17th World Conference on Earthquake Engineering, 17WCEE

Sendai, Japan - September 13th to 18th 2020

Status of wooden houses in Mashiki town two years after the 2016 Kumamoto earthquakes

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Abstract

Two tremendous earthquakes with seismic intensity 7 occurred in Kumamoto, Japan, at April 2016. Besides reinforced concrete and steel buildings, the damage of Japanese conventional wooden houses were severe. After this disaster, the investigation committee established by the Kyushu Branch of Architectural Institute of Japan (AIJ) conducted a complete survey on the Mashiki town in Kumamoto. In this survey, it showed that the damage was smaller as the construction year was newer. As the definition of damage level, the appearance survey method proposed by Okada and Takai was used in this research. The damage level from D6 to D0 indicates collapsed, destroyed, partially destroyed, partially damaged, and non-damaged, respectively. In the 2016 Kumamoto earthquakes, the percentage of damage level from D0 to D6 of wooden houses were 21%, 26%, 12%, 14%, 12%, 12%, 4%, respectively.

However, it was insufficient data to discuss the continuously habitation of damaged wooden houses after the earthquake. Therefore, the follow-up survey two years after the earthquakes in the same area was conducted in April 2018. The relationship between the damage level, the construction year, etc., and the usage situation such as demolition, rebuilding and repairing were clarified. As a result, it was found that 33 % of the total surveyed wooden houses in Mashiki town were demolished and cleared the land, and 16 % were rebuilt. In other words, approximately half of wooden houses were not existing two years after the earthquake. In addition, about 80 % of D3 houses and half of D2 ones were demolished. If the building damage was over D2, it was indicated a tendency to be difficult for continuously use. Furthermore, it was shown tendency that even if the houses were the same damage level and small damage level, the demolition was increased due to many surrounding house's demolitions.

Keywords: The 2016 Kumamoto earthquakes, Follow-up survey, Complete survey, Continuously use, Demolition

1. Introduction

Two tremendous earthquakes with seismic intensity 7 occurred in Kumamoto, Japan, at April 2016. Besides reinforced concrete and steel buildings, damage to Japanese conventional wooden houses were severe. After this disaster, the investigation committee established by the Kyushu Branch of Architectural Institute of Japan (AIJ), conducted a complete survey on the Mashiki town. The survey was conducted about the damage level, construction year, structure type, etc. of all. As a result of the survey, it suggested that the damage was smaller as the construction year was newer [1]. In Japan, there are two major revisions to the Building Standards, in 1981 and 2000, and there is a difference in the requirement of seismic performance for conventional houses.

At the site, two years after the earthquake, many buildings demolished and the one-story houses rebuilt at same place. Therefore, the follow-up survey two years after the earthquake in the same area was conducted in April 2018. The relationship between the damage level, the construction year, etc., and the usage situation such as demolition, rebuilding and repairing were clarified.

2. Outline of the survey

The 14 teams (pairs) of Kyoto University, Oita University, Hiroshima University, and Kyushu University students conducted this survey by for two days from 16th to 17 April 2018. The survey area was around the city hall in Mashiki town, same as in 2016. And the surveyed buildings were determined with 2,652 buildings (valid buildings: 2,350) of regardless of structure and scale, same as on a 2016.

In this survey, a method was used to visually confirm the outside appearance of the target building, and only items that could be judged from the outside appearance were evaluated. Therefore, whether the site was vacant, the building was rebuilt, or if there was an existing building, whether or not it was repaired was investigated.

3. Results of the survey

The situation of the affected building two years after the earthquake was analyzed by comparing with the result of the previous survey.

3.1 Status of buildings two years after the 2016 Kumamoto earthquakes

Fig. 1 shows the situation of all buildings in Mashiki town two years after the earthquake, with the proportion of vacant lots, rebuilding, repairs, and no repairs. The repaired building was counted as one whose roof, exterior wall, or foundation has been repaired. However, those which have been repaired outside the building, such as retaining walls, were excluded. The repairing of outside the building itself will be described in the subsequent section. The 33% of the buildings have been vacant and 16% have been rebuilt. That is indicating that nearly half of the buildings do not exist. Half of the buildings remained, but a comparison of the ratio of repairs and no repairs revealed that the ratio of buildings without repairs was higher.

