First aid:proposaland proof of emergency Earthquake-resistant einforcement method for wooden building with PP band(Cabletie for baggage)

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Building 4Humanity
DESIGN COMPETITION
Category 2:
Resilient Projects (Unbuilt)

Team Project Coordinator(s): Tadashi Saito
Team Members: Yoshiro Namba, Masakazu Terai, Hidenori Izumi, Koji Mabuchi
Project Location: Kumamoto Prefecture, Japan Team Code: B4H-DC2107

1 Introduction

In recent years in Japan, many earthquake damage suffered.

- 1995.1 The Great Hanshin Earthquake
- 2004.10 The Chuetsu Earthquake
- 2007.7 The Niigataken Chuetsu-oki Earthquake
- 2011.3 The Great East Japan Earthquake
- 2016.4 The Kumamoto Earthquake

In addition, as the possibility of the Tonankai / Nankai earthquake increases, the need for response after the earthquake is beginning to be discussed.

Especially, it is remarkable in the area which received much judgment of caution by emergency risk determination. Many houses are rehabilitated without being reinforced in affected areas.

As Figure 3 show, there are many buildings that require emergency reinforcement, and the area is wide in the Kumamoto Earthquake. If strong aftershocks occur in these areas, wooden framework will loosen and there is a possibility that it will lead to secondary disasters. The problem is that responses corresponding to each determination are not taken after the emergency risk determination.

The authors propose a simple method of emergency reinforcement for residences that are judged to be cautioned. This study aims to verify the effectiveness of emergency measures to be applied to wooden buildings based on the practice at the Kumamoto earthquake by the emergency reinforcement method.

2 Japanese wooden houses and Building Standards

As Figure 1 show, as of 2008, the percentage of wooden house construction in Japan is 58%, but it exceeded 80% 40 years ago . The reason why wooden buildings have developed in Japan is that wood has abundantly existed from long ago, and the building technology has been advanced along with progress of civilization and culture. Also, the distinctive hot and humid climate in Japan is one of the reasons. Wooden buildings with excellent breathability to make good use for alleviate the climate that has been damped as much as possible.

The urban building law was enacted in 1920 and the structural standards etc in wooden houses were decided. Since that time, the structure of buildings and earthquake resistance standards have been revised little by little while repeating the disaster. (Figure 2)

However, building outside the urban planning area, there is no required to apply for confirmation unless it is a building with more than 100 square meters of certain building, wooden building more than 500 square meters, non wooden building 200 square meters or more. Therefore, even after the establishment of the new earthquake resistance standards, there are cases where buildings are constructed regardless of building standards. In this way, there are many buildings with poor wall capacity and poor location balance of wall volumes. Currently, there are many buildings that do not satisfy earthquake resistance standards without applying for confirmation to Japanese wooden houses.

3 Outline of the 2016 Kumamoto Earthquake

The first earthquake (M6.5) occurred on April 14, 2016 in Kumamoto region, Kumamoto Prefecture, and the second earthquake (M7.3) occurred on the 16th. In addition, many aftershocks occurred even after these earthquakes.The series of earthquake damage in the Kumamoto earthquake became extensive and enormous.

In the case of large scale earthquakes, a large number of aftershocks will follow. In general, aftershocks are smaller than the main shock and occur near the main fault of the main shock. However, in the 2016 Kumamoto earthquake, the magnitude of the earthquake on the 16th is the largest in the series of earthquakes and is regarded as a main shock.

In the main shock of the 16th, strong shake of 7 on the Japanese seismic intensity scale was recorded in Mashiki-cho and Nishihara-mura, Kumamoto prefecture. In Mashiki-cho, it recorded a seismic intensity of 7 as the foreshock on the 14th, and it was encountered a strong shake twice during a short term. For this reason, some houses that were not destroyed by the 14th earthquake collapsed on the 16th. In addition to building damage, damage of cultural properties such as Kumamoto Castle, large-scale ground and sediment disasters, damage of agricultural land and agricultural facilities, etc. occurred in various places, mainly in Kumamoto Prefecture. 228 people dead (including related deaths), 2770 those injured, 42,226 fully and half destroyed houses (as of May 12, 2017. data by Fire and Disaster Management Agency).

4 Conventional emergency reinforcement

After the earthquake, various reinforcement methods were tried. Conventional reinforcement methods using compression force are introduced below. The schematic diagram is a radar chart based on experience on workability in disaster area.

4.1 Shoring

Combine wood in a rectangular shape and reinforce the inside of it with compression material. Make a structure that acts as an earthquake resistant wall between the horizontal members of the collapsed building.

【Advantage】: The shoring method can secure safety by construct it in the building which is about to collapse.

【Disadvantage】: Skill is required for work. Mobility is poor, such as loading of materials is required.

4.2 Replacing stick

Provide compressed material so that the cheeks stand against the direction of collapse of the building to prevent further collapse.

【Advantage】: Easily reinforce.

【Disadvantage】: It is difficult to secure safety.

4.3 Compression brace

Use the existing material such as the columns and beams of the building, and set the compression brace inside.

【Advantage】: It can be applied to necessary parts sensuously.

【Disadvantage】: The material is heavy and workability is bad. In some cases, thin material is mistakenly applied as a compression material.

