Fire Safety Measures Enabling Construction of Large Wooden Buildings (Part II)

To create a large-scale wooden structure, it is important not only to ensure the safe evacuation of occupants in the event of a fire, but also to take fire safety measures to prevent the fire from spreading and minimize damage to neighboring structures due to collapse, scattering of embers and other hazards. Through activities such as full-scale fire testing on three-story wooden school buildings, the Building Research Institute has been advancing research into ways to improve fire safety in large wooden buildings. (Part I of this feature appeared in our March issue.)

Full-scale Fire Testing on a Three-story Wooden School Building

Under the current Building Standards Law, three-story school buildings are required to be fire-resistive buildings (required to remain standing even after a fire). We conducted full-scale fire tests to shed light on fire safety issues when such a school building was constructed using members with a quasi-fire-resistive construction (members that do not collapse during a fire) already adopted in low-rise apartment buildings and similar structures. The test was conducted to review the fire prevention restrictions on three-story wooden school buildings, and represents part of the research project that was started in 2011[*1] (Figure 4 [numbering of visuals continues from Part I]).

While the Building Research Institute itself has conducted several full-scale fire tests on three-story wooden apartment buildings in the past, there is insufficient knowledge regarding fire properties and structural behavior for large buildings such as schools. To address this, we conducted a total of three full-scale fire tests, as shown in Table 1. Through the tests, we ascertained things such as the extent a fire spreads inside the structure, the extent of risk that the fire will spread to the surrounding area and whether the building would collapse if the fire continued for an extended period, and in doing so confirmed the effectiveness of the fire-safety measures.

First Full-scale Fire Test (Preliminary Test)

For the preliminary test, the interior of the first floor in particular was finished entirely with wooden materials, with the aim of gaining fundamental knowledge regarding the behavior of a fire in a large wooden construction.

When a wood crib resembling a fixture placed in the center of the first-floor staff room was lit, the flames immediately reached the ceiling and ignited the wood-finished ceiling as well as the walls. In a short time, flashover—in which the interior became engulfed in flames—occurred. Flames which emerged from the windows of the room in which the fire started rose to a height that reached the third floor, and the fire spread through windows to the upper floors. For this reason, rather than spreading in order from the first to second floor and then second to third floor, approximately thirty minutes after the fire was lit all three stories were burning simultaneously (Photos 7 and 8).

Thereafter, we observed the roof

Figure 4: Overall Plan of Research Project

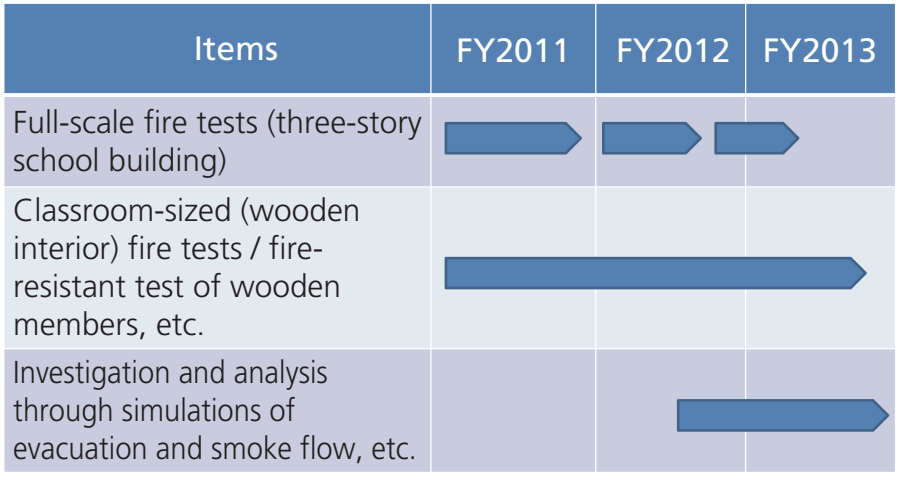
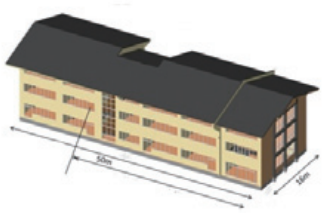
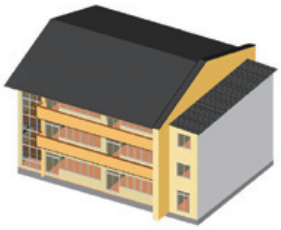
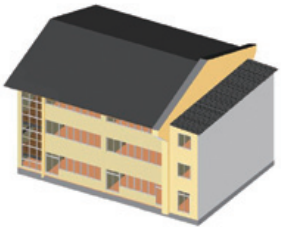


Photo 7: Fire spreading to upper floors due to emerging flames (six minutes after ignition)

Table 1: Purpose of Full-scale Fire Testing and Characteristics of Test Specimens

Test 1: Preliminary test Gain fundamental knowledge regarding the behavior of a fire in a large wooden construction	**Test 2: Preparatory test** Confirm the effects of countermeasures taken with regard to problematic phenomena that occurred during the preliminary test	**Test 3: Final Test** Verify knowledge with full scale test towards standardization
Tsukuba, February 22, 2012	Gero, November 25, 2012	Gero, October 20, 2013
		
Balconies / eaves: None Interior: Wooden walls, floors and ceilings Construction methods: Heavy timber, 2X4 construction	Balconies / eaves: Yes Interior: Non-combustible materials used for walls and ceilings Construction method: Heavy timber	Balconies / eaves: None Interior: Wooden walls and floors, ceilings made from quasi-non-combustible materials Construction method: Heavy timber

burning through, the formation of large flames above the roof and the spouting of a large volume of embers from the hole which had opened in the roof.

