PRINCIPLE OF SEISMIC ISOLATION FOR BUILDINGS (Draft)

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I WHAT IS SEISMIC ISOLATION?

1 Basic concept

Buildings must guarantee functionality, as well as protect contents and life safety not only against ordinary loads but also in earthquakes, typhoons or other hazards. Seismically isolated buildings have a flexible isolation layer which limits the transfer of forces from the ground to the superstructure. Energy absorption in the seismically-isolated level, can further reduce these forces.

2 Proof of performance

Seismic isolation performance has been demonstrated in the Northridge earthquake (1994), Southern Hyogo prefecture earthquake (1995), Niigata Prefecture Chuetsu earthquake (2004), Christchurch earthquake (2011) and the Earthquake off the Pacific coast of Tōhoku (2011). When observing records from isolated building in these earthquakes, it can be seen that lateral acceleration on the superstructure decreases to half or one third of the ground acceleration, reducing the force on non-structural elements, furniture and the like. In addition, isolated buildings experienced small interstory drifts, protecting structural and architectural elements.

3 Devices for isolation system

Isolation bearings provide stability under gravitational loads while allowing for lateral motion in earthquakes by having a low lateral stiffness. Additional energy is dissipated through yielding or viscous damping which can help control the lateral displacement of the isolator. It is important that the behavior of the isolator is stable and repeatable under multiple earthquake motions.

4 Applicable building and space requirements

Seismically isolated structures must be able to freely displace during seismic events. As long as a certain amount of space around the building is granted, seismic isolation can be implemented for most any building type or use.

5 Seismic isolation performance and design earthquake ground motion

It is necessary for structural engineers to properly select the appropriate earthquake ground motions and target performance. Ground motions selections should be based potential earthquakes that may occur at the building's location with varying frequency. Target performance should be based on client needs as well as engineering judgement.

Ⅱ BASIC PLAN

1 Ground condition

It is crucial in the design of seismically isolated structures to avoid any incline in the seismically-isolated level caused by ground settlement. Structural engineers should understand thoroughly the ground condition of the site, including the existence of active-faults nearby, the history of past earthquakes, soil properties such as shear wave velocity, or if liquefaction is an issue.

2 Superstructure

The superstructure should be designed not only to be safe under gravity loads; it should be designed to have a lateral strength so that it behaves elastically under seismic load.

3 Seismically-isolated level

Generally, the seismically-isolated level is located below ground to allow for easy access into to the building. Therefore, there should be enough space around the building to allow for lateral building movement.

4 Seismic isolation devices

4.a Plan and arrangement of devices

The design of the seismic-isolation layer, including the number, stiffness and positioning of seismic-isolation devices, should be done so that the seismic displacement response is within the specified design limit and no excessive rotations due to eccentricities would occur. Details of the installation should be carefully planned.

4.b Performance confirmation of devices

The capacity and durability of seismic-isolation devices should be carefully checked by investigating past experimental data or, in some cases, conducting additional experiments using real or large-scale test specimen.

5 Utility lines, plumbing and wiring at the seismically-isolated level

Mechanical, electrical and plumbing systems at the seismically-isolated level must be able to accommodate large horizontal displacement without failure or interruption of service, hence flexible 'seismic isolation joints' should be planned.

6 Maintenance

Specification for maintenance and inspection should be planned. Periodic inspection should be conducted to ensure proper clearance is being maintained for the assumed displacement, and seismic-isolation devices have proper performance capacity. It is important to plan when and how the inspection should take place.

Ⅲ DESIGN

1 Architectural design

The architectural design must be able to accommodate the lateral displacement of the structure at the isolation layer.

2 Structural design

2.a Design objective

The design objective for seismically isolated buildings is to reduce the seismic forces acting on the superstructure while limiting the response of the isolation bearings to within their performance criteria.

2.b Design earthquake force

The response spectra of the design earthquake motions can be generated considering the local soil conditions of the building site. These spectra can be used to calculate the expected shear force transmitted to the structure by using the equivalent stiffness and viscous damping of the isolation system. Seismic isolation devices are also designed using the calculated shear force, however, mounting parts should be designed considering additional stress caused by deformation of isolation devices. Furthermore, using observed earthquake records and the latest knowledge, the effect of duration of ground motion should be also considered.

2.c Design wind load

The structure and isolation layer must also be designed to ensure safety during extremely severe wind as seen in storms. It is necessary to consider the combination of wind loads in various directions (wind direction, orthogonal direction, and torsion) and duration. Also, the safety of the seismic isolation devices should be determined from the results of cyclic tests.

2.d Structure calculation

Based on the response spectrum method, using the earthquake response spectrum described in 2.b, the design shear forces along the height of the structure can be calculated. The lateral force distribution is used to design the structural elements.

2.e Confirmation of safety margin

Because the seismic safety of isolated buildings is dependent in large part on the performance of seismic isolation devices, it is important to fully characterize the devices and use the full range of potential property values in design.

Actual earthquakes may cause larger forces than the earthquake forces set by the code or the engineer. Therefore, it is necessary to confirm that the building is designed with sufficient safety margins.