Picture 1 : Damage caused by the earthquake

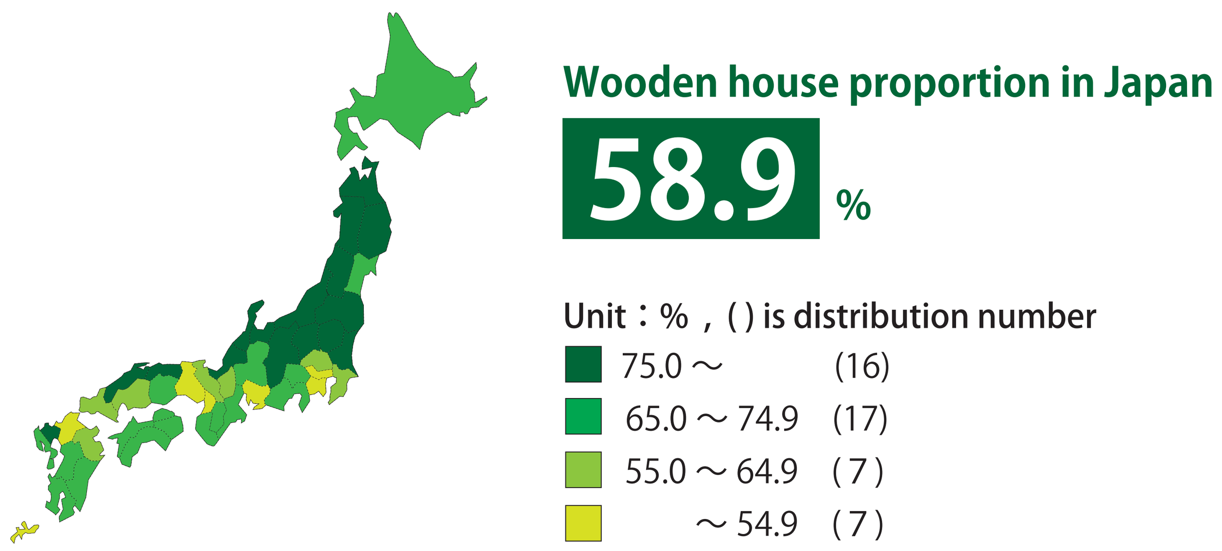

Figure 1: Percentage of wooden houses (2008)

