RESTORATION OF RESIDENTIAL BUILDING DAMAGED BY THE 1995 HYOGO-KEN NANBU EARTHQUAKE IN JAPAN

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ABSTRACT :

In this paper, a relationship between the attribute of wooden houses damaged by the 1995 Hyogo-ken Nanbu Earthquake(Kobe Earthquake) and the restored situation of those houses was considered. The purpose of this research is to clarify how to restore the severely damaged area at about ten years after the earthquake. Field researches were conducted immediately after the earthquake, 8 years after and 12 years after the event. The research fields were Higashinada Ward Kobe City and Hokudan Town in Awajishima Island. Higashinada Ward is an urban area and Hokudan Town is a rural area. As a result of this investigation, severely damaged wooden houses restored another kind of structures such as reinforced concrete or steel construction. Japanese traditional roof tiles of severely damaged houses have changed to a slate roof or metal plate roof. The difference of restore condition between urban area and rural area was also investigated. It was the same tendency that the damaged traditional wooden houses had been rebuilt to new type wooden houses or another kind of structures in both area. However, the ratio of another kind of structure was higher in urban area than in rural area. Roof tiles remained at higher ratio in rural area than in urban area. The result of this research is expected to have application for the decision of disaster restoration planning according to characteristics of the region.

KEYWORDS: Restoration, Earthquake damage, Kobe Earthquake, Wooden houses

1. INTRODUCTION

The Hyogo-ken Nanbu Earthquake was an inland earthquake of magnitude 7.3 which occurred at 5:46 a.m. on January 17, 1995. This was the first earthquake observed to have a maximum seismic intensity of 7 on the Meteorological Agency's seismic scale. In total, more than 200,000 building units were either completely or partially destroyed, and more than 5,500 people died as a direct result of the earthquake.

Immediately after the earthquake, we conducted research on building damage, especially on the damage to house, and human damage in an area of Higashinada Ward of Kobe City and in Hokudan Town on Awajishima Island where the seismic intensity was 7 and the damage was most severe. We selected these two area as research targets because we wanted to compare various aspects of the damage in Higanshinada Ward, which is an urban area, with that in Hokudan Town, which is a rural farming and fishing district. By comparing and studying these two regions, we sought to determine the influence of regional characteristics – urban or rural in this case – on the extent of the damage and post-earthquake restoration work.

Therefore, in this study, we compared the results of our damage assessments conducted in 1995 with our findings related to building reconstruction conducted in both region in 2003 and 2007. We compared our findings based on the differences between the respective urban and rural areas, and assessed the scale of the damage and the differences in reconstruction methods employed within the context of these regional characteristics.

2.RESEARCH IN HIGASHINADA WARD, KOBE CITY

2.1. General Outline of the Research

The districts targeted were the same as those researched immediately after the earthquake; Moriminami-machi, Honjo-cho, Fukaekita-machi and a part of Fukaehon-machi, all of which are located in eastern Higashinada Ward, which is adjacent to Ashiya City. The area measured 250 meters from east to west and 780 meters from north to south. The northernmost tip of the study area was the Akatorii intersection on National Route 2 and the southernmost tip was the Fukae intersection on Route 43. Taking into consideration the different regional characteristics, the aim was to analyze the research data by region and to identify whether any regional housing reconstruction trends were apparent. Consequently, given that the earthquake damage varied along a north-south axis within the targeted districts, all of the research districts were divided into three areas (A, B, and C) as shown in Figure 2.1. Based on the findings of the research conducted in 1995, we decided to restrict our analysis to data for wooden houses in the targeted districts. In the 2003 research, we surveyed the House Attributes of every dwelling within a target area using the indexes below.

