# Benefits of Seismically Isolated Buildings

In the final installment of our series introducing the varied activities of Japan's Building Research Institute (BRI), **Iiba Masanori** of the BRI's Department of Structural Engineering discusses the safety during and after earthquakes of buildings with a seismically isolated structure.

Since the 1995 Hanshin-Awaji Earthquake disaster, different regions throughout Japan have experienced comparatively large earthquakes, witnessing damage to buildings and structures. The 2011 Off the Pacific Coast of Tohoku Earthquake also caused extensive damage, reaffirming the need to ensure earthquake resistance to mitigate damage. In this earthquake, buildings with a seismically isolated structure ("seismically isolated buildings") were also subjected to strong earthquake motions, but the maximum acceleration response above the seismically isolated layer (layer with isolation devices) of the buildings was less than the maximum ground-acceleration, and there was little evidence of damage from the overturning and scattering of furniture and fixtures, confirming the seismic isolation effect. In recent years, in addition to the prevention of structural damage to buildings, safety inside buildings has also increasingly drawn attention. This report focuses on seismically isolated buildings, which are expected to have a response control effect under earthquakes. It demonstrates the features of seismically isolated structures.

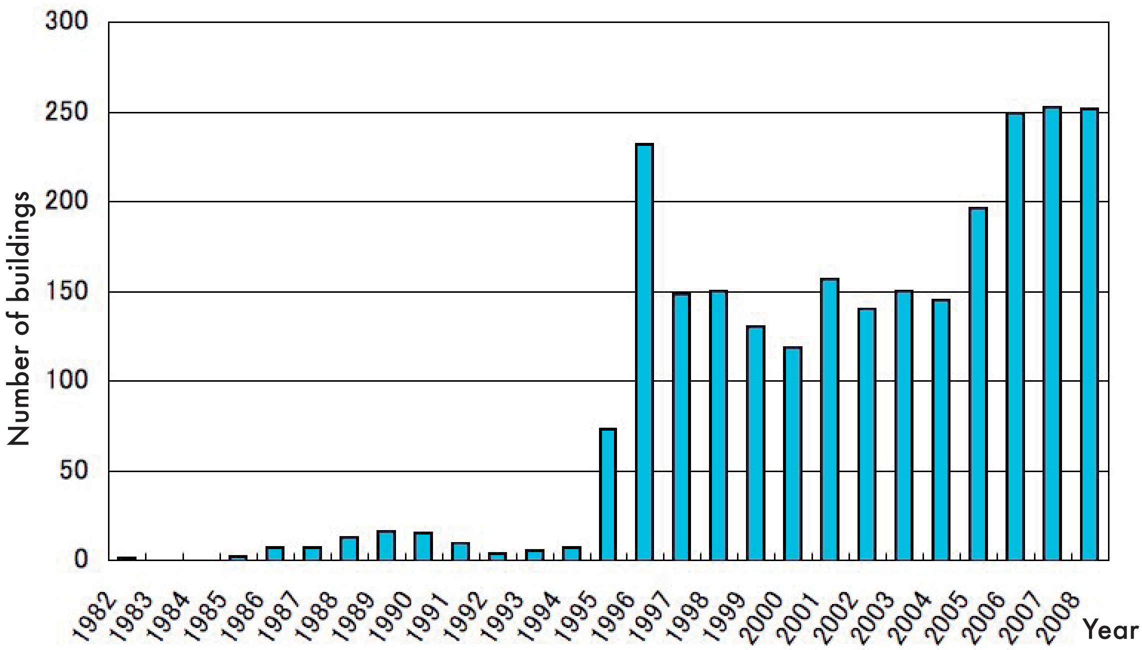
### Construction of Seismically Isolated Buildings

**Figure 1** shows trends in the number of planned seismically isolated buildings (excludes one and two storey detached houses) in Japan. The number of seismically isolated buildings stood at around 2,500 in December 2008. In addition, there were also around 3,300 detached houses with a seismically isolated structure. After the 1995 South Hyogo Prefecture Earthquake, the number of seismically isolated buildings being constructed increased sharply, reflecting more positive attitudes towards the use of seismically isolated structures. In 1996, condominiums with a seismically isolated structure became more common, and, since 1997, around 120–250 seismically isolated buildings have been planned each year. It has also become increasingly common for buildings such as government facilities and hospitals to serve as disaster shelters.