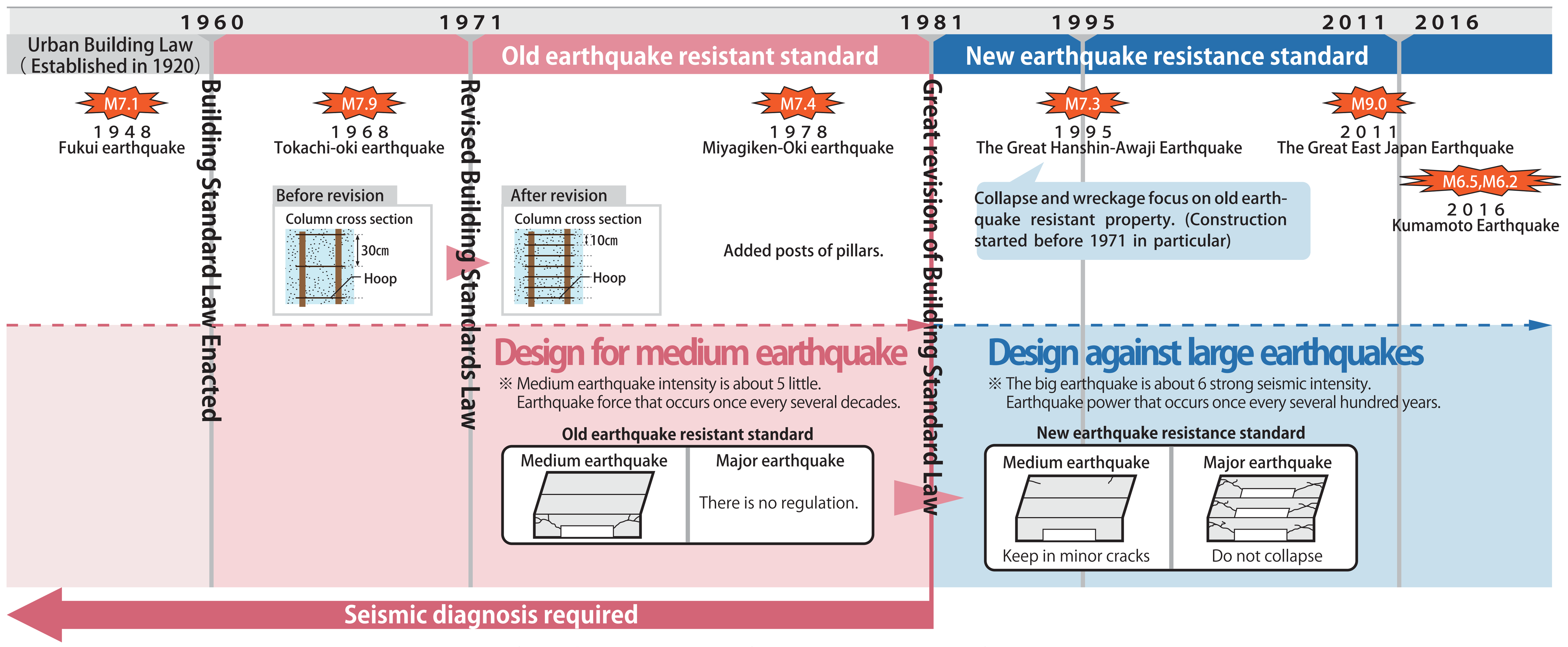

Figure 2 : Earthquake resistance standard change in Japan

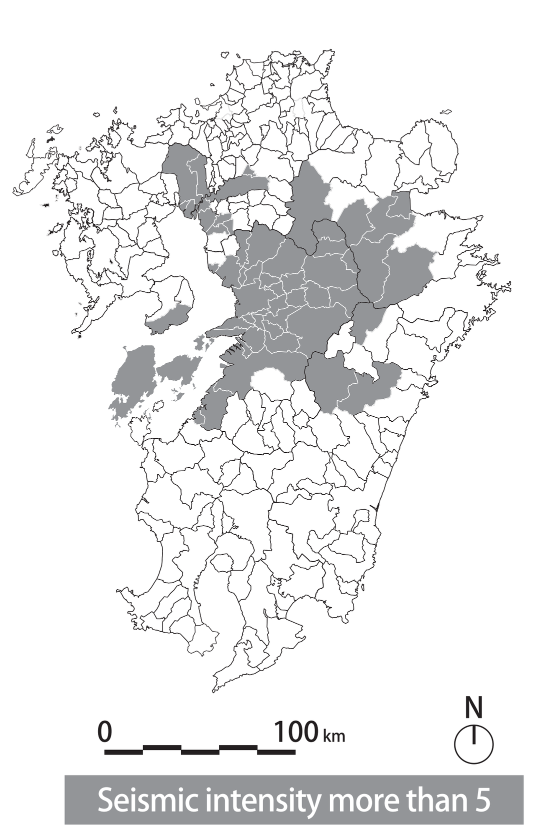

Figure 3 : Seismic intensity distribution of the Kumamoto earthquake

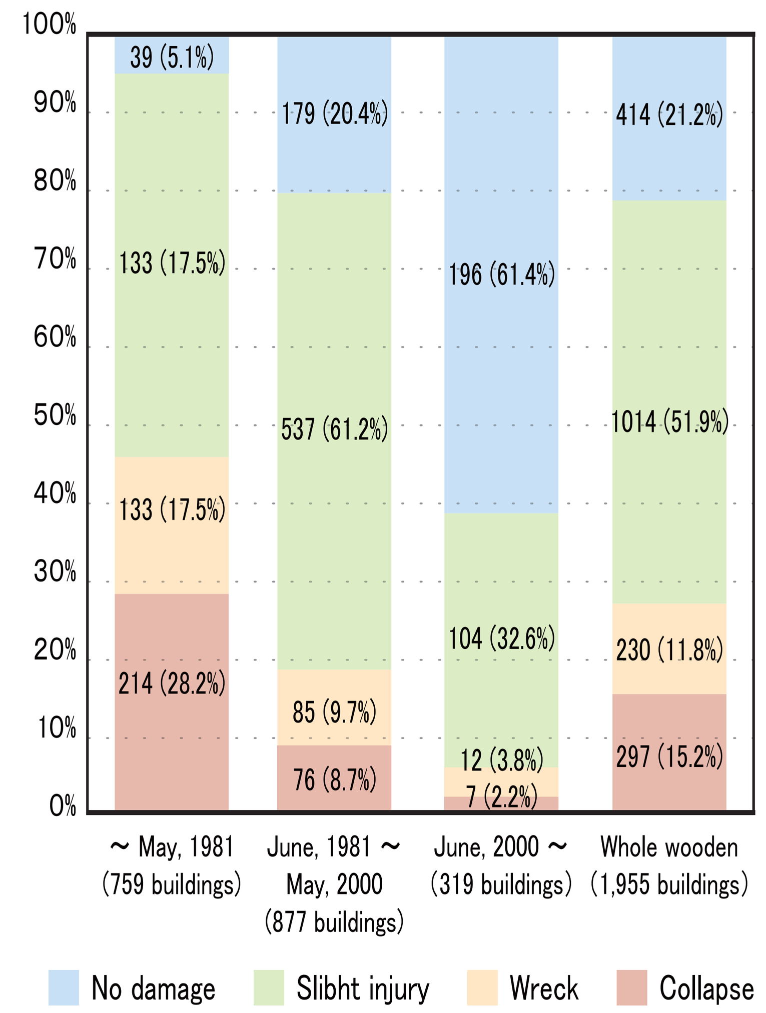

Figure 4 : Damage status by wooden building time

Structure	Damage level of building	Construction period			Total
		～ May, 1981	June, 1981 ～ May, 2000	June, 2000 ～	
Wooden	No damage	39 (5.1%)	179 (20.4%)	196 (61.4%)	414 (21.2%)
	Slight injury	373 (49.1%)	537 (61.2%)	104 (32.6%)	1014 (51.9%)
	Wreck	133 (17.5%)	85 (9.7%)	12 (3.8%)	230 (11.8%)
	Collapse	214 (28.2%)	76 (8.7%)	7 (2.2%)	297 (15.2%)
	Subtotal	759 (100.0%)	877 (100.0%)	319 (100.0%)	1955 (100.0%)
Other Structure	No damage	34 (37.3%)	124 (57.4%)	59 (75.6%)	217 (56.3%)
	Slight injury	42 (46.1%)	72 (33.3%)	16 (20.5)	130 (33.7%)
	Wreck	9 (9.8%)	14 (6.4%)	2 (2.5%)	25 (6.4%)
	Collapse	6 (6.5%)	6 (2.7%)	1 (1.2%)	13 (3.3%)
	Subtotal	91 (100.0%)	216 (100.0%)	78 (100.0%)	385 (100.0%)
Total	No damage	73 (8.6%)	303 (27.7%)	255 (64.2%)	631 (27.0%)
	Slight injury	415 (48.8%)	609 (55.7%)	120 (30.2%)	1144 (48.9%)
	Wreck	142 (16.7%)	99 (9.1%)	14 (3.5%)	255 (10.9%)
	Collapse	220 (25.9%)	82 (7.5%)	8 (2.0%)	310 (13.2%)
	Subtotal	850 (100.0%)	1093 (100.0%)	397 (100.0%)	2340 (100.0%)

Table 1 : Damage status of buildings by structure and construction period

Picture 2,3,4,5 : Damage of the Kumamoto earthquake

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5 Proposal for emergency reinforcement by PP band

The residents that received a cautionary judgment after the earthquake are not reinforced, or emergency reinforcements like those introduced in Chapter 4 have been done. However, these methods also had a problem in mobility and technical aspect by being a construction method relying on the compressive power of wood. Therefore, the authors propose a simpler emergency reinforcement method that makes use of the pulling force of the packing band.

5.1 Outline of Packaging Band Reinforcement Method

The reinforcement method with the packing band is to provide a simple tensile bracelet. Hang the packing band tied back using fastening hardware near the joint of columns and beam material. (Figure 6)

【Advantage】: Because material is light, it can be constructed with a small number of people easily. There are few preparations and it is easy to obtain at the time of disaster.

【Disadvantage】: Skill is required for work. Mobility power such as loading of materials is poor.

5.2 Minimal accessible items

Reinforcement with packing bands can be made with items that are easy to obtain even in the event of a disaster, and can be constructed with a few tools. It is cheaper than other emergency reinforcement methods because there are few preparations. What to prepare is packing band, hardware seal for packing band (spot seal below), fixed hardware, sealing device (Picture 7).

5.3 Minimal intervention make maximum effect!!

