Sustainable Solutions in Structural Engineering and Construction
Edited by Chantawarangul, K., Suanpaga, W., Yazdani, S., Vimonsatit, V., and Singh, A.

ISBN: 978-0-9960437-0-0

DEVELOPMENT OF A SEISMIC FITTING FOR WOODEN BUILDINGS

MITSUHIRO MIYAMOTO

Dept of Safety Systems Construction Engineering, Kagawa University, Takamatsu, Japan

Japanese wooden buildings are vulnerable to large earthquakes, and ensuring their seismic safety is a significant issue. However, many owners of wooden buildings hesitate to install seismic reinforcement because of the long construction period and high expense. There are many sliding doors in wooden buildings, which can be used for efficient seismic reinforcement. The objective of this study is to develop a seismic fitting for Japanese wooden buildings. Full-scale lateral loading tests were conducted for wooden frames that include a seismic fitting. The fittings can be constructed quickly and at a low cost. The parameters of the full-scale lateral loading tests were chosen in order to examine the effect of the fitting and the restriction condition surrounding a fitting on the seismic performance of a wooden frame. The relationships between the lateral load and deformation angle, the collapse mechanism, and the quantitative effect of seismic reinforcement for a wooden frame were clarified. From the results of the full-scale tests, it is found that the lift up of a seismic fitting should be restricted by a hanging wall for the seismic reinforcement of wooden frames.

Keywords: Sliding door, Seismic reinforcement, Japanese wooden building, Full-scale test, Hanging wall.

1 INTRODUCTION

Many large earthquakes have occurred in Japan since the Southern Hyōgo Prefecture earthquake in 1995, when many wooden buildings were greatly damaged. Powerful earthquakes have a high probability of occurrence in Japan; previous examples of such

Figure 1. Interior of wooden buildings.

Figure 2. Seismic fitting.

earthquakes include the Nankai, Tōnankai, and Tōkai earthquakes. Many Japanese live in wooden buildings that are vulnerable to such earthquakes; therefore, ensuring their seismic resilience has become very important. However, many owners of wooden buildings hesitate to install seismic reinforcement because of the long construction period and high expense. Wooden braces are generally set inside the walls for the seismic reinforcement of Japanese wooden buildings. It should be pointed out that installing the seismic reinforcement can lead to the loss of open space that is a feature of Japanese wooden buildings (Figure 1). It is therefore required to use existing wooden sliding doors for the efficient seismic reinforcement of Japanese wooden buildings. This study aims to develop such a seismic fitting.

In this study, the seismic fitting is defined as a seismic element, which is a modified sliding door (*shōji* or *fusuma*), as shown in Figure 2. The seismic fitting consists of wooden frames on both sides and an acrylic plate (Takahashi 2005). Seismic reinforcement using these fittings can be performed quickly and at low cost.

2 FULL-SCALE TESTS

Full-scale lateral loading tests for wooden frames that included a seismic fitting were conducted. The relationships between the lateral load and deformation angle as well as the collapse mechanism were clarified. The test parameters were chosen to help examine the effect of the seismic fitting and the restriction condition (e.g., a hanging wall) on the seismic performance of a wooden frame. One specimen was used for each parameter.

2.1 Outline of Specimen

A total of five specimens were used for full-scale tests, as shown in Table 1 and Figures 3–7. Four of the specimens were wooden frames that included a seismic fitting and one was the seismic fitting itself. The height and width of the seismic fitting were 1800 mm and 900 mm, respectively. The dimensions of the wooden frame were 40 × 40 mm, and the thickness of the acrylic plate was 4 mm. The height and width of the wooden frame specimen were 2795 mm and 2850 mm, respectively. The dimensions of the column and ground sill, beam, and threshold were 100 × 100 mm, 100 × 180 mm, and 100 × 45 mm, respectively. All wooden members were made of cedar from Tokushima Prefecture, Japan. Mud walls are usually used as a hanging wall in Japanese wooden buildings. However, because of the long construction period, a plaster board was used

Table 1. Details of specimens.

