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Heat Transfer Coefficient, Heat Release and Gas Hazard Tests for Expanded Polystyrene Heat Insulating Materials with Aluminum Foil

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알루미늄 호일 부착 발포 폴리스티렌 단열재의 열전도율, 열방출시험 및 가스 유해성 시험

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Abstract

The purpose of this study is to enhance heat insulation effect and to decrease fire hazard by attaching aluminum foil to expanded polystyrene, which is mainly used for insulating materials, to have fire retardant. The result of the test confirmed that the insulating materials, expanded polystyrene of 10 kg/m^3 and 14 kg/m^3 of density attached aluminum foil on both sides, showed 12%, 14% of improved heat transfer coefficient respectively compared to existing expanded polystyrene of the same density. Besides, they met all the standards for the testing of heat release and gas hazard. On the other hand, the one made of general expanded polystyrene could not meet the standards of the heat release test and the gas hazard test.
Keywords : Aluminum Foil, Expanded Polystyrene, Heat Insulating Materials, Fire Retardancy, Heat Transfer Coefficient

1. Introduction

Expanded polystyrene, polyurethane foam and glass wool are mainly used as insulating materials for buildings. Among these, expanded polystyrene is most commonly used. Expanded polystyrene is easy to construct due to its light weight compare to its volume. However, as it has a lower heat resistance temperature than other insulating materials, it has some disadvantages that the risk of fire is high, and toxic gas is generated when a fire occurs, etc.

When analyzing existing research on heat insulating materials for buildings, Shaik, S., and Talanki, A.B.P.S. (2016) performed the heat release test on seven materials such as reinforced cement concrete, expanded polystyrene, foam glass, rock wool, rice husks, resin-bonded mineral wool and cement gypsum with the theme of "Optimizing the Position of Insulating Materials in Flat Roofs Exposed to Sunshine To Gain Minimum Heat into Buildings under Periodic Heat Transfer Conditions." The experimental results show that expanded polystyrene emits the least amount of heat[1].

Kontogeorgos, D.A., Semitelos, G.K., Mandilaras, I.D. and Founti, M.A. (2016) carried out "Experimental Investigation of the Fire Resistance of Multilayer Drywall Systems Incorporating Vacuum Insulation Panels and Phase Change Materials." This paper investigates the fire resistance of innovative high thermally insulated multilayer drywall assemblies incorporating conventional insulation materials, phase change materials and vacuum insulation panels.

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The analysis of differential scanning calorimetry results indicated that at temperatures up to 200° C, the gypsum boards (both phase change materials) act as fire retardants because of the dehydration process. The vacuum insulation panels' layer found to significantly delay the penetration of the heat through the drywall configuration when compared to the other configurations[2].

With the theme of "Characteristics of Rigid Polyurethane Foam Blown by HFCs for LNG Storage Tank," Lee, Y. B., Choi, S. H. and Choi, G. H. measured the physical and mechanical properties of rigid polyurethane foam blown by HFCs and compared the results with the properties of rigid polyurethane foam synthesized using HCFC-141b. From this, they reviewed the feasibility of substituting the HFCs foaming agent for HCFC-141b in heat insulating materials for LNG storage tanks. As a result, the physical properties and mechanical properties of the rigid polyurethane foam blown by HFC-365mfc are suitable for use as heat insulating materials for LNG storage tanks. Compared with rigid polyurethane foam blown by HCFC-141b, there was no difference or very small difference in mechanical strength and there was no difference in thermal conductivity. Therefore, rigid polyurethane foam blown by HFC-365mfc were judged to be substitutable for heat insulating materials of rigid polyurethane foam blown by HCFC-141b as heat insulating materials for LNG storage tanks[3].

The study of Kang, H. J., Jin, E. M. and Kang, S. P. in regard to "Strength Characteristics of Lightweight Insulating Mortar Using Wasted Foam Polystyrene Heat Insulating Materials as Recycling Aggregate" was carried out to examine the properties of mortar strength with increasing volume of wasted foam polystyrene as basic data for the development of lightweight insulating mortar using wasted foam polystyrene heat insulating materials for the purpose of recycling waste materials and developing environmentally-friendly materials. As a result, compressive strength and flexural strength of lightweight insulating mortar using wasted foam polystyrene heat insulating materials as recycling aggregate showed a tendency to decrease as the volume of recycled aggregate increased. It showed that the compressive and flexural strength in this paper was relatively low compared to the water-cement ratio of 70% because the insufficient number of mixing revolutions at the water-cement ratio of 50% could not achieve dense compaction[4].

