FIRE RETARDANT AND GASEOUS HAZARDOUS SUBSTANCES EVALUATION OF THERMAL INSULATION MATERIALS FOR COMPOSITE PANELS

Seunghwan Wi[1], Young Uk Kim[1], Sungwoong Yang[1] and Sumin Kim[1]*

[1] Department of Architecture and Architectural Engineering, Yonsei University, Seoul 03722, Republic of Korea
* Corresponding author (kimsumin@yonsei.ac.kr)

Abstract

Traditionally, insulation materials have been developed to prevent heat loss or gain in buildings. Polymer compounds such as polyurethane, polystyrene, and polyethylene have been used to improve the performance of insulation materials during the modern industrialization process. However, because most insulating materials based on complex organic chemicals are combustible, they are susceptible to fire, and there are limitations such as the emission of harmful chemicals. The reason for the high number of casualties caused by insulation materials in building fires is that insulation materials based on complex chemical substances generate a large number of toxic gases, which causes suffocation. Therefore, the fire resistance performance of five types of insulation materials used in actual construction sites was evaluated in this study. Based on the total heat release (THR) and heat release rate (HRR), phenolic foam (PF) was the insulation material that satisfied the criteria of the non-combustible grade as a result of the flame-retardant performance evaluation. Fourier-transform infrared spectroscopy (FT-IR) spectroscopy was used to perform a quantitative and qualitative evaluation of gaseous hazardous substances generated during the combustion of insulating materials by ISO 19702. The Fractional effective dose (FED) value was derived using the results of the analyses of eight gases by ISO 13344.

Research Background

- **In addition to the mitigation of carbon emissions through the reduction of building energy consumption, the prevention of fire spread in buildings is important an important task globally. Therefore, a growing interest towards building materials that can simultaneously contribute to energy savings and provide good flame-retardant performance in buildings exist. According to the fire statistics published by the Korea National Fire Agency (Korea National Fire Agency, 2020), building fires account for the highest proportion. The insulating material with excellent flame retardant performance is crucial because it can prevent diffusion in case of fire and ensure sufficient evacuation time. Additionally, the low emission performance of harmful gases during combustion can prevent suffocation by toxic gases during fires. Therefore, in this study, fire performance evaluation was conducted on 5 types of organic insulation materials and 3 types of composite sandwich panels.**

Figure 1. The cases of occurrences of fires in South Korea

Materials and Methods

• Materials

- **The fire retardant performance of the thermal insulation material was evaluated according to KS F ISO 5660-1: Heat release rate test method-cone calorimeter method, the total amount of heat released (THR), the maximum heat release rate (HRR), and the degree of combustion of the thermal insulation material. For the analysis of gaseous hazardous substances in insulating materials, quantitative and qualitative evaluation of gaseous hazardous substances during the combustion of insulating materials was conducted through FT-IR (Fourier-transform infrared spectroscopy) according to ISO 19702.**

Table 1. Composition and thermal properties of insulation materials

Classification	Type	Main raw material	Thermal conductivity (W/m·K)	Flame retardant (by manufacturer)	Case
Thermal insulation	Expanded Polystyrene (EPS)	Polystyrene	0.031	Combustible	EPS_1
	Extruded Polystyrene (XPS)	Polystyrene	0.025	Combustible	XPS_1
	Rigid urethane foam (PIR)	Polyurethane, Polyisocyanurate	0.020	Non-combustible	PIR_1
			0.023	Non-combustible	PIR_2
			0.020	Combustible	PIR_3
			0.023	Combustible	PIR_4
	Polyurethane foam (Spray)		0.028	Combustible	SPU_1
			0.027	Combustible	SPU_2
			0.022	Non-combustible	SPU_3
	Phenolic Foam (PF)	Phenolic resin	0.020	Non-combustible	PF

