10th International Conference of the International Institute for Infrastructure Resilience and Reconstruction (I3R2)
20–22 May 2014
Purdue University, West Lafayette, Indiana, USA

The Study on Fire Safety by a Real-Scale Combustion Experiment of Composite Material

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ABSTRACT

In this study, a real-scale combustion experiment was carried out for a Styrofoam and glass wool sandwich panel to figure out the fire safety for the composite material used for a building. In the experiment, a heat release rate of a sandwich panel was measured by the ISO 9705 fire test method. Research has also tested and compared temperature change in the Large Scale Calorimeter (LSC) experiment equipment to evaluate the structural safety of the structure body. As a result of the experiment, the structural body with the Styrofoam sandwich panel collapsed which was caused by propagation, and in case of the glass wool sandwich panel, the combustion did no propagate inside. Since the composite material experiences various types of fire hazards depending on the combustion characteristics of the core material, the exact combustion characteristic should be expected by the full-scale combustion experiment.

1. INTRODUCTION

To avoid flame diffusion in buildings on fire, the performance to prevent the flame propagation should be secured in the finishing material inside and outside the building. To do this, various combustion experiments are generally carried out for the finishing materials. However, since recently, composite materials are used, such as sandwich panels, aluminum panel, etc., the combustion characteristics surveyed by the existing small-scale combustion experiment can be expressed in a different way at the actual fire accident. According to a fire at a high-rise building in Korea in 2010, the flame inside the building was rapidly and vertically propagated to the outside aluminum composite panel in the high-rise building finished with an aluminum composite panel. Figure 1 shows the accident.

There are a metal panel, concrete panel, dryvit, stone, tile, glass, etc., for the external finishing material of a building; the metal panel and concrete panel are classified depending on the type of core material. In case the incombustible material as a finishing material is used outside and the combustible material is used inside, since it is difficult to figure out the combustion characteristics, a lot of fire damage can occur at an actual fire accident. Therefore, the aim of this research is to find out the combustion characteristics for the composite material through a full-scale combustion experiment. Styrofoam and glass wool are used on the inside of a building as a composite material for the combustion experiment; a sandwich panel using a zinc steel sheet is used outside.

2. EXPERIMENT

The combustion experiment of the sandwich panel was carried out with the Styrofoam and glass wool as “ISO 9705-Fire experiments-Full-Scale room experiment for Surface products.” Moreover, an experiment for comparison has been performed in the Large Scale Calorimeter (LSC). In particular, the heat release rate and heat flux was surveyed by the ISO 9705 fire test, and in the comparison experiment for the LSC, the temperature change was measured for the core material of ceiling.

In the fire test method of ISO 9705, the sandwich panel was installed inside of the fire room (2.4×3.6×2.4 m), as shown in Table 1, and the fire behavior is evaluated for the sandwich panel by being directly exposed to the flame using the propane burner as a fire source in the corner. For the fire experiment, the data is collected for 2 minutes after starting the experiment. Then, the fired strength of the burner is increased from 100 kW (exposed for 10 minutes) to 300 kW (exposed for 10 minutes).

Figure 1. Fire in a high-rise building using the composite material

Table 1. ISO 9705 fire test

Fire test room [meter]	. 2.4×3.6×2.4 (Opening : 0.8×2.0) . material : Firebrick . Thickness : above 20mm
Burner [Propane]	. Sand(2–3mm), Gravel(4–8mm) . 170×170×145(size)
Fire test time	. Total Time : 25 minute . Burner : 100, 300 kW (10 minute)
Fire test results	. HRR, Heat flux