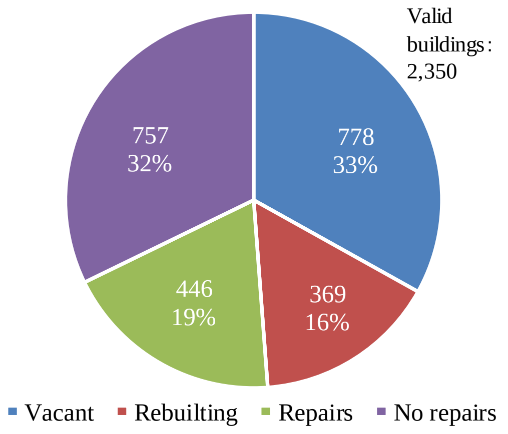


Fig.1 Status of total buildings in Mashiki town two years after the earthquake

Fig. 2 shows the building status of wooden houses by damage level. The values in the figure indicate the number of buildings. When defining the damage level, the appearance survey proposed by Okada and Takai was used in this research [2]. The damage level from D6 to D0 indicate collapsed, destroyed, partially destroyed, partially damaged, and non-damaged, respectively (Table 1). As the damage level increases from D0 to D6, the ratio of demolition of buildings shown as vacant lots and rebuilding tends to increase. In addition, at all damage levels, the proportion of vacant lots was higher than that of rebuilding, indicating that the reconstruction of buildings was not progressing so much. As for the remaining buildings, it was found that about 17% of buildings in the D0 were repaired. In D1, 56% of the remaining buildings were repaired, and in D2, 77% were repaired. It was confirmed that the higher the damage level, the lower the percentage of continuous use without repairs. It was also found that more than 80% of D3 houses classified as partially destroyed and about half of D2 houses classified as partially damaged were demolished after the disaster. Although the relationship with the actual damage certificate is not cleared, regarding continuous use, there is rough judgment criteria between partial destroy and partial damage. If the building damage was over D2, it was indicated a tendency to be a problematic for continually use.

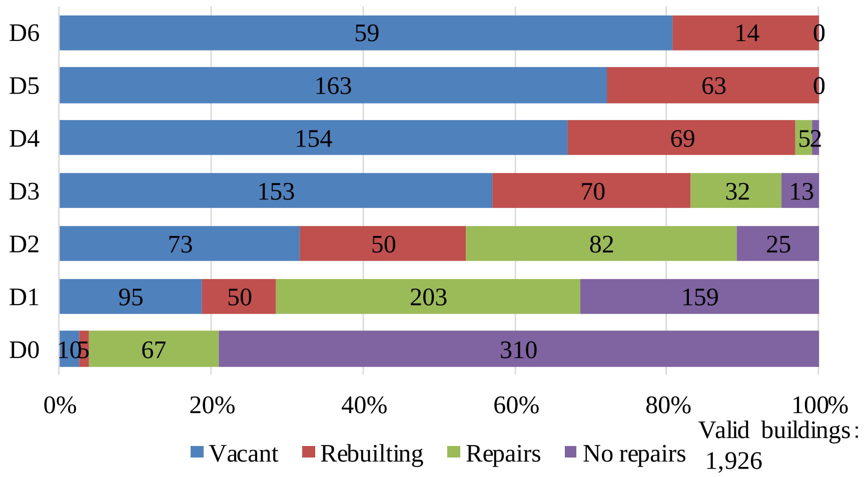
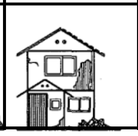
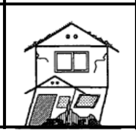
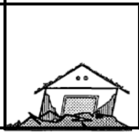


Fig.2 Status of wooden houses by damage level

Table1. Relationship between damage situation and damage level of wooden houses [2]