The test building comprised sections of heavy timber construction and 2X4 construction. We verified that most of the members tolerated the heat of the fire for one hour after the fire was started. However, from around the one-hour point onwards, members began to break, and ultimately the entire structure collapsed about two hours after the fire was started. In addition, for the sections exposed to extreme heat due to the rapid spread of the fire, there were some members that failed sooner than expected.

Second Full-scale Fire Test (Preparatory Test)

The preliminary test brought to light various issues, including the early spread of the fire to upper floors and the spread over the firewalls. To address these issues, in the preparatory test we constructed a test specimen that incorporated countermeasures, such as non-combustible interiors and the installation of balconies and eaves, with the aim of shedding light on the effects of fire-safety measures.

While the flames immediately reached the ceiling after the fire was lit, as the ceiling had been made non-combustible it did not ignite, and flashover did not occur. In response, 50 minutes later a flaming torch was thrown in to relight the fire, and after approximately 37 minutes the fire had spread to the entire room in which the fire had started (Photo 9).

Flames from the south-side windows of the room in which the fire started continued to emerge and approached the third floor, but due to the balcony and eaves, the fire did not spread immediately to the upper floors. Thereafter, the fire spread to the second floor when its floor burned through. When the floor of the second floor had burnt through, large flames emerged from windows on both the south and north sides of the second floor, and the fire spread to the inside of the room on the third floor from openings (Photo 10).

Also note that while an inflow of light smoke was observed in the staircase after 68 minutes, as there was almost no rise in temperature, this is not regarded as an impediment to evacuation. In addition, the fire did not spread to the other side of firewalls.

Photo 8: Three stories burning simultaneously (33 minutes after ignition)

Photo 9: Flashover occurs in ignition room (89 minutes after ignition)

Photo 10: Flames also emerge from second floor opening (131 minutes after ignition)

Photo 11: Flashover occurs in ignition room (68 minutes after ignition)

Photo 12: Fire spreads to the second floor (83 minutes after ignition)

Photo 13: Fire spreads to the third floor

Photo 14: After test completion (following day)

Third Full-scale Fire Test (Final Test)

In light of the results from the preliminary and preparatory tests, the final test was conducted to verify proposed revisions to fire-safety standards. In the preparatory test, balconies and eaves were confirmed to be effective in preventing the spread of fire to upper floors, but in the final test, we refrained from installing balconies and eaves and instead only adopted the non-combustible ceilings, with the aim of verifying what degree of effect this would have in preventing the spread of fire to upper floors.

After the fire was lit, the wooden interior walls caught fire, and the flames reached the ceiling approximately three minutes later, but the non-combustible ceiling failed to ignite and after around ten minutes the fire died down naturally. When the fire was subsequently relit 20 minutes later, the flames again reached the ceiling, and after approximately 66 minutes the flames spread rapidly under the ceiling, with the fire spreading throughout the room in which it started (Photo 11).

The window glass on the second floor broke due to emerged flames from the south-side window of the room in which the fire started. This was followed by flames entering the interior from the north-side windows and the walls starting to burn, and 87 minutes later the entire interior of the floor became engulfed in flames (Photo 12).

Emerged flames from the first and second floors reached near the eaves, and the fire spread to the third floor from an opening. However, water was sprinkled intermittently from sprinkler equipment installed on the third floor, and the test continued with the burning controlled in the third floor (Photo 13).

Inflow of light smoke from gaps in the first floor fire door was observed after 68 minutes using a video camera set up in the staircase, but no fire spread to the staircase. In addition, with respect to the opposite side of firewalls, although inflow of light smoke through gaps in fire doors was observed, the fire did not spread (Photo 14).

Results of the Full-scale Fire Tests

Based on the results of the full-scale fire tests, we were able to gain an idea of the fire-safety measures needed in large wooden structures that use visible wooden building materials.

To ensure safety evacuation, it is necessary to prevent fire spreading to upper floors during its initial stages. We found that making the interior finishing of ceilings non-combustible and delaying the occurrence of flashover is effective as a measure to prevent the early spread of a fire to upper floors. We were also able to verify that when wooden materials are used for all interior finishing, the installation of balconies and eaves prevents a fire from spreading to upper floors.

Additionally, firewalls need to be installed to ensure a fire does not spread beyond a certain size. We managed to verify that improved firewalls prevent the lateral spread of a fire.

We confirmed that even when a fire continues for around one hour, members as a quasi-fire-resistive construction due to a burning marginal layer design do not break, and possess sufficient fire-resistive performance.

In Closing

In light of the results of fire-resistant tests on wooden members and fire experiments on wooden interior spaces conducted in addition to the results of the full-scale fire tests, we are currently making progress in the compilation of proposed revisions to fire-safety standards. In the near future, we expect that large wooden buildings reflective of their wooden construction, like three-story school buildings that ensure safety in the event of fire, will come to fruition.

*1 Conducted as joint research with the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) National Institute for Land and Infrastructure Management through the MLIT Wooden Building Standards Enhancement Promotion Project (Waseda University, Akita Prefectural University, Mitsui Home, Sumitomo Forestry, Gendaikeikaku Architectural & Planning Office).

This report was compiled by Hagiwara Ichiro (director), Kagiya Koji and Suzuki Junichi (chief research engineers) at the Department of Fire Engineering, Building Research Institute.