Disaster Protection Technology of Traditional Wooden cultural Buildings

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ABSTRACT :

Japanese traditional wooden cultural buildings have been survived for long times. The key technology for surviving may be "regular maintenances with appropriate intervals", and this technology brings the sustainability of buildings.

KEYWORDS: *Japanese traditional wooden cultural buildings , Sustainability of buildings, Regular maintenance with appropriate intervals*

1. BACKGROUND

Wooden cultural buildings like temples are one of the symbols of emperor's power in ancient times. These buildings are also the base of the believer's belief. So these buildings are required to exist permanently. However, Japan suffers many strong earthquakes that might damage those buildings, and Japan has warm and humid climate, which might deteriorate members (= timber) of those buildings. These cultural and natural backgrounds developed the preservation and restoration technologies of wooden buildings in Japan.
Today wooden cultural buildings like temples are still the bases of the believer's beliefs. Moreover, these buildings have high cultural value. Therefore, wooden cultural buildings are required to continue to exist permanently. In addition, the development of the structural design technology that can quantitatively evaluate Japanese traditional structural elements is also required.

2. DESCRIPTIONS

2.1. Feature and attribute

2.1.1 The preservation technology of wooden buildings

The following two points are indispensable to the preservation technology of wooden building.

(1) Regular maintenance with appropriate intervals

Almost all of the materials used for the construction of those cultural buildings are wood. These materials might deteriorate with the passage of time, since the climate is warm and humid in Japan. Therefore, all or several parts of the buildings are checked whether they need to be repaired. Generally, all parts of the cultural wooden buildings in Japan are dismantled and repaired approximately every 300 years, and meanwhile roofs are repaired approximately every 100 years (Table 2.1).

Table 2.1 Example of Toshio-dai-ji

		Events
	Later half of 8C.	Construction
	1185	Earthquake(M=7.4)
about 100year		
	1270	repair the Kondo (frame reinforcement)
	1323	repair the Kondo
	1361	Earthquake(M=8.3)
	1596	Earthquake(M=7.5)
about 100year		
	1693	repair (change the system of the roof)
about 200year		
	1898	repair (change again the system of the roof)
about 100year		
	1998	repair (mainly repair roof)

(2) Maximum reuse of members of buildings (= timber) and
minimum replace of damaged members

At the time of maintenance, the members that have been damaged seriously are replaced with new ones. Usually most of the damaged members are such part as the roofing materials and the edge of the columns where these members suffered damages easily. On the other hand, other members located at other parts with good condition remain in use even if they have been used for hundreds of years.

At the time of replacing materials, maximum reuse of members of buildings (= timber) and minimum replacement of damaged members are considered as much as possible. For example, when the inside of a column is found out damaged at the time of dismantlement, the inside part, where the member is damaged, will be removed, and a new material substitutes for the part removed. Therefore, outside of the columns don't change (Figure 2.1).

Figure 2.1 Example of maximum reuse and minimum replace

2.1.2 Quantitative evaluation of Japanese traditional earthquake resistant elements

Today, by using Earthquake-resistant design techniques such as "Limit Strength Method" and "earthquake response analysis" (Figure 2.2), it is possible to quantitatively evaluate Japanese traditional earthquake resistant elements such as "restoring force for stabilizing made by column rocking (Figure 2.3)", structural performances of "nuki" (= a kind of joint of column and beam, Figure 2.4), and "tuchi-kabe" (Figure 2.5), which enable structural designers to evaluate quantitatively the structural performances of the buildings. Designers can evaluate earthquake resistant performances of those cultural wooden buildings as well as other modern architectures like Steel and RC buildings. They can reinforce the building if necessary. Designers can also evaluate the effect of past reinforcements which have not been evaluated quantitatively so far.

