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Bülach, April 17

BRIDGE ICES BEFORE ROAD

WHAT HAPPENS WHEN LEAD RUBBER BEARING SEISMIC ISOLATION AND COLD CLIMATE REGIONS MEET EACH OTHER? Carlos Mendez-Galindo, Borja Baillés and Samy Rassy have dedicated themselves towards the field of earthquake and structural engineering. In this context they are outlining the obstacles and hidden aspects to be aware of when lead rubber bearings (LRB), low temperature, highway bridges and seismic isolation come together.

The increasing awareness of the threats posed by seismic events to critical transport infrastructure has led to the requisite of seismically retrofitting highway viaducts and other bridges in order to improve their ability to withstand strong earthquakes. Continuously evolving technology and, the improving evaluation and design abilities of practitioners, have also contributed to the need for such solutions - as have, of course, increasingly stringent national design standards.

Bridges are ideal candidates for the adoption of base isolation technology due to the relative ease of installation, inspection and maintenance of isolation devices. Although seismic isolation is an effective technology for improving the seismic performance of a bridge, there are only certain limitations of its use – mainly in the context of exceptionally soft or weak soils where high period ground motion is dominant. As shown in Figures 1 and 2, seismic isolation improves the performance of a bridge under earthquake loading partially by increasing the fundamental vibration period. Thus, the vibration period of a bridge is moved away from the high-acceleration seismic ground period and seismic energy transfer to the structure is minimized. This reduction in seismic energy transferred into the structure allows for more slender structural elements which results in great economies for the construction project. The seismic isolation system provides a relatively high vibration period compared to a conventional non-isolated structure. Based upon principles of structural dynamics, increasing the difference between the natural frequency of the isolated superstructure and the predominant earthquake input frequencies reduces the seismic energy transferred into the superstructure. Therefore, seismic isolation is most effective in relatively rigid structural systems and will provide limited benefits for highly flexible bridges. Another consideration is related to the large deformations that may occur in seismic base-isolation bearings during a major seismic event, which causes large displacements in a bridge deck. This may result in an increased probability of collision between deck and abutments. This effect can be avoided by the installation of capable expansion joints. Damping is crucial to minimize the seismic energy flow to the superstructure and to control the horizontal displacements of the bearings.

There are seismic areas in Canada, Russia, Japan, USA (Alaska) and Iceland, leaving these regions exposed to both extreme cold temperatures and seismic threats. From all the areas, Quebec in Canada is probably one of the most populated region. A particularly active seismic area is the Charlevoix Seismic Zone which is a seismically active area next to the Saint-Lawrence River in northeastern Quebec, Canada. With over 200 small earthquakes occurring each year, the Charlevoix Seismic Zone is one of the most active seismic zones in Canada (Fig. 3). And as such, it comes to no surprise that the Canadian region is leading worldwide the investigation of LRB seismic isolation technology at very low temperatures.

Perfect fit: lead rubber bearings

Among the great variety of seismic isolation systems, lead rubber bearings (LRB) have found wide application in bridge structures. This is due to their simplicity, reliability and economic cost as well as their combined isolation and energy dissipation abilities in a single compact unit. Using hydraulic jacks, the superstructure of a bridge that requires seismic retrofitting can typically be lifted to remove the original bearings, easily replacing them with suitable LRBs.
LRBs consist of alternate layers of natural rubber (NR) and steel reinforcement plates of limited thickness, and a central 99.9 % pure lead core. They are fabricated with the rubber vulcanized directly to the steel plates, including the top and bottom connection plates, and can be supplied with separate anchor plates, facilitating future replacement.
LRBs limit the energy transferred from the ground to the structure in order to protect it. The rubber/steel laminated isolator is designed to carry the weight of the structure and make the post-yield elasticity available. The rubber provides the isolation and the re-centering. The lead core deforms plastically under shear deformations at a predetermined flow stress, while dissipating energy through heat with hysteretic damping of up to 30 %.

In practice, bridges that have been seismically isolated using LRBs have been proven to perform effectively, improving the bridge seismic response during earthquake shaking. For instance, the Thjorsa River Bridge in Iceland survived two major earthquakes, of moment magnitudes (Mw) 6.6 and 6.5, without serious damage and was open for traffic immediately after the earthquakes as reported by Bessason and Haflidason[5]. In parallel, mageba will isolate its third bridge in the area of Quebec in 2017 after proving successful testing at –30 ˚C. The requirements of the new Canadian Seismic Norm S6-14 require seismic at –30 ˚C for 14 days and then 14 days at –8 ˚C. Interchange A20-A73 and A40-A73 are two examples of mageba LRB-isolated structures in Quebec.

In our studies, we concluded that lead rubber bearings, which are widely used to seismically isolate highway bridge structures, display a significant vulnerability to low temperatures (e.g. –30 °C) unless designed and fabricated for such conditions. In particular, their design should ensure that they display only minor variations in their effective stiffness at such temperatures. In specific cases it may require the development of a new rubber mixture, the modification of the general design of the isolators, and verification of low-temperature performance by means of extensive full-scale prototype testing.

