b)) from the Jotun Thai Co., Ltd. production line, and PU foam (Fig. 1(c)) that was left over from the installation of the building wall for heat insulation make up the raw materials used to create light-weight geopolymers in this research. The chemical composition for both materials determined using an X-ray fluorescence spectrometer by (Horiba XGT-5200) are shown in Table 1.

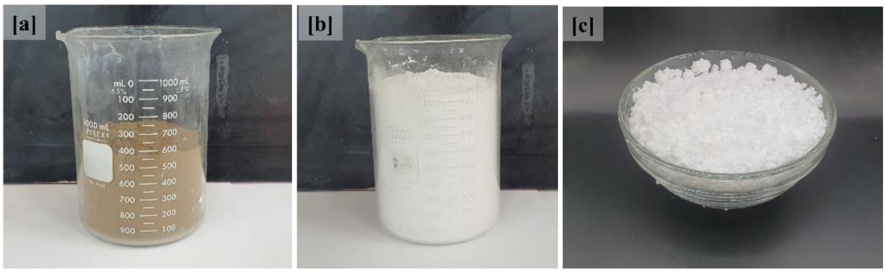

Figure 1. *Raw materials, (a) fly ash (FA), (b) powder coating sludge (PSC) and (c) PU foam.*

Table 1. *Table Chemical composition (wt%) of fly ash and powder coating sludge [6]-[7]*

Chemical/Materials	FA %	PCS%
Al_2O_3	8.29	3.21
SiO_2	16.91	8.32
Fe_2O_3	23.16	-
SO_3	6.64	4.83
CaO	39.16	1.25
K_2O	5.47	-
TiO_2	0.37	58.25
BaO	0.00	25.14

The shows FA that the content of silicon oxide (SiO_2) 16.91% to aluminum oxide (Al_2O_3) 8.29% ratio by mass of the source Si-to-Al should preferably be in the range is 2.04 this is a good ratio of geopolymer materials in terms of compressive strength [3]. The calcium oxide content was also very high and the iron oxide (Fe_2O_3) content was relatively high. The sum of main chemical composition SiO_2, Al_2O_3 and Fe_2O_3 were 48.36%, while the CaO content of FA is high at 39.16%. The high calcium content suggested that it belonged to the class C [4]-[5].

In the PCS there is also a titanium oxide (TiO_2) 58.25% and barium oxide **(**BaO**)** 25.14% were found in the largest amounts in the PCS. In the PCS also found that the composition of the element Al_2O_3 = 3.21% SiO_2 = 8.32% by (wt%).

In Fig. 2(a), the fly ash contains spherical forms with variously sized, relatively smooth exterior surfaces. This FA is therefore classified as a high-calcium class C fly ash. The majority of particles had interiors that were hollow and filled with smaller ones. The disclosed vitreous, unshaped, fragmented grains of PCS powder are depicted in Fig. 2(b).

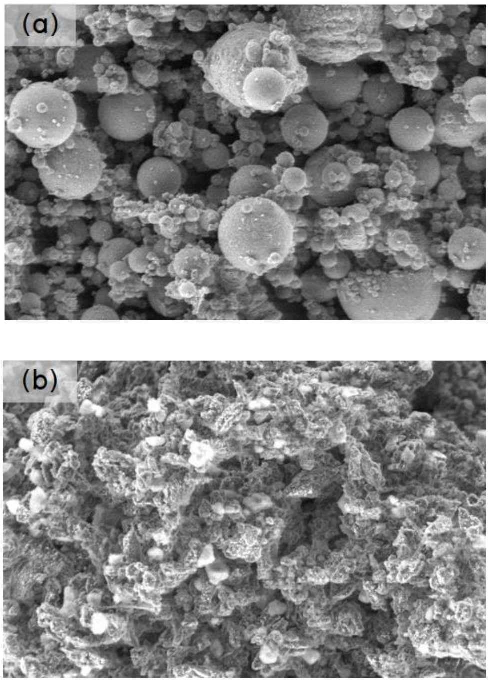

Figure 2. *Microstructure of (a) FA and (b) PCS powder at the magnification of 5000X*

Analytical grade sodium hydroxide in pellet form and sodium silicate solutions (Na_2O = 16.53%, SiO_2 34.27%, water = 49.2%,)

2.2. Preparation

Figure 3. *The compressive strength tests*

Geopolymer preparation was divided into two types of binding system which are FA - PCS - PU foam with alkaline liquid activator. The liquid alkaline activator was prepared by mixing a 14 M sodium hydroxide solution with sodium silicate solution at a weight ratio of 2:1. The activator solution was thoroughly mixed and stored at ambient conditions for at least one day prior to use. FA 70 wt.% and 30 wt.% PCS were mixed dry with 0 to 50 vol.% of PU foam. The slurry was casted in 5x5x5 cubic molds, then sealed and left at the room temperature an hour. The samples were hardened at 80 °C for four hours and cured at room temperature for 7, 14 and 28 days, respectively. The compressive strength was tested following the ASTM 109 standard as shown in Fig. 3. Moreover, the density of the geopolymer composite was determined according to Fig. 4