Emergency reinforcement by the packing band can be constructed from two persons. The procedure of the operation is as shown in Figure 7. The construction procedure has been simplified so that even general people can work.

① Prepare two spot seals and connect them with cellophane tape in advance.
② Secure the mounting hardware with screws (which may be nailed) near to the column beam joint part and the column base joint part.
③ Secure the packing band with one spot seal.
④ Secure one side of the packing band by spot seal, the other side is passed through ametal fitting on the diagonal side, and fixed by passing through the other side of spot seal. It is generally difficult to tighten a tensile force of 100 kg or more with a person's hand. However, by using the principle of the moving pulley, a strong tensile force can be exerted.

5.4 Tensile strength of packing band

In order to confirm the tensile strength per one packing band, a tensile test was conducted. Figure 8 shows the relationship between the tensile stress and the strain of three packaging bands. The packaging band starts to tear partially from the tensile stress degree of about 30 N/mm². It has been confirmed that it withstand up to about 125 N / mm² after starting to split.

5.5 Reinforcement to N House

【Location】: Minami-ku, Kumamoto-city, Kumamoto Prefecture.
【Implementation date of emergency reinforcement】: May 9, 2016.
【Emergency Danger Level Determination】: Careful Attention
【Reason】: Attention to the fall of the tile notation.

It is a house built by a local carpenter. Because it is outside city planning area, have not received confirmation at the time of construction. The large sweep window is arranged to open the south side, but the wall quantity is short. We reinforced the packaging band to recover the wall volume in an emergency, and verified workability and effectiveness. (Picture 6, Figure 5)

Two months after reinforcement, we interviewed the owner. Meanwhile, there was an earthquake of less than 5 seismic intensity, damage was also coming out in the neighborhood. However, there was a report that there was no damage in this reinforced houses. Also, I received a report saying that the noise in the aftershocks has also decreased.

5.6 Application examples obtained by real verification

5.6.1 K type bundle

When there is an obstacle at the binding position, tensile force is applied in a K-shape to bind it while avoiding the obstacle.

5.6.2 Application to Blue Seat Tension

As a countermeasure against leakage due to falling of the roof tile, by covering the blue sheet with the packing band, wind blowing up can be suppressed.

6 Summary

Natural wooden buildings with poor walls and poor balance of wall arrangements are scattered outside city planning areas. If such buildings are not reinforced by next earthquake, possibility of collapse is high. Even if you escape difficulties in a main shock, it is fully expected that risk increases with repeated aftershocks.