<table>
<tr><td>Specimen</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr>
<tr><td>Number of seismic fittings</td><td>1</td><td>0</td><td>1</td><td>2</td><td>1</td></tr>
<tr><td>Number of sliding doors</td><td>0</td><td>3</td><td>2</td><td>0</td><td>2</td></tr>
<tr><td>Hanging wall</td><td></td><td colspan="3">Plaster board</td><td></td></tr>
<tr><td>Height</td><td>1800 [mm]</td><td colspan="4">2795 [mm]</td></tr>
<tr><td>Width</td><td>900 [mm]</td><td colspan="4">2850 [mm]</td></tr>
<tr><td>Column
Ground sill</td><td rowspan="4"></td><td colspan="4">100×100 [mm]</td></tr>
<tr><td>Beam</td><td colspan="4">100×180 [mm]</td></tr>
<tr><td>Threshold</td><td colspan="4">100×45 [mm]</td></tr>
<tr><td>Joist</td><td colspan="4">45×45 [mm]</td></tr>
</table>

as an alternative hanging wall in this test. The strength of the plaster board is almost the same as that of the mud walls. The column was connected to the beam or ground sill using only a short tenon with a height, width, and thickness of 90 mm, 80 mm, and 30 mm respectively, to remove the effect of moment resistance at each connection. The seismic fitting was connected to the column and threshold with screws. A 15-mm floor plate and 45-mm square joists were set between the lower threshold and the ground sill.

Specimen 1 was the seismic fitting itself. Specimen 2 was a wooden frame that included three sliding doors, which is defined as the standard specimen. Specimens 3 and 4 were wooden frames that included one and two seismic fittings, respectively. Specimen 5 was a wooden frame that included one seismic fitting without a hanging wall.

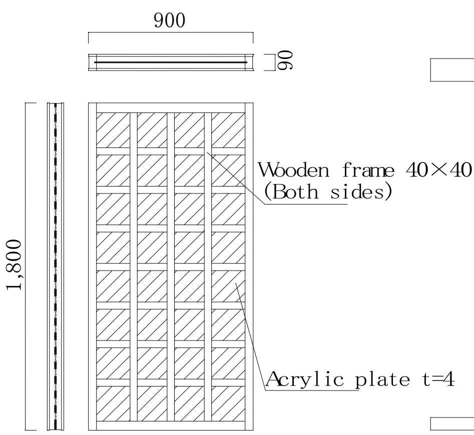

Figure 3. Schematic of specimen 1.

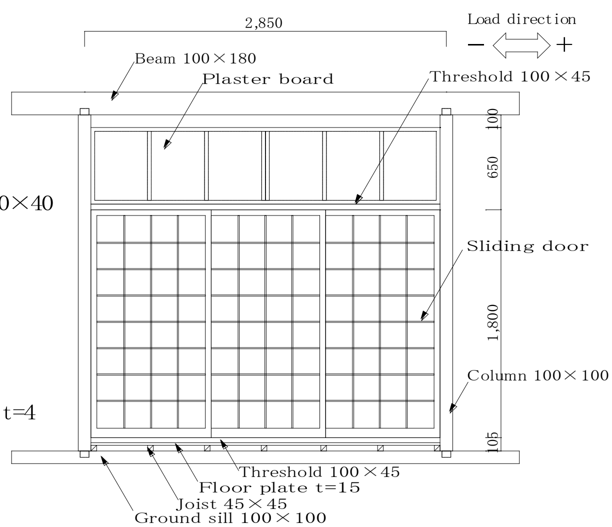

Figure 4. Schematic of specimen 2.