Authors: Carlos Mendez-Galindo, Borja Baillés and Samy Rassy, all three work for mageba

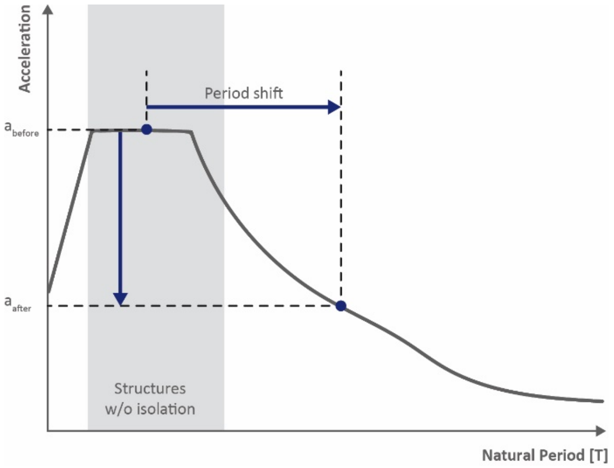

Fig. 1: Reduction of acceleration by seismic isolation only.

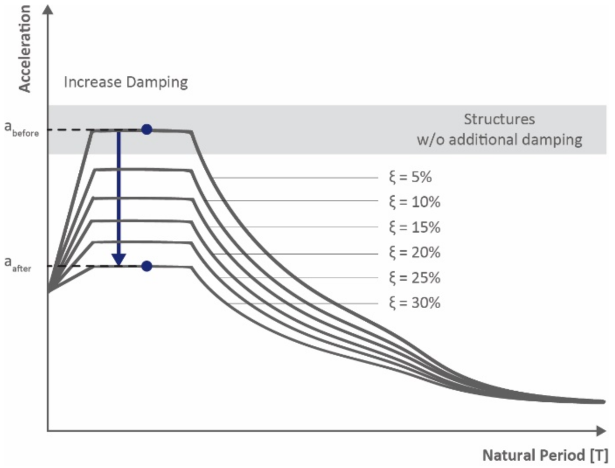

Fig. 2: Reduction of acceleration by additional damping.

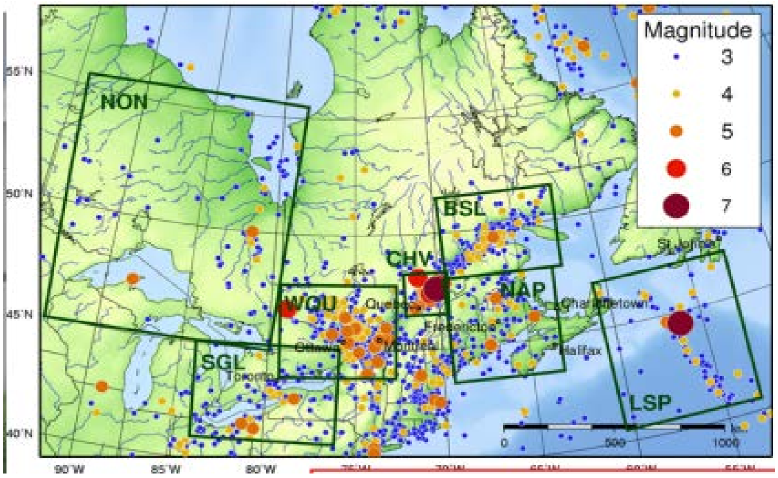

Fig. 3: Seismic Active areas in Eastern Canada – notably the Charlevoix seismic Zone in northeastern Quebec. With over 200 small earthquakes occurring each year, the Charlevoix Seismic Zone is one of the most active seismic zones in Canada.

Fig. 4: The A40/A73 Interchange –a structure sesimic isolated with LRBs by mageba

Fig. 5: The A20/A73 Highway Interchange in Levis, Quebec. Another structure seismic isolated with LRBs by mageba

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About mageba Group:

mageba is a Swiss company with its head office in Bulach, Switzerland. It is one of the world's leading suppliers of structural bearings, expansion joints and other high quality products and services for the transport infrastructure and building construction sectors. In the last 10 years, mageba has also significantly expanded its range of products and services relating to earthquake protection and structural monitoring.

The company was established in 1963 and today has over 800 employees worldwide, of which more than 100 are engineers. Some 120 people work at the head office in Switzerland.

mageba has subsidiary companies in Australia, Austria, China, Croatia, Czech Republic, Germany, Hungary, India, Mexico, Russia, Slovakia, South Korea, Turkey, United Kingdom and the USA. It is also exclusively represented in more than 50 other countries by authorized partner companies. mageba has to date supplied bearings and expansion joints for more than 20,000 structures, meeting even the exceptional challenges posed by a number of the world's largest bridges.

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