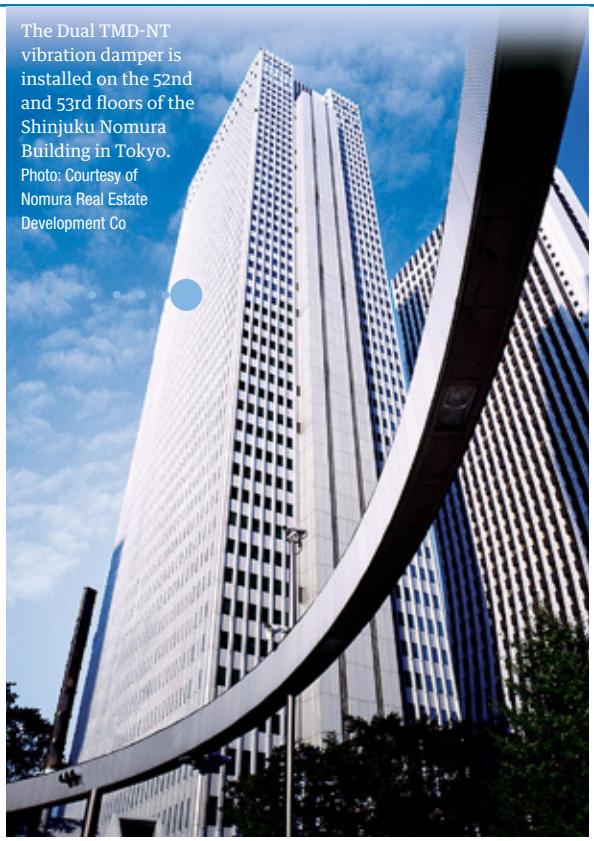
Introducing Tuned Mass Dampers

A 53-story skyscraper in Tokyo has been retro-fitted with a new system that effectively counters the long-period ground motion caused by earthquakes.

TAKASHI SASAKI



The Dual TMD-NT vibration damper is installed on the 52nd and 53rd floors of the Shinjuku Nomura Building in Tokyo. Photo: Courtesy of Nomura Real Estate Development Co

Japan has been hit by many major earthquakes in the past. According to the White Paper on Disaster Management 2014 issued by the Cabinet Office, around 20% of earthquakes with a magnitude of 6.0 or more around the world, or more precisely 326 such earthquakes, occurred in and around Japan during the period from 2004 to 2013 alone. Japan has long been active in trying to attenuate earthquake damage. Initiatives have included the construction of an observation network, disaster drills, the toughening of quake resistance standards for buildings and houses, and disaster management education.

The construction of buildings that will not collapse or be damaged in an earthquake is another measure. Traditionally, Japan has focused on earthquake resistance. This means that thick, strong members are used for columns and beams to achieve sufficient building strength for protection from seismic tremors. However, although this may prevent damage to the building, including collapse, an earthquake may still cause severe damage to internal fittings and equipment, as well as to any people inside the building at the time the quake strikes. For this reason, efforts are now being made to develop seismic isolation and damping technologies.

"Seismic isolation is a technology according to which an elastic device such as rubber bearings is inserted in the foundations of the building to block the vibrations from reaching the building. The building is in a state of suspension in the air. Even in the event of a powerful earthquake, the building will never be deformed," explains Dr. Masashi Yamamoto, general manager of the Earthquake Engineering Department at the Takenaka Research and Development Institute of Takenaka Corporation, a major Japanese general construction firm. "Supplemental damping is a technology of introducing dampers and equivalent devices that absorb the vibrations into a building. Given that the building is directly supported by the ground, seismic tremors reach the building but the dampers absorb the seismic energy to mitigate the deformation of the building and curtail the duration of its shaking."

Since the 1995 Great Hanshin-Awaji Earthquake, which caused a huge number of buildings to collapse, many detached residential houses and buildings incorporating seismic isolation and supplemental damping technologies have been constructed. Base isolation structures are superior to damped buildings in reducing the shaking of buildings. However, seismic isolation requires a space between the

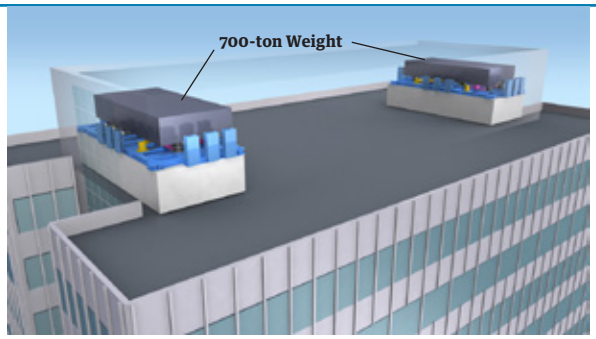


Image showing the two Dual TMD-NT vibration dampers
Image: Courtesy of Takenaka Corporation


Close-up view of one of the TMD-NT vibration dampers: The Dual TMD-NT absorbs vibrations large and small. The double-staged rubber bearings support 700-ton steel weights.
Photo: Courtesy of Nomura Real Estate Development Co

building and the ground in which the rubber bearings or other isolation systems are installed. In addition, it entails a slightly higher construction cost. Meanwhile, supplemental damping technology is subject to less severe conditions for introduction.

Japanese construction firms have been erecting buildings that introduce quake resistance, seismic isolation and supplemental damping technologies according to the building conditions. However, the 2011 Great East Japan Earthquake brought a new problem to the surface, one that concerns slow seismic tremors called long-period ground motion. This motion caused skyscrapers in central Tokyo, around 400 kilometers from the epicenter, to shake significantly for dozens of minutes. Some people were trapped inside elevators, and building interiors and doors were damaged.

"After undergoing long-period ground motion as a result of a major earthquake, high-rise buildings and long or large bridges are shaken massively due to sympathetic vibration. In addition, this shaking tends to last for a long time," says Dr. Yamamoto. "Of course, earlier earthquakes also brought about long-period ground motion, but it was not recognized by ordinary people as a problem until the Great East Japan Earthquake."

Studies have been carried out on technologies addressing long-period ground motion. An example of the achievements of these studies is the Dual TMD-NT vibration damper that was jointly developed by Takenaka Corporation and Nomura Real Estate Development Co. and introduced from 2015 into the Shinjuku Nomura Building, a 53-story skyscraper with a height of 209.9 meters, located in the sub-center of Tokyo and completed in 1978. While it has sufficient quake resistance performance, the scale of the vibrations caused by long-period ground motion had become an issue. The tuned mass damper (TMD) is a device equipped with a weight weighing 700 tons that is designed to move in the opposite direction to the vibration of the building, thereby cancelling it out. Two TMDs have been installed near the top of the building, specifically on its 52nd and 53rd floors. They are expected to reduce the amplitude of the vibrations caused by long-period ground motion following an earthquake as powerful as the 2011 Earthquake by 20% to 25% and shorten the duration of the vibrations by around 50%. It is Japan's first instance of introducing a system that has dual mechanism respectively optimized for small and large vibrations, addressing long-period ground motion into a building.

"The biggest feature of the Dual TMD-NT lies in the fact that the system absorbs not only vibrations resulting from strong earthquakes but also the minor but frequent vibrations caused by typhoons and other strong winds. That brings about considerable improvements in safety and reassurance to people in high-rise buildings, no matter whether they are for residential use or business use," Dr. Yamamoto remarks. "For seismically isolated buildings and supplemental damped buildings, regular inspections performed by specialist engineers are important. In addition to the development of new technologies, we will be working hard to achieve long-term support."