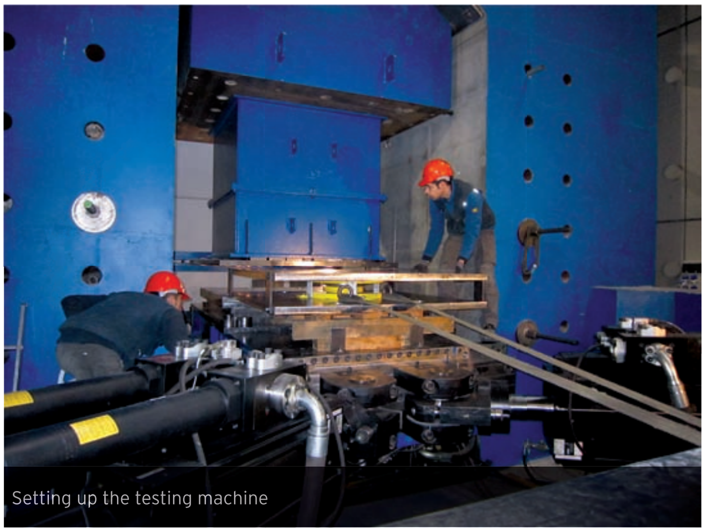
MEASURING UP


Setting up the testing machine

A new European norm regulates the design, production and testing of most types of anti-seismic devices. **Gianni Moor, Carlos Mendez** and **Colm O'Suilleabhain** explain what this means for the bridge industry

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 last August of the new European norm for anti-seismic devices, EN15129. 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. From August this year, only manufacturers certified to supply seismic devices with the CE label will be able to provide these devices in Europe.

This is a significant development for the bridge industry in Europe, due to the critical role bridges play as lifelines in the aftermath of an earthquake. The cost associated with repair or replacement of damaged bridges is likely to be small compared with the economic impact caused by disruption to traffic after an earthquake and during the long reconstruction phase.

In order to assure functionality of bridges, they must be designed to safely withstand the devastating forces of seismic ground movements. Past earthquakes have served as full-scale tests and the often tragic results have forced engineers to reconsider design principles and philosophies. Recent earthquakes have repeatedly demonstrated, for example, that during an earthquake, adjacent spans of multi-span bridges often vibrate out-of-phase, causing significant damage to the structures.

The need for safer bridges has stimulated the adoption of a common earthquake protection strategy which has seen conventional bearings being replaced by seismic isolation devices. An isolation system placed between the bridge superstructure and its supporting substructure is generally capable of increasing both flexibility and energy dissipation.

Flexibility in the horizontal plane will lower the frequency of the bridge, decreasing earthquake-induced acceleration, while the energy-dissipating capacity of the seismic isolators will considerably reduce the damaging energy exerted to the bridge piers. Moreover, when isolation bearings are installed on the top of a bridge's piers, the lateral force from the superstructure during a seismic event can be distributed among all piers, avoiding the concentration of lateral forces at specific locations.

Seismic isolation systems provide an alternative to conventional earthquake resistance design such as strengthening of structural elements, and have the potential for significantly reducing seismic risk without compromising safety, reliability, and economy of bridge structures. Together with the adoption of new performance-based design criteria, this has resulted in seismic isolation technologies already becoming the preferred option for many structural engineers.

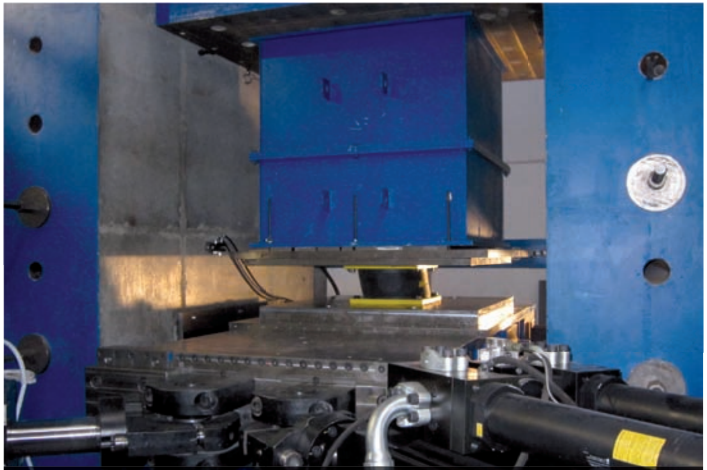
The main objective of a seismic isolation system is to increase the natural period of a structure. However, instead of elongating the period to high values, an adequate seismic design emphasises increased energy dissipation capability and distribution of lateral forces to as many substructures as possible. Bridges are ideal candidates for the adoption of seismic isolation technology due to ease of installation and inspection of isolation devices.