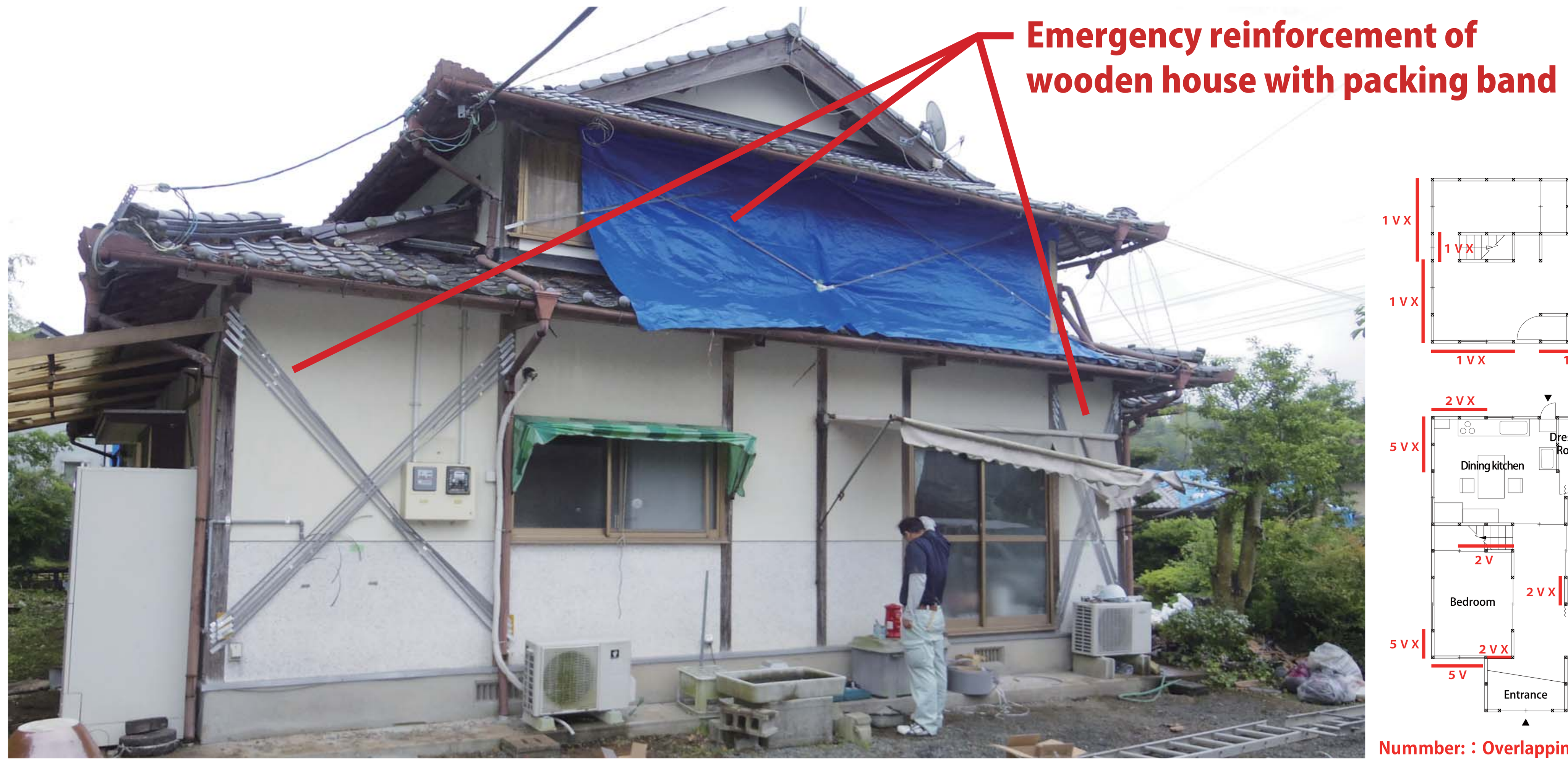
The reinforcement method introduced in this research can cope with such situation.This construction method is superior to the other reinforcement methods in the following points.

① Stockpiling available
② Quick reinforcement
③ The number of construction workers can be small

From this point of view, it is a construction method that can be an essential reinforcement method as an emergency measure immediately after an earthquake. On the other hand, summarize the disadvantages of this method.

① Degradation of materials due to ultraviolet rays
② Relatively weak strength

Therefore, it can not proceed with long-term use. It is a method of emergency reinforcement. In addition, safety can be enhanced by using shoring and other methods in combination with reinforcement for the entry of the rescue team. Furthermore, since wooden buildings can be reinforced quickly with few scratches, we can expect to move to reconstruction early without damaging the local architectural culture.