### Swaying of Seismically Isolated Buildings and Conditions Inside Seismically Isolated Buildings under Earthquakes

Since the 1995 South Hyogo Prefecture Earthquake, scientists have obtained a large number of seismic acceleration records showing the state of swaying

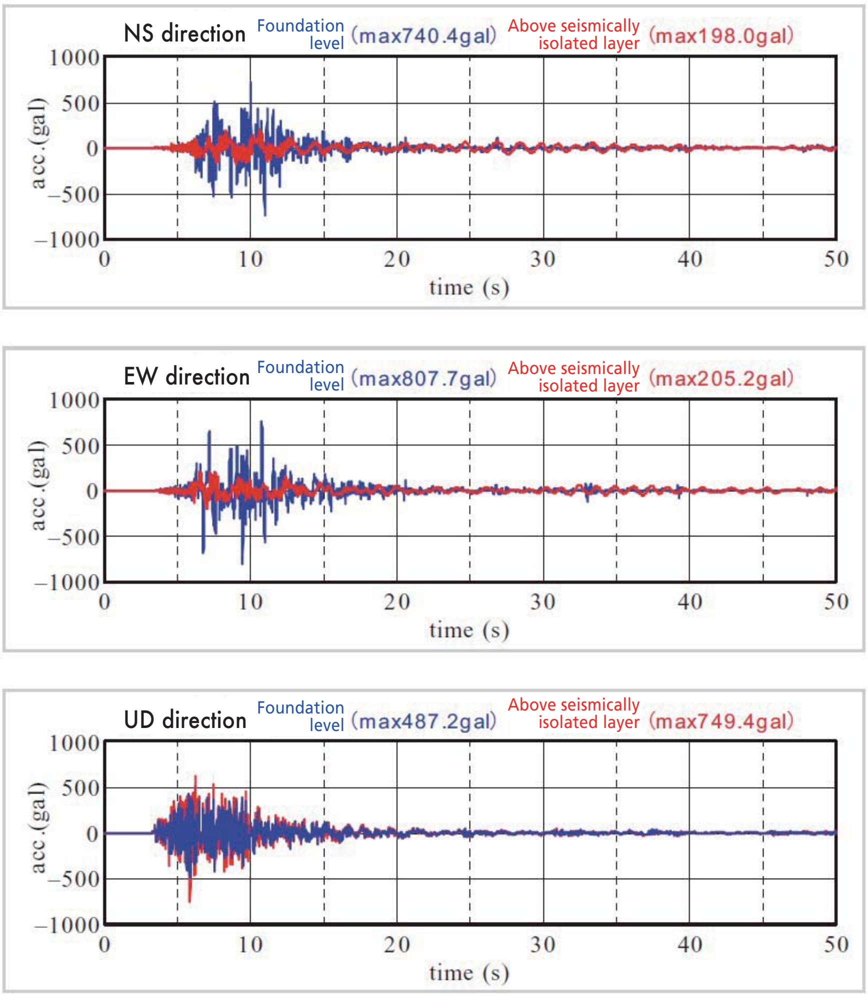
**Figure 1: Trends in planned number of seismically isolated buildings by year from 1982 to 2008**




*Source*: Japan Society of Seismic Isolation of seismically isolated buildings. To give an example, **Figure 2** shows the measurement results of a seismically isolated building in Ojiya at the time of the 2004 Mid Niigata Prefecture Earthquake. In this building, the seismically isolated layer is located between the foundation and the first floor, and the figure shows the acceleration waveforms and maximum acceleration values at two levels. The ratio of maximum horizontal acceleration at first floor level to that at foundation level is 0.27 in a north south (NS) direction and 0.25 in an east west (EW) direction, indicating that maximum acceleration is reduced to almost ¼. On the other hand, in a vertical (UD) direction, with no seismically isolated structure, the ratio of maximum acceleration at first floor level to that at foundation level is 1.54, confirming that acceleration is amplified.