Damage Level	D0	D1	D2	D3	D4	D5	
							

The target area is divided into 100 m grids, and the relationship between the ratio of buildings with a damage level of D3 or higher in each grid and the demolition (vacant land + rebuilding) ratio in the grid is shown in Fig. 3. About the grid division of the survey area, refer to Reference [3]. The trend of the higher ratio of D3 building in the grid, the higher the demolition building ratio of belonging to that grid was showed. On the other hand, it was found that even if the ratio of D3 buildings was the more less (damage was relatively small), there were areas where the building demolition ratio was high. In buildings D0-D3, in addition to the actual damage level of the building, it was thought that there were decision-making factors to demolish the damaged building. Therefore, the effects of the demolition of surrounding buildings was investigated. Fig. 4 shows the relationship between the demolition ratio of all buildings in each grid and the demolition rate of buildings by damage level belonging to the grid. Many of the data show that the demolition ratio by damage level on the vertical axis is 0% or 100%, it was difficult to understand the trend. Therefore, in Fig. 5, the horizontal axis represents the building demolition ratio of each grid sectioned at every 20%, and the vertical axis represents the average value of the demolition ratio for each damage level in the grid within that range.

It was found that the higher the demolition ratio in the grid, the higher the ratio of demolition of buildings with the same damage level. The same tendency was observed in the case of buildings that were judged to be partially damaged. It is indicating that the demolition status of surrounding buildings has affected the decision to demolish the damaged buildings even in buildings with low damage levels. In other words, it was found that as the damage scale of the earthquake increases, the demolition ratio of low-damage houses might increase.

If the surrounding buildings are not demolished, the demolition ratio of D3 building shows 35% or more, while the D2 building demolition ratio shows relatively close value of the D1 building's one. However, as the demolition ratio of the surrounding area increases, the demolition ratio sharply increases. Therefore, the demolition ratio of the D2 building suggests the possibility of increasing due to the influence of the demolition ratio of the surrounding buildings. This suggests that it is necessary to keep the damage level within D2 in order to aim for continued use after the disaster.

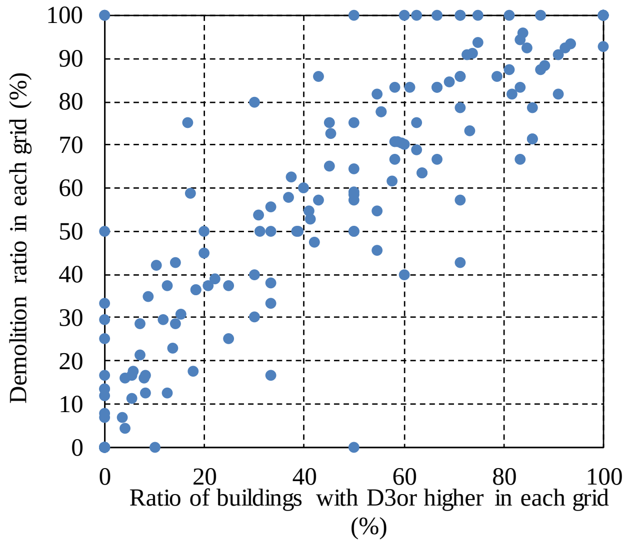


Fig.3 Relationship between the ratio of buildings with a damage level of D3 or higher in each grid and the demolition ratio in the grid

