Development of Foamed Glass from Recycled Glass and Bottom Ash for Use as Thermal Insulation Application

Author Juralak Phoyu 650510146 , **Advisor** Asst. Prof. Dr. Worapong Thiemsorn
Department of Industrial Chemistry, Faculty of Science, ChiangMai University ,ChiangMai, 50200, Thailand
E-mail : Juralak_p@cmu.ac.th

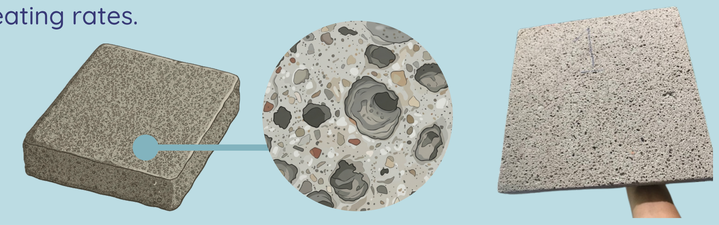
Abstract

The objective of this research was to develop foamed glass prepared by a wet process using cullet powder and bottom ash as the major raw materials, together with inorganic fillers and a foaming agent, in combination water as the solvent. The mixture was mechanically foamed using a high-speed mixer until a viscous slurry was obtained. The slurry was then poured into a high-alumina mold (12 × 12 × 4 inches), dried at 40 °C, and fired at 800 °C with heating rates of 2, 3 and 4 °C/min, followed by furnace cooling. After cooling, the foamed glass was cut into specimens with dimensions of 12 × 12 × 1 inches. The properties of the foamed glass were investigated, including pore structure, average pore size, water absorption, bulk density, compressive strength, and thermal conductivity. The experimental results revealed that the foamed glass showed a uniform cellular structure with an average pore size of 1.6 mm. The water absorption and bulk density were 49% and 0.4 g/cm³, respectively. The compressive strength was 2.45 MPa, and the thermal conductivity was 0.130 W/m·K, demonstrating its potential for use as a thermal insulation material. The average pore size decreased at a heating rate of 2 °C/min, while the bulk density and compressive strength increased.

Introduction

Foamed glass is a lightweight, porous material produced by incorporating gas bubbles into a glass matrix. It has attracted considerable attention due to its unique combination of properties, including low density, high thermal insulation, good mechanical strength, chemical durability, and excellent fire resistance. Because of these advantages, foamed glass has been widely applied in building insulation, sound absorption, lightweight construction materials, and environmental applications. In recent years, foamed glass is manufactured by the wet process. It has emerged as an alternative fabrication route that offers several advantages, such as better control of pore structure, improved homogeneity of the mixture, and the possibility of producing highly porous materials. The wet process can be controlled by adjusting the foaming conditions, slurry viscosity, additives and firing condition [1,2].

In this work, foamed glass using cullet powder and bottom ash as the major raw materials, together with inorganic fillers and a foaming agent, was developed by a wet process with different heating rates.

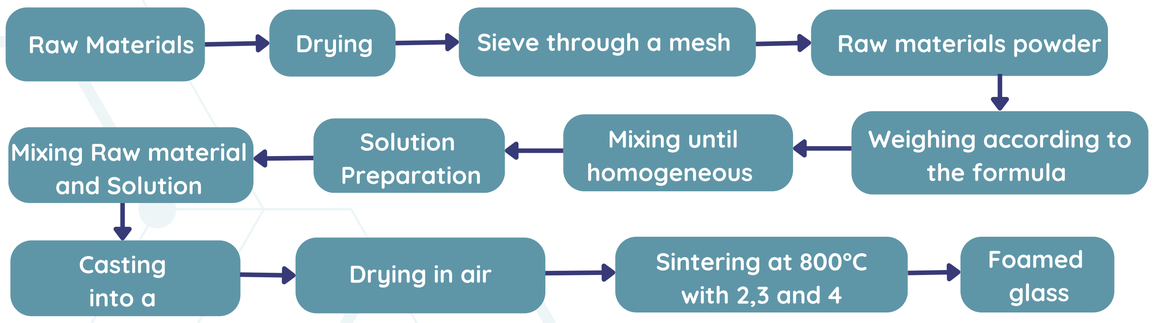


Objectives

1. To develop foamed glass using cullet and bottom ash through a wet process for use as a thermal insulation panel with dimensions of 12 × 12 × 2 inches.
2. To investigate the effect of heating rate on the mechanical and thermal properties of the foamed glass.

Experimental procedures

Preparation of Raw Materials and Foamed glass



Preparation and Characterization of Foamed glass

Results and discussion

The heating rate during firing has a significant influence on the density of foamed glass prepared by the wet process, because it controls the balance between gas generation (foaming) and glass viscosity (sintering/softening). In this work, the foamed glass prepared by a wet process was controlled in terms of composition, mixing speed, mixing time, and mixing technique. These parameters were constantly controlled, resulting in a suitable slurry.

Property of Foamed glass

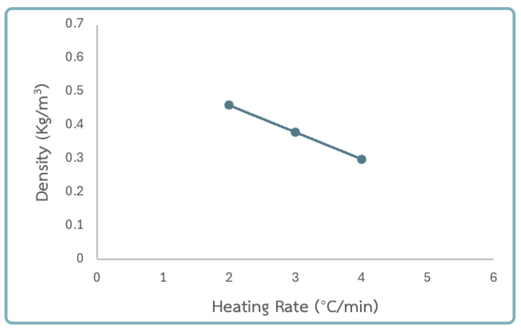


Figure 1 The relationship between Heating rate and Density

As the heating rate rises from 2 to 3 and 4 °C/min, the temperature increases quickly. The glass particles soften quickly, allowing gases generated from the foaming agent to be trapped by the viscous glass. The gases have high pressure and expand. As a result, larger and more pores are formed, and the structure becomes less compact, causing the density to decrease.