The survey items for assessing reconstruction initiatives in 1995 and then subsequently in 2003 and 2007 were as follows:

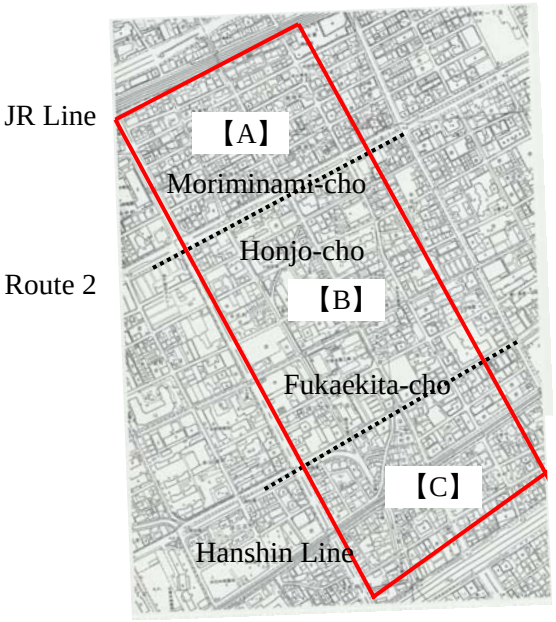


Figure 2.1 Research area in Kobe

2.1.1. 1995 initial damage assessment(Number of target units: 709)
Building damage: Collapses, Total destruction, Partial destruction, Minor damage
Roof material: Roof tiles, Metal, etc.
Intended purpose: Residential use only, Shops and residential housing, Apartments
Termite damage: Observed, Not observed
Type of roof tiles: Hooking crosspiece, Mud roofing
Building age: Less than 30 years, More than 30 years

2.1.2 . 2003 and 2007 restoration research items(Number of target units :815)
Construction materials: Wood, Light-gauge steel and concrete panel, Steel and reinforced concrete
Roofing materials: Tiles, Metal plates, Slate, etc.

Intended purpose: Residential use only, Shops and residences
Number of stories: The numbers were entered
Form: Single family houses, Housing complexes, Apartment blocks and tenements
Reconstruction: Undertaken, Not undertaken

2.2. Research Results and Examination

Based on the data related to reconstruction efforts of each of the surveyed buildings in 2003, we analyzed the relationship between the extent of the building and human damage caused by the earthquake in 1995, as well as the new construction and roofing materials, and intended functions of the buildings in 2003.

The principal findings are shown in the flow charts such as that shown in Figure 2.2, which depict the relationship between building damage and the change in the intended purpose of the buildings. After dividing the targeted district into three areas according to regional characteristics, we compared the building reconstruction of these areas in terms of the construction materials and the intended purpose of the buildings.