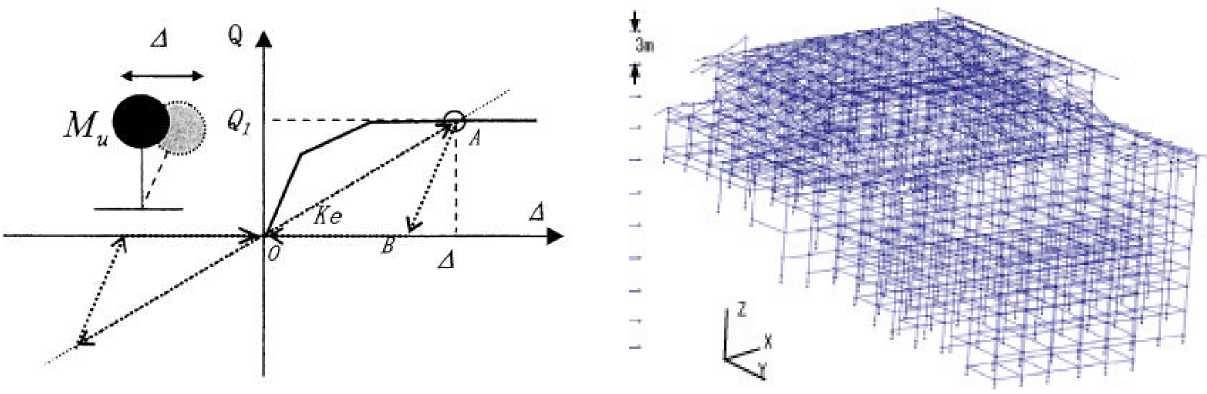

Figure 2.2 Example of analysis models like "Limit Strength Method" and "earthquake response analysis"

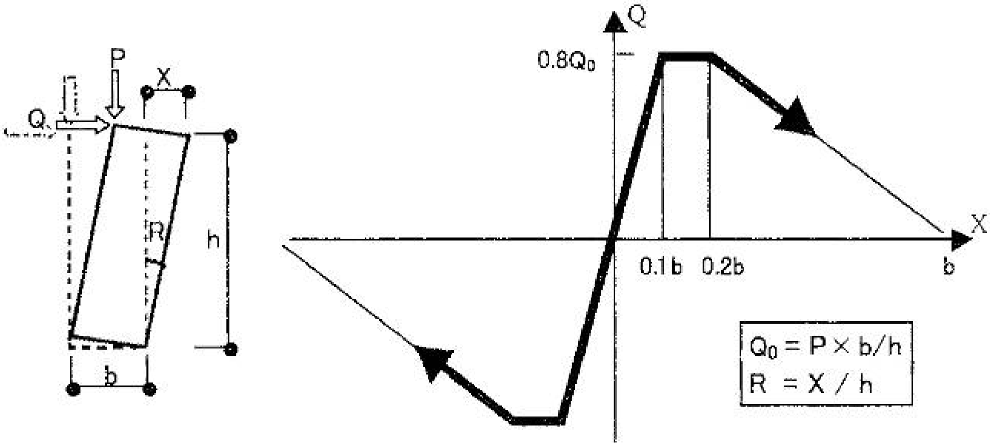

Figure 2.3 Restoring force for stabilizing made by column rocking

Figure 2.4 Example of “nuki” (= a kind of joint of column and beam)

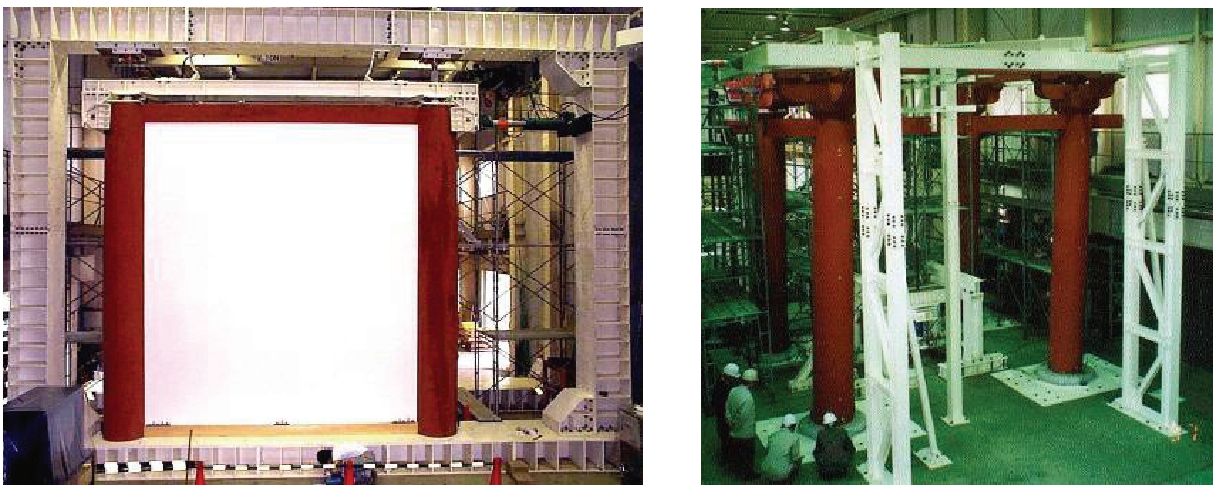

Figure 2.5 Example of “tuchi-kabe”

3. NECESSARY PROCESS TO IMPLEMENT

3.1. The preservation technology of wooden buildings

3.1.1（Structural and）Deterioration investigation of the buildings

At first, the levels of deterioration of members are investigated. By these investigations, designers estimate members that should be replaced at the time of dismantlement.