The study of Choi, G. R., Gong, B. S., Park, T. W. and Choi, M. A. on "The Analysis of Combustion Characteristics of Expanded Polystyrene Heat Insulating Materials for Buildings" analyzed the combustion characteristics of expanded polystyrene heat insulating materials for building which had been frequent problems when fire occurs[5]. "A Study on Enhancing Methods of Thermal Conductivity of Polyurethane Foam Insulator for LNG Carrier Using Polyurethane Foam Insulation for Various LNG Carrier Using Various Raw Materials" was carried out by Lee, Y. B., Kim, W. N., Jang, M. G. and Choi, G. H. in regard to the improvement of insulation performance using various raw materials for the polyurethane foam insulator which had been widely used as an insulator for the LNG carrier in the past[6].

Kim, C. J., Youn, J. R. and Lee, J. H. studied "Processing of Polyurethane Microcellular Foam for Thermal Insulation[7]." With the theme of "Characteristics of Thermal Conductivity of the Polyisocyanurate Aerogel for Insulator," Lee, O. J., Woo, S. J., Lee, K. H., Lim, J. W. and Yoo measured the thermal conductivity of the polyisocyanurate aerogel for an insulator. The measurement results showed that the thermal conductivity created by the collision of gas molecules was affected by the average pore size at low pressure when the pore size is small like the aerogel. When the aerogel is used as an insulator using vacuum panels, the thermal conductivity created by the solid lattice affects the thermal conductivity and density of the raw materials. The catalytic ratio and aging temperature are factors that can affect the reaction in the synthesis of the PIR aerogel. The higher the reaction rate, the higher the density and the higher the thermal conductivity[8].

Jeong, Y. S., Jeon, E. D. and Yoon, S. H. carried out experimental study on the change in the thermal conductivity of the extruded polystyrene insulation materials (XPS) in long-term storage at a constant temperature and humidity room over a long period

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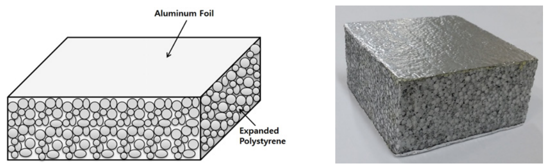
of time in their study, "Experimental Study of Thermal Conductivity of Extruded Polystyrene Insulation Materials for a Long Time." The experimental results show that the thermal conductivity of the XPS gradually increased with time. It was identified that the special-grade specimen increased to 167% and the 1st grade specimen increased to 163% compared to the first measured value after 3,100 days. In particular, the change in the initial 4-month period is about 50% of the total period variation. If the performance measurement is performed within 4 months immediately after the XPS is produced, it can be judged to be relatively advantageous compared with the thermal conductivity after applying it to the actual building. The tendency of the thermal conductivity of XPS over time showed almost the same pattern in both the special-grade specimen and the 1st grade specimen. The density change was found to be reduced by 2 ~ 3% in the 9th measurement compared to the initial measurement[9].

Chae, H. B., Kwon, I. G., Kim, H. J., Jeong, K. S. and Won, J. H. investigated the combustion gas characteristics of polyurethane foam which is widely used as a building material and compared them with the combustion gas characteristics of phenolic foam which is currently popular as a substitute material in their study, "Comparative Analysis of Combustion Gases for Phenolic Foam and Polyurethane Foam Insulations." Experimental results showed that the gas toxicity of general polyurethane was the highest in both the gas toxicity test and the gas-detecting tube test. On the other hand, phenol foam was shown to have the lowest gas toxicity compared to polyurethane in all experiments[10].

Analysis of the above studies shows that previous studies focused on fire hazard, combustion characteristics, heat transfer coefficient, etc. of polyurethane foam or expanded polystyrene, which are mainly used as insulating materials. Also, In addition, a way of adding a substance to the expanded polystyrene by fire retardant method had been studied. The purpose of this study is to create an insulating material that can enhance heat insulating efficiency and decrease the fire hazard of expanded polystyrene, which was used as existing insulating materials for buildings, by attaching aluminum foil to it.

