BUILDING DAMAGES OF MODERN WOODEN ARCHITECTURES IN JAPAN BY THE 2011 OFF THE PACIFIC COAST OF TOHOKU EARTHQUAKE

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1 INTRODUCTION

Many of the early modern wooden architectures [In this paper, ‘early modern’ means 1853-1926, from the end of the Edo era to Taisho era] in Japan were damaged by the 2011 off the Pacific Coast of Tohoku Earthquake [Tohoku eq. here after]. They are built with traditional Japanese and newly imported Western techniques, so they have various building construction types, and it has been difficult to classify the building elements of them and evaluate their seismic performance. On the other hand, these years, they have been re-appreciated as local symbols and properties, so it is important to try to classify the construction elements of them and to clarify the seismic characteristics through the investigation of the vibration damages.

1.1 Purpose and Methods

The purpose of this paper is to clarify the characteristics and vulnerabilities of modern wooden building construction elements. As a preliminary research, we classified the building elements of early modern wooden architectures based on the preceding research [1], the reports of repairs [2], and on-site measurements. Then, we investigated the vibration damages of them by the Tohoku eq., focusing on the building elements classified above.

1.2 Vibration Damages of Wooden Architecture by the 2011 off the Pacific Coast of Tohoku Earthquake

The magnitude of the main shock was 9.0(Mw), and the maximum acceleration was approximately 2700 gal at K-net Tsukidate, Kurihara City. Among the cultural property buildings in Tohoku region, 58 out of 162 Important Cultural Properties designated by the national government, and 131 out of 699 Registered Cultural Properties were damaged [3]. Especially, concerning timber cultural properties, cracks on mud walls, inclinations of columns and falling off of horizontal member have been observed. On the other hand, there is not any report of complete destruction of modern wooden architectures, and there are few reports focused on the ‘modern’ building elements.

2 BUILDING CONSTRUCTION ELEMENTS OF THE INVESTIGATED BUILDINGS

Among the early modern wooden architectures in the three heavily damaged prefectures (Fukushima, Miyagi and Iwate), we chose 16 early modern wooden buildings. They included all the Important Cultural Properties designated by the national government (seven cases), five Important Cultural Properties designated by the prefectural government, Cultural Properties designated by the town government and two Registered Cultural Properties. The damage investigation was performed during August 2011 to September 2012.

2.1 Classification of Building Construction Elements

The building construction elements of the 16 investigated buildings were classified as follows [figure 1].

FIGURE 1: Construction Elements of Investigation Objects

2.2 Modern Wooden Construction Elements

Among the building construction elements above, the following elements started being used during the ‘early modern’: siding boards, wooden lathes, bonded-footing, girts, braces, king trusses, queen trusses, and slate tiles.

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3 RESULTS OF THE DAMAGE INVESTIGATION

3.1 Degree of Building Damage

The damages are evaluated to 4 degrees (from heavier damaged order, ‘Total Destruction’, ‘Heavy Damage’, ‘Partial Damage’, ‘No Damage’) based on the preceding research [4]. In addition, concerning the cost of repairs, such damages which need total repair of the walls and jacking up of foundations are also evaluated as ‘Heavy Damage’.

As a result, 9 out of the 16 buildings were Heavy Damage, 6 were Partial Damage, and 1 was unknown.

The ‘Heavy Damage’ include dislocation of stone-bonded perimeter footing, shear failure at the joint of floor posts, falling down of horizontal members and falling off of almost all the plaster and mud walls. The ‘Partial Damage’ include cracks of walls and foundations, falling down of ridge roof tiles, disconnection of knee braces [Figure 2].

![Figure 2: The Degree of Damages, and its details](image)

3.2 Damages of Walls

On all of the investigated buildings, the cracks and falling off of finishing material (mud, plaster) were observed, except 1 building which we could not investigate inside. The ratio of buildings which need whole repair of walls are shown as in table 1. No damages were observed on sidings, and the frames inside the walls.

![Figure 3: Falling off and Cracks of Plaster finish](image)

3.3 Damages of Foundations

On 4 buildings, damages of foundations were observed. The types of the damages are shown as in table 2. The dislocations of perimeter stone-bonded footing were observed on 2 buildings, and their footings were only at perimeter, and not under the sleepers. In addition, the dislocations were concentrated at the corners and the places where the partition walls were inside.

![Table 2: Types of Damages of Foundations](image)

3.4 Other Damages

The damages of the frames were observed on 2 buildings. They included bending failure at the joint of a few braces and columns, falling down of lintels, inclinations of columns. The damage of the roof structure was observed only on 1 building. It was heavily damaged by the destruction of a neighboring warehouse. The falling down of a few roof tiles were observed on 6 buildings.

4 CONCLUSIONS

1) By the building damage investigation of early modern wooden architectures in 3 heavily damaged prefectures, 9 out of 16 buildings were evaluated as ‘Heavy Damage’, and they included 9 falling off of wall finishes and 2 dislocations of perimeter stone-bonded footings. The damages of bonded footing were observed in such buildings which have no footings under sleepers.

2) The characteristics of damages on early modern wooden architectures were falling off of plaster finishes and the dislocation of perimeter stone-bonded footing.

3) The frames and roof structures are not heavily damaged, even it was made with modern building construction elements or not.

In the next step of the study, to analyse the seismic performance quantitatively, the dislocation of stone-bonded footing, the sticking of finishes and the seismic responses are need to be examined.

5 REFERENCES