3.1.2 Planning for restoration considering maximum reuse of members and minimum replacement of damaged members

The repair plan is proposed based on the deterioration investigation. At the time of planning, maximum reuse of members and minimum replacement of damaged members are considered.

3.1.3 Checking the dismantled members during the dismantlement

At the time of dismantlement, the deteriorations of the members which can't be found at the deterioration investigation are checked, and if necessary, these members are added to the repair plans.

3.1.4 Rebuilding

After the repair, the buildings are rebuilt.

3.2. Quantitative evaluation of earthquake-resistant elements

3.2.1 Structural investigation

Structural performances are also investigated at the same time as investigating deterioration. In these investigations, the earthquake-resistant elements of the traditional building of Japan are picked up.

3.2.2 Modeling for applying to structural design techniques

Earthquake-resistant elements which picked up are modeled. These modeled elements are applied to structural design techniques such as "Limit Strength Method" and "earthquake response analysis". Designers can evaluate earthquake-resistant performances quantitatively by using these methods.

Fig.6 Toshodaiji Kondo

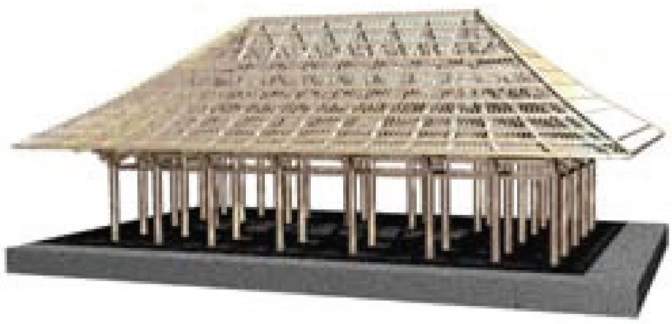

Fig.7 Analysis model of Tosho-dai-ji

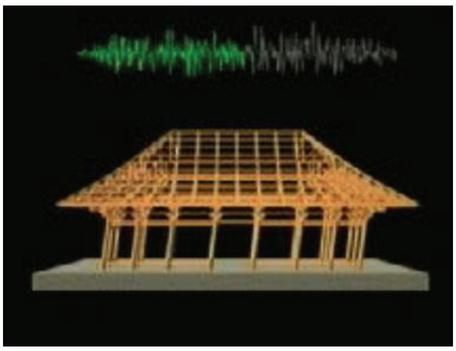

Fig.8 Toshodaiji Kondo

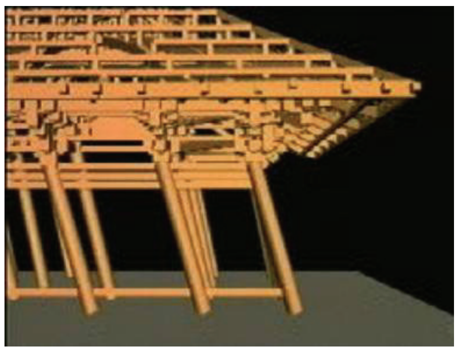

Fig.9 Analysis model of Tosho-dai-ji

4. STRENGTH AND LIMITATIONS

4.1. The preservation technology of wooden buildings

4.1.1 "Regular maintenance with appropriate intervals"
"Regular maintenance with appropriate intervals" enables buildings to survive for long time. Although they are damaged by the earthquake, if the buildings have the records about building plans, they can restore original form of buildings.
4.1.2 "Maximum reuse of members of buildings"
"Maximum reuse of members of buildings" also enables buildings to restore original form of buildings. These technologies are considered to be connected with sustainability of buildings.

4.2. Quantitative evaluation of earthquake-resistant elements

The designer comes to be able to evaluate earthquake resistant performances for the assumed force of the cultural wooden building as well as other modern architectures. The designers can reinforce the buildings if necessary.

