APPLICATIONS OF SEISMIC DISSIPATION AND SEISMIC ISOLATION IN MEXICO

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Abstract

The design of critical structures to resist the effects of earthquakes continues to gain importance worldwide.

More recently, in Mexico, they have begun to resume and implement advanced seismic protection systems.

The main objective of these systems is always the people's safety. However, the integrity of the structures and their serviceability immediately after an earthquake play an essential role in the speed of the emergency response, particularly bridges, hospitals and schools. Additionally, the cost associated with repair or reconstruction of damaged structures is likely to be small compared to the economic impact caused by the disruption of serviceability after an earthquake and during the lengthy reconstruction phase.0

Seismic isolation systems provide an alternative to conventional earthquake resistance design such as the strengthening of structural elements (columns or beams) and have the potential for significantly reducing seismic risk without compromising safety, reliability, and economy of structures. As an alternative to seismic isolation, energy dissipation becomes essential in terms of seismic protection. The use of useful devices able to dissipate high amounts of energy ensures that other structural elements do not undergo excessive demands that could cause significant damage and new focus in financial business interruption aspect.

This article presents some applications of seismic protection and the new ideas of seismic devices that are retaking after the earthquake on September 19 in Mexico. Mexico is an inactive seismic area that has experienced strong earthquakes. The development of the engineering expertise in the region, together with the availability of affordable and effective systems have encouraged the use of advanced seismic protection technologies, such as elastomeric LRB's and pendulum isolators, as well as viscous dampers. The study cases presented in this paper serve as evidence of the increasing interest of designers, contractors and owners for safer and efficient structures, which above all ensure the safety of the population, and mitigate structural damage.

Keywords: Mexico, New Seismic Devices, Energy dissipation, seismic isolation.

1. INTRODUCTION

The city of Mexico has considered as a highly seismic zone given by its land, during the several actions of an earthquake the buildings to achieve ethical behaviour and even stand, depend primarily on the flexibility of the elements and stiffening systems structural that form them.
However, to ensure that they absorb the levels of kinetic energy that generated during a movement, they usually exceed their elastic capacity in simple terms, they reach the damage to maintain their stability and not collapse.
After of the seismic 1985 and the damages in essential hospitals of the México city prevented the care of injured people, for that the Mexican engineering needs a solution to avoid this condition and the solution it is straightforward. After the seismic 2017, Damages occurred in residential buildings, have caused a social movement where society demands more security and better response and performance of buildings to damage and their operation after the earthquakes. Moreover, even, in some cases, that does not have to be changed after an earthquake, that is, they are not sacrificial. In the earthquakes of September 7 and 19, 2017, in buildings that had hysterical dampers that were activated and operated in the earthquake of September 7, 2017, they functioned properly, but when the earthquake of September 19, 2017, presented They had already worked and were not changed, the buildings in which they installed showed slight damage.

The buildings of vital importance to attend emergencies after an earthquake should not suffer any damage that prevents their operation and for that have the idea to concentrate the energy of the quake on deformable elements that can easily change after that.

2. DESIGN CRITERIA IN MEXICO

The seismic design of base-isolated structures should satisfy two limit states according to the guidelines

available in MANUAL OF CIVIL STRUCTURES (MOC)-2008: service limit state, where deformations should review to prevent damage and warrant that the isolation system is activated and, collapse prevention limit state, where strength and deformation capacities of the isolation system and structural elements (below, above and within the isolation interface) will be asses to check that they can withstand force and displacement demands from the maximum credible earthquake (MCE).

Base-isolated structures should be designed considering the action of three simultaneous orthogonal components for the ground motions (two horizontal and one vertical), and their combinations are recommended three historical and two artificial ground motions. In case the place does not have historical ground motions, recommended three artificial ground motion and one artificial ground motion with scale 1.5 for the security.

The recommendation to Height limits is specified for the most common structural systems used in buildings and addressed by the code. The proposed height limits are based in base-isolation guidelines of the United States (i.e., ASCE-7 2005), but they were adapted to Mexican design conditions (i.e., Tena-Colunga 2005). However, a window is open in MOC-2008 for special base-isolated structures that may surpass the limiting height values. Taller base-isolated buildings could be built only if a group of experts independent from the original design (peer-review committee) authorizes such projects.

It is also established in MOC-2008 that if the structure above the isolation system contains distinctive elements such as passive energy dissipators or dampers, their design should also meet the criteria established for such devices within the Manual and that the proposed design values for active damping and the seismic reduction factor should be fully justified. This statement is included as it is recognised that such mixed systems are becoming more commonly used worldwide today, so guides should be set for a coherent seismic design.

The 1985 Mexico City earthquake caused resonance at the particular site period of 2 seconds, as shown clearly in the spectra in Figure 1.0. An isolated structure on this type of site should be counter-effective for this type of ground the design need especially carefully for the displacement.

The design in Mexico City for an isolated system is obligatory to no-linear analysis and time history analysis to prevent damages in the building to protect and after much research, the period of 2 seconds is only in the lake area in the central part of the city of Mexico; taking this into account, the designs must be more careful, especially when moving the insulator and there is an example of an insulated hospital that has been a success in the field with accelerations of two seconds.

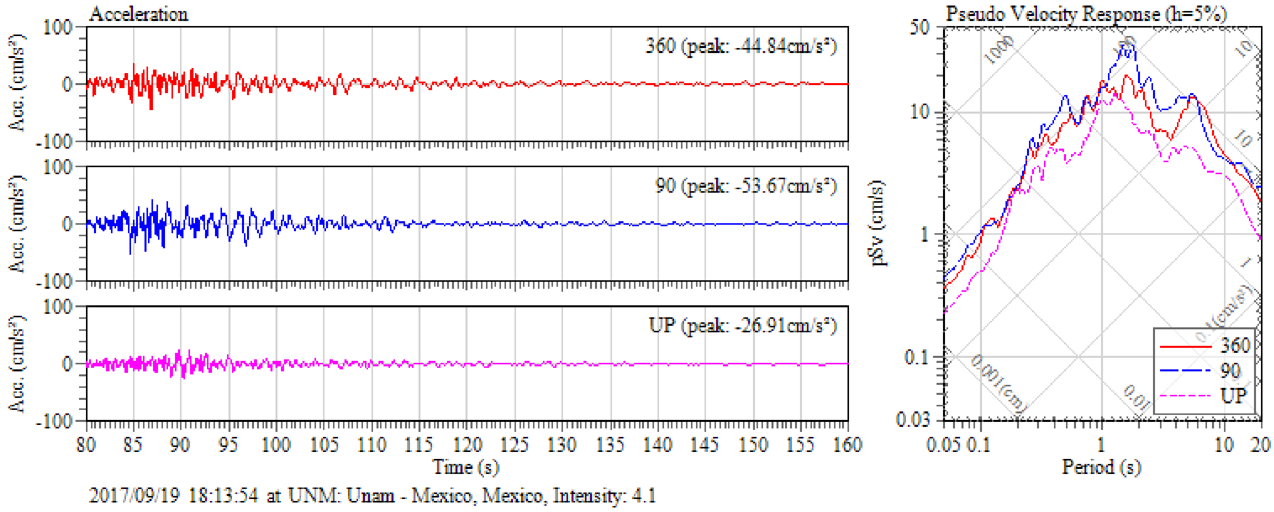

Figure 1 Acceleration record provided by SSN, UNAM

3. SEISMIC ISOLATION

Seismic isolation involves the provision of specially designed bearings, known as seismic isolators, which will support a structure's superstructure in normal circumstances but isolate them, primarily in the horizontal plane, from the violent, ground movements that might occur during an earthquake. The flexibility thus provided in the horizontal plane lowers the structure's natural frequency, increasing its natural period and thereby reducing the accelerations. Initially, after the 1985 earthquake, there was an idea in Mexico of not being able to occupy the base insulators in the structures because the period of the terrain was very high (2 seconds) which forced the insulators to periods higher than the terrain (above 3 or 4 seconds) and this implied large displacement, so the solutions based on isolation were initially discarded.

Another important contribution of an effective seismic isolation system is the re-centring it can provide after an earthquake, avoiding residual displacements which would otherwise disrupt the structure's serviceability. It is very often possible to retrofit seismic isolation to an existing structure if required, by temporarily lifting the superstructure and replacing its conventional bearings with suitably designed isolators.

3.1 Lead Rubber Bearing (LRB)

A type of seismic insulator widely used for its advantages that it brings to the building and its easy installation in both new and reinforcement projects is the LRB (Lead Rubber Bearing) because they are the solution that combines the functions of key insulation, energy dissipation and refocused on a single compact unit.

LRBs are similar to standard reinforced elastomeric bearings with steel connection plates on the top and bottom for connection to the superstructure and substructure, with a key difference: they also include a cable plug in the core, joining a connection plate to the other, which deforms plastically when subjected to large horizontal forces during an earthquake and thus dissipates energy, reducing it locally by up to 30%, through hysterical damping and heat generation. Thanks also to its relatively small size and robustness, and corresponding advantages in relation to installation in a new structure, adaptation in an existing structure and inspection and maintenance (generally limited to periodic visual inspections), LRBs are the most used Seismic isolation solution in the world.

3.2 Ball Isolator system

Another type of seismic insulator design After the 1985 seismic event in Mexico is the ball insulator, also known as friction insulator, this device designed and implemented by the engineer Manuel González Flores.

The seismic device using steel plates connects the base with the superstructure in the steel plates is a sliding surface and another one that contains the granules; The idea is that the friction generated between the surface and the pellets helps to dissipate the energy of the earthquake and allows a rigid movement of the structure that supports the base reducing its acceleration.

Several publications have proposed their mathematical functionality and have demonstrated their viability as a seismic device through smaller-scale models by changing the densities of the granules but not of greater interest, such as larger-scale tests.

In any case, the seismic devices that I will mention, this is the one that had less interest in demonstrating its functionality, so it does not have an investigation of its hysteretic behaviour in the face of an earthquake.

3.3. Seismic pendular isolation system.

Seismic insulation is a structural design technique used to mitigate or reduce potential earthquake damage. Seismic insulators are elements that are usually installed between the foundation and the superstructure in order to isolate the latter from ground movement. If the insulation system provides the structure with a fundamental period of oscillation that significantly exceeds the dominant terrain, the magnitude of the seismic forces that will act on the superstructure will be significantly reduced. The most commonly used insulators such as rubber or neoprene layer compounds can reduce and, in some cases, eliminate structural damage provided, they do not suffer deformations that endanger the stability of the building.

3.4 Case of Study

Case of Study Via Vallejo

This building, housing two different Marriot hotels, the Courtyard and the Fairfield, is being constructed on top of a large new mall called Via Vallejo in the centre of Mexico City. The 10-floor building, shown in Fig. 4, has been designed to not only withstand the effects of the severe earthquakes in Mexico City but also to ensure the serviceability of the hotel during and after the seismic event. To improve the seismic response of the building, the responsible design engineers performed extensive, complex, three-dimensional dynamic analyses which confirmed that the best strategy was to seismically isolate the hotel from the mall underneath. This is being achieved by the provision of 18 LRBs to support the entire hotel structure (Fig. 4). The hysteresis loop is shown in Fig. 3.

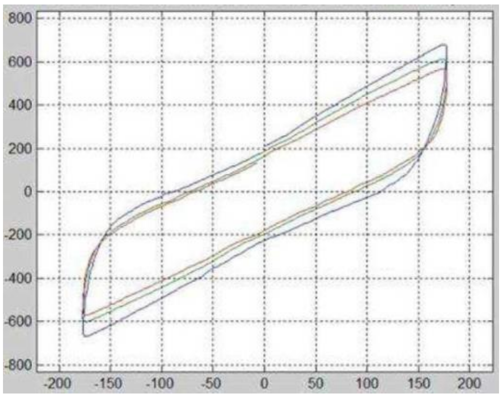

Figure 2 Hysteresis loop LRB's

Figure 3 Isolator Building Hotel Via Vallejo

Case of Study High School No. 68 Mexico City

Diurnal Secondary School No. 168 located on Avenida Legaria and Lago Ximilpa, Miguel Hidalgo Delegation. (fig 4); It is a 4-level structure and is formed by rigid concrete frames, reinforced by means of steel winds, with a system of steel slab floor and masonry walls. The superstructure is displaced on a foundation drawer at an approximate depth of 2.50 meters and this is supported on concrete piles. The seismic insulator is a friction type, which is formed by means of two steel plates spliced on its main surface and these, in turn, are separated by means of steel pellets The base insulators are placed between the foundation and the column, a neoprene plate and a concrete bench are observed, which serve to level the structure due to differential subsidence of the foundation (fig. 5). The insulator is protected with a plastic to prevent the entry of dust and moisture that deteriorate the plates and pellets, preventing oxidation and a bad sliding of the insulator.

Figure 4 The separation between the foundation and the building

Figure 5 Ball isolator devices

Case of Study building of the printing press of the newspaper "REFORMA in Mexico City and" El Mural" in Guadalajara.

In Monterrey, in 1990, Engineer Federico Garza-Tamez develops a base isolation system with pendular devices, which he installed in 1992 in the “El Reforma” newspaper printing hall, in Mexico City, and later in the newspaper “El Norte”, in Guadalajara Jalisco. This system had been previously tested in the laboratory of the University of Illinois at Urbana-Champaign, Illinois by Dr Douglas A. Foutch, demonstrating its effectiveness. The system takes advantage of the pendular action to isolate the structure from seismic excitation. The supports have a connection plate, which hangs on cables or steel bars that connect to another connection plate so that the pendulum action between the connection bars is what allows dissipation and isolation.

This device has some problems such as the possible tension in the supports (tall buildings), the movement in the face of small movements (for which the installation must be accompanied by elasto-plastic type dampers), and long-term maintenance, but they are already being resolved at this time when conducting investigations and its installation in bridges is being proposed.

Figure 6 Pendular isolator(Garza Tamez)

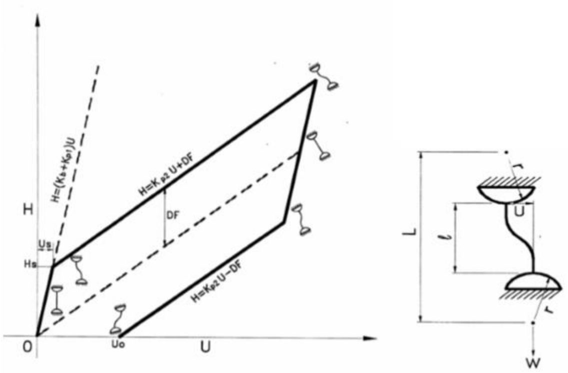

Figure 7 Device operation diagram

4. ENERGY DISSIPATION/DAMPER

4.1 Energy Dissipation ADAS (Added Damping and Stiffness Element)

One of the seismic device applicated before the 1985 earthquake in Mexico City is the ADAS element (Added Damping and Stiffness Element) this devices work. This device was developed initially to dissipate energy in the pipe supports of nuclear plants (Steimer and Godden, 1980; Steimer et al., 1981). In 1987 Bergam and Goel at the University of Michigan (Bergman and Goel, 1987) experimentally tested an ADAS device. In 1988 Javier Alonso (Alonso, 1989) tested two ADAS elements one to three scale to study their mechanical properties and evaluate their possible use in the energy dissipation of buildings. The hysteretic behaviour of this type of components is shown in Fig 9. Later, the same kind of elements was placed in a one to three scale steel building that was tested on a vibrator table (Whittaker et al., 1989). It was experimentally proven that these types of elements are capable of dissipating large amounts of energy and that can help control the seismic response of buildings. Although these elements They were not developed in Mexico, it is precisely in this country that there are more applications of these devices. The ADAS elements have been incorporated into three existing buildings in Mexico City (Martínez Romero, 1993) and in two new buildings in the city of Acapulco (Martínez Romero, 1997).

The ADAS system is composed of parallel plates; this helps that depending on the number of sheets that have adjusted to the sheer energy that you want to dissipate, other advantages of these devices are its ease of replacement in case it flows. Unlike other sacrificial devices that may be more difficult to replace, these plates are placed in easily accessible places where the connection is easy to replace.

4.2 Viscous Damper

Shock absorbers are velocity-dependent devices that consist primarily of a piston, a piston rod and a cylinder pipe. They allow free movements of a structure during service conditions, but control displacements and dissipate energy during sudden movements due to earthquakes or during exceptional loading from traffic, wind, etc. The resistance force provided by the unit depends on the flow of a viscous fluid from one chamber of the cylinder pipe into the other, through small holes whose size determine the damping characteristics of the shock absorber. By dissipating energy from sudden, exceptional loading, shock absorbers reduce the impact on the structure, protecting it from damage. This allows the design of the structure to be optimized, avoiding conventional strengthening which might be rarely or never needed during the lifetime of the structure.

The viscous fluid used is protected against ageing by special additives, while the fluid itself protects the device from inner corrosion. The viscosity of the fluid remains nearly constant with respect to temperature variations, making the system thermally compensated. The sealing, which prevents the loss of the fluid and consequent diminishing performance, is the most critical element of the hydraulic system and must be designed and constructed to the highest quality standards. Only high-grade seals that demonstrate quasi-zero wear and absolute physical and chemical compatibility with the viscous fluid should be used.

4.3 Case of study

Case of study: Hospital & Headquarters of Secretary of Social Security (IMSS México)

The first building reinforced with this system is this same technology was applied to the General Office building of the Institute, also located in the centre of the city, Reforma Avenue almost opposite where the Torre Mayor is currently located. The second building reinforced with this system in Mexico was the IMSS Cardiology Hospital in Mexico City, also affected by the 1985 Michoacán earthquakes, so, in the face of the collapse suffered by several hospitals, a reinforcement was sought that allowed To the hospital continue working. The adaptation of energy sinks was a pilot project at the IMSS facilities. It began in 1990 and concluded in 1992.

The construction of this reinforcement was proposed by the IMSS Directorate and entrusted to its project area, which worked together with technicians from the University of Berkeley, California - patent holder - in architectural and engineering design. Subsequently, the Institute's construction area hired the companies that were responsible for the work

Also, in Mexico, Shock Absorbers have been installed in a high structure: “La Torre Mayor”, a structure located on Avenida Reforma de la Ciudad de México and which was once considered the largest skyscraper in Latin America.

The building rests on a pedestal formed by 251 foundation piles, supported at almost 50 m deep, crowned by a thick slab of reinforced concrete that serves as a background to the practically square structural drawer, with almost 80 m per side and 16 m deep, where 4 parking basements are housed. The tower structure has 55 levels, which can be accessed through 20 elevators.

Figure 8 Secretary of Social Security Mexico Building (IMSS)

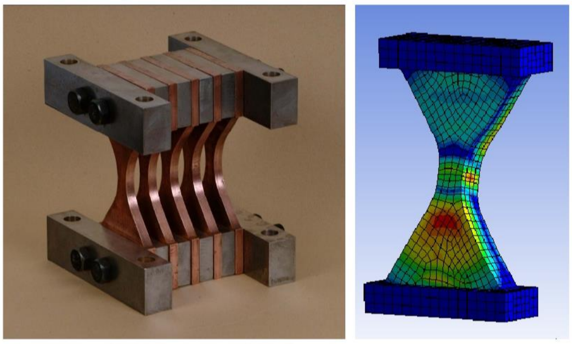

Figure 9 ADAS system (USA Laboratory test)

Case of study: TELMEX building of Lerma 256, Mexico City

Telmex, which is the largest telephone company in Mexico, owns several buildings in Mexico City. One of these buildings went into obsolescence as it failed to respond to the new specifications of the seismic regulations of Mexico City. The Lerma building is a 17-story structure, including four parking floors, twelve office floors and a penthouse. This building has dimensions of 25 m x 15.3 m in plan. The high risk of damage in an earthquake caused the development of a structural reinforcement project to be required. After a detailed evaluation of the options, the decision was made to use dampers at different levels to improve the dynamic response of the structure to an earthquake. The evaluation was continued with multiple shock absorber configurations, considering several combinations of load, displacements and number of devices, to finally decide on the installation of 76 Shock Absorber (SA) type dampers that were located in strategic areas of the building structure Two types of SA type dampers were selected, for maximum loads of 800 kN and 600 kN respectively, both for displacements of +/- 50 mm. The details of the dynamic properties of the dampers are shown. The results of real-scale tests are shown.

Figure 3 Telmex Building

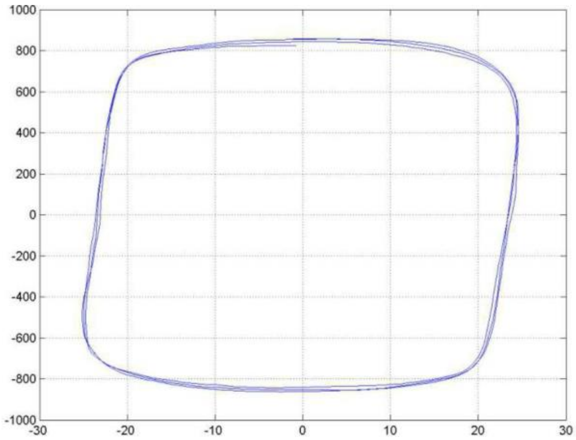

Figure 4 Hysteresis loop viscous damper

5. CONCLUSION

The applications of technologies such as seismic isolation and energy dissipation in Mexico began after the damage caused by the 1985 earthquake, one of the most memorable disasters in Mexico; engineer Martínez Romero incorporated into the rehabilitation of two significant buildings for the health of Mexico seismic devices called ADAS, while engineer Manuel González Flores develops base insulators employing pellets a system in his daring moment. However, over time to control a viable system in my personal opinion, these systems only they need a little more research. Then there was no development, nor were these issues promoted until the last earthquake of 2017.

Currently, Mexico is again promoting these technologies, including new devices that are in the academic area. However, they are still high-cost devices, the importance of their use in buildings of vital importance such as Hospitals and City Halls.

6. Acknowledgements

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