Expert Knowledge

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Seismic protection for bridge and building structures

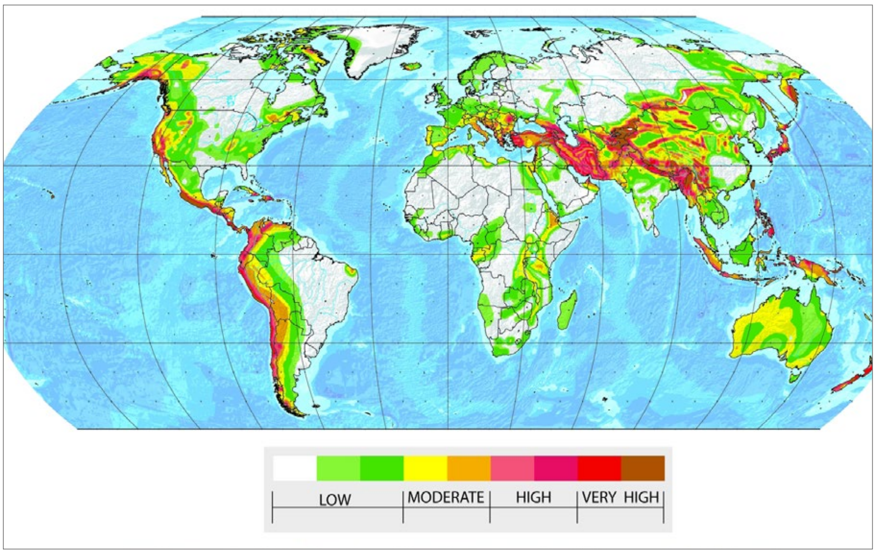
Seismic risk = Seismic hazard x vulnerability

Introduction

Since his appearance on earth, man has attempted to understand the origin of earthquakes, and the first interpretation was that of divine punishment. Throughout the centuries there have been many fantastic explanations that cited dragons and other imaginary creatures and only in 1600 the first justification based on rudimentary science appeared, the so-called “plutonic theory”. This attributed the origin of the collapse of underground caverns.

It was not until the end of the 1800’s that the true origin of these disastrous natural phenomena was discovered, namely the collision of tectonic plates in very slow movement.

The task of solving the problem can be attributed to Earthquake Engineering. Even though it is a relatively new branch of engineering, advances in this field have already played a significant role in reducing seismic hazard through the improvement of the built environment, thus making possible the design and construction of Earthquake-resistant structures.



1 Seismic hazard world map

A good design is not the only key

The conventional anti-seismic design of structures relies primarily on their strength, which should be adequate to enable them to withstand the effects of seismic vibrations. If the design is good, it should save the structure from collapse in even a strong earthquake, but damage can still be expected to certain structural elements and especially to non-structural elements and items such as the building’s contents.

Safe structures are vital to our society

Nowadays, the damage that can be caused by earthquakes is recognised all around the world to be a serious issue for all kinds of structures – and especially, in the case of buildings, for strategically important and public ones. Strategically important buildings such as hospitals and fire stations must continue to serve their purpose in the aftermath of an earthquake, and public buildings, such as schools, must be seismically safe because even the collapse of partitions and other non-structural elements, and falling objects, may cause severe injuries to the building users.

The importance of bridges

Having a bridge damaged or collapsed stops the emergency services for hundreds of buildings, so their importance is very high. After an earthquake a fire is extremely likely, and if the fire fighters cannot get to the place, the casualties will be higher.

Damage to other, less critical buildings also causes significant economic and social difficulties for the affected population, and should also be minimised. It should also be noted that nowadays, even in the case of non-strategic buildings, a building’s contents are frequently of higher value than the structure itself, and generally much more vulnerable to damage by seismic vibrations.

Risk of fatalities in non-protected structures

Many existing buildings around the world are not seismically safe because earthquakes were not taken into account in their design or due to deficient construction. Masonry structures, if conventionally built, are particularly prone to seismic damage, and many reinforced concrete buildings, even recently constructed ones, are of inadequate quality. Moreover, earthquakes of unexpected intensity have occurred recently in many areas of the world, highlighting the limitations of the probabilistic methodologies that are generally used to assess the seismic classifications of different regions, resulting in the evaluation of heightened risk levels in certain areas.

Energy Dissipation and Seismic Isolation

Energy dissipation by means of viscous dampers

Viscous dampers have been widely used in major civil structures in recent decades to mitigate the effects of earthquakes. Their use in high-rise buildings in seismic areas is a challenge for designers, since the dampers should reduce the vibrations induced by both strong winds and earthquakes, and the optimal behaviour in these two situations is generally not the same. Consequently, the design requirement for viscous dampers to be used in high-rise buildings is often that they should have two different behaviours in the different velocity ranges corresponding to wind and earthquake.