Picture 6 : Packing band construction example

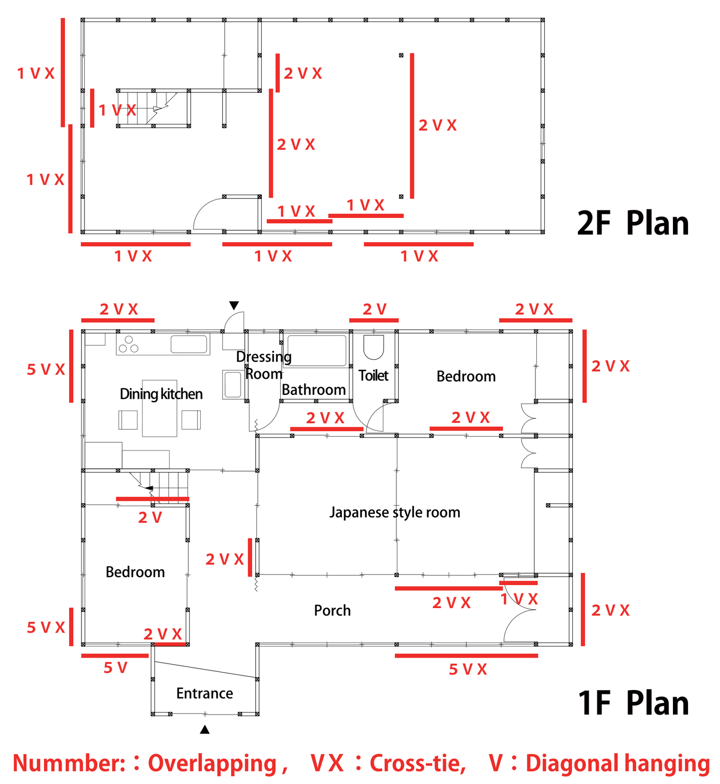


Figure 5 : Placement of reinforced parts

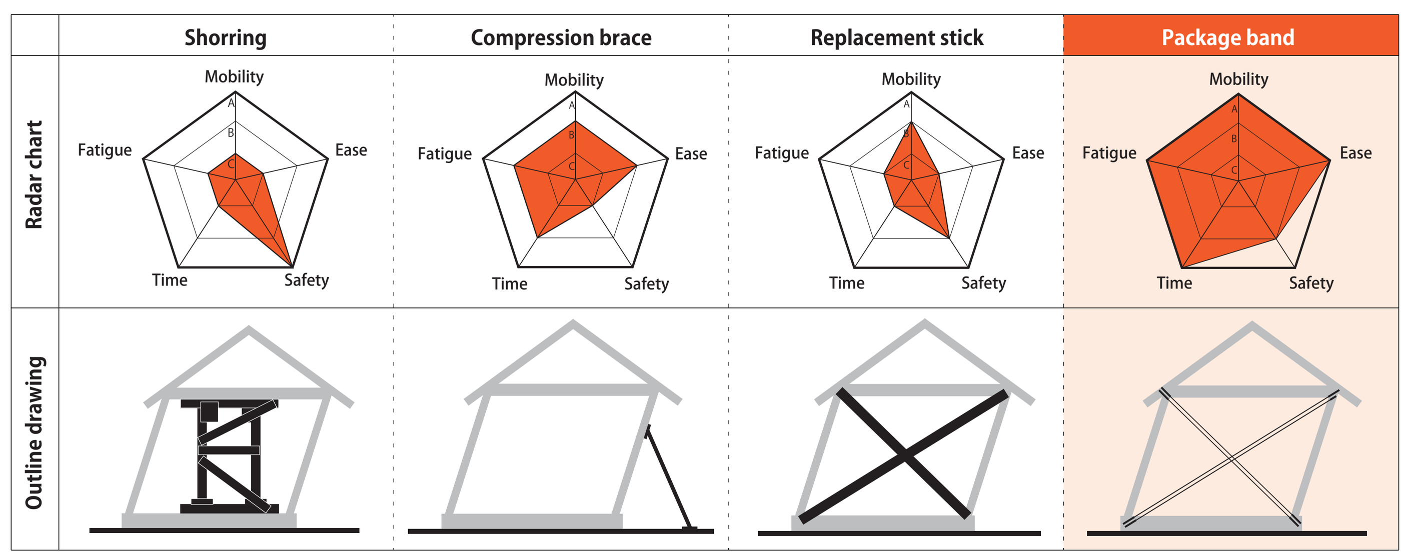
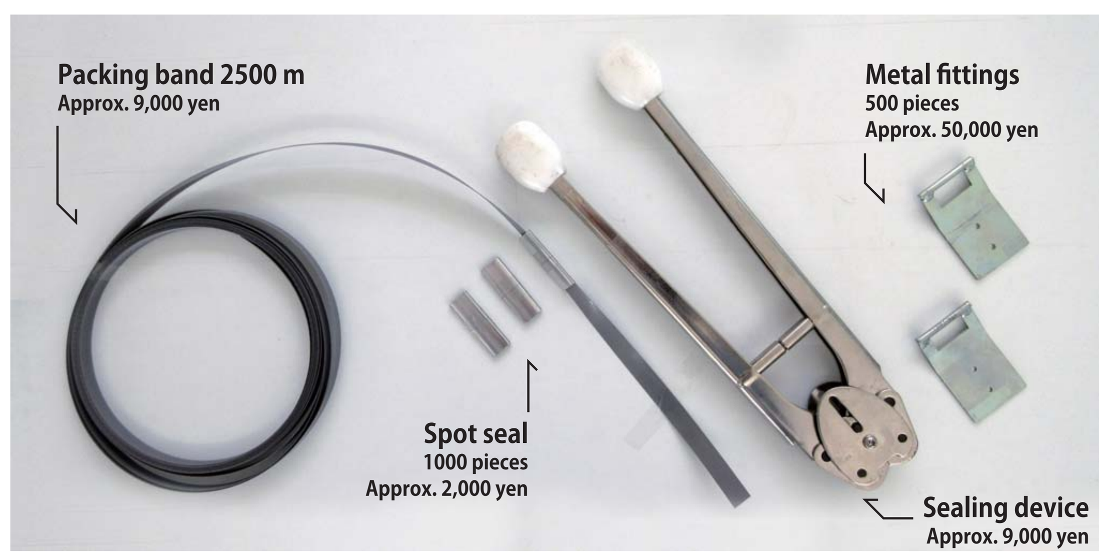


