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Fire Performance of a Wooden Façade System Based on the Draft European Test Method: Assessing the Contribution from the Side Wing

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Fire Performance of a Wooden Façade System Based on the Draft European Test Method: Assessing the Contribution from the Side Wing

G Zhao*, A Dragsted, M F Frederiksen, A Haastrup, C F Schou and K Livkiss

Danish Institute of Fire and Security Technology, Hvidovre, Denmark

*Corresponding author email: gzh@dbigroup.dk

Abstract. This study presents the results of large-scale fire tests conducted on a ventilated wooden façade system, based on the draft European testing method to assess the fire performance of the façade systems in cases with and without combustible material on the side wing. Spruce has been used as cladding material. Two distinct tests were conducted to evaluate the effect of adding combustible material to the side wing on the fire performance of the façade system. Test results indicated a significant difference in fire behaviour with the addition of combustible materials on the side wing. In the test without combustible material on the side wing, flame spread was confined to the first floor. In contrast, test with wood panels on the side wing, exhibited more severe burning and damage, with flames spreading to the base of the second floor. Heat flux and temperature measurements highlighted the increased fire intensity and spread due to the combustible side wing. The findings emphasize the critical role of façade configurations in building's fire safety design.

1. Introduction

Large-scale façade fire testing has been applied as a tool to evaluate the safety level and help ensure façade design complies with fire safety regulations and building codes. There are different test methods throughout Europe with different types of fire source, heat exposure to the façade, duration time of the test, pass criteria and so on. The project, 'European Approach to Assess the Fire Performance of Facades,' led by RISE, has been in development [1] [2] of a harmonized European testing method for facades and provide regulators with means to regulate the fire performance of façade systems.

Large-scale fire tests, conducted at DBI based on the draft European testing method to evaluate façade fire performance of a ventilated wooden façade system as part of the 'BioFacades: Uphigh' project. The tests employed the same fuel and corner configuration as specified by the European method, though with differences in wall height and window sizes, and did not adhere to the pass and fail criteria established by the new European test method. This project aims to assist fire engineers in verifying if detailed designs meet functional requirements of the building regulation. This study specifically examines two tests, emphasizing the impact of combustible materials on the side wing.

2. Façade system and test method

The wooden board as cladding material is from Frøslev, 21 x 120 mm and with tongue-and-groove connection joints. The density is measured 470 kg/m³ with a moisture content of 12.6% after 48 h in the conditioning room. The thermal conductivity was measured with the hot plate method, it increases from 0.12 W/(m·K) to 0.15 W/(m·K) as the temperature rises from 20°C to 85°C. The façade system was mounted on vertical concrete façade rig, and consists of an insulated back wall, ventilation cavity and vertically oriented non-fire treated wood cladding affixed to timber frame. Horizontal flame deflectors, extending 32.4 cm outside the cladding at various heights, were used to restrict flame spread. The flame deflectors were made with 2 mm steel with a 4-degree slope down, see in Figure **1** (a).

The facade rig was constructed based on the draft method outlined in [1], modifications were made to the primary wall to allow for two floors with height that are typical in real buildings, with its height extended to 1.5 m above the recommended minimum height of 8.5 m, while the width was kept at 3.2 m. The side wing, adhering to the minimum standard dimensions, measured 8.5 m in height and 1.5 m in width and was positioned at a 90° angle on the right side of the main structure. Each floor above the chamber features openings measuring 1.76 m x 1.98 m, surpassing the dimensions of 1.2 m x 1.2 m specified in the standard test. There are 10 tests in total in this façade test campaign, here only Test A and Test B are presented. Test A refers to the test with non-combustible side wing and Test B refers to the test with wood panel on the side wing, see in Figure **1** (b) and (c).

(a) (b) (c)

Figure 1. Build-up of the façade system (a) and the experimental set-up of Test A (b) and Test B (c).

The fuel load is provided by spruce wood crib and was constructed flowing the principles in [1]. The dimensions of the spruce sticks were approx. 45x45 mm and the external dimension of the 24-layer wood crib was 1.5m x 1m x 1.08m (width x depth x height). The wood crib was stored at approx. 20°C before the tests. The crib was placed 100 mm from the back wall and centered from the sidewalls of the combustion chamber. The density of the wood was approx. 500 kg/m^3. The peak HRR is approximately 3.4 MW as reported in [3] where the fire size of wood crib constructed in the same way has been studied. A mechanical exhaust of 80.000 m^3/h was evenly distributed at the ceiling. The tests were instrumented with thermocouples (type-K), plate thermometers and heat flux meters(Schmidt-Boelter gauge).

