Current State of Retrofitting Buildings by Seismic Isolation in Japan

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SUMMARY:
We investigated the retrofitting buildings by the seismic isolation on the basis of documentations and questionnaire surveys in Japan. From the surveys by 2011, we collected the data on construction sites, building usage, locations of isolators, building size, and the ratio of in-use buildings during retrofitting work. We obtained the following results; 1) the construction sites are concentrated in the Pacific Ocean side, 2) the highest rate of the building usage is the government office building, 3) about two thirds of buildings installed the isolation devices between existing floors, 4) the sizes of buildings have been becoming larger, and 5) 70% of retrofitting works were carried out in in-use buildings.

Keywords: Seismic isolation retrofit, Research survey, domestic cases

1. INTRODUCTION

The seismic isolation retrofit is the one of the most effective methods for seismically upgrading buildings, because it drastically reduces the acceleration response during earthquake. Since Japan has been under extremely high seismic hazard, the technologies of the seismic isolation retrofit has been developed and applied to a lot of buildings, especially since the Great Hanshin-Awaji Earthquake of 1995. According to Kani (2009), seismic isolation retrofit building accounts for 4% among about eighty seismic isolation buildings up to 2007. Nonetheless, there are few studies for investigating the current state of the seismic isolation retrofitting in Japan. In this study, we investigate seismic isolation retrofitting buildings by documentations and questionnaire surveys by 2011, and summarize the results in terms of construction sites, building usage, locations of isolators, building size, and the ratio of in-use buildings during retrofitting work.

2. RESEARCH SURVEY AND RESULTS

We have investigated more than one-hundred cases on the basis of documentations and questionnaire surveys, and collected the data of ninety buildings in the eighty-nine sites, where the seismic isolation retrofitting works were completed by 2011. We did not include three collapsed buildings during earthquakes, because they were newly constructed by the base isolations.

From the result of research, an implementation area, a building use, a position of seismic isolation layer, a transition of the building scale, an usability of building during retrofitting are shown below.

2.1. Construction Sites

Figure 2.1.1. shows the locations of the seismic isolation retrofitting buildings in the unit of prefecture. The seismic isolation retrofitting sites are concentrated in the area of the Pacific side such as Kanto, Tokai and Kinki regions, where earthquake hazard is high. The ratio in those regions occupies about

90% of the total number. Especially, forty-two cases, which are equivalent to about the half of the total number, are concentrated in Tokyo. Next to Tokyo there are seven cases in Aichi, six in Shizuoka, and five in Osaka.

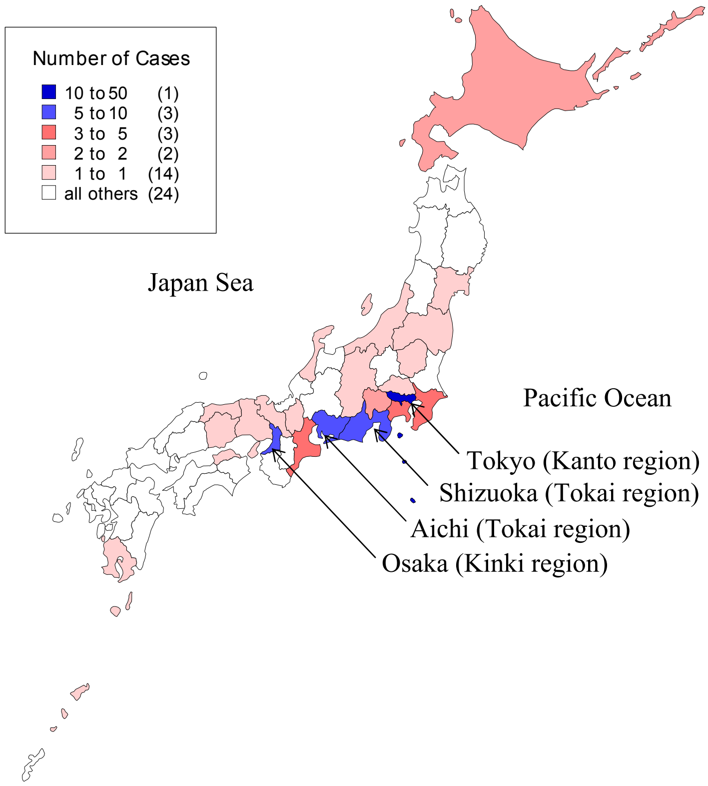

Figure 2.1.1. Implementations of seismic isolation retrofit building in each prefecture

2.2. Building Usage

Figure 2.2.1. shows the ratio of the building usages among seismic isolation retrofit buildings. The largest ratio of usage is the government office building, which accounts for more than one-third of the total numbers. The first prefectural office building, which was retrofitted by the seismic base isolation, was the case of Yamanashi prefecture (Masuzawa and Hisada, 2004). The second largest ratio of the usage is the private office building and it accounts for 18%. In addition, there are many applications to school buildings and temples including historical heritages. Recently, seismic isolation retrofitting has been applied to hospitals, but only two cases so far. For the first example for the hospital, see details in Masuzawa and Hisada (2009).