Figure 2. Photo of real scale fire tester

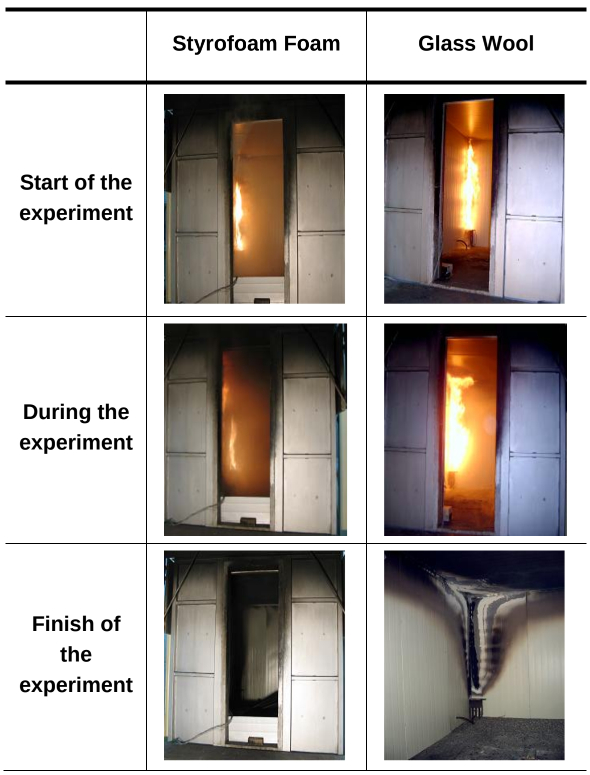


Figure 3. Photo of ISO 9705 fire experiment results of sandwich panels

Figure 2 shows the fire experiment equipment for the ISO 9705 experiment method. The gas generated in the experiment is directed into a duct without any efflux to the outside. To do this, over 3.5 m^3/s are maintained for the air volume inside the duct. An oxygen consumption calorimeter is used to measure the heat release rate, which has a basic principle generating 13.1 MJ/kg for every 1 kg of oxygen consumption (Babrauskas, & Grayson, 1992)

The combustion experiment was stopped under the condition of flashover or collapse. The standard of the flashover per unit space is shown below (National Fire Protection Association, 2002).

1. Exceed 1 MW heat release rate
2. Exceed 20 kW/m^2 for the heat flux in the floor
3. Exceed average temperature of 600°C in the smoke layer
4. Break out the flame through the door
5. Ignite paper by radiant heat in the floor

3. RESULTS

3.1. Real Scale Experiment by ISO 9705 Fire Test

As a result of the sandwich panel experiment, the flame that started in the corner of the specimen transferred to the ceiling in the Styrofoam sandwich panel which led to rapid propagation and burning to the core material of the ceiling. The ceiling collapsed 7 minutes after starting the experiment. The combustion was not propagated in the glass wool sandwich panel but in the corner. Figure 3 shows the combustion experiment of the sandwich panel.

Table 2 shows the maximum heat release rate and maximum heat flux for the sandwich panel based on the experiment results. The Styrofoam sandwich panel showed low heat release rate due to the initial stop of the experiment caused by the support problem, but the heat flow of the floor was high at 32.2 kW/m^2. For the glass wool, the maximum heat release rate was approximately 288.5 kW. Other than with some exceptions of the heat capacity of the burner, it is considered that the combustion of the core materials does not occur due to nonflame propagation.

Table 2. Maximum value of ISO 9705 experiment results

	HRR Max.	Heat Flux Max.
Styrofoam Foam	432.3 kW	32.2 kW/m^2
Glass Wool	288.5 kW	9.4 kW/m^2

3.2. Real-Scale Combustion Experiment Using LSC

In the study, to survey the combustion propagation for the core material in the full-scale experiment of the composite material, a mock-up was fabricated , measuring 2.4(L) × 3.6(W) × 2.4(H) m, as shown in Figure 4 using the Styrofoam and glass wool sandwich panels. Also, the temperature change was surveyed at a total of six points (T1–T6) of the core material in the ceiling, which is the weakest point during a fire to survey the combustion propagation of the core materials. Moreover, to test the temperature change by the flame diffusion, the temperature change was measured at the T7 location above the entrance.

The fire was tested in a LSC, and the glass wool and Styrofoam sandwich panels were used for the experiment. Figure 5 shows a mock-up of the sandwich panel installed; a wooden clip was used inside the mock-up as a fire source.

The result of the experiment is shown in Figure 6. The flame was ignited in the corner of the mock-up 1.5 minutes after beginning the experiment in the Styrofoam sandwich panel. The flame rapidly propagated in the ceiling which collapsed 2 minutes after starting the experiment. For the glass wool sandwich panel, the structural body did not have any problems until extinguishing the wood.

In the Styrofoam sandwich panel, the flashover was generated 2 minutes after starting the combustion experiment, and the structural body collapsed approximately 5 minutes after the experiment,ending the test. For the glass wool sandwich panel, the experiment ended when the combustion reaction of the internal wooden clip ended.

As a result of the measuring the temperature change in the core materials, the temperature changed in points 1 and 4, which were near the fire source, 80 seconds after starting the experiment. Points 2 and 5 were also affected in the same timeframe. For the glass wool sandwich panel, the flashover did not occur until the end of the combustion reaction of the wood. The internal temperature changed after approximately 120–150 seconds.