Scope of application

- Structures where seismic isolation is not suitable (for example very tall, slender structures).
- Structures whose dominant vibration modes are within a wide frequency range.
- Retrofitting of existing buildings and bridges.
- Local protection of non-structural and/or structural elements that are more sensible to oscillations during an earthquake event.
- Horizontal bearing/connection (ex. between 2 neighbouring buildings; (re)distribution of loads on a bridge during the dynamic event).

Seismic isolation

The objective of seismic isolation systems is to decouple the building structure from the damaging components of the earthquake input motion, i.e. to prevent the superstructure of the building from absorbing the earthquake energy. The entire superstructure must be supported on discrete isolators whose dynamic characteristics are chosen to uncouple the ground motion. Some isolators are also designed to add substantial damping. Displacement and yielding are concentrated at the level of the isolation devices, and the superstructure behaves very much like a rigid body. Some of the commonly used isolation systems are laminated rubber (or elastomeric) bearings and sliding isolation systems.

Scope of application

Earthquake protection of structures by means of the base isolation technique (using seismic isolators) is generally suitable if the following conditions are fulfilled:

- The subsoil should not produce a predominance of long-period ground motion.
- The structure should be quite squat (proportions height/width & height/length not greater than 2) with sufficiently high column loads.
- It is possible to increase the flexibility of the structure at its base (for example enough space to move during the earthquake).
- Lateral loads due to wind are less than approximately 10 % of the weight of the structure.

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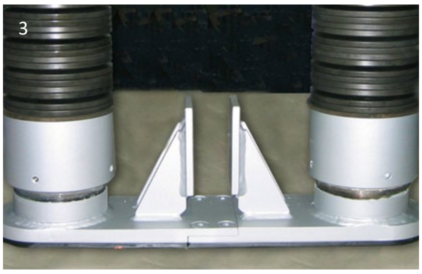
3 

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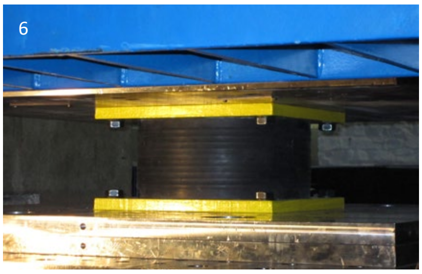
6 

1 Shock Absorbers (SA)
2 Pre-Loaded Spring Dampers (PSD)
3 Spring Disk Dampers (SDD)
4 Curved Surface Sliders (“pendulum isolators”)
5 Lead Rubber Bearings (LRB)
6 High-Damping Rubber Bearings (HDRB)

Certification and testing

European Certification

Although Europe is not as seismically active as other parts of the world, the design of critical structures to withstand the effects of earthquakes continues to gain importance. This was underlined by the publication in August 2011 of the European Norm for Anti-Seismic Devices, EN 15129. This norm regulates the design, production and testing of most existing types of anti-seismic devices, and crucially, also allows the development of new devices, as long as they fulfill the established performance criteria.
Since August 2011, only anti-seismic devices that have been certified according to EN 15129 can be used in the member countries of the CEN (European Committee for Standardization).

International Certification

mageba's seismic protection devices have been tested and certified under the most accepted and well-known international codes, including EN 15129 (Europe), AASHTO, CALTRANS and FEMA 451 (USA), as well as CAN/CSA-S6-06 (Canada).
Additionally, mageba has developed seismic devices with special features such as LRB's for low temperature application (down to −30 °C), High Damping Rubber Isolators with higher damping ratios, large pendulum isolators of up to 140,000 kN of vertical load capacity, and viscous dampers of up to 7,200 kN maximum load.

There is a strong and technically capable design department dedicated to the research, development and application of advance seismic protection technologies, including seismic isolation and energy dissipation. The adaptability to a wide range of norms ad specifications are one additional advantage of these seismic protection systems.

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Testing

Building and bridge design codes for seismic isolation and energy dissipation include specific requirements for the testing of isolation bearings and damping devices.

The testing is intended to serve two purposes:

- firstly, to confirm the physical properties of the isolation and damping devices used in the design process and to demonstrate acceptable behaviour under the maximum expected earthquake loading
- and secondly, as a means of quality control to confirm the properties of the devices that will actually be used in the structure

For large structures, and structures in areas of high seismicity, the testing requirements may place great demands on the available testing equipment. Normally testing is performed on full-scale samples at condition identical to the one from the maximum expected design earthquake, which for large structures, and structures in areas of high seismicity may place great demands on the available testing equipment.

Samples of testing possibilities for seismic isolators and dampers: