

Seismic Isolation Architecture at the Tzu Chi Hospital Receives International Recognition



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On June 2, 2013, Nantou County suffered an earthquake registering 6.2 on the Richter Scale, which resulted in severe rock slides that disrupted traffic, while nearby Taichung area detected a maximum quake level of 5. Fortunately, the Taichung Tzu Chi Hospital was equipped with 455 seismic isolation pads and 88 dampers; these measures allowed the hospital to remain stable. The next day, to ensure that the building returned to its original position after swaying during the quake, Engineering Team leader Xu-Fu Yu personally entered the underground seismic isolation level to inspect the state of the building shift.

The seismic isolation level is situated below the second floor of the basement, between the foundation and the building. It is a semi-open space that is dark and damp, with the air carrying a mixed stench of septic tank and mildew. There are cobwebs and bugs all over. The seismic isolation level is low in height and laden with incorrectly laid pipelines, so getting to the shift marker required overcoming major obstacles. However, the nimble and well skilled Mr. Yu was able to quickly locate the shift marker within this underground maze. He confirmed that the building only shifted about one centimeter, which was well within the acceptable range. Mr. Yu elaborated that whenever there was a quake greater than 5 in magnitude,



In the Unity Building of Hualien Tzu Chi Hospital equipped with seismometers in the underground, middle level, and roof top respectively. Photo depicts a seismometer located in the second basement floor.

he would come down to take shift measurement and report back to the Tzu Chi Construction Division. If there is any abnormality, others will be sent down to make repairs.

After recording the condition of the building shift, Xu-Fu Yu then led a



Photo shows Director Min-Chao Lin(right) of Construction Dept. of Tzu Chi Foundation discusses with volunteer Mr. Yen about Taichung Tzu Chi Hospital construction.

team from the manufacturer to further identify expansion joints that require re-reinforcement. In no time, he again disappeared into the maze of the seismic isolation level.

The First Seismic Isolation Building in Taiwan, Thoroughly Bound to a Singular Compassionate Mind

The Taichung Tzu Chi Hospital could be considered the largest medical structure with seismic isolation in Taiwan and perhaps even in the world. However, the first Taiwanese building with seismic

isolation to begin construction would be the Taipei Tzu Chi Hospital in the year 2000. Yet, the first to be occupied for use was the Hualien Tzu Chi Hospital ER building, also known as the Unity Building, which finished construction in 2005.

Because of its smaller scale, the Unity Building of the Hualien Tzu Chi Hospital campus was completed sooner. Being the earliest seismically isolated building in Taiwan, its place in Taiwanese architectural history is noteworthy due to the experimentation and trend-setting. Hidden within the seismic isolation level is a secret: it is the only hospital building

Hualien



Taipei



Tzu Chi Medical Mission starts the earthquake proof building. Taipei Tzu Chi Hospital is the first being built quake-proof building. The Unity Building of Hualien Tzu Chi Hospital is the first completed and commenced quake-proof building. Taichung Tzu Chi Hospital establishments are the largest scale quake-proof building then in the world.

Taichung



in Taiwan that houses a seismograph. Should an earthquake take place, information like severity, horizontal shift amount, structural impact, and so forth will be directly transmitted to the Central Meteorology Bureau and the National Earthquake Center. Consistency between the originally implemented quake protection designs and the actual seismic events would then be verified.

Prior to the September 21, 1999 major quake, Taiwan had no regulation concerning buildings with seismic isolation. Thus, the standards for seismic isolation construction took data and documents from the U.S. and Japan as design template. Following installation of the seismograph at the Unity Building in Hualien, practical parameters and real events were collected so that the National Earthquake Center accordingly adjusted coefficients and models, so that rules overseeing seismic isolation in Taiwan gradually matured and became localized. This is one continued and direct contribution that Tzu Chi had made for the people of Taiwan over the years. Exploring the core of its origin, we see that this effort began with the singular compassionate mind of Master Cheng Yen.

A few days after the 1999 quake, director of the Tzu Chi Foundation Construction Division, Min-Chao Lin accompanied Master Cheng Yen to survey aftermaths of the disaster. In the

process, they observed that the hospitals in the ravaged area were not able to operate, as patient beds were piled along the roadsides while medical personnel could only stand helplessly. Mr. Lin recalled that to worsen the troublesome situation, many walls in the hospital were laid with ceramic tiles, which cracked and fell during the quake. The chipped pieces of tiles were covered with blood stains, likely from cuts suffered by folks trying to escape the building. "After witnessing the aftermath first hand, we realized that whether on the ground or on the wall, the cracked ceramic tiles were like sharp blades. They were very dangerous." In the discussion conference that followed the survey trip, Master Cheng Yen reflected with lament that the hospital should have been a place to save people but during the disaster it needed assistance instead. Therefore, the Master called upon the Construction Division to find a way such that when an earthquake struck and the disaster victims poured in, the hospital could continue its function of rescuing lives.

Creating a Hospital Where Surgeries Continue During Earthquake

So, the Tzu Chin Construction Division and architectural commissioners began searching through all the possible



The seismic isolation pads could absorb 50~60% energy caused by an earthquake. Photo Depicts the pads set in the Taichung Tzu Chi Hospital establishment.

solutions.

Min-Chao Lin stated, “In fact there were two simple words of focus, and they were the Master’s ‘Compassionate Mind’”, and precisely from the guidance of this compassionate mind, the Construction Division researched the related technologies and partnered with the National Earthquake Center to collaborate with experts and consultants of architecture, so that the dawning of large scale medical facilities with seismic isolation was begun. With the completion of Tzu Chi Hospital, the ascent of Seismic Isolation architecture was put into motion.

Having continuously researched and

promoted seismic isolating construction, Min-Chao Lin also elaborated bluntly: because seismic isolation pads are more expensive, the methods of their deployment in buildings tend to vary. In Japan, seismic isolated buildings cost about two to four percent more than typical buildings. In Taiwan, the trend started with Tzu Chi, and it deviates from notions of the past, which weighed toward avoiding quakes and tolerating quakes. Typical quake tolerant buildings are constructed with “tolerance”, while the upper portions of seismic isolated buildings are constructed with “rigidity”. Thus at that time, the Tzu Chi

Construction division had to contend with restrictions on traditional quake-tolerant buildings on the one hand, and conforming to the guidelines of seismic isolated buildings on the other. Of course, the Tzu Chi hospital upon its completion was both seismic isolated and quake tolerant.

Seismic Isolation Pad the Key Player, Shock Absorbing Measure Far Exceeding Standard

The key player in seismic isolating architecture is the Seismic Isolation Pad, which shoulders the critical responsibility of protecting the building and dissipating earthquake energy. It is endearing nicknamed “the Vajra Throne” by Tzu Chi members. The Unity Building on the Hualian Tzu Chi Hospital campus has 88 of these installed, while the Taipei Tzu Chi Hospital has 349 in place. However, the Taichung Tzu Chi Hospital leads the pack with 455 deployed, making it the largest earthquake-protected medical facility in the world. Presently, it is the hospital that has the most seismic isolation pads installed.

Seismic Isolation Pad is a cushion woven from rubber. It consists of an approximately three millimeter thick layer of rubber pad intersecting with a millimeter thick layer of steel board. The exact assembly, diameter, and span of

the seismic isolation pad are determined based on the size and weight of the building in question.

There are two types of seismic isolation pad. One is the simple combination of rubber and steel, and the other is the “Lead Core Rubber Pad”, which has rubber wrapping around a lead core.