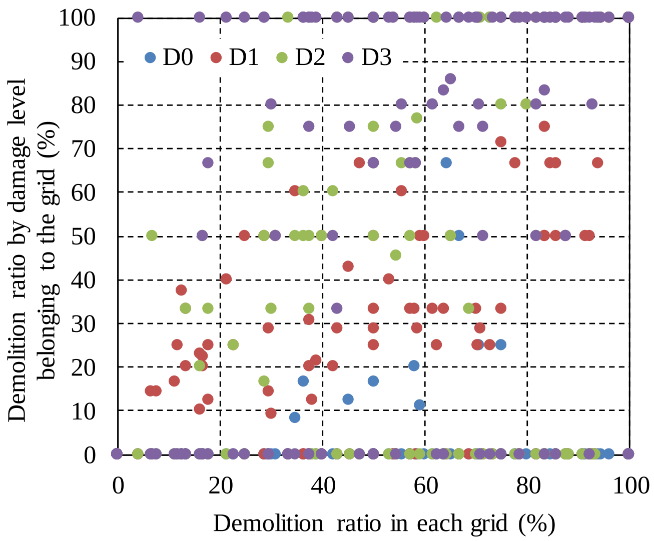


Fig.4 Relationship between the demolition ratio of all buildings in each grid and the demolition ratio of buildings by damage level belonging to the grid

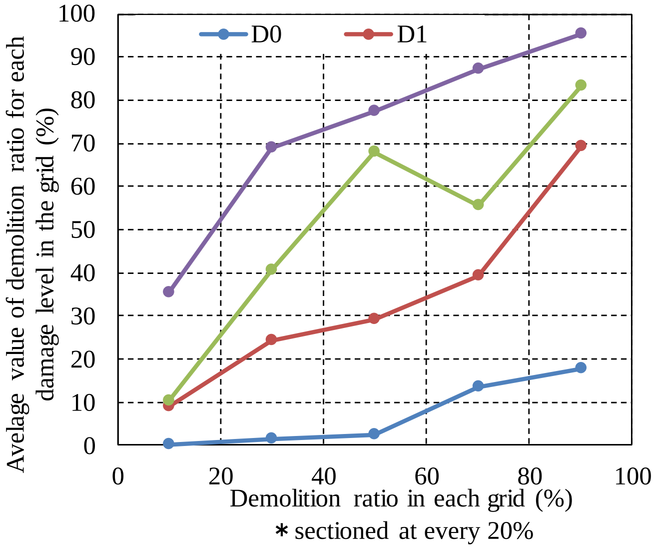


Fig.5 Relationship between the demolition ratio of all buildings in each grid and the demolition ratio of buildings by damage level (sectioned at every 20%)

Fig. 6 shows the status of wooden houses by building age. It was shown that the survival ratio was lager as the construction year was newer. The ratio of repaired buildings constructed before 2000 was higher than that in non-repaired buildings, but the proportion of buildings without repairs was higher in after 2000 buildings. One of reasons is considered that the buildings based on new standards have higher seismic performance, and less damage. However, it was found that 18 % of the buildings built since 2000 have been demolished after the disaster.

