Examples of Conservation Work for Historical Wooden Buildings in Japan -The cases of Sojjii-soin Daisodo (Half-dismantling) and Butsuden (Full-dismantling)

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Sojjii-soin
Sojjii-soin is one of the main temples of Zen Buddhism. It is situated in Wajima, Ishikawa Prefecture in Noto Peninsula, at the center of Honshu, the main island of Japan (Fig1,2). The temple was founded in 1324. Since then, it has been honored as the heart of Zen Buddhism in Japan. However, the buildings of the temple had experienced several big fires. So, almost all the buildings remaining today are from early 20th century.

Noto Peninsula Earthquake
Noto Peninsula Earthquake happened April 25th 2007. It recorded Magnitudes 6.9 and brought region one death and several hundreds of casualties. Also number of completely destroyed houses was 684 houses (Fig3), and partially destroyed houses counted around 30,000 houses.

Fig1. Place of Sojjii-soin
Fig2. Sojjii-soin From Google earth
Fig3. Completely destroyed houses by the earthquake
**Conservation Project**

Immediately after the earthquake, agency of cultural affairs registered Sojiji-soin’s buildings to registered cultural property. Thanks to this action, Sojiji-soin’s conservation project is able to receive some aids for architectural consultation fee.

The project is divided to two main periods. The first period was from 2008 to 2014, and the second period is from 2015 to 2021. Throughout the project, 15 registered cultural properties are to be conserved. To avoid repeating same destruction by earthquake, seismic diagnoses were taken place at the beginning of each period. And Daisodo, Butsuden were analyzed that they need to be installed seismic reinforcement.

**Daisodo (Sermon Hall: 787m², built in 1907)**

**Damage of Daisodo**

Daisodo is a main building of this temple, post-and beam structure mainly by zelkova.

Front part of the ground for the building slid 15cm forwards and sank 16cm downwards. And stone wall fell off (Fig4). As a result of movement of the ground, plaster wall fell off, showing the bamboo frames. Not only walls were damaged, but also pillars were tilted that joints of thresholds for sliding doors loosened (Fig5). The tilted pillars caused floor to sink, and it was dangerous to have ceremonies. For post-and-beam structure, the loosened joints and deformation of structure are critical damage for safety.

**Result of Seismic Diagnosis**

Result of seismic diagnosis was that Daisodo fails seismic resistance. So structural reinforcement was designed.

**Conservation Practice**

The aims of conservation project were a) repair the damaged timber/walls/other architectural facilities, b) install the reinforcement to prevent further damage.

Half-dismantling method was chosen for Daisodo’s conservation. Dismantled parts were roof tiles, roof structure (partially), floor, plaster wall, terrace, attached toilet and preparation room. Dismantled timbers were inspected, catalogued, and repaired or replaced depending on the decay.

Beneath are the main processes of the conservation project.

1) **Dismantle attached toilet, preparation room and terrace.**

2) **Install steel piles to support the ground and prevent further slide (Fig6).**

One of the reasons that caused the ground slide was that front part of the ground was artificial and not stable. Prior to conservation project, we ran entire ground survey to decide which method shall be suitable for the building and the ground. As a result, we could see that there is solid layer about 7 meters beneath of the building. So steel piles were piled to the ground to prevent the artificial ground from further slide.
The stones were about 1 m², and thicknesses were about 80cm to 1m. So we removed stones first, and dig the ground to construct the underground beam. For piling the piles, we could not use auger, so we used the 3000kN of building self-weight to pile. For each pillars, we piled 4 to 8 piles according to the structural analysis. After construction of underground beam, we put back the base stones.

During jacked-down procedure, we corrected the tilted or deformed pillars. The deformation of space between pillars led to loosened joints, so we corrected order of pillars according to original drawing from 1907. Zelkova is unpredictable materials of movement after dismantling, so we tried to avoid dismantling the structural pillars or beams as much as possible. Finally tilted pillars and loosened joints were fixed as the original drawing.

It took almost a year from Jacked-up to Jacked-down.

3) Dismantle the floor and make preparation for jacked-up (Fig7).
The weight of buildings was about 3000kN. The entire building was jacked-up. We used about 30 interlocking jacks. Prior to the procedure, decorative materials, such as chandelier and altars were stored in air-conditioned room to prevent any damage.

Floors are dismantled, making spaces for jacks, saddles and central control devices.

4) Jacked-up, Remove base stones, Pile the steel piles under the pillars, Construct underground beam, Jacked-down (Fig 8-11).
Jack-up procedure took 5 days to bring the entire building to 1.1m above from the ground. After Jack-up, level monitoring was done every day. During jacked-up period, we had experienced the Great East Japan Earthquake. At Soji-ji, it measured quite strong tremor, but there was no harm to the jacked-up building.
5) Construct temporal structure to cover. (Fig12)
Sojiji-soin is also known as famous sightseeing spot. So we constructed the temporal structure with visitors' facility. Visitors were able to see the process of conservation work.

6) Dismantle roof tiles, plaster walls. (Fig13)
Roof tiles were dismantled, washed and inspected to reuse. Plaster walls were dismantled. The inner soils were stored to reuse.

7) Inspect status of roof structure, decide where to dismantle, repair or replace.
Roof tiles were loosened because of the earthquake and harsh environment. It caused water leak and made timbers decay. According to inspection, each corners had severe damage, especially North West. And the projecting roof for decorating the building was also severely damaged. The North West corner needed to install steel frame to support the timber. However it was not enough strong to support the whole weight of the roof, we inserted the additional supporting timber on both sides (Fig14-15).

