Seismic Isolated Structures Applied to from Detached Houses to High-rise Apartments in Japan

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Abstract: Japan was a country of the wooden architecture. Superior earthquake engineering such as Five Story Pagoda was possessed. In European countries where the earthquake is few, their technology is starting from stone structures, and it is basic to make structures of architectures strong, stiff and tight. On the contrary, it can be said that the wooden structures of Japan was a technology that allows deformation and enables the energy absorption. Japan opened the country to the world in 1867, and new architectural technologies were introduced from Europe and America. A lot of buildings were constructed by using new technology, new materials of steel and concrete. These many buildings were damaged and collapsed by earthquakes in these 140 years. It was clear that the earthquake engineering had advanced greatly in the 20th century. Although, there is a limit in the earthquake performance of conventional method, that fix the building to the foundation. It entered 1980’s that the seismic isolated structures were put to practical use, and it has been arriving now. The current state of the seismic isolated structures of Japan is discussed here, and three examples of the seismic isolated structures to the housing are introduced.

1. INTRODUCTION

The next three stages are in the performance levels of defence of building structures to big earthquakes:
1) Function maintenance: Function of building and activity of every day can be maintained after the earthquake.
2) Property value: It is possible to use it again if it suffered big earthquake. After some repair of the building, the property value of building can be kept.
3) Life safety: It must defend people's safeties though building may become a demolition after the earthquake.

The performance is different though the seismic structures can be greatly classified into the following four:
1) Strength oriented structures: The structure is constructed enough and strongly, and a large plastic deformation is not caused due to the big earthquake. Because the acceleration in the building grows very high, the function maintenance is difficult though the property value and the life safety can be maintained.
2) Ductility oriented structures: The structure is made not too strongly, and a large plastic deformation is allowed during big earthquakes. After the earthquake, the building might be demolished though only the life safety is performed.
3) Passive controlled structures: Earthquake energy is absorbed by the various dampers installed into the building. Because the acceleration in the building is not small, the maintenance of the function partially becomes difficult. In some case after the earthquake, it is necessary to repair.
4) Seismic isolated structures: The building is isolated from the foundation, and the earthquake energy could not enter to the building. It has the highest earthquake resistance to be able to defend three items such as function, property and life. Thus, it is an earthquake engineering to be able to trust the seismic isolated structure under the present situation.

2. FEATURES OF SEISMIC ISOLATED STRUCTURES

The acceleration in the seismic isolated building becomes 10% of the fix based conventional buildings, and becomes 100cm/sec2 to 200cm/sec2. The story drift angles would be 1/1000 to 1/200 in the seismic isolated buildings though a usual building generated exceeding 1/100 to 1/50. Base shear coefficient becomes about 0.1 to 0.13 in the seismic isolated structure, and it makes easy to design columns and beams though the base shear coefficient becomes 0.25 to 0.55 in a usual building. It can be said that the seismic isolated structure becomes cheap from the fixed base building when the number of stories exceeds 8 or 10.
The seismic design regulation of Japan demands only life safety; neither the function maintenance nor the property value are demanded. Because it costs enormous for the individual to buy the house, the second cannot be bought. It is necessary to maintain the function maintenance and the property value. It is a reason why this presses the spread of seismic isolated houses. Still, it is an amount of about 1% of buildings constructed in a year. We want to extend this up to 10%.

3. STATISTIC DATA OF SEISMIC ISOLATED HOUSES IN JAPAN

The number of seismic isolated buildings has been increasing, since the 1995 Hyogo-ken Nanbu Earthquake. The number of detached houses with seismic isolation has been increasing also. This progress is according to the frequent occurrences of big earthquakes in Japan. Figure 1 shows construction of buildings with seismic isolation (SI) except detached houses. The first seismic isolated building was built in 1983. Half of them are condominiums shown in Figure 2. Figure 3 shows the number of detached houses with SI of which capture ratio is 60%. Very recently high-rise buildings with SI have been built as offices or condominiums shown in Figure 4, mostly they are condominiums.

Figure 1 Number of SI Buildings by year in Japan (Not including detached houses)

Figure 2 Number of SI Condominiums by year in Japan

Figure 3 Number of SI Detached Houses by year in Japan

Figure 4 Number of SI High-rise Buildings by year
4. DETACHED WOODEN HOUSES ON SEISMIC ISOLATE SYSTEM

More than 2200 seismic isolated wooden houses were designed and constructed by One Company, Ichijo Housing Co. Ltd. in Japan. Many photographs and figures of a typical example of them in Toyota City are introduced here. The areas of ground floor and second floor are 108m², 63m² in respectively. The structure supported by 21 small sliding devises, which friction coefficient is about 4%. The 4 elastic rubbers stabilize the structure in horizontal large movement.
Concrete Foundation

Steel Frame Basement on isolating devices
5. CONDOMINIUM OF CHUORINKAN CONSIDERING ENVIRONMENT

Architects: Hiroyuki Usami, Kazunori Shirabe, Nikken Housing System Ltd.
Structural Engineers: Hirofumi Kamikouchi, Yuji Yokoyama, Nikken Housing System Ltd.
Contractor: Tokyu Construction Co. Ltd.

This project has 7 apartment buildings. Environmental aspects and seismic safety are most important issues in the design process of the project. Then, the height and the shape of each building were designed to be different and these complex configurations are very comfortable for the residents. Sun shine effects and wind flow effects are very nice for them. For the earthquake issue, the seismic isolation system is applied to each building. The natural rubber bearings, the lead dampers and the steel dampers are installed as seismic isolation devices. The tallest of them is 17-story building. The weight of this super structure is 10,200 tons. While we are taking into account only the flexibility of rubbers and we assume that the super structure is perfectly rigid, the first natural period of the building is 4.8 sec. The sum of yield force of the dampers is 215 tons, and then yield shear force coefficient of dampers is 2.1%.
Global Plan

Expansion around buildings

Comfortable Courtyard

Natural Rubber Bearing
6. THREE RESIDENTIAL TOWERS ON THE YOKOHAMA BAY

Three high-rise apartments of reinforced concrete structure and seismic isolation system were constructed on the Yokohama Bay Area. Architects and structural engineers are the excellent members of the Mitsubishi Jisho Sekkei Inc. in Tokyo. The sizes of a typical building are 33.3m x 32.6m and the height is 99.8m, and the total weight of this building is a 61,339 tons. The lead dampers and the steel dampers are installed, sum of yield forces is 1,152 tons and it is 1.87% of the weight of super structure. An equivalent period when rubber bearing deformed 100% shear is 5.42sec. The core wall and the perimeter framework combine up this structure. This structural system raises flexibility of design of habitation area. Concrete was formed into the pre-cast and rational construction was performed.

REFERENCE