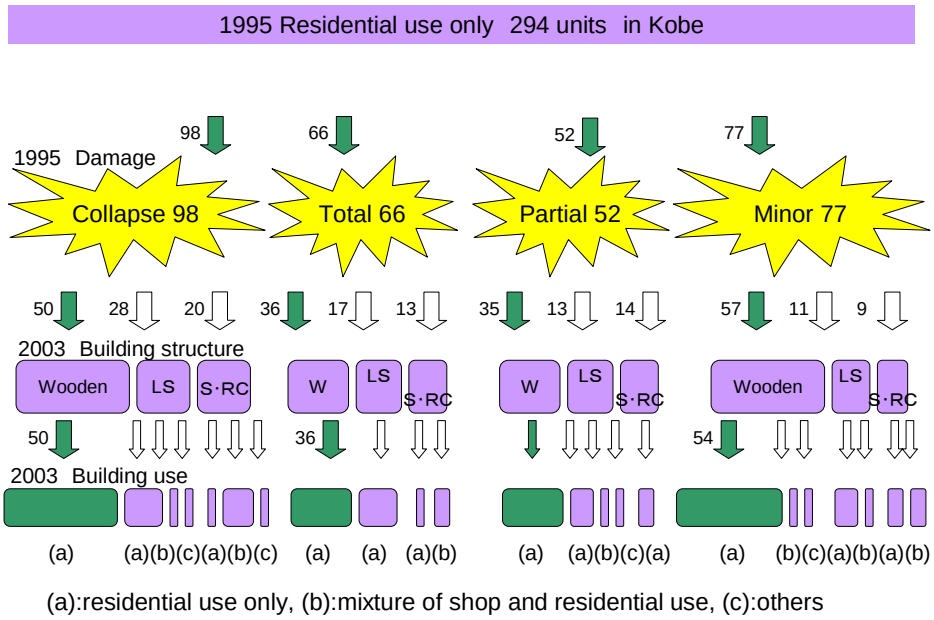


Figure 2.2 Restored situation of wooden residents in Higashinada Ward, Kobe City

Examination of the survey results, primarily using the cross-table method, revealed the following: Regarding the use of construction materials, it appeared that the lower damage was, the higher greater the likelihood that reconstruction of a wooden structure by another wooden structure would be i.e. retention of the same building materials (Collapse 43%, Total destruction 47%, Partial destruction 62%, Minor damage 65%). In other words, the owners of the buildings which suffered severe damage tended to select materials other than wood upon reconstruction, and it is inferred that this tendency occurred in response the extent of building damage. Further, concerning roofing materials, reconstruction from roof tiles to roof tiles (i.e. use of the same materials for reconstruction) was 6% in cases of collapsed buildings, 4% in cases of total destruction, 3% in cases of partial destruction, and 36% in cases of minor damage; a marked difference was thus observed between partial destruction and minor damage.

Area A, which was on National Route 2 and contained numerous single-family houses, experienced the most extensive building damage, and rates of collapse and total destruction were 63%. However, at 70%, the rates of reconstruction observed in the 2003 research were relatively higher than they were previously.

Further, regarding the use of construction materials for reconstruction, the percentage of wooden, which is characteristically high in residential districts, was higher than in other areas. Area B, which was located in the center of the targeted district, contained numerous buildings that were not constructed of wood, such as factories and kindergartens. As for houses, a comparatively large number of multipurpose buildings that were not exclusively used as residences, such as combined house and shop buildings, were observed. The percentage of construction material use after reconstruction for these areas was 37% for wood and 43% for steel and reinforced concrete, indicating that rates of steel and reinforced concrete use were higher than that of wood upon reconstruction. Area C was a downtown area with relatively smaller houses compared to the other two areas to the north. More than half of the houses in this area experienced minor damage. The proportion of raw land in 2003 was 37%, which was the highest among the three areas. It is thought that the restoration work in this area was relatively slow because the small size of each building site made the redevelopment work difficult.

Based on these findings, the restoration and reconstruction methods employed in the targeted area over the 10-year period following the earthquake could be sorted into groups based on factors as the damage occurring immediately after the earthquake and the construction material employed in reconstruction.