3. Results and discussion

In Test A flame spread was confined to the 1^{st} floor during the entire test. In Test B flames were primarily on the 1^{st} floor but with a minor fire at the base of the 2^{nd} floor. This 2^{nd} floor fire began at around 36 minutes, spreading through an edge path on the sidewall, a scenario unlikely if with a continuous wall design. This has been depicted in Figure **2**. In Test B, the burning was much more severe than in Test A and the damage area is much larger as well.

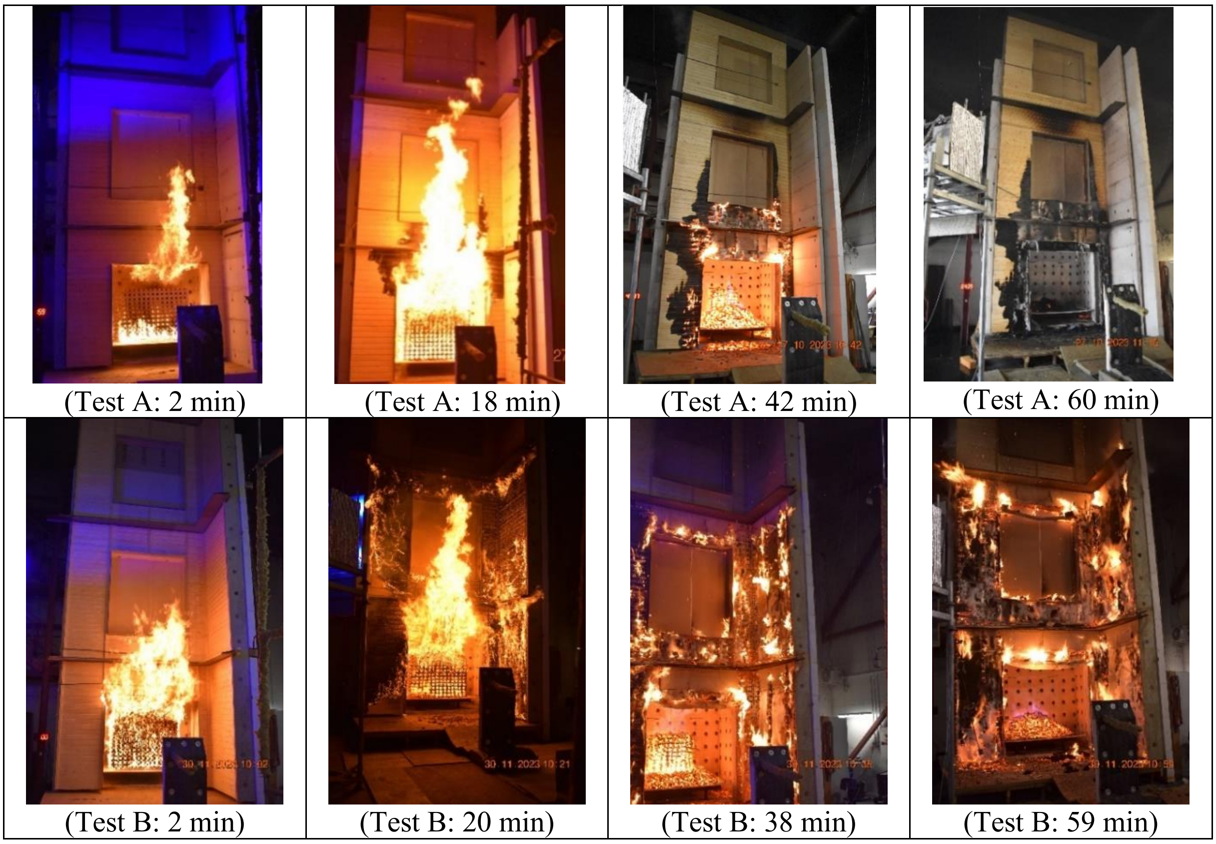

Figure 2. Snapshots captured at different times during the tests (both tests concluded after 60 mins).