**Photograph 1** shows the scene inside a room after an earthquake in the aforementioned building and a non-seismically isolated building. Whereas, in the seismically isolated building, the tableware on the shelves was in perfect order, in the non-seismically isolated building, everything including the shelves, papers and kitchen equipment was scattered. An interview with the caretaker of this facility, which is a health center for the elderly, confirmed that the facility maintained its functions, including caring for long-stay patients, after the earthquake. **Figure 3** shows the results of a survey in which staff were asked how frightened they felt during an earthquake. Whereas most of the staff surveyed in the non-seismically isolated building replied that they were "very frightened," in the seismically isolated building, equal numbers of people replied that they were "very frightened" and "a little frightened." The seismic isolation system does not stop the building from shaking completely but it prevents objects from being scattered inside the building and reduces the sense of fear during the earthquake.

**Figure 2: Acceleration waveforms at foundation level and first floor level**




***Source***: Tamari Masatoshi, Mitsubishi Jisho Sekkei Inc.

**Photograph 1: Comparison of conditions inside building after earthquake**

(a) Seismically isolated building

(b) Non-seismically isolated building

***Source***: Tamari Masatoshi, Mitsubishi Jisho Sekkei Inc.

## Features of Seismically Isolated Buildings

*(1) Structure of seismically isolated buildings and isolation devices*

**Figure 4** shows the structure and features of a seismically isolated building. As shown in **Figure 5**, the seismically isolated layer is usually located between the first floor and the substructure (foundation) of the building. Isolation devices are categorized into isolators, dampers and restoring devices. Isolators support the vertical load of the superstructure in the long term, and also produce a large horizontal deformation under an earthquake. Usually isolators are made of laminated rubber bearings. Laminated rubber bearings consist of horizontal layers of thin rubber and steel plates, and have large horizontal deformation capacity, as shown in **Photograph 2**. Dampers are installed to reduce horizontal response during earthquakes. The dampers absorb a large proportion of the earthquake input energy to the building, mitigating the energy transmitted to the superstructure and controlling the response during an earthquake.

*(2) Features of earthquake response of seismically isolated buildings*

Since laminated rubber bearings have a very low horizontal spring constant, no more than around 1/1000 of their vertical spring constant, they can elongate the natural period of a building, reducing its acceleration response.

**Figure 6** shows an acceleration response spectrum with damping ratio of the building (earthquake ground motion used for analyses is 1940 El Centro NS, maximum acceleration value is 341cm/s$^2$). The horizontal axis of the acceleration response spectrum indicates the natural period of the building, the vertical axis indicates maximum acceleration response. In the case of a non-seismically isolated building with a natural period of around 0.5 seconds (equals building with 5–10 storeys), the acceleration response is larger. On the other hand, in the case of a high-rise building with a long natural period (2–4 seconds), the acceleration response is smaller. Seismically isolated structures have these earthquake response features and elongate the period of buildings through the installation of isolation devices. The building with a longer period, that is, both high-rise buildings and seismically isolated buildings, has a larger earthquake displacement response. Whereas, in the case of high-rise buildings, the deformations of each