3. RESEARCH IN THE HOKUDAN DISTRICT, AWAJISHIMA ISLAND

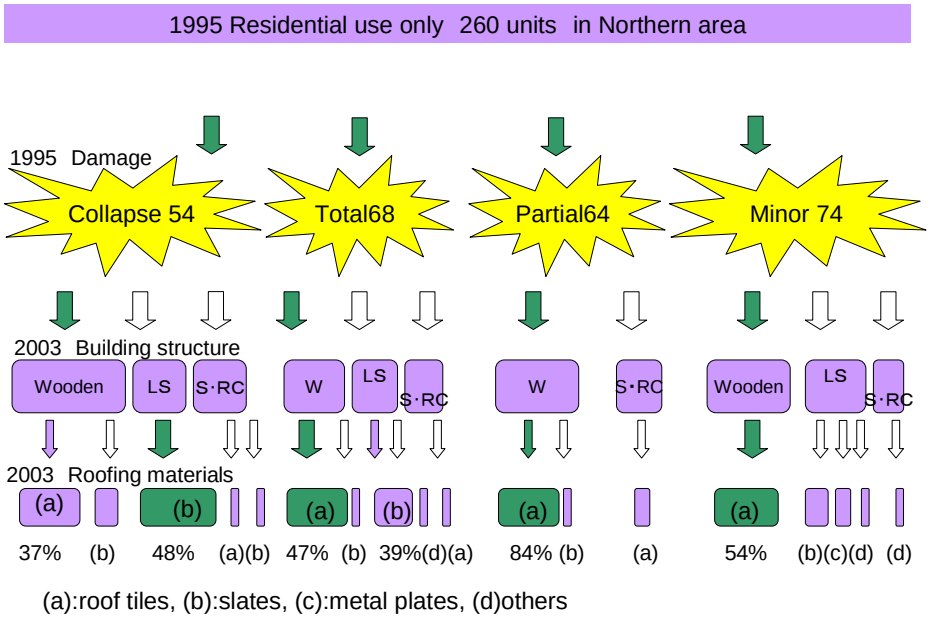
3.1. General Outline of the Research

The study area of Hokudan Town consisted of a narrow belt-line region stretching from north to south, located at the northwest end of Awajishima Island. The Nojima fault, which is considered to be the seismic source of the Hyougo-ken Nanbu Earthquake, traverses this town longitudinally for nine kilometers along the coastline. The main communities of Hokudan Town existed close to this fault, and the narrow coastal area region was characterized as having high-density housing. The specific focus of this research was on the five northern districts of Ezaki, Hirabayashi, Okawa, Todoroki and Hikinoura, as well as the Toshima district, which is in the central district of Hokudan Town. A comparison was made between the northern districts and Toshima district using the same research items as those used in the Higashinada Ward study and the number of buildings targeted in the survey was as follows:
Northern area: Year 1995:278 units, Year 2003: 301 units
Toshima district: Year1995:478 units, Year 2004:646 units

3.2. Results and Discussion

In the north of Hokudan Town, which was located closer to the seismic source, certain regions suffered extensive damage due to the slip fault while others suffered comparatively minor damage. Consequently, the extent of reconstruction in the area was only 43%, with 44% of the buildings in use today without having required any major repairs or maintenance. Of the buildings that were not reconstructed, several were abandoned, suggesting that the northern area was not yet entirely restored. In addition, in the Toshima district, which is comparatively urbanized and the site of the Town hall, numerous of buildings were either partially or completely destroyed due to the unstable ground. The extent reconstruction in 2003 was 51%. The town redemarcation project is still in progress, and new arterial roads have recently been constructed on the northern side of Toshima. There are a marked number of buildings that are still under construction on unused land, housing complexes and buildings used for purposes other than dwellings have increased in Toshima district compared to the northern districts. Figure 3.1 shows the damage and the reconstruction situation of each region.

Before the earthquake, the majority of the buildings in Hokudan Town were wooden structures. However, after 10 years of reconstruction work, an increase in the number of non-wooden structures has been observed (light-gauge steel concrete panels: 22%, steel and reinforced concrete structures: 11%). With regard to roofing materials, the use of materials other than roof tiles, such as slates and metal plates, has increased to 46%. We focused on the reconstructed buildings, and examined the relationships between the extent of damage due to the earthquake and the change in the materials used for building structures and roofing, etc. during reconstruction.