Figure 4. *Weigh and measure sample to determine density*

3. Results and Discussion

3.1. Effect of PU foam (vol %) on compressive strength

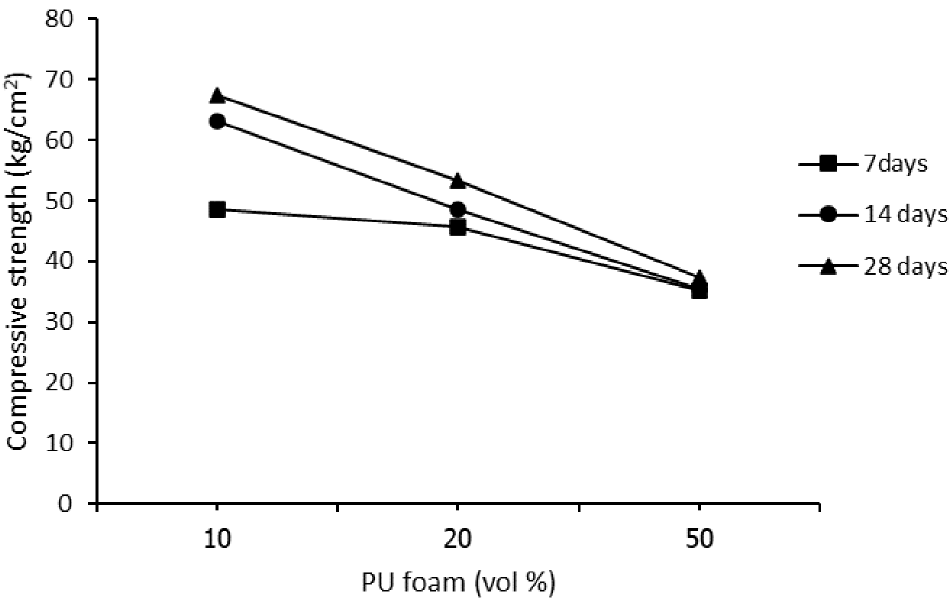

Figure 5. *Effect of PU foam (vol %) on compressive strength*

Fig.5 showed the effect of PU foam (vol %) on compressive strength. The PU foam was varied by volume for 10, 20 and 50 %, respectively. It was found that the compressive strength was decreased when the percentage of PU foam was increased because the higher of PU foam causing expansion of the geopolymer composite and all trend of curing time was similar. The compressive strength with the PU foam 50% by vol. and curing time of 28 days was 37.2 kg/cm^2 and it can be seen that the compressive strength of this study was higher than the block lightweight concrete type C9-C12 about 31%. In the other hand, the compressive of this study was lower than the previous study that was synthesized by fly ash and waste powder coating [1]. Therefore, the geopolymer of this study is suitable to instead of the lightweight material and low strength.

3.2. Effect of PU foam (vol %) on density

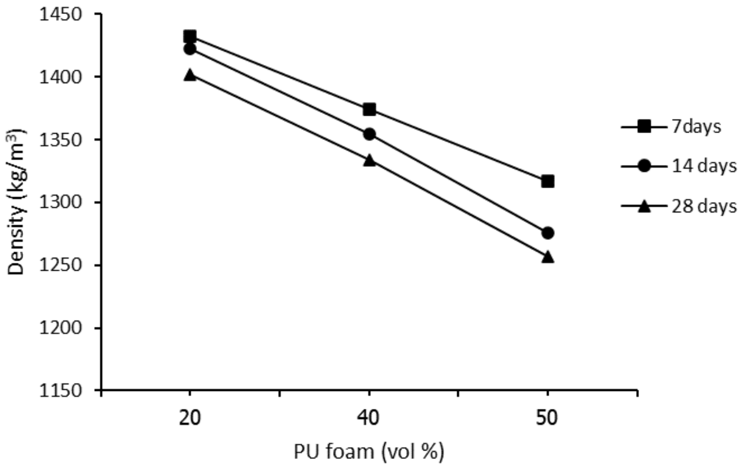

Figure 6. *Effect of PU foam (vol %) on density*

When the PU foam was increased from 20 to 50% by vol., the density was suddenly decreased as shown in Fig. 6. In case the curing time of 28 days, it was found that the lowest density was about 1,257 kg/m^3 with PU foam 50% by vol. It can be concluded that a longer curing time causing moisture content of the sample was reduced therefore, the weight of the sample was decreased. In addition, the increase of PU foam caused high expansion of the sample, then the weight was decreased. Moreover, it can be seen that the density in case of the curing time of 28 days and PU foam 50% was lower than the block lightweight concrete type C16 about 10.2%. However, it can be seen that the density of this study was lower than the geopolymer that was synthesized by fly ash and waste powder coating [1] about 21%. Therefore, it can be confirmed that the geopolymer which was synthesized by fly ash, waste powder coating and PU foam can be used for lightweight.

3.3. Forming of geopolymer insulator

To evaluate the possibility of commercial geopolymer production, this study tried to form the geopolymer insulator by synthesis of fly ash, waste powder coating and PU foam in 50 cm x 60 cm x 1 in as shown in Fig. 7. It was found that the geopolymer can be formed easily and it was possible produced as commercial production in future.

Figure 7. *Forming of geopolymer insulator by synthesis of fly ash, waste powder coating and PU foam*

4. Conclusions

This research presented the synthesis of fly ash, waste powder coating and PU foam to produce lightweight geopolymer composite. It was found that the density of this study was lower than the geopolymer that was synthesized by fly ash and waste powder coating. Therefore, it can be concluded that the geopolymer of this study is one of the alternative solutions for producing the lightweight geopolymer composites in future. Moreover, thermal conductivity coefficient (k), acoustic performance, XRD and SEM will be tested in future.

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