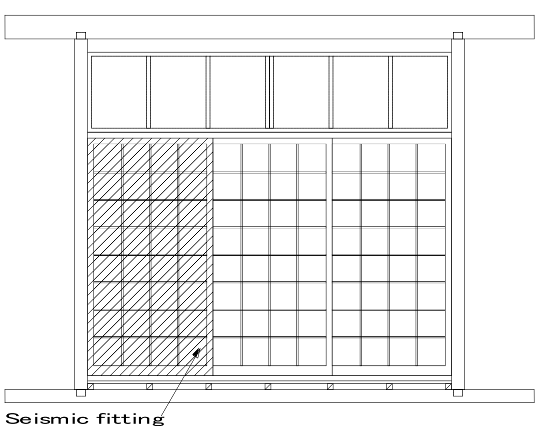

Figure 5. Schematic of specimen 3.

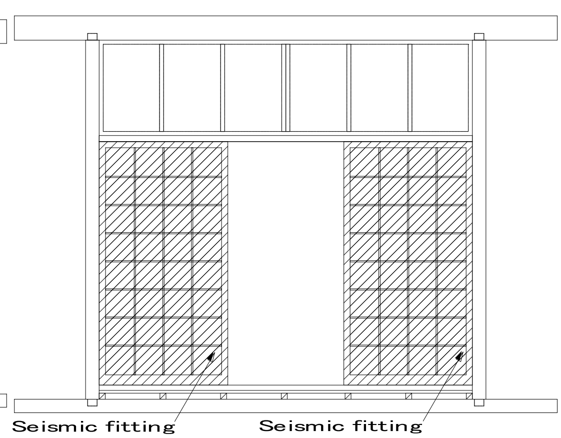

Figure 6. Schematic of specimen 4.

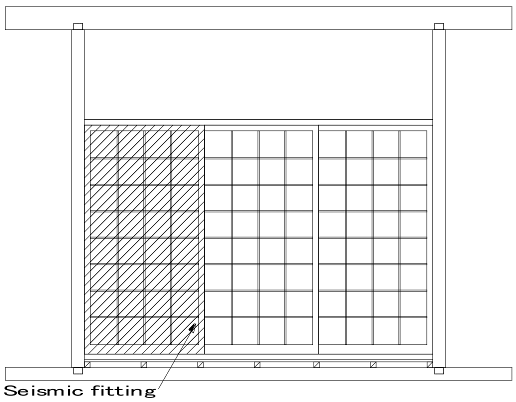

Figure 7. Schematic of specimen 5.

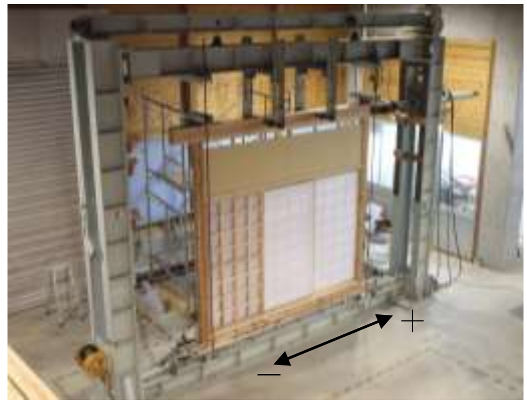

Figure 8. Photograph of the loading instrument.

2.2 Test Method

Figure 8 shows a photograph of the loading instrument. The ground sill of the specimen was fixed with anchor bolts. The specimen beam was subjected to lateral loads through a servo actuator by a tie-rod system. The specimen was subjected to cyclic lateral loads, with the real shear deformation angle γ_0 being gradually increased symmetrically from 1/600, 1/450, 1/300, 1/200, 1/150, 1/100, 1/75, to 1/50 rad. Three cyclic loadings were applied. Finally, the specimen was deformed to 1/15 rad at both ends. In this experiment, the plus and minus directions are defined as shown in Figure 4. The lateral loads applied to the specimen were measured using a load cell that was attached to the edge of the servo actuator.