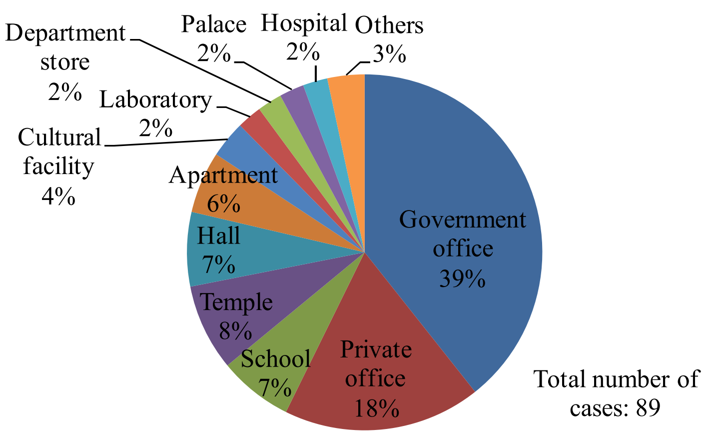

Figure 2.2.1. Ratio of the building usages among seismic isolation retrofit buildings

2.3. Locations of Seismic Isolation Layer

As in Figure 2.3.1, the location of the seismic isolation layer is classified into two cases: one under the foundation, and the other between existing floors. Figure 2.3.2. shows the percentage of the locations of the isolations. When a building uses both cases, we choose the case where the area of the layer is larger. According to NEDO (2007), the cases under the foundation are about 90% of the whole seismic isolation buildings. In this study, the cases between existing floors are 57%, and about half of those buildings are installed devices in the lowest layer. Figure 2.3.3. shows the ratio on the floors locating the seismic isolation layer among the cases between existing floors. The largest ratios are the cases of the first basement level or the first floor.

Figure 2.3.4. shows the distribution of the periods for the seismic isolation retrofitting work. The most of the work periods for installing devices between existing floors are less than twelve months. Those terms are considerably shorter than those for the cases of installation under the foundation. This is the reason why most seismic isolation layer are installed between existing floors.