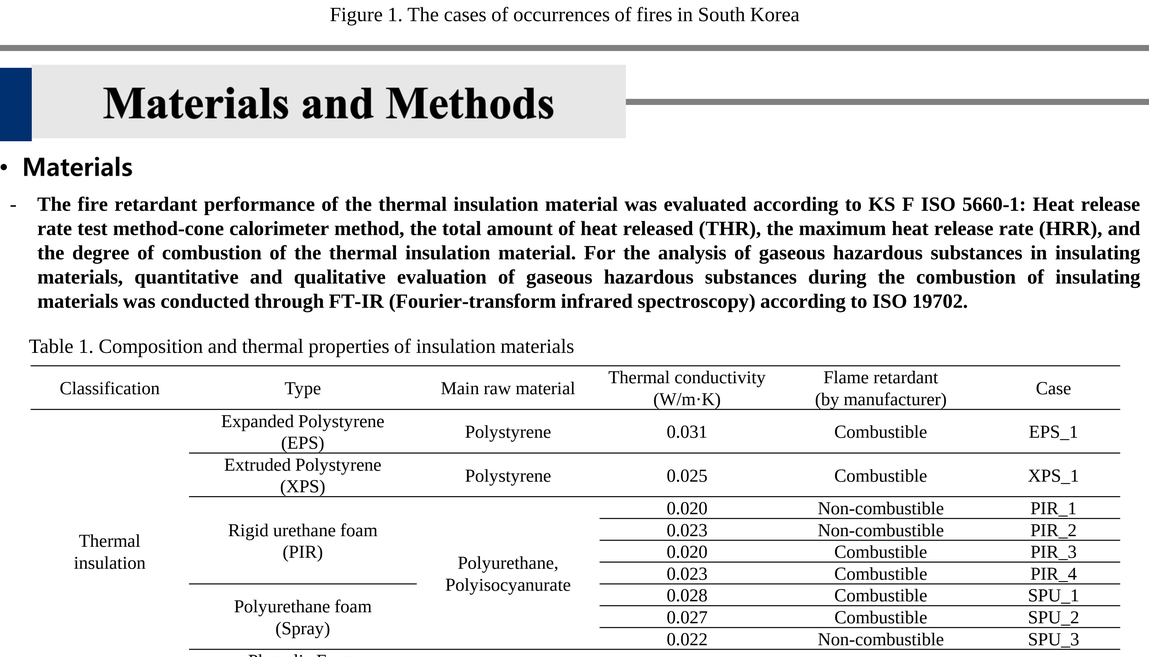

Figure 2. Thermal insulation materials to be analysed.

Results and Discussion

• Flame-retardant performance results

- **The results of the fire-retardant performance of the thermal insulation materials are shown in Fig. 3. Two distinct types of polystyrene insulation were evaluated for their fire retardant properties. The total amount of heat released by EPS was calculated to be 24.66 MJ/m^2, and the rate of heat release was determined to be 424.49 kW/m^2. In the case of XPS, the total heat release was calculated to be 33.19 MJ/m^2, and the rate of heat release was calculated to be 466.69 kW/m2, both of which did not meet the flame retardant performance class recommended for the building's fire spread prevention structure. Both EPS and XPS are considered heat sensitive since they are thermoplastic polystyrene-based insulators.**
- **The total heat release (THR) and heat release rate (HRR) must meet flame-retardant rating criteria, and the toxicity must be determined separately using the average behavioral stop time of rats. PF was the most satisfying insulation material evaluated in terms of total heat release and heat release rate.**

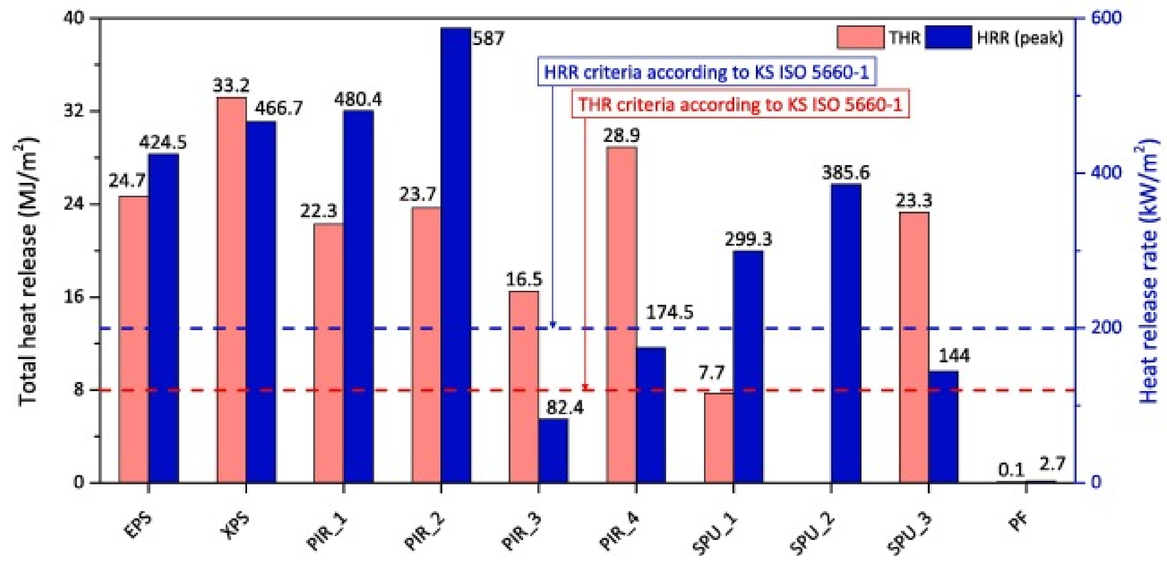

Figure 3. Fire retardant performance results of thermal insulation materials.