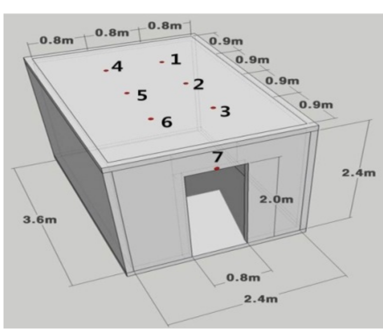


Figure 4. Combustion experiment mock-up size & temperature measurement points

a. glass wool

b. Styrofoam

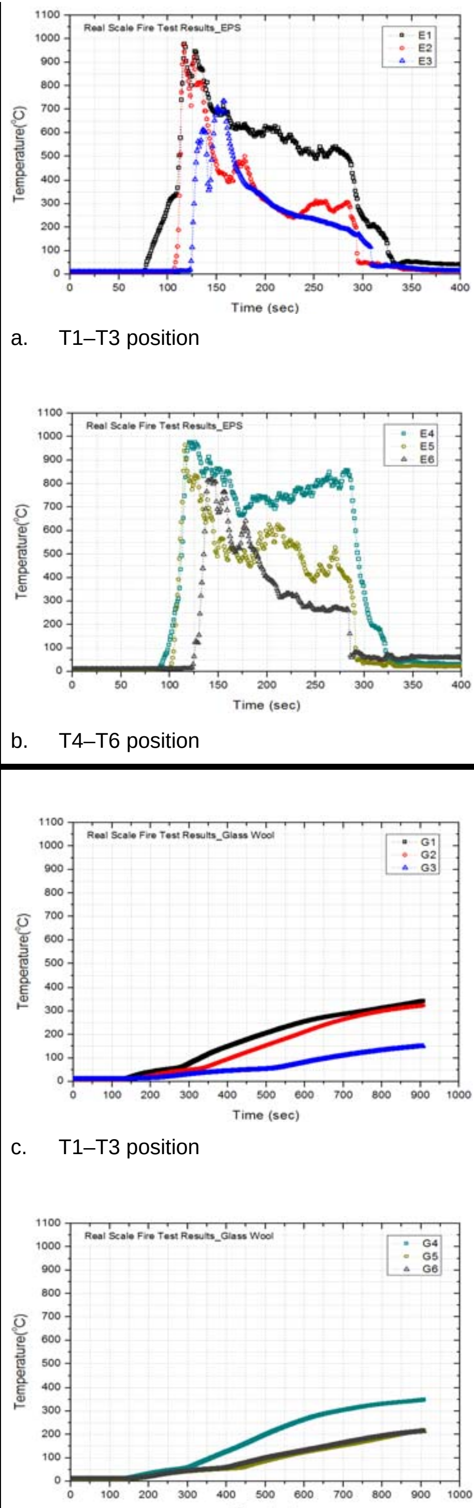
Figure 5. Combustion experiment mock-up

a. Ignition

b. Growth

c. Flash over

Figure 6. Photo of combustion experiment results



Styrofoam

a. T1–T3 position

b. T4–T6 position

Glass Wool

c. T1–T3 position

d. T4–T6 position

Figure 7. Temperature measurement results

Table 3. Maximum temperature

		Temperature in 120 sec	Max. Temperature
Styrofoam Foam	1	876.7 ℃	979.3 ℃
	2	846.6 ℃	973.9 ℃
	3	12.8 ℃	12.8 ℃
	4	976.8 ℃	976.8 ℃
	5	810.3 ℃	964.8 ℃
	6	12.1 ℃	12.1 ℃
Glass Wool	1	11.5 ℃	343.6 ℃
	2	10.9 ℃	323.7 ℃
	3	11.0 ℃	150.3 ℃
	4	11.2 ℃	348.8 ℃
	5	10.7 ℃	219.4 ℃
	6	10.9 ℃	213.7 ℃

Table 4. Proposed classification criteria for surface products experimented to ISO 9705[4)]

Class	Minimum time to flashover (min)	Heat release rate(HRR)		
		Peak[a] (kW)	Peak[b] (kW)	Average[a] (kW)
A	20	300	600	50
B	20	700	1000	100
C	12	700	1000	100
D	10	900	1000	100
E	2	900	1000	-

a: Burner excluded. / b: Burner included

Table. 3 shows the maximum measured temperature. Since the Styrofoam sandwich panel collapsed 2 minutes after the experiment, ending the test, the temperature is indicated at the same time. In the Styrofoam sandwich panel, 976.8°C was measured in the core materials as the maximum temperature; the maximum exceeded 960°C except in Points 3 and 6 near the mock-up entrance. For the glass wool sandwich panel, the temperature did not change in the time when the sandwich panel collapsed, and the maximum temperature was 348.4°C at Point 3 near the fire source.

4. CONCLUSION

The combustion performance of materials in buildings should be evaluated to prevent fire propagation and protect the people using the essential fire safety design method. However, as more composite materials are used in buildings, such as sandwich panels, problems for methods to evaluate the combustion performance with the existing single materials have been found.

Therefore, in the study, we attempted to find the combustion characteristics for the composite materials through a full-scale combustion experiment. The classification standard for the combustion characteristic of the sandwich panel is divided into 5 steps by the maximum heat release rate as shown in Table 4.

The Styrofoam generating the flashover is Class E, while the glass wool sandwich panel is Class A, based on the results of the ISO 9705 fire experiment.

In the full-scale comparison experiment using the LSC, the flashover occurred 2 minutes after starting the experiment of the Styrofoam sandwich panel but there were no structural problems for the glass wool sandwich panel until the end of the experiment.

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