5. RESOURCES REQUIRED

5.1. Facilities and equipments required

Usually at the time of dismantlement of the buildings like temples, temporary housing is needed to protect the entire building from wind and rain (Figure 5.1).

Fig.5.1 Examples of temporary housing

Moreover, spaces where the exchanged materials are processed and dismantled members are kept are needed. New materials (Timber) are needed for replacing damaged members. In order to dismantle, repair and rebuild the building, the carpenters who are expert at building and repairing cultural buildings are needed. They are usually called "Miya-daiku" in Japan (Figure 5.2).

Figure 5.2 Miya-daiku

At the time of deterioration investigation and structural investigation, experts in deterioration of the timber and structure of the cultural wooden buildings are needed. Organization in which carpenters, experts and parties concerned in the building discuss are also needed.

6. APPLICATION EXAMPLES

6.1. "Toshodaiji Kondo Heisei Dai shuri" (= Large Scale repair with dismantlement of Toshodaiji Kondo)

6.1.1People involved

(1) The carpenters who are expert at building and repairing cultural buildings are needed.
(2) At the time of deterioration investigation and structural investigation, experts in deterioration of the timber and structure of the cultural wooden buildings are involved.
(3) Parties concerned in the building are also involved.
(4) Organization in which carpenters, experts and parties concerned in the building discuss are also needed.

Figure 6.1 Toshodaiji Kondo

6.1.2 Total workload required

Chart 6.1 is Schedule for repair. It takes about 10 years to complete.

Chart 6.1 Time schedule for repair

1998	April	Start the investigation for the repair
	October	Special committee for repair was start
2000	January	Start the repair
	December	Construct tempary housings for covering the temple
2001	April	Start the investigation with dismantlement
2003	December	Finish the investigation
2004	January	Start the excavation investigation of the base
2005	January	Start the rebuilding the temple
2006	November	Jyoutoushiki (=ceremony of putting up the ridge beam of a new house)
2007	Septmber	Complete the rebuiding (schedule)
2008	March	Complete the dismantlement of temporary housing (schedule)

6.1.3 Evidence of positive results

(1)Tangible

Because of the damages of Hyogo-ken Nanbu Earthquake in 1995, this temple needs large scale of repairs with dismantlement and improvements of structural performances. This time the latest structural analysis technologies are applied to this temple.

The deterioration and structural investigation enable designers to evaluate deterioration and structural performances of the temple and propose the repair plans considering for maximum reuse of members and minimum replace of damaged members.

Earthquake-resistant design techniques enable structural designers to evaluate the structural performances of the buildings quantitatively. Designers can also evaluate the effect of past reinforcements which have not been evaluated quantitatively so far.

Figure 6.2 Example of deterioration and structural investigation

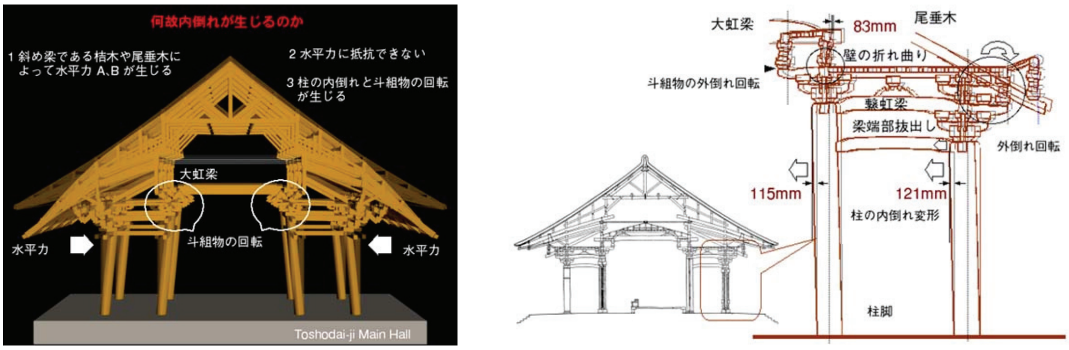

Figure 6.3 Example of analysis of current structural performances

(2) intangible

Preservation technologies such as “Regular maintenance with appropriate intervals” and “Maximum reuse of members of buildings” are considered to be connected with sustainability of buildings (Figure 6.4)

Figure 6.4 Example of repair with dismantlement(1)

Figure 6.4 Example of repair with dismantlement(2)

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