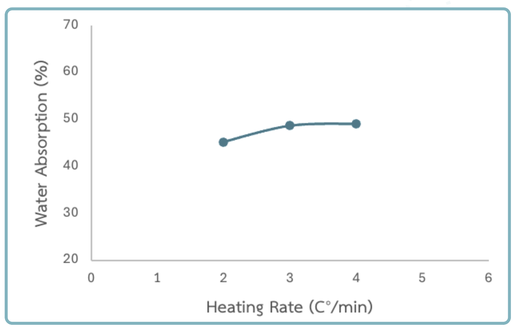


Figure 2 The relationship between Heating rate and Water Absorption

At a high heating rate, gas is generated rapidly while the glass softens quickly. This may lead to rapid bubble expansion, pore coalescence, and partial collapse of the cell walls. As a result, open and interconnected pores may form. In this work, water absorption increased with increasing heating rate.

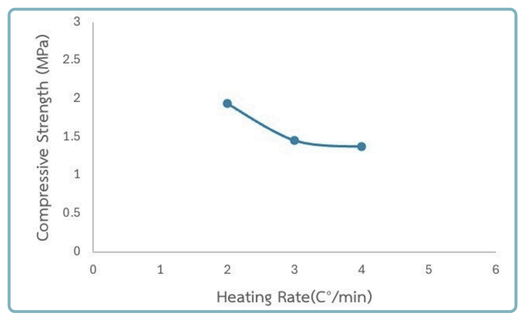


Figure 3 The relationship between Heating rate and Compressive Strength

At a high heating rate, rapid gas generation and fast softening of the glass phase can cause excessive pore growth, pore coalescence, and thinning of the cell walls. The structure becomes highly porous, larger pore size and less uniform, which weakens the foamed glass.

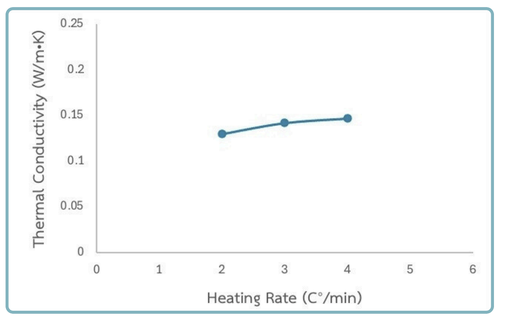


Figure 4 The relationship between Heating rate and Thermal Conductivity

As the density decreases, the open-pore size becomes larger, the structure becomes less uniform, and the structure becomes less compact, causing the thermal conductivity to increase slightly. When the pore size becomes larger, several heat transfer mechanisms are affected. Radiative heat transfer increases because larger pores allow infrared radiation to pass more easily through the foamed glass. In contrast, closed pores trap air or gas inside isolated cells. The trapped gas has very low thermal conductivity at the lower heating rate.

Characteristics of Foamed glass



2 °C/min

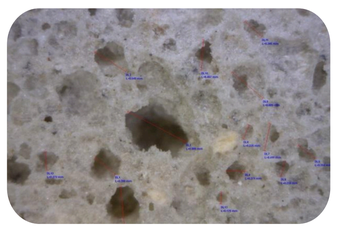


3 °C/min

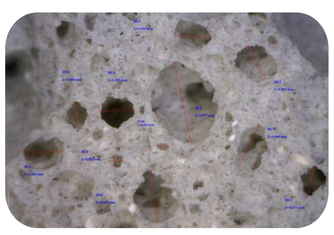


4 °C/min

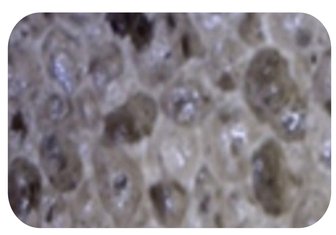
Morphological of Foamed glass



2 °C/min



3 °C/min



4 °C/min

Conclusion

In this work, foamed glass with dimensions of 12 × 12 × 1 inches was prepared by a wet process using cullet powder and bottom ash as the major raw materials, together with inorganic fillers and a foaming agent, with water as the solvent. The preparation was successful. At a heating rate of 2 °C/min, the foamed glass showed a uniform cellular structure with an average pore size of 1.6 mm. The water absorption and bulk density were 49% and 0.4 g/cm³, respectively. The compressive strength was 2.45 MPa, and the thermal conductivity was 0.130 W/m·K, demonstrating its potential for use as a thermal insulation material. The average pore size, bulk density, and thermal conductivity increased, while the compressive strength decreased with increasing heating rate.

Acknowledgement

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References

[1] J. Bai, X. Yang, S. Xu, W. Jing, J. Yang, Preparation of foam glass from waste glass and fly ash, Materials Letters, Vol. 136, 2014, pp. 52-54.
[2] S. S. Owoeye, G. O. Matthew, F. O.Ovienmhanda, S. O. Tunmilayo, Preparation and characterization of foam glass from waste container glasses and water glass for application in thermal insulations, Ceramics Ingternational, Vol. 46(8), Part B, 2020, pp. 11770-11775.