3.1. Temperatures inside the combustion chamber

Temperatures were measured using plate thermometers positioned approximately 30 cm above the wood crib inside the combustion chamber. This data can serve as an indicator in evaluating the repeatability of the burner in the test, notwithstanding the unavailability of heat release rate data due to the test facility's constraints. Figure **3** (left) shows the results of 4 Tests. Temperatures inside the chamber increased rapidly after ignition, reaching a peak temperature of over 1000°C, except for Test 1, which was considered a complete failure and terminated at 18 minutes. Following the peak, there was a similar decay period where temperatures gradually decreased until the end of the tests.

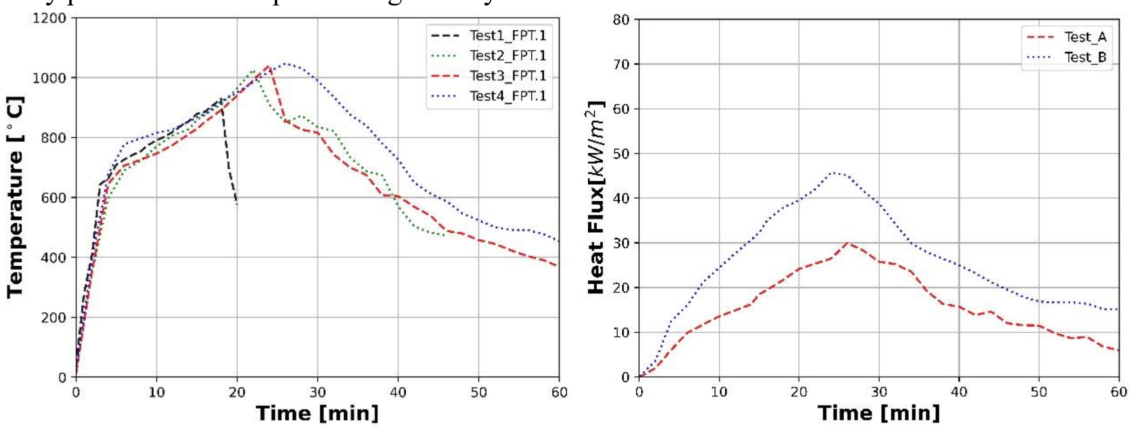

Figure 3. (left) Temperatures inside the combustion chamber in four tests and (right) heat flux at 3 m away from the facade and 1.4 m above the ground level.

3.2. Heat flux and temperatures opposite the facade.

Heat flux at 3 m opposite the façade and 1.4 m above the ground level were recorded, results of Test A and Test B are presented in Figure **3** (right). Throughout most of the test duration, heat flux values were higher in Test B, peaking at 30 kW/m² in Test A and 46 kW/m² in Test B. This difference indicates the contribution from the additional burning on the side wing and the subsequent increased burning on the main facade. Temperatures location 1 is at 3 m away from the façade and 1.4 m above the ground, location 2.1 is at 5 m away from the façade and 2.5 m above the ground and location 2.2 is at 5 m away from the façade and 4.5 m above the ground. The results are presented in Figure **4** (left). Similar trend was observed in all three locations, with higher values recorded in Test B. The most significant difference between two tests, 130 °C, was observed at location 1.

3.3. Temperatures on the facade

Figure **4** (left) presents the temperatures right above the combustion chamber and 5 cm away from the surface of the façade on the main wall. The results indicate that Test B consistently yielded higher temperatures than Test A, reaching a peak of 1060°C at 28 minute, compared to Test A's peak of 785°C at 15 minute.

