Seismic retrofit strengthening of age-old Japanese traditional building "Chusonji-Temple Hondo"

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Summary

For seismic retrofit strengthening of Chusonji-Temple Hondo, we proposed to adopt "Super Wooden Wall" that had been developed as a seismic resisting element for traditional wooden structures. Though the durability and aesthetics of "Super Wooden Wall" are as same as those of a traditional dropped wooden sliding wall, its seismic resistant performance is superior to that of a conventional structural plywood. Consequently, the seismic resistant performance of the Hondo was found to have improved sufficiently, with its original appearance of the founding era remaining intact.

Keywords: Super Wooden Wall; connection; long dowel; wall magnification; traditional building.

1. Introduction

Chusonji-Temple Hondo reconstructed in 1909 is a main building of the lot. Because Tohoku Earthquake (March 11,2011) caused some cracks on some of its Mud walls, seismic retrofit strengthening was needed to ensure its structural safety in earthquakes.

2. The policy of seismic retrofit strengthening

Figure 1 shows an external appearance of Chusonji-Temple Hondo. Evaluating the seismic resistant performance of the Hondo based on the "Seismic resistant evaluation Standards of Important cultural properties (buildings)" revealed the risk of collapse in big earthquakes, and we reported to the client that some seismic retrofit strengthening to the building was necessary. In planning seismic retrofit strengthening, the client indicated following three requirements.

Fig.1:Exterior of Chusonji-Temple Hondo

1. Prevent Hondo including *Naijin* (Inner temple) in which principal image is newly rested entirely from the damage of earthquake.
2. Remain the appearance of Hondo.
3. Follow the traditional method of construction in founding era.

To satisfy these requirements, we presented three structural concepts in the strengthening, "wall arrangement balanced well in plane", "seismic retrofit with no additional walls", and "existing structure replaced as little as possible". In addition, durability was indispensable so as to maintain good functionality of the building for a long time. Therefore, we proposed to adopt "Super Wooden Wall", which has similar appearance to dropped wooden sliding walls but more effective stress transfer mechanism between wooden wall panels. This method is able to improve seismic resistant performance of traditional wooden buildings with high quality of aesthetics and spatial flexibility.

3. Mechanism of Super Wooden Wall

The Super Wooden Wall has unique mechanism in the joint parts. The wooden panel is joined to the next panel above or the beam with "long dowels", preventing deformation and destruction in the dowel joint parts. The panel is also joined to the outside column with tenon, preventing vertical slip

of panels. This mechanism improves stiffness and strength of the wooden wall remarkably. In addition, to create this wall as easy as possible, we proposed systematic method to create Super Wooden Wall, putting pre-constructed unit consisting of wooden panels and outside frame materials on existing frame and fixing this unit inside existing beams and columns by structural screws.

Figure 2 shows the load-deformation relationship given by full-scale tests. The relationships have similar tendency in all cases, and the load is practically proportional to the thickness of wooden panel and the number of long dowel of the specimens. Moreover, their hysteresis behaviors are stable at the reverse cyclic loading. Figure 3 shows the comparison of above relationship estimated by the analysis with that given by the tests. It says that restoring force characteristics in analysis is approximately equal to the results of the tests just until the load decreases due to destruction.

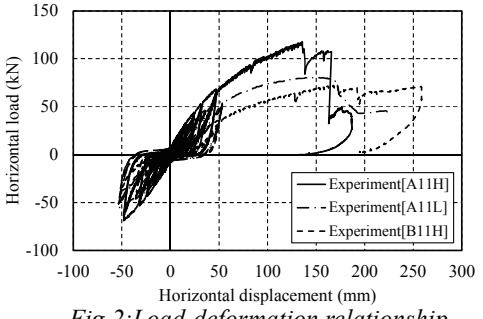

Fig.2:Load-deformation relationship

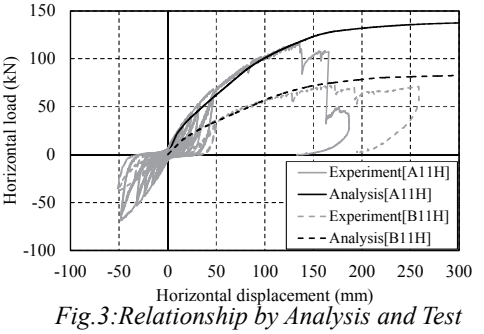

Fig.3:Relationship by Analysis and Test

4. Planning of seismic retrofit strengthening

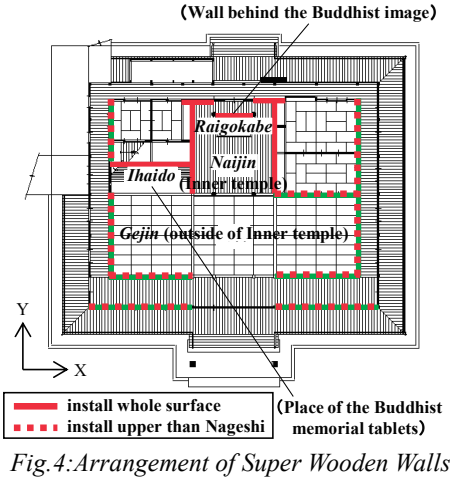

Fig.4:Arrangement of Super Wooden Walls

In formulating plan of seismic retrofit strengthening of Chusonji-Temple Hondo, existing openings were planned to remain as it was. The arrangement of Super Wooden Walls is shown in Figure 10. In addition, to ensure the mechanism transferring earthquake force smoothly to Super Wooden Walls, horizontal braces were set into the attic space and the foundation strengthening was carried out under the floor around the *Naijin*.

According to the evaluation of seismic resistant performance estimated by limit strength calculation method, it is revealed that the structural performance of the Hondo satisfies the safety criterion defined in the "Seismic resistant evaluation Standards of Important cultural properties (buildings)".

5. Construction plan

In the process of construction at the base of columns of the Chusonji-Temple Hondo in its seismic retrofit strengthening, the building itself is structurally unstable. For this reason, we planned to complete strengthening of the Hondo for a short period, by taking measures to prevent the building from destruction due to following earthquakes including aftershocks of Tohoku Earthquake.

6. Conclusion

To realize seismic retrofit strengthening of Chusonji-Temple Hondo remaining its original appearance and functionality, we decided to adopt Super Wooden Walls to the Hondo. This system ensures structural safety of the Hondo in big earthquakes. Moreover, it is revealed that the analytical model of Super Wooden Wall is able to represent the actual response of it.