Because an earthquake represents an energy force emanating from the earth crust, the bigger the quake the greater the energy. The simple rubber and steel construction is inadequate for large scale buildings, in terms of energy absorption and conversion process. Instead, the lead core rubber pad is employed for seismic isolation instead. Because lead melts at a set temperature, when the earthquake is over and cooling has taken place, it will return to its original shape. Thus, it is better suited for absorbing energy. Chao-Min Lin made a clever analogy: the seismic isolating construction is like a car that rubber tires are lined with steel belts, which would be analogous to the seismic isolation pads. The difference here is that the pads are more intricate, with a layer of rubber over a layer of steel.

“Energy” is measured by how much objects moves after being applied force. In years past when there was no seismic isolation pad, the force of incoming earthquake pounds directly against buildings, and the energy is

absorbed solely by the structural frame of the buildings, which more easily incurs dangerous damages. Because seismic isolation pad can ensure balanced horizontal movement, when the earthquake hits, the leveled force rides upon the movement of the seismic isolation pad to exercise and dissipate the energy. Approximately 50 to 60 percent of the earthquake force are exercised and eliminated through the seismic isolation pad, while the remaining portions are endured by the architecture.

Because the seismic isolation pads designed for the Tzu Chi hospitals are enormous in size, with diameters exceeding one meter, in order to ensure the quality of the American seismic pad manufacturers, the Construction Division calculated that during major earthquakes, the pads should only levelly move left and right by sixty centimeters, which

when added to the eighty centimeters of seismic isolation joint, provides a space of 120 centimeter for level movement. These measurements exceed original design specifications and should make certain hazard free movement.

Chao-Min Lin states, usually design specifications are set at twice the required tolerance value. However, in making sure that that the deformation of seismic isolation pad does not pose a problem, Tzu Chi required that these seismic isolation pads be able to endure a 40 percent deformation by shearing force, which amounts to a four factor improvement upon the original design specifications. For example, if the actual event value is 1, then the design specification usually would be 2, but the Tzu Chi implementation is actually 4. Chao-Min Lin commented with pride, "We are the only one in the world to achieve this."



Tzu Chi Foundation invited the Dynamic Isolation Systems to test the pads. The pads could endure horizontal shifts by 60 cm intervals.



A worker moves a 1.84-ton damper targeting to its lock.



One steel ring damper of 600 kg is a key element for quake-proof in a randomly-shaped building.

Enduring Shaking of Magnitude 7 Quake

Upon their completion, the Tzu Chi buildings should be able to withstand a magnitude 7 quake, in accordance with Taiwanese regulations. Here, the magnitude endured is referring to the actual magnitude at the location of the building. For the well-known recent quakes such as the Sichuan Quake of 2008 and the 921 Quake in 1999, the publicized magnitudes of 8 and 7.2 were respectively measured at the epicenter. Typical metropolitan cities are usually some distance away from the epicenter, such that the degree of tremor when reaching the cities would have

diminished, where a 5 or 6 magnitude endured would imply a major quake.

Furthermore, to prevent damages to the seismic isolation pads, during constructions of the Taipei Tzu Chi hospital and the Taichung Tzu Chi Hospital, careful simulations were set up in the seismic isolation level under consistent temperature and humidity conditions to contrast the stress endured against point of maximum pressure at the building center of gravity. Two smaller sized seismic isolation pads were installed at these sites so that in the future, they can be used for inspecting whether isolation performance is still on a par with original design specifications.

Chao-Min Lin commented that seismic isolating construction implies that



One Tzu Chi volunteer cleans in the isolation pads area during Taipei Tzu Chi Hospital's construction period.



With the hospital situated at a location of frequent earthquake occurrences, the installed movement gauges all returning to original state and the seismic isolation system was well maintained. It delivered good quality isolation.

during an earthquake the building will shift horizontally like a moving boat. Thus, there must be seismic isolation joints all around the seismic isolation level in the foundation, so that the structure can shift without hindrance. Variables like dust and fire can affect the effectiveness of the seismic isolation pads. For example, the rubber pads cannot be exposed to flames, so the rubber pads used by the Tzu Chi Hospitals are all wrapped in iron, and the seismic isolation level are equipped with sprinkler system. After a decade of use, the isolation pads, including the exterior iron, are all in near perfect condition.