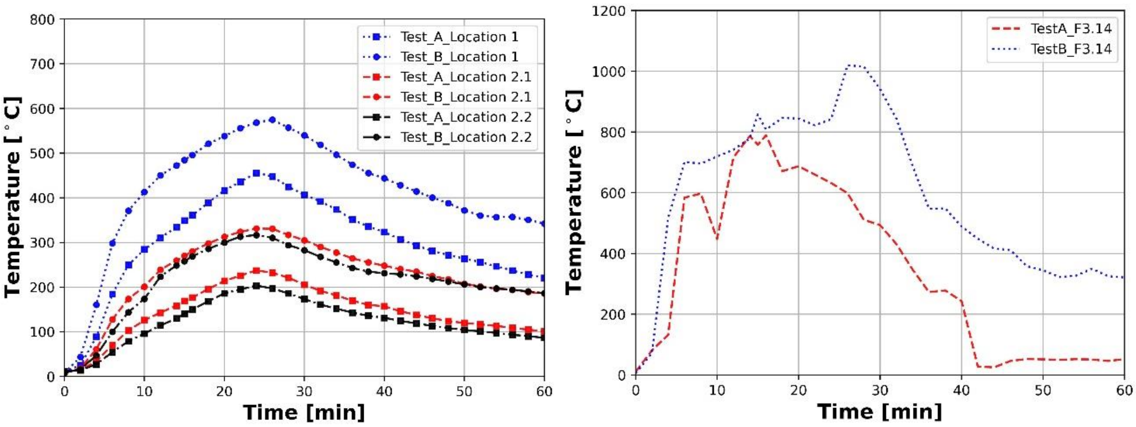

Figure 4. (left) Plate thermometer temperature outside the chamber at locations 1, 2.1 and 2.2, and (left) temperature right above the chamber on the main wall.

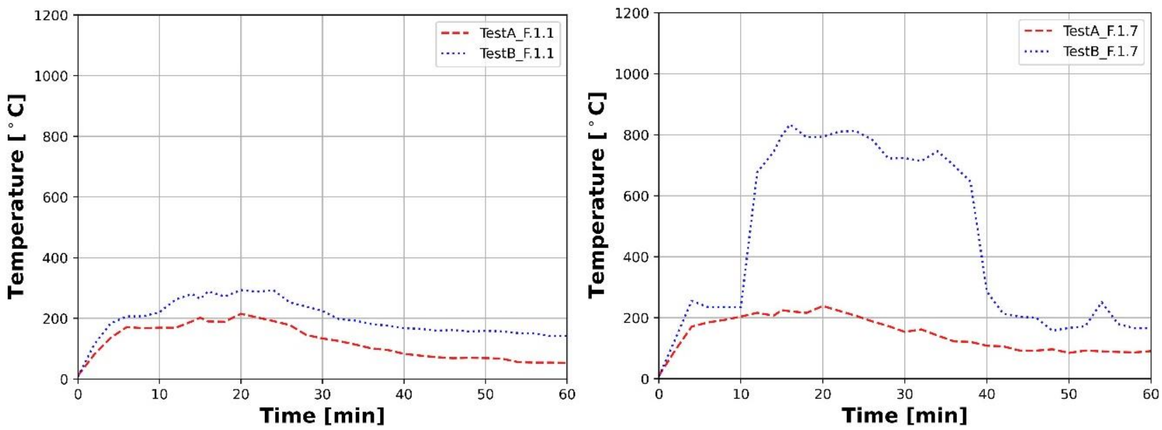

Figure 5. Temperature on the 2nd floor (left: F.1.1) and the 1st floor of the main wall (right: F.1.7).

Figure 5 illustrates the temperature at two locations: F.1.1, 300 mm above the 2nd floor window, and F.1.7, directly above the window on the 1st floor, both 1 m from the corner. The temperatures on the second floor remained below 300°C for both tests, with Test B consistently about 100°C higher than Test A. This suggests the additional combustible materials on the side wing have a limited impact on the thermal exposure on the 2nd floor. Figure 5 (right) displays temperature on the 1st floor of the main wall, showing temperatures below 220°C throughout Test A, whereas in Test B, temperatures hovered around 800°C from 10 to 40 minutes. The elevated temperature observed in Test B is mainly due to the increased combustion of material on the side wing, resulting in a large burning area on the main wall and, consequently, a more extensive fire on the facade. Figure **6** depicts the temperatures from two additional points on the 1st floor of the main wall, located 0.5 m from the corner and at heights of 1.01 m (F.1.10) and 1.51 m (F.1.9) above the deflector. Both points are lower than location F.1.7. Comparable to location F.1.7, Test B's temperatures reached up to and above 800°C and sustained these elevated levels for a more extended period than observed at F.1.7. Similarly, Test A exhibited relatively low temperatures at these two locations, which remained below 200°C for most of the test duration.