Figure 6 : Outline drawing of each emergency reinforcement method



Picture 7 : Reinforcing tool

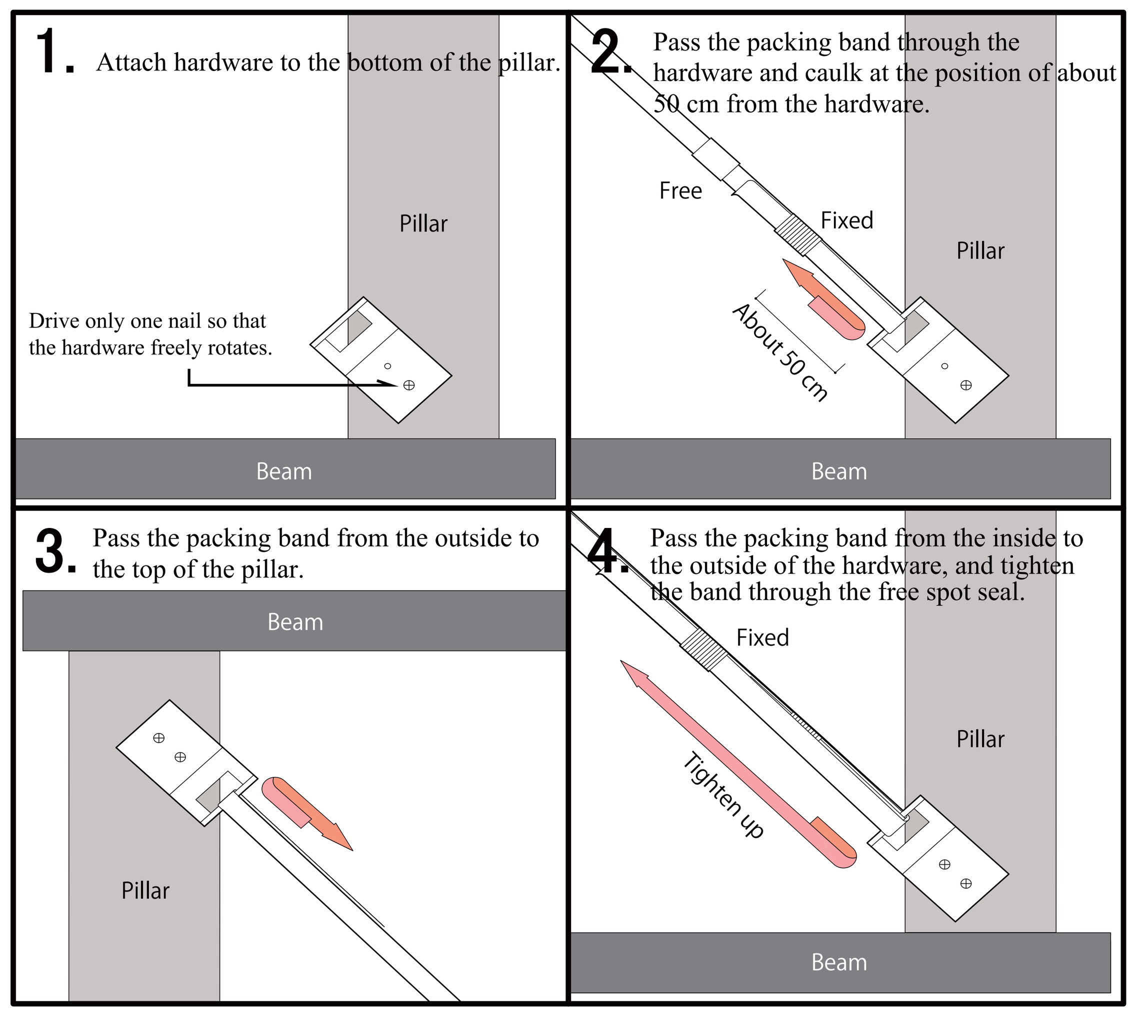


Figure 7 : Reinforcement procedure

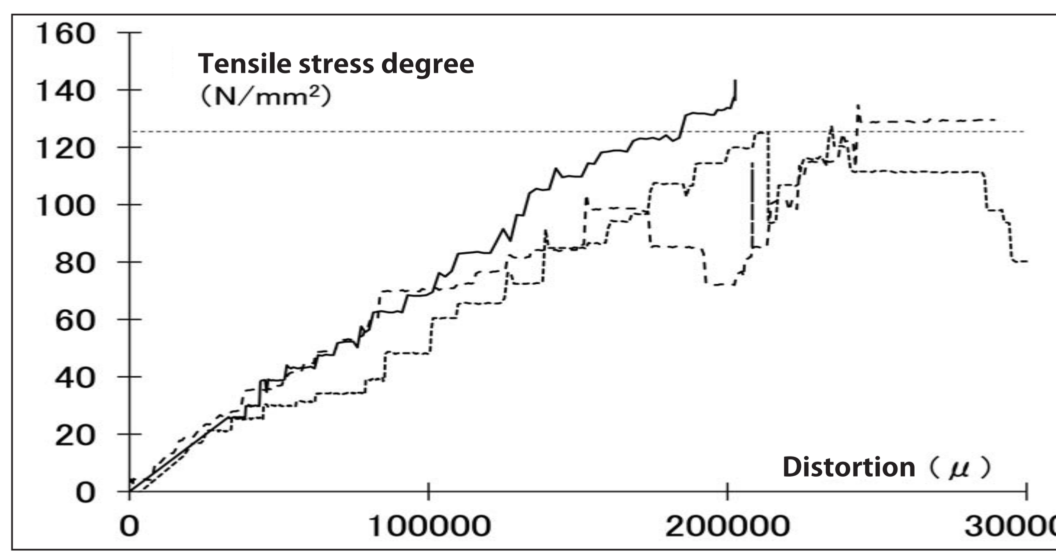


Figure 8 : Tensile test results

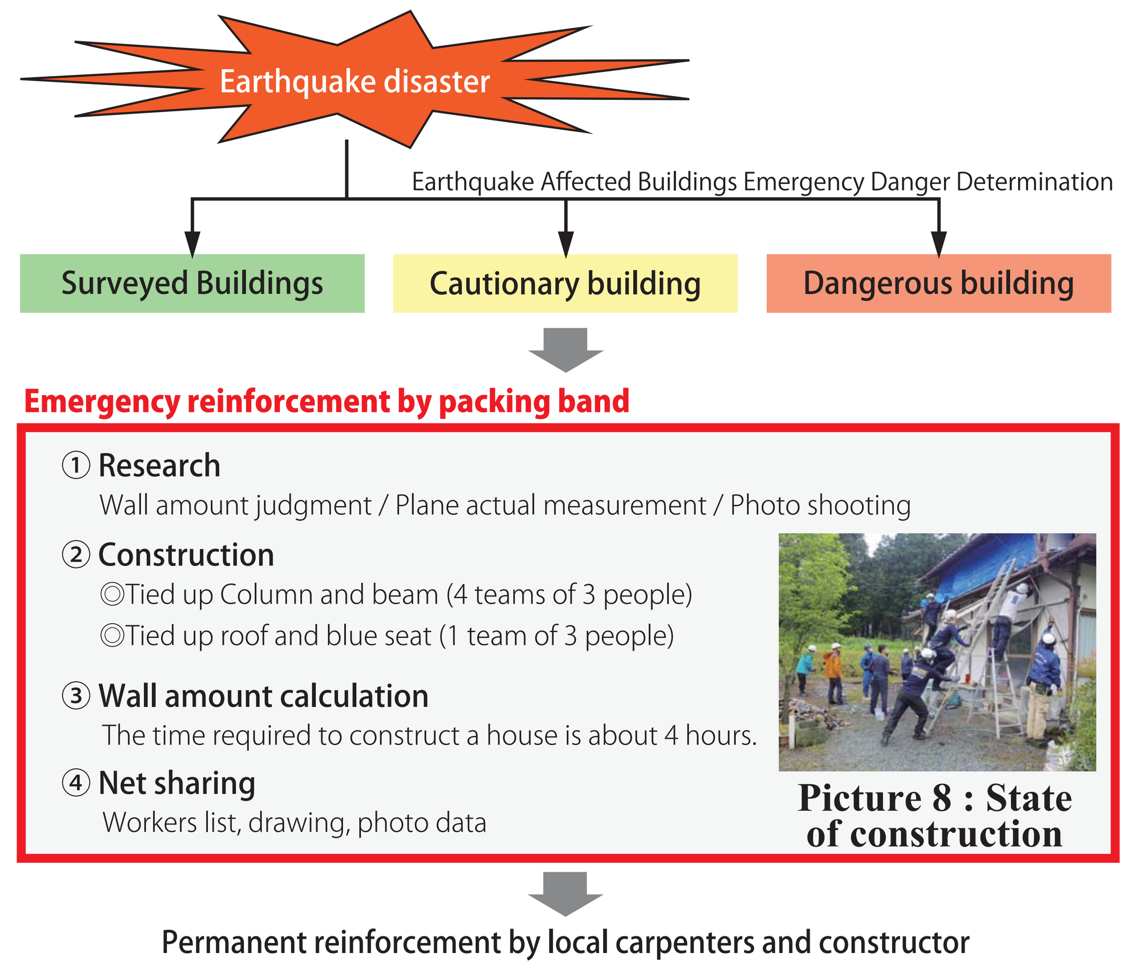


Figure 9 : Procedure for reinforcement

Picture 9 : K type tying example

Picture 10 : Blue Seat Tension Application Example