**Figure 3: Results of survey on sense of fear during earthquake**

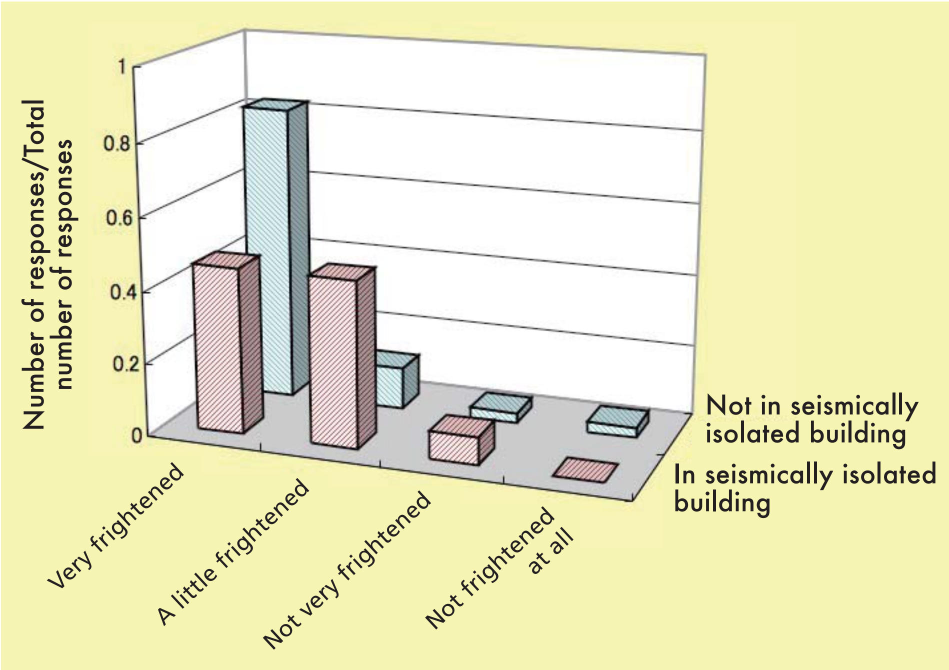
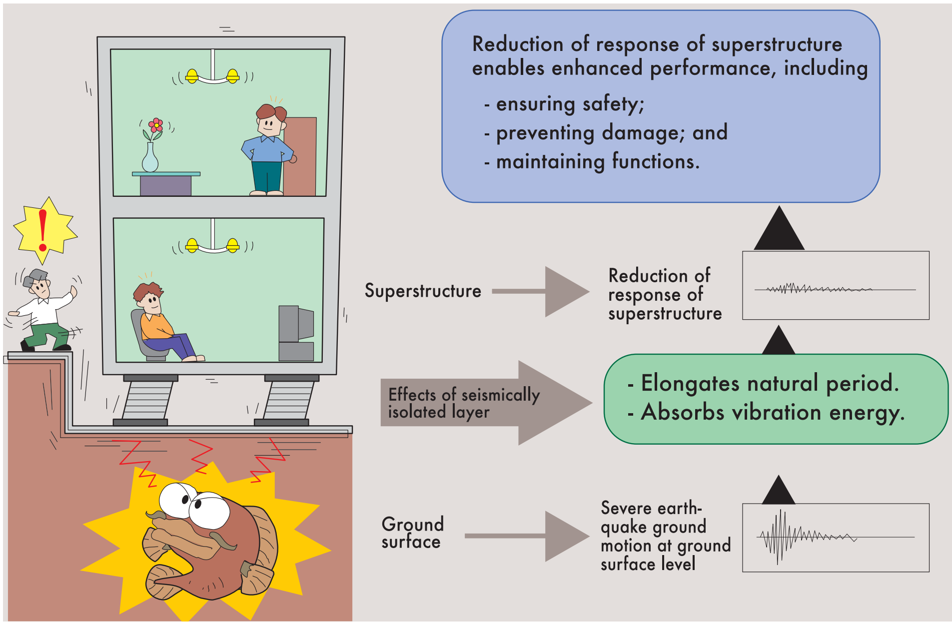
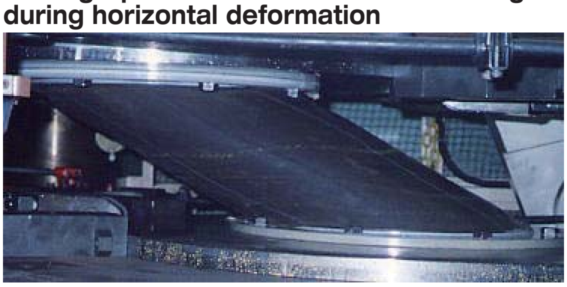



**Figure 4: Features of seismically isolated structure**




**Photograph 2: Laminated rubber bearing during horizontal deformation**



floor are accumulated, resulting in larger deformation at the top of the building, in the case of seismically isolated buildings, large displacement occurs in the seismically isolated layer. When the displacement of the seismically isolated layer is large, the isolation devices are required to have large horizontal deformation capacity, which may increase the price of the isolation devices and cause problems for building planning. Therefore, dampers that absorb the earthquake motion energy are installed to ensure a damper ratio of at least around 20% and to reduce horizontal displacement of the seismically isolated layer.