The projecting roof was seriously damaged. Important structural timber decayed so that they are structurally useless. So those timbers needed to be replaced (Fig16-17).
8) **Draw 1:1 roof structure and decide the policies of conservation.**

Roof structure was moved because of the earthquake, and decayed timbers caused the roof to deformation. So to reassemble the replaced timbers, we needed to make the original shape clear. During the inspection, we also surveyed the level marks, angle of the rafters, and other information to draw the 1:1 ideal picture of the entire roof.

9) **Reassemble roof tiles, plaster walls.**

After the repairing the roof timbers, the roof tiles were reassembled. Then temporal structure was dismantled. Plaster walls were reinforced that the thickness of the walls increased, and the inner frame was also improved.

10) **Install reinforcement under floor, Reassembling floor and etc.**

To increase the seismic resistance and support the post-and-beam structure, we put solid grid and penetrating tie beam under the floor (Fig18). Floors, attached facilities were reassembled. We renewed fire alerts.

11) **Completion and Publication**

It took 52 month to entire conservation project (Fig19). We issued 350 pages of conservation report after the project.
Butsuden (Buddha Hall: 523m2, built in 1918)

Damage of Butsuden

Butsuden is situated at right angle to Daisodo. It is also post-and-beam structure, but by Hiba arborvitae. It is similar to cypress and is typical material for this area. Compared to zelkova, Hiba arborvitae is easier to handle after dismantling.

Because of the earthquake, Butsuden sank 10cm. And the tilt of the pillars measured maximum 14/1000, which is more than double to present building standard low’s capacity. Before the conservation projects deformation of roof became worse and more dangerous for users, thus scaffolds were installed to support roof (Fig 20).

As Daisodo, plaster wall fell off (Fig21), corridor tilted (Fig22). Also, roof structure was loosened by the deadly shake from the earthquake. Butsuden is the place for worship, but sometimes it is used as visitors’ facility for staying overnights. So it requires severe safety for public. Not only from the earthquake, but also from critical water leak, they caused the damage to the building. It is known that Noto peninsula is area of heavy rain, snow and humidity. However the style of the roof was not considered for this harsh climate. So heavy rain and snow stacked on the roof for a while and thawed water leaked into the roof structure. This leads to the decay of the timber and caused the roof structure being unstable. Decay and fragile roof structure resulted dislocation of timber by the earthquake (Fig 23).
Result of Seismic Diagnosis
As same as Daisodo, Butsuden fails seismic resistance. Structural reinforcement was designed as Daisodo. Butsuden was decided to install seismic resistant plaster base, so we took samples of the wall for further inspection.

Conservation Practice
The aims of conservation project were same as Daisodo, a) repair the damaged timber /wall/other architectural facilities, b) install the reinforcement to prevent further damage. Daisodo could take half-dismantling method. However Butsuden got damage on the most important pillars, which are two out of four of main corner pillars. And not only pillars, but also beams and corner timbers were apparently decayed. And some of those decayed timbers were lost completely so there was no way but to replace the timber.

Butsuden is post-and-beam structure so all pillars and beams are connected. And it is not possible to dismantle pillars partially. Thus half-dismantling method was not appropriate to apply, for Butsuden needed to replace the decayed pillars and beams nearby.

Beneath are the main processes of the conservation project.

1) Dismantle attached buildings and construct temporal structure to cover. (Fig24)

2) Dismantle roof tiles, plaster walls, and entire structure.
Full-dismantling method begins from inspection. Before dismantling roof tiles, we recorded styles of roof tiles, their condition, and materials and estimated the percentage of reusable roof tiles. Concerning dismantling the structural timber, first we took record of the shape, joints and measurements. During dismantling, each timbers were carefully removed from each other. Before storage, each timbers were again inspected for planning repairs (Fig 25-31).

Figs3. Roof structure dislocated
Fig24. Temporal structure to cover
Figs5. Dismantling roof tiles
Figs6. Decayed structural timber
2) Dismantle roof tiles, plaster walls, and entire structure.

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On the end of February, we have completed dismantling the entire structure (Fig. 30).

The timbers were put in huge storage (Fig. 31).
In the end of project, we will issue conservation report. The contents of conservation report are regulated by agency of cultural affairs.

Conclusion

Conservation practice varies in every project. None of them are same, even in the same temple. As above, Japan is a country of frequent earthquake, great difference with temperature and high humidity. In this severe climate condition, timber does decay; get damage by fungus and insects. And buildings are post-and-beam structure and structural timbers are also ornamental timbers. Culturally, aesthetically and functionally, to put additional timber beside pillars or other structural/ornamental timber is not adoptable in Japanese traditions. So in conservation work, there is need to replace those timbers. We put all efforts to avoid full-dismantling conservation work, however in some cases it is not avoidable. Nevertheless, when there are standards and international principles, they should be respected at projects by highly responsible architects.

3) Construct underground slab and reassembling the structure.

After dismantling timber structure, we will construct underground slab to make the entire structure being stable on it, preventing further cracks and unequal settling by earthquake. When foundation is ready, we will reassemble the entire structure according to the previous inspection and plans. Then we will install structural reinforcement materials. Those are seismic resistant plaster base, horizontal brace at the top of pillars, and solid grid under the floor.