

A New Base-Isolation System using Gage-Pendulum Principle for Light Timber Structures for the Safety of Their Structural and Non-Structural Components

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ABSTRACT: This paper reports the results of damage survey to some public halls in Nagaoka city, the closest urban area to the epicenters of Niigata-Chuetsu earthquake. Because of the distance from the epicenter less structural damage to them was found. However the damage that these facilities were suffered, damage to suspended facilities especially to suspended ceilings, was so serious that they could not continue their functions after the earthquake.

Key Words: Base-Isolation, Timber Structures, Non-Structural Components, Ceilings

1. INTRODUCTION

Earthquake is the critical problem for every structure constructed in seismic regions (figs.1 and 2). In order to avoid fatal collapses of the structure against the heavy inertia force under the excitation of ground motion during earthquakes structures in seismic regions are usually constructed with stronger skeleton and old existent structures are reinforced to be “earthquake resistant”. However since



(a) A historical timber temple



(b) An old church

Figure 1: Historical structures collapsed by Kobe Earthquake in January, 1995

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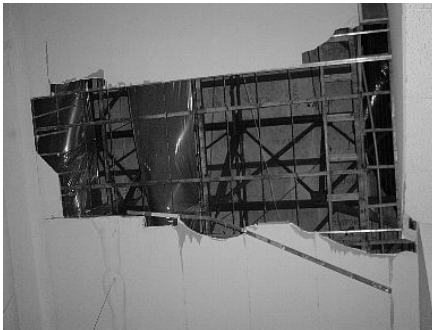


(a) A Wooden house 1



(b) A Wooden house 2

Figure 2: Wooden houses collapsed by Chuetsu-Oki Earthquake in July, 2007



(a) Collapse of ceilings 1

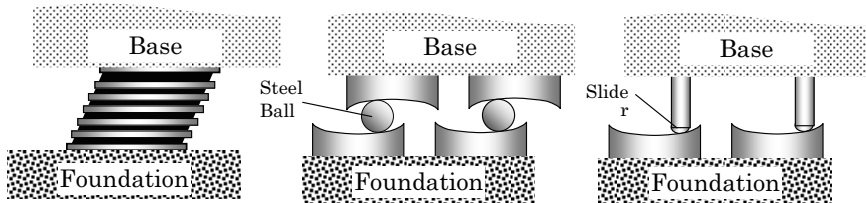


(b) Collapse of ceilings 2

Figure 3: Non-structural components damaged by earthquakes

the purpose of the “earthquake resistant structure” is “not to collapse” it never relieves the seismic load. Therefore “non-earthquake resistant” parts, especially “non-structural components”, are exposed to the seismic load and deformation that is induced during earthquake (fig.3). Damage to non-structural components are sometimes very dangerous to the people using the structures and when the structures are of the historical importance it may cause serious damage to the historical heritages preserved in and around the structures. In 1997 the famous wall paintings in the church in Assisi were damaged by an earthquake although the church itself survived.

Base-isolation systems are the structural systems that isolate the super structures, using special bearing devices (fig.4), from the ground motion during earthquakes. Base-isolation systems make it possible to drastically reduce the seismic loads and deformations induced to both the structural components and non-structural components. In this paper a new base-isolation system for timber structures is proposed and the results of its real scale shaking table tests are reported.



(a) Rubber Bearing

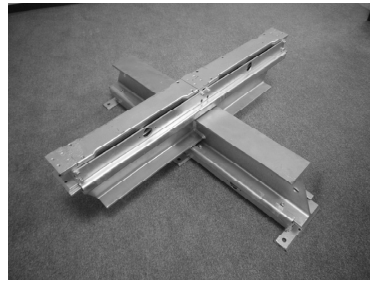
(b) Friction Pendulum 1

(c) Friction Pendulum 2

Figure 4: Typical Base-isolation devices with recovering mechanisms



(a) Gage pendulum



(b) VP-isolator

Figure 5: The new base isolation device

2. A NEW BASE ISOLATION SYSTEM

The base-isolation system proposed is based on the new concept of pendulum, the gage pendulum (fig.5(a)), of which recovering force generated by the gravity force and the shape of the gap between a pair of curved lines. This system does not require any slope for the ball to roll to produce the pendulum movement. Using this concept the final configuration of the base-isolation device became cross rail style as shown in fig.5 (b) and was named “VP-isolator”.

3. FULL SCALE SHAKING TABLE TEST

In order to check the performance of this base-isolation system a series of full scale shaking table test using real wooden house was carried out. The size of the base of the house was 6.37(m) x 7.28(m) = 46.37 (m²) and the height of the house was 7.4m. Total weight of the house was 240kN. Six VP-isolators and four hydraulic dumpers are installed and connected between the base and the foundation of the house. After the tests of base-isolated house the same house was directly connected to the foundation without base-isolation system and another series of shaking table tests were carried out to investigate the behavior of “earthquake resistant” house.