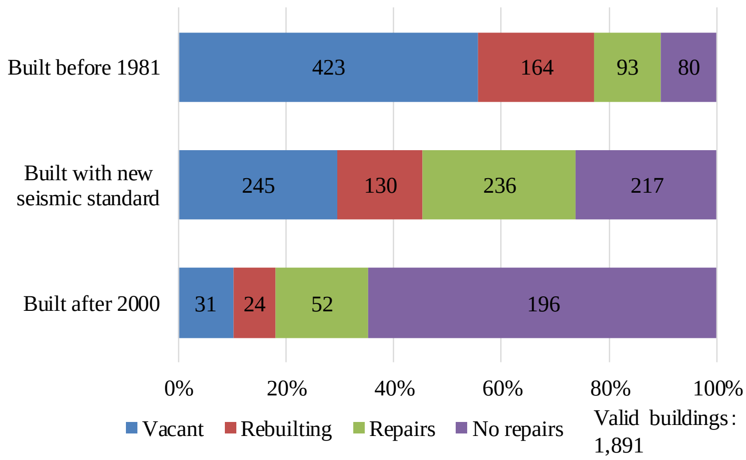


Fig.6 Status of wooden houses by building age

Fig. 7-9 show a comparison building status by building age and damage level. At damage levels less than D0 and more than D4, the ratio of the building's survive did not change, hence the age of the building was not significantly related to the judgment on continued use of the building at the excluding D1-D3. However, in D1, about 40% of the buildings built before 1981 were demolished, while about 25% of buildings built with new seismic standard and buildings built after 2000 were demolished. In D2, about 60% of the buildings built before 1981 were demolished, while about 50% of buildings built with new seismic standard and 40% of buildings built after 2000 were demolished. In D3, about 90% of the buildings built before 1981 and about 80% of the buildings built with new seismic standard were demolished, while about 50% of buildings after 2000 were demolished. The buildings built before 1981 have a higher ratio of demolishing buildings than others, even if the damage level is same. In addition, comparing the building between built after 1981 and built after 2000, buildings built after 2000 show the tendency of higher ratio of continuous use without repair, even the same damage level. However, more than 20% of D1 and 40% of D2, respectively, of the buildings built in the 2000s were demolished.

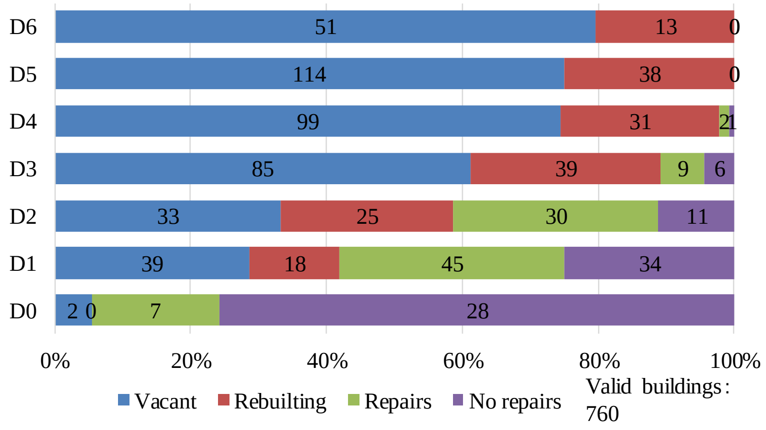


Fig.7 Status of wooden houses built before 1981

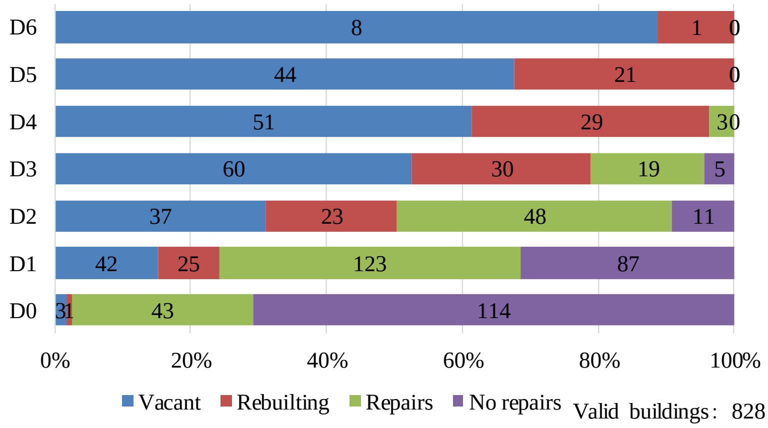


Fig.8 Status of wooden houses built with new seismic standard

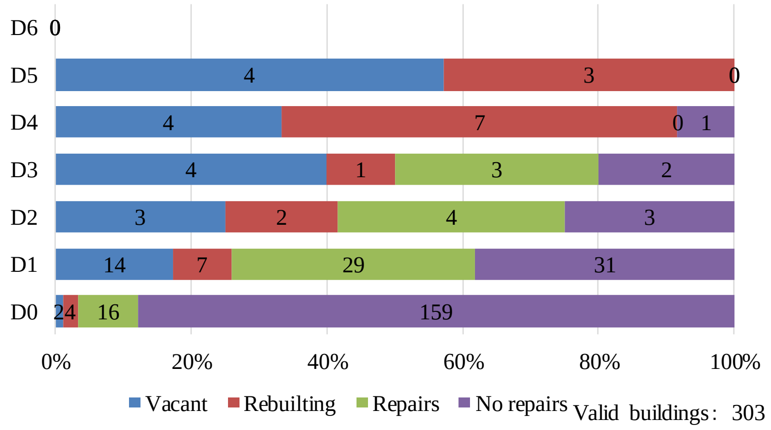


Fig.9 Status of wooden houses built after 2000

3.2 Repair status of existing buildings

Fig. 10 shows the number of repairing content in the repaired building. If there were a building where multiple contents were repaired, the number of contents were simply added as the building. In Fig. 10, whole means the total number of buildings with any repairs, and the each content shows the number of repairing and the ratio to whole's number. The repaired or not of the building was determined by comparing with previous survey photos. Repairs of the roof, the exterior walls and the foundations were judged from the outside appearance. For example, if the exterior wall has been repainted compared to the previous survey photo, it included in "Repair of the exterior wall". In most cases, it was difficult to determine the repair status of the interior, the structural frame, the floor plan from outside appearance. The common repairing parts were the roof changing from roof tiles to slate, changing the exterior walls members, and repairing the foundations tiles and clack. And, there were the case of the condition of the building could not be checked sufficiently due to fences and block walls. Regarding repairs other than for buildings, there were many repairs for block walls and retaining walls, and around the entrance.

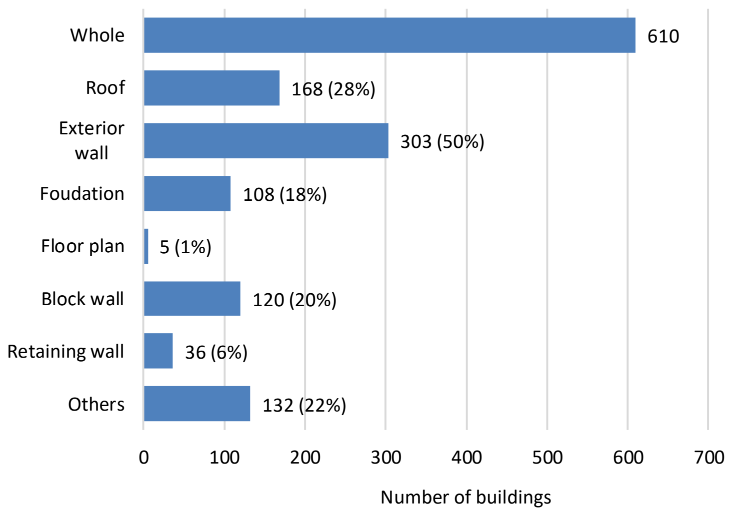


Fig.10 Number of repairing content in the repaired building

Fig. 11 shows the breakdown of repair contents by damage level. This section shows the results of a survey on a building whose roof, exterior wall, or foundation has been repaired. The breakdown of the repaired buildings was about 40% for roofs, 70% for exterior walls, and 24% for foundations. For roof repairs, the ratio of repairs trended to increase as the damage level increased, but for exterior walls, there was no significant difference in the ratio of repairs in the repair building from D0 to D3. Even for buildings classified as D0, some buildings have their roofs and exterior walls repaired. In this survey, even if it is not clear whether the roof or exterior wall has been damaged, it is counted as repairing in the case of any change. Therefore, it might include mere repainting. In addition, the damage of the foundation was not included in the damage level judgment at 2016, therefore an example in repaired the foundation with a D0 building is included.

Fig. 12 shows the breakdown of the repair contents of the repair buildings by construction year. The ratio of repaired roofs was about 40% for buildings built before 1891, but it was shown about 10% for buildings built after 2000. The ratio of repaired roof trended to increase as the damage level increased. As a reason, the damage level of the building was smaller than before 2000. However, the ratio of exterior wall and foundation repairs did not differ significantly by construction year.

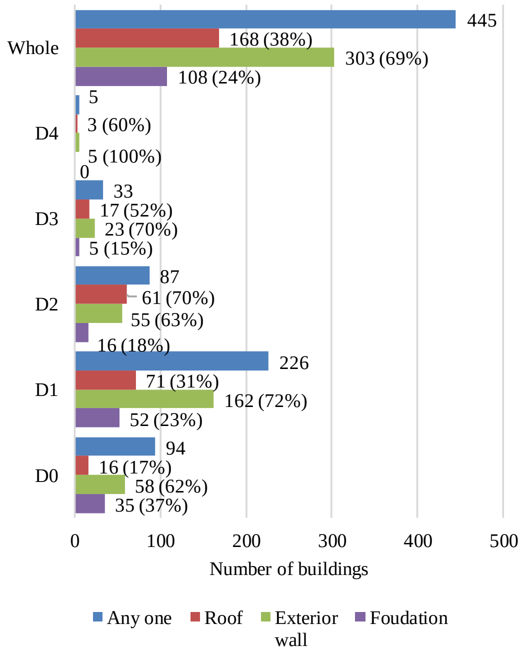


Fig.11 Breakdown of repair contents by damage level

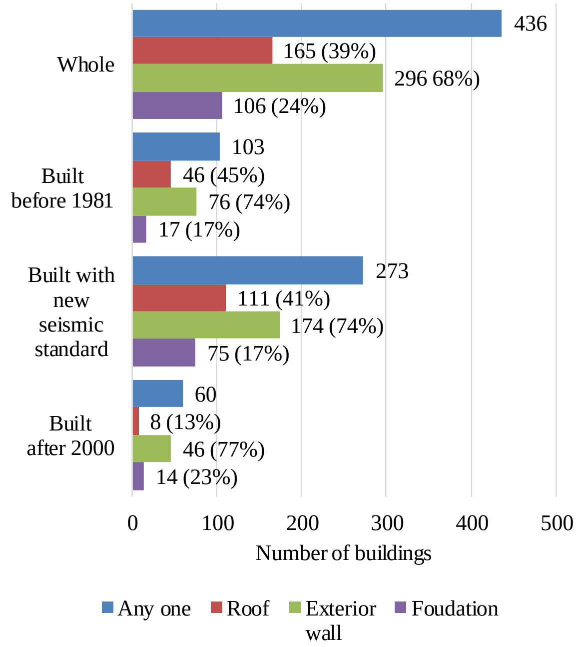


Fig.12 Breakdown of the repair contents of the repair buildings by construction year

4. Conclusion

Many wooden houses were severely damaged in the 2016 Kumamoto earthquake. In Mashiki town, two years after the earthquake, it was found that 33% of the houses were cleared and 16% were rebuilt. Approximately half of houses were not existing two years after the earthquake. It suggested that the ratio of buildings remaining and the ratio of buildings that are continuously used without repair trend to increase as the construction year was newer.

In addition, about 20% of houses built since 2000 have been demolished, and about 45% of D3 buildings have been demolished. Also, about 80% of D3 houses classified as partially destroyed and half of the D2 houses classified as partially damaged were demolished. If the building damage was over D2, it was indicated a tendency to be a problematic for continually use. Furthermore, it was found that even if the houses were the same damage level, demolition increased due to many demolitions surrounding houses. The houses classified by partially damaged were the same tendency.

The results of this survey suggest that it is necessary to keep the damage level within D2 in order to aim for continued use after the disaster.

5. References

[1] AIJ (Architectural Institute of Japan). (2018): 2016 Kumamoto Earthquake disaster survey report, 29-53

[2] Okada S, Takai N (1999): CLASSIFICATIONS OF STRUCTURAL TYPES AND DAMAGE PATTERNS BUILDINGS FOR EARTHQUAKE FIELD INVESTIGATION, *J. Struct. Constr. Eng., AIJ*, No.524, 65-72

[3] Sumida K, et al. (2019): Survey of Construction Situation in Mashiki Town Two Years After the 2016 Kumamoto Earthquakes, *Journal of JAEE (Japan Association for Earthquake Engineering)*, Vol.19, No.1, 1_21-1_33