**Figure 5: Seismically isolated building**

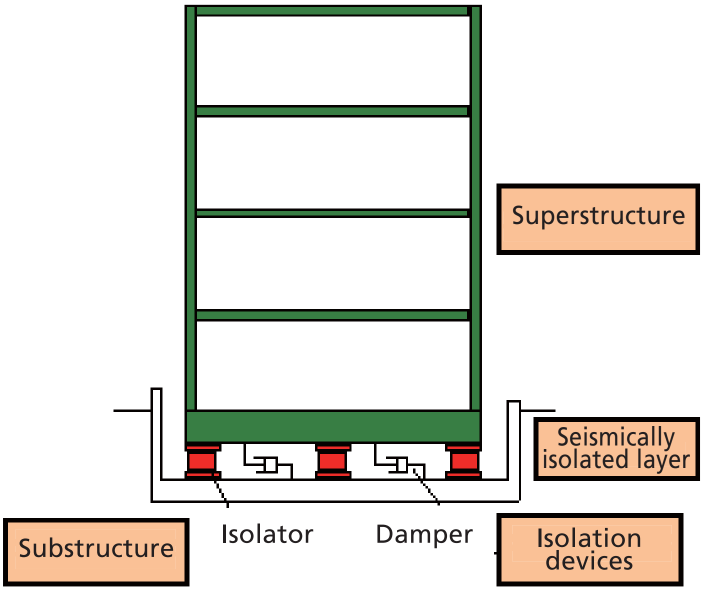
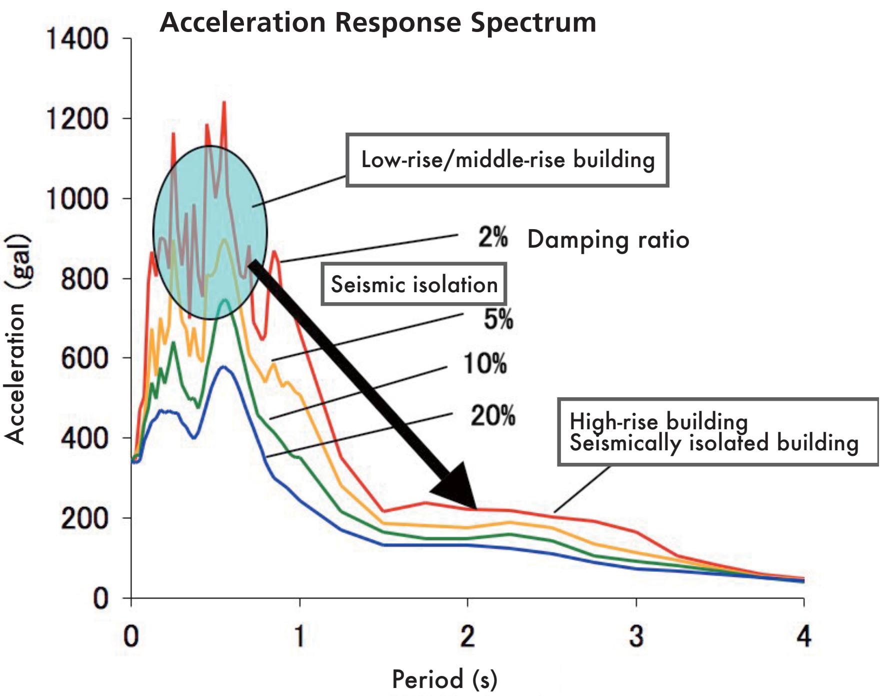



**Figure 6: Maximum earthquake response of building**




*(3) Maintaining safety and functions of seismically isolated buildings*

The use of isolation devices to obtain large deformation capacity and elongate the natural period of buildings allows reduction of the acceleration response of the superstructure. Controlling the response of the superstructure can be expected to:

(1) reduce damage to structural members and non-structural members;
(2) prevent furniture and fixtures from overturning and falling;
(3) ensure an escape route;
(4) ease anxiety; and
(5) maintain functions after an earthquake or speed up the recovery of functions

### Issues to Be Addressed in the Future

With the installation of seismometers and other equipment, we are now able to check the response of seismically isolated buildings during earthquakes. Seismic isolation can be selected as one way of saving lives and minimizing damage. The use of seismic isolation allows us to ensure safety and relief. With no clear picture as yet of the performance of seismically isolated buildings in the 2011 Off the Pacific Coast of Tohoku Earthquake and the damage they sustained as a result, issues which need to be addressed in the future include the following.

(1) Since the displacement response of the seismically isolated layer increases under long-period earthquake motion whose period is close to the natural period of the building, it is necessary to survey the regions where long period earthquake ground motion is observed.
(2) The earthquake response of seismically isolated buildings is much dependent on the performance of isolators and dampers (performance of seismically isolated layer). It is necessary to gain an understanding of the properties of isolation devices and work on the early identification of any issues.

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