Furthermore, because the installation of seismic isolation pads number in the hundreds at the Tzu Chi Hospitals in

Taichung and Taipei, the Construction Division posted a floor plan at the location of every pad, each of which clearly marks the location of the particular pad in the building. This is a pioneering measure that has never been done in any other country.

Controlling The Speed of Tremor, Ground Damper Prevents Fishtailing

Besides seismic isolation pads, the quake isolation measures employed by Tzu Chi also includes Ground Dampers. The damper is a sort of level, hydraulic lever. During first moments of an earthquake, buildings take on very severe impacts from the quake force.

For typical rectangular shaped building, the speed of shift would be controlled by the ground dampers. Also, there is a kind of steel ring ground damper that is shaped like a butterfly, which is used with non-rectangular buildings. Taking the Taipei Tzu Chi hospital as example, its shape is not exactly rectangular. Rather, this structure consists of arc, square, and rectangular sections. When an earthquake strikes, the arc area of a building would likely take on whipping motion from extreme fishtailing. The steel ring ground damper is precisely for reducing the severity of the whipping motion.

To assess whether the seismic isolation system fully served their function, at the center point of the seismic isolation level within the building, also referred to as the position of the “geometric planet”, a movement gauge is installed. After an earthquake, one only needs to check whether the gauge has returned to its original center axis. If it did not return, then there should be some remaining stress in the seismic isolation pads that has yet to be released.

Well-Hospital Site Prepared as Shelter for Disaster Relief

In May 2013, DIS (Dynamic Isolation Systems), the company which specializes in manufacture of seismic isolation pads

sent engineers to inspect the state of products that have been in use for nearly a decade at the Tzu Chi Taipei Hospital. With the hospital situated at a geographic location of frequent earthquake occurrences, the installed movement gauges all returning to original state, and the underground seismic isolation system was well maintained and delivered good quality isolation. The inspectors were 100% satisfied.

Master Cheng Yen stated, when the earthquake strikes, schools and hospitals must not collapse, because the school is an emergency shelter and the hospital is a rescue center. For this sake, Tzu Chi has taken on the mission of rebuilding 50 schools in earthquake damaged areas. In doing so, Tzu Chi promoted the advancement of the SRC construction methodology in the Taiwanese architecture world. Also, Tzu Chi made a dedicated effort to research seismic isolation systems for medical architectures, constructed seismically isolated buildings. The construction staff used hard materials to protect delicate beings. For those boulders that guard lives, they are constantly kept in the best state, so that during earthquakes, medical functions can continued to be carried out and precious lives can be saved.

SRC Building, Students Protector

For architectures that adapt to earthquake, apart from seismic isolation, there are also quake tolerant constructions. One such is SRC (Steel and Reinforced Concrete) construction, which is a combination of the SS (stainless steel structure) and RC (reinforced concrete structure). This quake tolerant construction is capable of absorbing greater amounts of earthquake energy.

SRC is a building technique invented by the Japanese. Because of its high cost, deployment is less frequent. Following the 921 Earthquake in Taiwan, Tzu Chi assisted in the reconstruction of 51 schools, and the Construction Division of the Tzu Chi Foundation invited renowned builders and architects from all over Taiwan to meet and discuss construction methodologies. Stainless steel is light and quake tolerant, but tends to shake more severely, while reinforced concrete shakes less but cracks more easily. After some debate, most experts felt that multi-story schools are not common, so using high quality stainless steel construction or reinforced concrete should ensure safety. However, in the end, because Master Cheng Yen wished to implement “the safest and the most worry-free” construction, it was decided that all the schools that Tzu Chi was rebuilding shall employ the most expensive SRC technique. Every school rebuilt by Tzu Chi, even the single story ones, was rebuilt using the SRC stainless steel reinforced concrete construction.