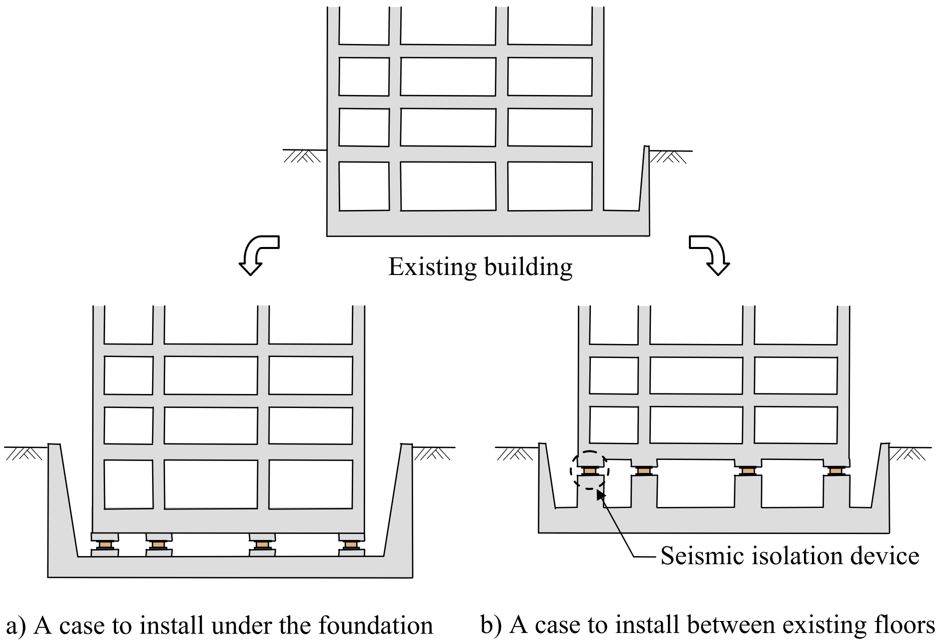

Figure 2.3.1. Location of seismic isolation layer

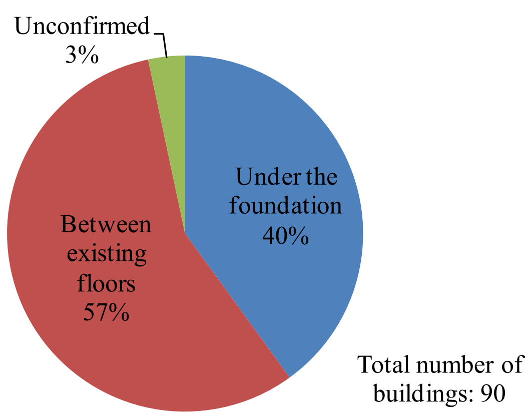

Figure 2.3.2. Ratio of the location of seismic isolation layer

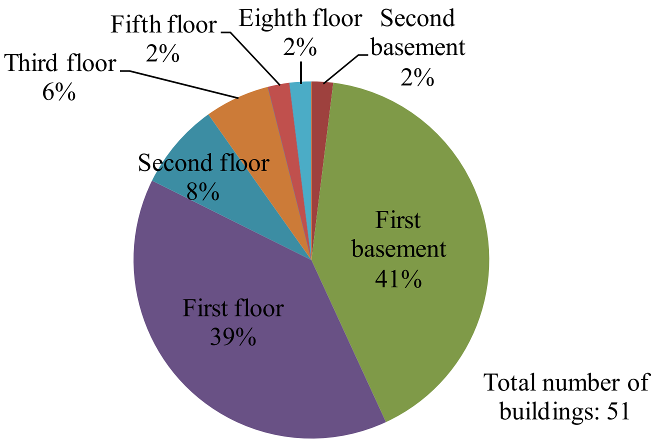

Figure 2.3.3. Ratio of floors of seismic isolation layer in the cases to install between existing floors

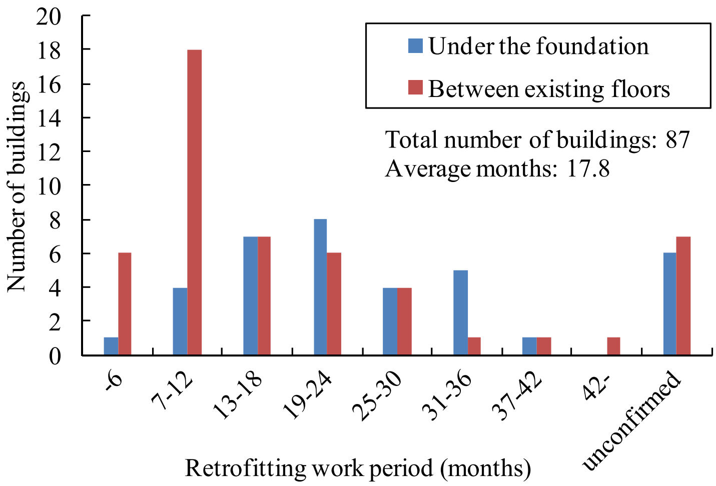

Figure 2.3.4. Distribution of the periods for the seismic isolation retrofitting work

2.4. Building Size

Figure 2.4.1. shows the relationship between the completion years of seismic isolation retrofitting works and the total floor area of the buildings. Figure 2.4.2. shows the relationship between the completion year and the number of aboveground floors. The sizes of the buildings where the seismic isolation retrofitting were applied to, have been becoming gradually larger. Figure 2.4.3. shows the relationship between the completion year and the maximum axial force of seismic isolation devices at long-term loading among sixty-four buildings. The distribution of the maximum axial pressure of rubber bearing at the long-term loading was 9-13MPa. Therefore, when the diameter of rubber bearing could be identified, we estimate the maximum axial force using the mean value of 11MPa. The maximum axial forces have been also increasing gradually, and those trends agree with those of a total floor area and the number of floors.