Figure **7** (left) presents temperatures at the 2nd floor of the side wing, measured along a vertical line 0.5 m from the corner at heights of 0.4 m (F.2.6), 0.9 m (F.2.5), and 1.4 m (F.2.4) above the deflector. Temperatures on the 2nd floor of the side wing remained below 220°C, similar to those on the 2nd floor of the main wall, except at 0.4 m above the deflector in Test B, where it started to increase after 40 minutes and reached 890 °C due to a small fire on the 2nd floor near the deflector. Figure **7** (right) shows temperature on the 1st and ground floors of the side wing, taken 0.5 m from the corner at various heights. In Test A, without combustible material on the side wing, temperatures remained below 200°C, while in Test B, the temperatures are much higher than 200°C as they were in flames.

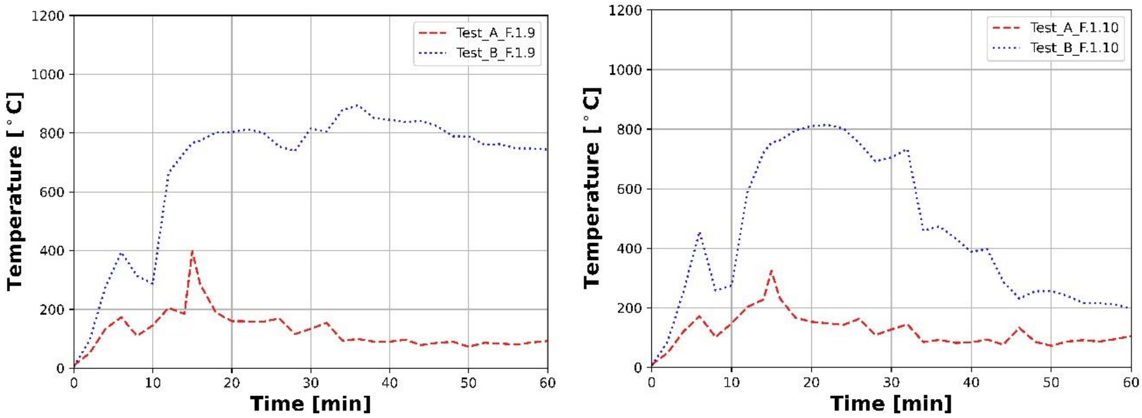

Figure 6. Temperature on the 1st floor of the main wall: (left) F.1.9, (right) F.1.10.

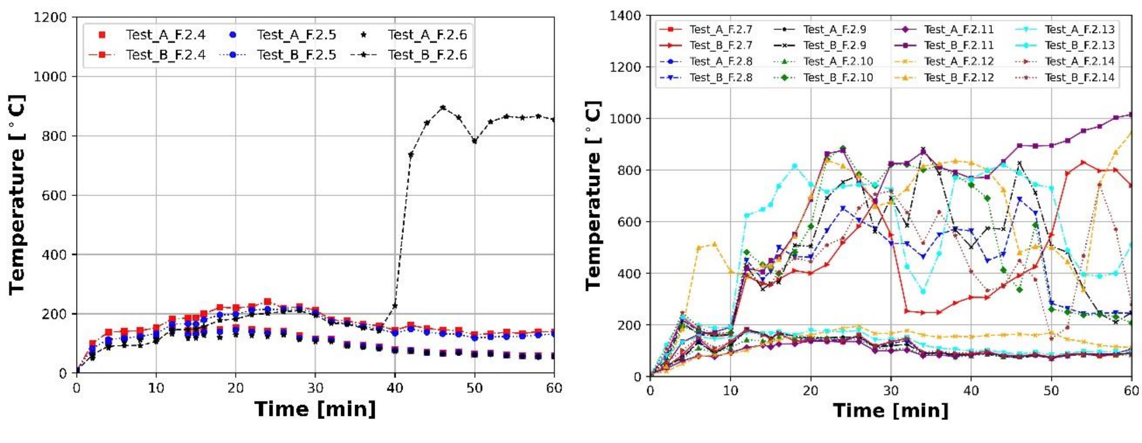

Figure 7. Vertical temperatures on the side wing: (left) 2nd floor, (right) 1st floor and ground floor.