2.3 Results and Discussion

Figure 9 shows the relationship between the load and deformation angle of each specimen. Figures 10–13 show the fracture mode of specific specimens. The loads on specimen 1 and 2 in both directions are almost constant until 1/15 rad. The load on specimen 3 is approximately 5 kN, and the load on specimen 4 is approximately 10 kN larger than that on specimen 2 at 1/15 rad. The load on specimen 3 in both directions and that on specimens 4 and 5 in the plus direction are also relatively constant until 1/15 rad, and larger than the load on specimen 2, owing to the effect of the seismic fitting for the wooden frame. However, the load on specimens 4 and 5 decreases in the minus direction. For specimen 4, this is because the bending stress of the column is concentrated on the connection to the upper threshold, owing to the deformation of a plaster board in the out-of-plane direction. The column and plaster board were damaged, as shown in Figures 10 and 11. For specimen 5, the deformations of the thresholds were large, owing to the lift up of the seismic fitting, and they were separated from the column, as shown in Figures 12 and 13.

Figure 14 shows the relationship between the shear deformation angles of the specimens and the seismic fittings. For specimen 3, the shear deformation angle of the seismic fitting is approximately 0.06 rad, at a shear deformation angle of 0.06 rad for the specimen. However, for specimen 5, the shear deformation angle of the seismic fitting is about 0.01 rad at the same shear deformation angle for the specimen. From the results of specimen 1, there is a large difference between the loads of approximately 2.0 kN at 0.01 rad and approximately 7.5 kN at 0.06 rad. Therefore, it is found that as the shear deformation angle of a seismic fitting becomes larger, a seismic fitting is more effective as the seismic reinforcement for wooden frames. In other words, the lift up of a seismic fitting should be restricted for the seismic reinforcement of wooden frames without a hanging wall such as with specimen 5.

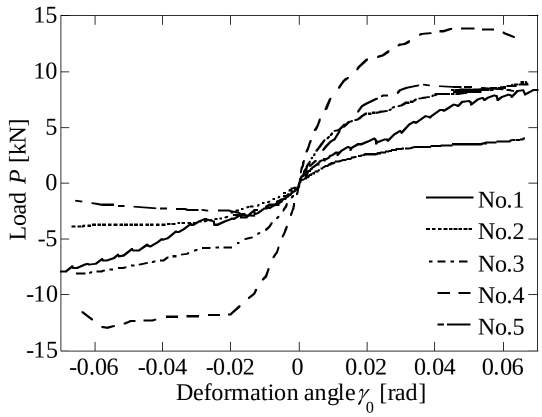

Figure 9. Relationship between load and deformation angle.

Figure 10. Column damage on the plus side in specimen 4.

Figure 11. Deformation of plaster board in the out-of-plane direction in specimen 4.

Figure 12. Deformation of upper threshold in specimen 5.

Figure 13. Deformation of lower threshold specimen 5.

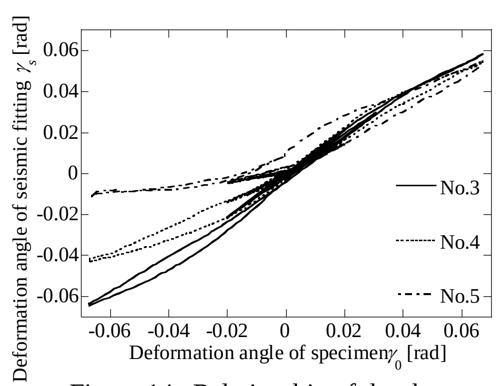

Figure 14. Relationship of the shear deformation angles of the specimen and the seismic fitting.

3 CONCLUSIONS

In this study, full-scale lateral loading tests for wooden frames including a seismic fitting were carried out. The relationships between the lateral load and deformation angle, their collapse mechanism, and the quantitative effect of seismic reinforcement for a wooden frame were clarified. From the results of the full-scale tests, it is found that the lift up of a seismic fitting should be restricted by a hanging wall for the seismic reinforcement of wooden frames.

Acknowledgments

This research was supported by the Tokushima Prefectural Government and the Tokushima Prefecture Society of Architects & Building Engineers. We gratefully acknowledge this support.

Reference

Takahashi S., Fujita K. and Koizumi M., A Study on the Reinforcement of Opening in Existing Wood House with Consideration of Permeability, in *Summaries of Technical Papers of Annual Meeting*, *AIJ*, C-1, 409-410, September, 2005.