2. Structure of Expanded Polystyrene Heat Insulating Materials with Aluminum Foil

As shown in [Figure 1], the insulating material of interior and exterior wall for buildings was constructed by attaching aluminum foil to existing expanded polystyrene to reduce the radiant heat from the outside. It is formed to have heat insulation, not to be burnt easily in a fire by adding the insulating material with high fire retardant on the walls of buildings, and to decrease the hazard of suffocation by reducing smoke.



(a) Structural Drawing (b) Photo

[Figure 1] Expanded Polystyrene Heat Insulating Materials with Aluminum Foil on Both Sides

3. Test for Measurement of Heat Transfer Coefficient and Testing of Gas Hazard

3.1 Test for Measurement of Heat Transfer Coefficient

An experiment was conducted to compare the thermal conductivity of expanded polystyrene with aluminum foil on both sides of expanded polystyrene with density of 10 kg/m^3 and 14 kg/m^3 manufactured according to KS M 3808: 2011. The thickness of the expanded polystyrene was 50 mm and the thickness of the aluminum foil adhered to both sides was 6 μm. As a result of the experiment, it was confirmed that the heat insulating materials with aluminum foil on both sides of the expanded polystyrene have 12% and 14% improvements in thermal conductivity respectively compared to the conventional expanded polystyrene with the same density as shown in <Table 1>.

<Table 1> Test for Measurement of Heat Transfer Coefficient

	Heat Transfer Coefficient		Improvement rate
Density (kg/m^3)	Expanded Polystyrene with Aluminum Foil	Expanded Polystyrene	
10	0.0407	0.0460	12%
14	0.0326	0.0428	14%

<Table 2> Heat Release Test and Gas Hazard Test

Test Items		Value of the Test Result		Criteria
		Expanded Polystyrene with Aluminum Foil	Expanded Polystyrene	
Heat Release Test	Total heat release amount	0.6	22.2	8 or less
	Time (s) during which heat release rate keeps exceeding 200 kW/m^2	0	0	10 or less
Gas Hazard Test	Stop Time (min.)	14.34	8.55	9 or more

3.2 Heat Release Test and Gas Hazard Test

Experiments were carried out to compare the heat release and gas hazard properties of expanded polystyrene with aluminum foil on both sides and common expanded polystyrene. The heat release test was carried out according to KS F ISO 5660-1: 2008 and the gas hazard test was carried out according to KS F 2271: 2006. As a result of the tests, the insulation material manufactured by attaching the aluminum foil to the expanded polystyrene satisfied both the acceptance criteria of the heat release test and the gas hazard test as shown in <Table 2>. The result confirms that the heat insulating material is excellent in flame retardancy. On the other hand, the heat release value of the insulation material manufactured as general expanded polystyrene was 22.2MJ/m^2 deviating from 8MJ/m^2 which was the acceptance criterion of the heat release test. In addition, the stop time value for the gas hazard test of the insulation material manufactured as general expanded polystyrene was 8.55 min., which is less than 9 min. which was the acceptance criterion of the gas hazard test.

4. Conclusion

The purpose of this study is to decrease fire hazard by attaching aluminum foil to expanded polystyrene, which is mainly used for insulating materials, to have fire retardant and to create the insulating material that can enhance heat insulation effect. The result of the test confirmed that the insulating materials, expanded polystyrene of 10 kg/m^3 and 14 kg/m^3 of density attached aluminum foil on both sides, showed 12%, 14% of improved heat transfer coefficient respectively compared to existing expanded polystyrene of the same density.

In the heat release test and the gas hazard test, the heat insulating material manufactured by attaching the aluminum foil to the expanded polystyrene satisfies the acceptance criteria of both the heat release test and the gas hazard test. On the other hand, the heat insulating material made of general expanded polystyrene satisfied the acceptance criterion of the time during which the heat release rate of the heat insulating material made of general expanded polystyrene kept exceeding 200 kW/m^2 as the time was measured as 0 but the total heat release amount and the stop time did not satisfy the acceptance criteria.

Future researches also need to develop expended polystyrene with lower thermal conductivity, heat release and gas harmfulness than conventional expanded polystyrene.

5. Conflict of Interest

The author confirms that this article content has no conflict of interest.

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