Among the different seismic isolation systems, elastomeric isolators such as lead rubber bearings and high-damping rubber bearings have found wide application in bridge structures, as have curved surface sliders, also known as pendulum isolators. This is due to their simplicity and the combined isolation and energy dissipation functions in a single compact unit. Both types of isolators provide a high level of damping. In terms of seismic protection, this is a crucial aspect to minimise the seismic energy flow to the superstructure and to limit the horizontal displacements of the isolators. In lead rubber bearings, the lead plug deforms plastically and thus dissipates energy through hysteretic damping. In the curved surface sliders, the energy is dissipated by friction between the sliding material and a curved stainless steel sliding surface.

The first testing of seismic isolation systems in accordance with EN 15129 has recently been carried out, at the European Centre for Training and Research in Earthquake Engineering in Pavia, Italy. The full-scale testing of two lead rubber bearing isolators and four curved surface slider isolators was carried out by specialist manufacturer Mageba. All tests achieved positive results, paving the way for certification with the CE label, verifying conformance with the applicable norm.

The Lasto lead rubber bearing isolators each had a diameter of 500mm and a total height of 286mm, and they were designed for a maximum displacement of 250mm and a maximum vertical load of 3,450kN. The samples were subjected to 14 different tests, most of them including dynamic conditions, with a total of 37 cycles, and with frequency and amplitude varying from one test to the next. The frequency ranged from 0.1Hz to 2Hz, while the amplitude varied from ±7mm to ±250mm. The velocities reached during the testing also varied, from as little as 0.02m/s to as much as 1.63m/s. Each isolator was also subjected to two compression tests, with loading gradually increasing up to the maximum value of 3,450kN. For all dynamic testing, which included simultaneous vertical compression, the applied vertical pressure of 6MPa represented a vertical load on the samples of 1,131kN.

In the case of the Reston curved surface sliders, two different types of device were tested: two Mono isolators with a single curved sliding surface, and two Duplo isolators which have two curved sliding surfaces. These feature the special sliding material known as Robo Slide – it is a modified, ultra-high molecular polyethylene with extremely high



Testing of the Lasto lead rubber bearing isolators

A Reston pendulum bearing under test

resistance to wear and high bearing capacity, developed specially for the bridge industry. Both Mono and Duplo isolators were designed to withstand the same dynamic demands: a maximum vertical design force of 4,000kN and a maximum horizontal displacement of 259mm, and were designed with a radius of curvature of 3.6m. The four full-scale curved surface sliders were subjected to 15 tests, of which 11 involved dynamic conditions. Each isolator underwent a total of 48 cycles during the whole testing campaign. The load bearing capacity test indicated in the norm requires a load of up to twice the maximum vertical force, which in the case of the curved surface sliders reached 8,000kN. Due to the importance of friction in this type of device, a test for frictional resistance force under service conditions was performed on the isolators, as well as a long-term friction test (up to 10,000m) of sliding material samples.

The sliding isolation tests are among the most important for curved surface sliders, since they test key parameters such as maximum design displacement and maximum design velocity. EN 15129 specifies ten different sliding isolation tests. These include a service test at a vertical load of 4,000kN, and a number of further tests such as seismic, dynamic, bi-directional, benchmark, property verification and integrity of overlay, at maximum displacement of 259mm and velocities of up to 0.275m/s. Finally, an ageing test with three full cycles was carried out on the same isolators in which the Robo Slide material had been artificially aged at a temperature of 70°C for 14 days. All the testing was supervised by an independent surveillance body which confirmed compliance with the requirements of EN 15129.

All of the testing carried out was completed successfully; the lead rubber bearing testing resulted in damping values of up to 25% and energy dissipated per cycle of up to 115kNm. This proved excellent performance in terms of displacement, load bearing capacity, stiffness and energy dissipation.

The testing of the curved surface sliders also demonstrated very high damping values of more than 30%, and energy dissipated per cycle of up to 95kNm, as well as the required coefficient of friction of the Robo Slide material. The results confirmed that all of the tested seismic isolators fulfil the strict standards established by the European norm EN 15129

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