3.4. Burning area on the façade

The total burning area results were determined based on the test videos and photos. Worth mentioning that blue light imaging method [4] were employed during the test, enabling a better visualization of areas through flames, and determining the extent of burning areas that might otherwise have been obscured at certain times. Figure **8** illustrates the progression of flame spread on wood façades in the tests with Test A on the left and Test B on the right. Color-coding was utilized, ranging from red (indicating the early test phases) to yellow (representing the later stages), to illustrate the progression of flame spread. The timeline from test's initiation to when flames spread to the specific façade area is represented in mm:ss. In Test B, the entire ground floor area, which is on the same level as the combustion chamber, was engulfed in flames by the 23:28 mark. Conversely, in Test A, there remained a small area that was never burnt. The flame spread to the first floor occurred more rapidly in Test B, with the first area above the deflector covered in fire at 06:26, compared to 12:50 in Test A. Additionally, while only about 42% of the first floor's total area was burnt in Test A by the time marker 20:41, Test B experienced complete burning of the entire first floor area by time marker 22:45. By the 36:28 mark in Test B, flames had reached the second floor, in contrast to Test A, where the fire was confined to the first floor for the duration of the test. The progression of the flame spread in the conducted tests highlights significant differences in fire behavior across different configurations.

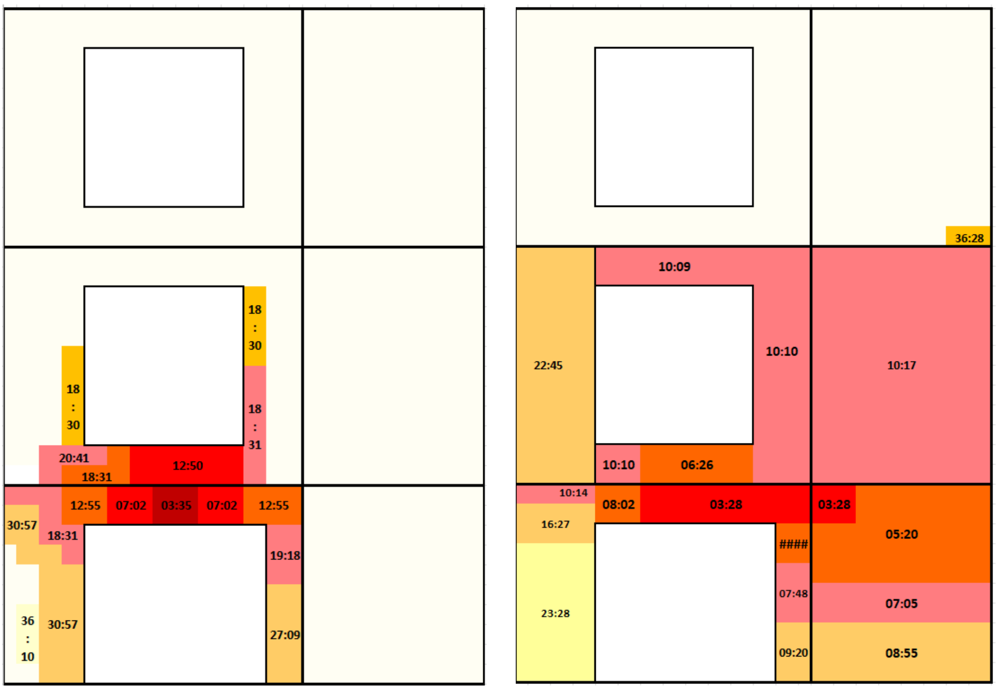

Figure 8. Flame spread comparison between Test A (left) and Test B (right).

4. Conclusions

Large-scale fire tests were conducted based on the draft European testing method. Results of two distinct tests were studied, one with non-combustible material on the side wing (Test A) and the other with combustible wood panels (Test B). Temperatures inside the combustion chamber were presented, indicating a reasonable repeatability of the tests. Test B consistently showed higher heat flux and temperatures at various locations, indicating the additional contribution of combustibles on the side wing to the overall fire intensity and façade exposure. Temperatures directly above the combustion chamber in Test B were consistently higher than Test A, reaching a peak of 1060°C at 28 minutes, compared to Test A's peak of 785°C at 15 minutes. The flame spread to the 1st floor occurred more rapidly in Test B, with the first area above the deflector covered in fire at 06:26, compared to 12:50 in Test A. Only about 42% of the 1st floor's total area was burnt in Test A by the time marker 20:41, while Test B experienced complete burning of the entire 1st floor area by time marker 22:45. The findings emphasize the critical role of façade configurations in building's fire safety design.

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