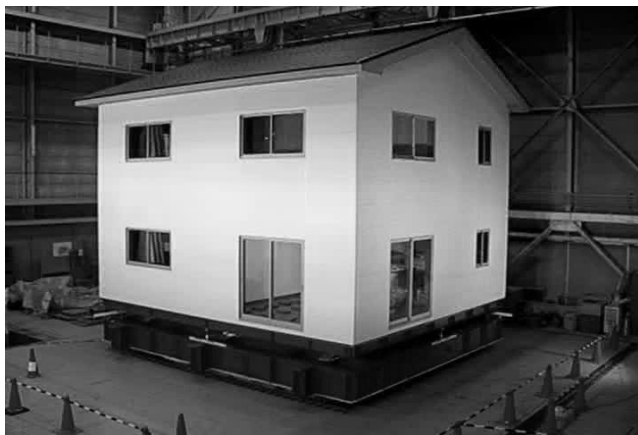


Figure 6: General view of the full scale shaking table test.

Several real earthquake ground motions recorded, Kobe 1995 (max. 818gal), Hachinohe 1968 (max. 233gal) and Ojiya 2004 80%(max. 1046gal), were reproduced by the shaking table. Some results of the tests are shown in figs.7 and 8. In the figs. the crosses show the results of base-isolated house and the circles show the results of the earthquake resistant house. With base-isolation system acceleration level was reduced to about one-fifth of that of earthquake

resistant house. Contrarily, relative displacement between the base and the foundation became much larger. This large displacement absorbed the large

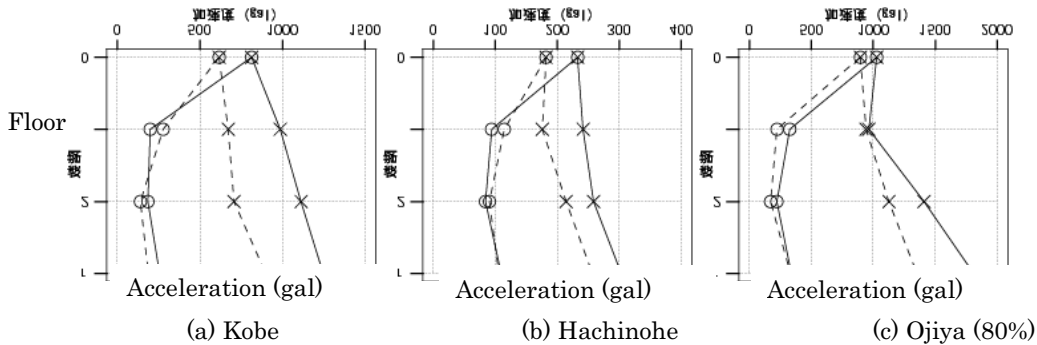


Figure 7: Response acceleration

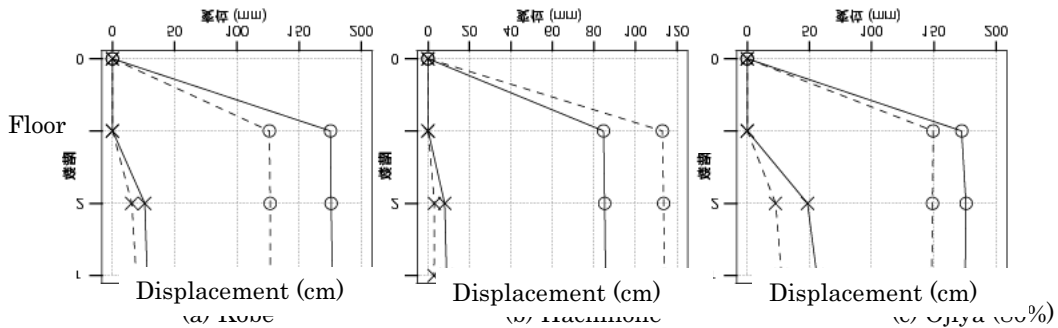


Figure 8: Response relative displacement

ground motions. For the base-isolated house structural components and non-structural components remained perfectly safe while in the earthquake resistant house structural components, especially timber braces, and non-structural components, such as wall panels and furniture were heavily damaged.

4. CONCLUSIONS

A new base-isolation system based on the new concept of gage pendulum was proposed and developed. Through the full-scale shaking table test the high performance of the system was proved. Both structural and non-structural components were perfectly guarded by the base-isolation system.

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