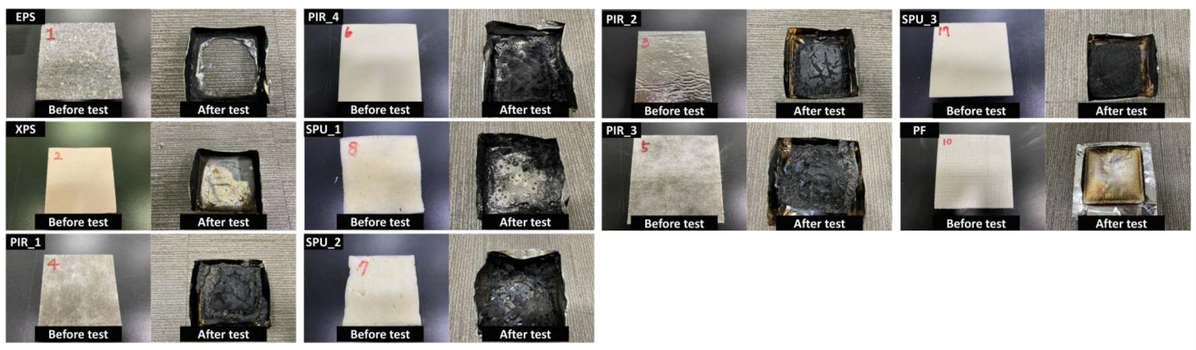

Figure 4. Test results of cone calorimeter

• Gaseous hazardous substances results

- **Table 2 shows the FED results of thermal insulation materials. Based on the 8 gas analysis results, according to ISO 13344, the FED value was derived as the sum of the ratio of the half-lethal concentration LC50 to the average gas generation per minute. National Fire Protection Association (NFPA) suggests that almost all occupants can be evacuated when the FED value is 0.8 or less. Three types of insulation materials, PF_2, SP EPS, and SP PF had an FED value of 0.8 or less. However, four types of PIR insulation materials and three types of SPU insulation materials had an average FED of 2.0 or higher, which was analyzed to be very dangerous in case of fire.**

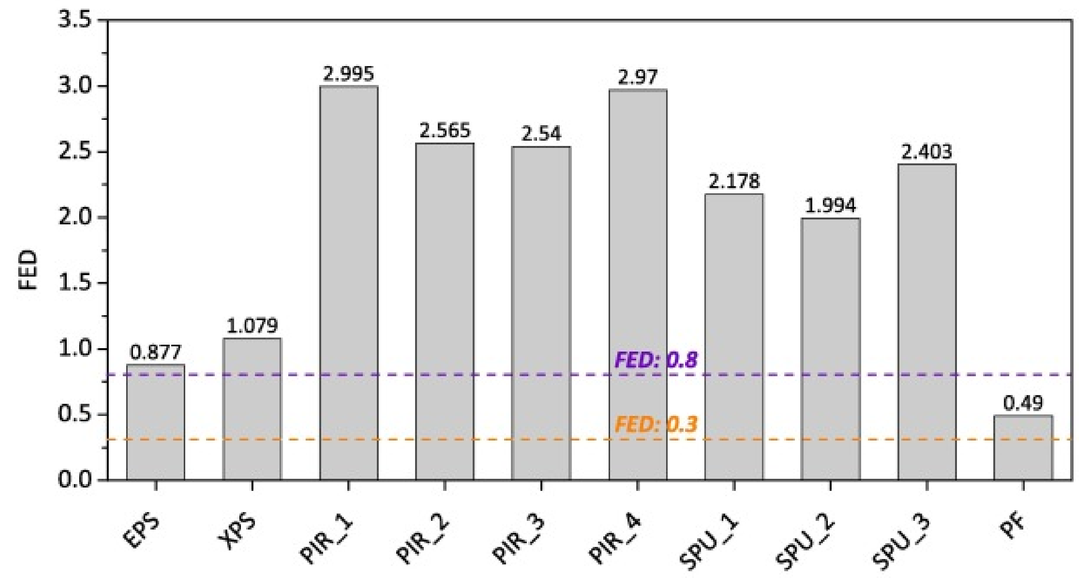

Figure 5. FED analysis results

Conclusion

- **This study comprehensively evaluated the fire safety performance of 5 types of organic insulation materials and 3 types of composite sandwich panels in terms of these policies, industry trends, and fire safety of buildings. As a result of the flame-retardant performance evaluation, PF were the insulation materials that satisfied the criteria of the non-combustible grade based on the total heat release (THR) and heat release rate (HRR).**
- **As a result of analyzing the 8 types of gases emitted during the combustion of 5 types of organic insulation materials, it was confirmed that CO was released in large quantities at an average of 19000 ppm or more in the PIR and PUS insulation groups. Based on the 8 gas analysis results, according to ISO 13344, the FED value was derived. The toxicity of combustion gas in case of fire was evaluated according to the FED value.**

Acknowledgements

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