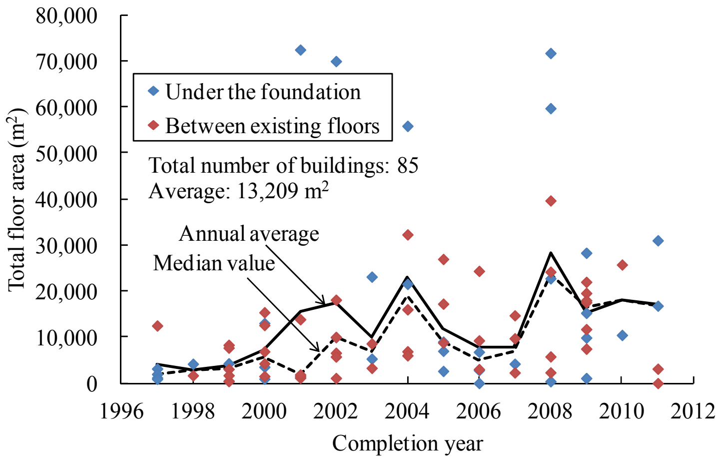

Figure 2.4.1. Relationship between completion year and total floor area

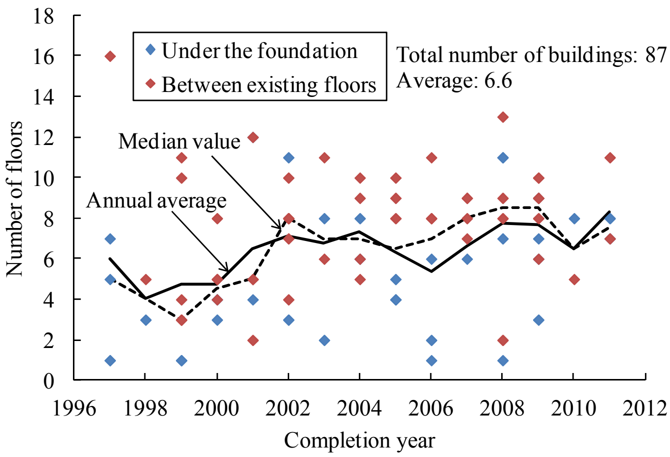

Figure 2.4.2. Relationship between completion year and number of aboveground floors

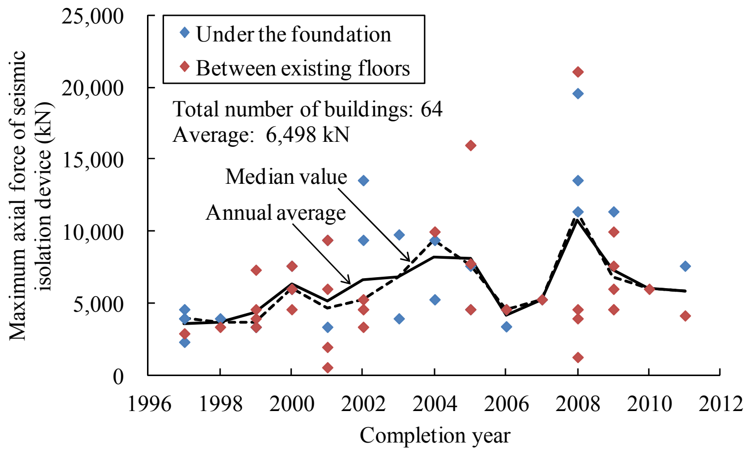

Figure 2.4.3. Relationship between completion year and maximum axial force of seismic isolation devices

2.5. Usability of Building during Retrofitting Construction

Figure 2.5.1. shows the ratio of the retrofitting work with buildings usage. This indicates that 70% of the total constructions were carried out under the in-use buildings. Table 2.5.1 shows the ratio of the retrofitting work building usage for each building use. The ratio in a Government office, a private office, a school, a Laboratory, a department store and a hospital exceed 80%.

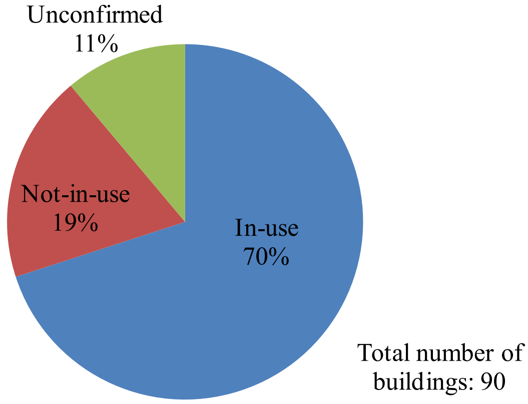

Figure 2.5.1. Ratio of the retrofitting work with buildings usage

Table 2.5.1. Ratio of the retrofitting work with buildings usage for each building use

Building use	Government office	Private office	School	Temple
In-use (%)	89	81	83	14
Building use	Hall	Apartment	Cultural facility	Laboratory
In-use (%)	17	60	0	100
Building use	Department store	Palace	Hospital	Others
In-use (%)	100	0	100	67

3. CONCLUSIONS

We obtained the following conclusions from the documentation and questionnaire surveys on the seismic isolation retrofit buildings.

1) The construction sites are concentrated in the Pacific Ocean side, where earthquake hazard is higher than other areas. Particularly, Tokyo counts about half of the total numbers.
2) The highest rate of building usage is the government office building, then private office buildings, school buildings and temples follows.
3) About two thirds of buildings installed the isolation devices between existing floors, which are much larger than the ratio of the devices installed under the foundation.
4) The sizes of buildings have been becoming larger, which estimated from the number of floors, the total floor area of buildings and maximum axial force of seismic isolation devices.
5) 70% of retrofitting works were carried out in in-use buildings.

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