Retrofit of Wooden Temple Based on Long-Life Eco-Friendly Concept

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Summary

Traditional wooden temples in Japan are constructed by construction methods which use natural materials and allow easy teardown. By extending the life of buildings by periodical repair, wooden temples produce only low environmental loads. The roof tiles are replaced in every hundred years so that the waterproof property is maintained, and the whole building is torn down and damaged parts are replaced in every several hundred years so that the structural performance is assured. When an earthquake occurs, easily replaceable parts resist, and the buildings become tough antiseismic structures due to their deformation capacity given by wood denting.

This paper introduces a repair case of the world's largest wooden temple. In this case, the anti-seismic capacity is reevaluated by the modern technology, and then efficient reinforcement is achieved. In addition, deteriorated roof tiles are utilized as a component of another useful material.

Keywords: restoration; traditional wooden temple; long life; low environmental loads; recycle of clay tiles; antiseismic reinforcement;

1. Introduction and outline of building

Fig. 1 Full view of Goei-do

This paper introduces a repair case of Goei-do, the world's largest traditional wooden Temple built in 1895. The building is repaired using traditional techniques under consideration of environmental preservation. In this case, the antiseismic capacity which has been understood unclearly through experiences is quantified through element experiments and reevaluated by the modern technology, and then efficient antiseismic reinforcement is achieved.

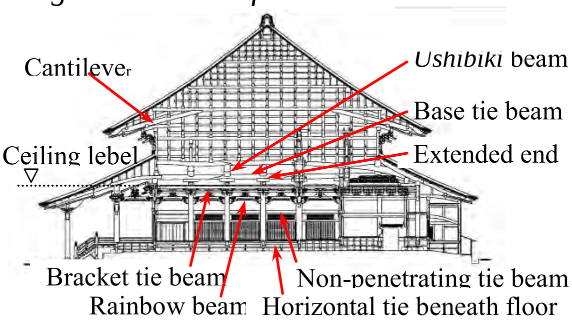

Fig. 2 Cross-sectional view in the east-west direction

Goei-do has the front on the east side. Its width is 63.6 m in the front and 51.7 m on the sides, and its height is 38 m. Pillars on the outmost periphery surround the area of approximately 3,300 m^2. The peripheral frame in the south, east and north is open completely, and a mud wall is provided in the western periphery.

Major structural members are stacked from the bottom without using nails, and fixed by the weight from the above. Roof tile is fixed to the base with clay.

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2. Repair Work

This paper mainly describes “Retiling the roof” and “Providing antiseismic reinforcement”.

In retiling, the clay tile fixation method was changed from the wet method (fixation with clay) to the dry method (fixation with wires and nails). As a result, the earthquake load was reduced. In addition, removed clay was recycled into humidity-conditioning material and earthquake-resistant panels to reduce the waste.

3. Earthquake retrofitting

In the design of this repair work, we have evaluated properly this elastic structural characteristic leading to the seismically isolated structure through various experiments to understand each antiseismic capacity. We have invented reinforcement which does not deteriorate the deformation capacity of the traditional wooden building. In evaluating the antiseismic capacity, we set the restoring force characteristic of each bearing force element based on experiment results, and evaluated the response at earthquake using the time history analysis. With regard to the mud wall on the west side, we set the maximum shear stress based on the authoritative guideline.

The distortion angle at which the building moves the pillar diameter, the ratio between the pillar diameter and the pillar length in other words, is “1/14 to 1/11” (=700/9500 to 700/8000). Accordingly, we set the limit distortion angle at earthquake to “1/15 rad”.

We performed the time history response analysis based on the restoring force characteristic obtained, and grasped the current antiseismic capacity. Major problems in the antiseismic capacity of Goei-do are summarized that “1) The building is too heavy; 2) The building suffers eccentricity caused by the peripheral mud wall on the west side; 3) The horizontal bearing force is small compared with the building weight”.

We have added dry mud wall panels which have proper bearing force and excellent deformation capacity to the upper portion of the peripheral frame in three directions (south, east and north). In addition, we have provided a ladder-shaped wooden beam having proper bearing force and high deformation capacity at pillar capitals in the east-west direction.

Fig. 3 show the time history analysis result (maximum displacement on the first layer) using the model after reinforcement. The eccentricity caused by the mud wall on the west side is mitigated in the north-south direction, and the difference in displacement on the east-west frame surface is considerably reduced. The maximum response distortion angle is improved to 1/15 in both the north-south direction and the east-west direction.

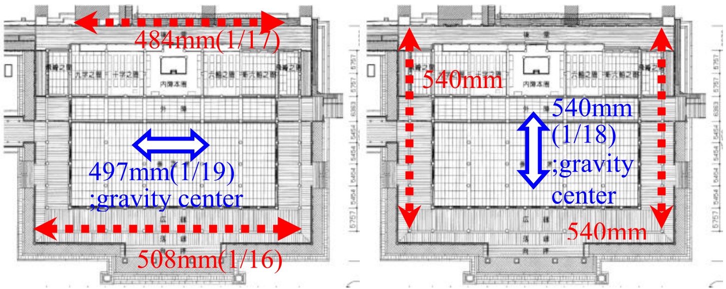

Fig. 3 Maximum response values caused by wave-1 after reinforcement

4. Conclusion

Traditional buildings are often regarded as cultural property. It is necessary to not only assure the antiseismic safety but also preserve the historic value without spoiling the beauty.

In this repair work, the antiseismic capacity is improved by utilizing traditional techniques under consideration of waste reduction. We think this case is useful as data to utilize the nature of traditional buildings, long life and low environmental loads, for modern buildings.