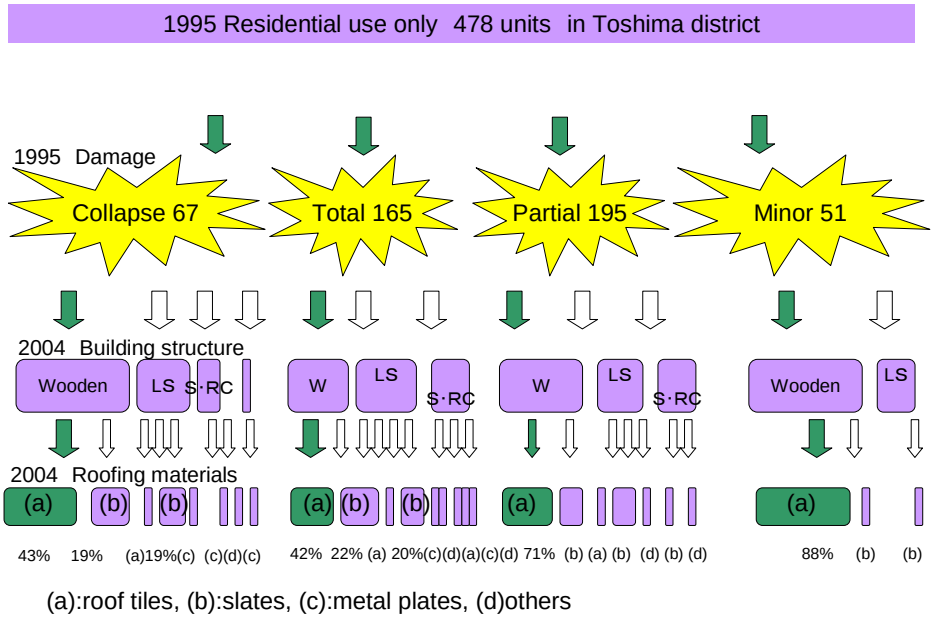


Figure 3.1 Restored situation of wooden residents in Awajishima Island

For example, the following can be observed in the Northern district,
1)Transition to non-wooden structures (structures before the earthquake; wooden)
Collapses:55%>Total destruction:44%>Partial destruction:6%>Minor damage:50%
It appears that the greater the building damage was, the higher the extent of reconstruction from wooden structures to non-wooden structures. However, this finding is not a generalized trend as buildings with minor damage in the northern area showed low reconstruction rates, resulting in high reconstruction percentage per unit.

2) Reconstruction using roofing materials other than tiles(Primary roofing material before the earthquake: tiles)
Collapses:67%>Total destruction:52%>Partial destruction:10%>Minor damage:50%
Human damage occurred:50%>Human damage not occurred:43%
The relationship between building damage and the change in roofing materials exhibited the same tendency as that observed for building structure. Also, in cases where there was human damage, the percentage of tile-to-tile reconstruction was low.

The following can be observed in Toshima district,
1)Reconstruction from wooden structures to non-wooden structures
Collapses:38%=Total destruction:38%>Partial destruction:23%>Minor damage:12%
With regard to changes in building materials, the percentage was generally low when compared to that of the northern districts, but a similar tendency between the areas was observed. In the Toshima district, the recently constructed arterial roads meant that reconstruction rates were generally high irrespective of the extent of damage.
2)Reconstruction from residential use only to a mixture of shop and residential use
Collapses:17%>Total destruction:15%>Partial destruction:9%>Minor damage:0%
Although the number of units converted was low, it was observed that the intended purpose of the buildings was changed at the time of reconstruction in areas severely damaged by the earthquake.

We also analyzed the reconstruction patterns based on the extent of building damage in the northern area and the Toshima district. In the northern area, half of the collapses and 40% of the total destruction cases were reconstructed using light-gauge steel concrete panels (slate roofs). The other half of the collapses and cases of total destruction, as well as most of the cases of partial destruction, were reconstructed using wood for roof tiles. Further, for buildings in the Toshima district that either collapsed or were totally destroyed, approximately half were reconstructed using wood (tiled roofs) while the remaining structures were reconstructed using wood (slate roofs) or light-gauge steel concrete panels (slate roofs). For buildings that were only partially destroyed, 70 to 80% were reconstructed using wood (tiled roofs). Compared to the northern area, reconstruction patterns were diverse and property owners employed several choices.

As described above, the greater the earthquake damage to buildings was, the more flexibility regarding the use of building materials, roofing and the intended purpose of the properties affected changed. Surprisingly, considering that the proportion of wooden structures in Hokudan Town currently exceeds 60% of all extent structures, a minimum of 80% of these households use tiles for roofing, indicating that restoration was highly influenced by the traditional building culture and industry of the region.

4. CONCLUSION

In this study, we assessed the damage incurred by wooden houses immediately after the Hyogo-ken Nanbu Earthquake in Higashinada Ward, Kobe City and Hokudan Town, Awajishima Island in 1995 and analyzed the post-earthquake reconstruction activities in both districts. To this end, we focused on the differences between the urban region and the rural area of farming and fishing at the macro level, and on the relationships between the scale of damage and the characteristics of the intended uses of the buildings in each region at the micro level.

We found that, in the Hokudan district, the tendency to reconstruct buildings using traditional housing materials was stronger than in Higashinada Ward. In addition, the process of reconstruction differed depending on the region. Also, it was found that the scale of damage as well as the most prevalent building-use in the region affected the extent of houses reconstruction.