SEISMIC ISOLATORS

GOODCO Z-TECH
A product of Canam-Bridges

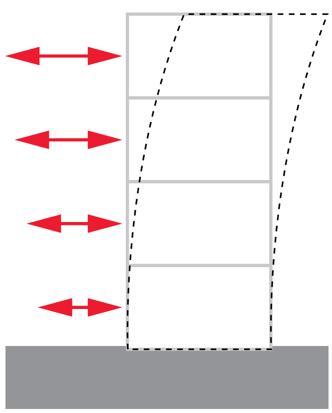
SEISMIC ISOLATION

Seismic isolation is one of the most effective ways to minimize structural damage and save lives during and immediately after any seismic event. It is also a cost-effective method to meet performance-based design requirements for minimal or repairable damage.

The installation of Goodco Z-Tech seismic isolators at key locations in a structure will increase its horizontal flexibility at the isolation layer. When an earthquake hits an isolated structure, the displacements will be concentrated in this isolation layer, resulting in a structure that will "sway" more softly with respect to the ground compared to a non-isolated (fixed-base) structure (Figure 1). Most of the displacement will be felt by the isolators instead of the structure.

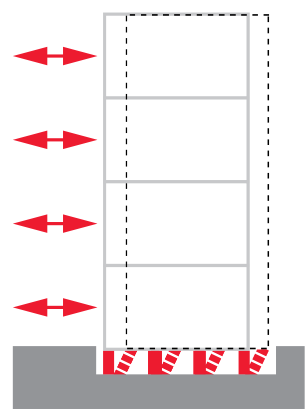
The isolators will also filter the acceleration transmitted from the ground to the structure. Only higher-frequency acceleration will be transmitted to the structure, reducing the forces in the members. This filtering of the acceleration isolates the structure. As the forces in the members are reduced, the structural design yields a lighter structure. The base-isolated structures can be designed to stay completely operational during and immediately after an earthquake at a lower construction cost than conventional, fixed-base structures.

Overall, seismic isolation works in a similar way as automobile suspension. The suspension absorbs the shocks due to uneven roadway, creating a smoother ride for the car occupants. Isolators absorb the seismic shock, isolating the building occupants from the earthquake movements.



Without base isolation

Figure 1.a: A conventional fixed-base (FB) structure
Fixed-base construction leads to large accelerations and considerable inter-storey drift. Even though a building may not collapse during an earthquake, significant damage occurs to its structural and non-structural elements, rendering it unusable.



With base isolation

Figure 1.b: A base-isolated (BI) structure
Deformations are concentrated in the isolation layer. The superstructure remains nearly intact. Structural and non-structural elements have little to no damage, and the structure remains usable so that operations can continue during and immediately after the earthquake.

APPLICATIONS

- Hospitals, emergency and communication centres, or any other essential community infrastructure that needs to be operational during and immediately after an earthquake
- Bridges that must remain fully serviceable for emergency traffic immediately after an earthquake
- Museums and data centres, or any other structures with valuable contents or operations
- Medium to high-rise residences and office buildings with high occupancy
- Heritage structures where extensive retrofitting is impossible
- New construction and retrofit projects

ADVANTAGES

- Lower acceleration in structures due to period shifting
- Less displacement in structures due to damping
- Minimum residual displacement in structures due to self-centering capacity
- Lighter structure than with conventional construction
- Operations can continue during and immediately after an earthquake
- Minimal strengthening required in retrofit projects
- Re-use of bridge piers and abutments in bridge deck replacement projects
- Custom-made to meet project requirements

ISOLATION **PRINCIPLES**

DESIGN PRINCIPLES

Seismic isolation reduces the seismic demand on a structure by increasing its lateral flexibility. As the structure's fundamental period is directly related to its lateral flexibility, the period of the structure also increases. In a typical spectral acceleration response, longer periods are associated with lower accelerations, reducing the base shear transmitted to the structure. The isolators also provide supplemental damping, which decreases the displacement demand typical of higher-period spectral responses.

Conventional, fixed-base structures rely on ductility to dissipate the energy transferred to the structure in the event of an earthquake, leading to irreparable damage but life safety and collapse prevention. Instead, base-isolated structures have less energy transferred to the system due to the increase in period. They rely on the hysteretic behaviour of the isolators to dissipate this energy while maintaining the integrity of the structure.

Overall, a base-isolated structure is lighter and more economical to build, while providing a higher level of service during and after an earthquake than a conventional, fixed-base structure.

DESIGN CONSIDERATIONS

For buildings, the isolation layer is typically located between the superstructure and the foundation, but other configurations may exist. The isolation layer for bridges is located between the bridge deck and the abutments and piers, with isolators acting as bridge bearings under service loads.

For the preliminary design of base-isolated structures, typical damping values can be approximated as 25% for buildings and 15% for bridges. During the design stage, both the period shift and the energy dissipation must be considered in the analysis of base-isolated structures.

Goodco Z-Tech seismic isolators can be designed for a wide range of damping values and can include fuses. Goodco Z-Tech standard products can accommodate damping values ranging from 5% to 35%. They can also be specially designed to accommodate higher damping values.

Highway 20/73 Interchange – Lévis, Quebec

SEISMIC ISOLATOR TYPES

Goodco Z-Tech offers a wide range of seismic isolators. The optimal choice for the isolator will depend on the structure's characteristics and the project specifications. Care must be taken in the choice of the device to optimize the benefits of the isolation system. Contact Goodco Z-Tech experts to determine which type of seismic isolator is best suited to your project and the preliminary dimensions of the device.

LAMINATED BEARINGS

For some structures, low-damping isolators can significantly reduce construction costs. In these cases, standard laminated bearings can provide approximately 5% damping. Since this type of bearing is very common, its use as an isolator is very cost-effective.

High-damping rubber bearings are built in the same way as standard laminated bearing pads, but with a different rubber compound that provides more damping. This increased damping is provided by additives mixed into the rubber during its manufacturing process. High-damping rubber bearings can provide approximately 10% damping. They are another cost-effective method to provide damping to a structure.

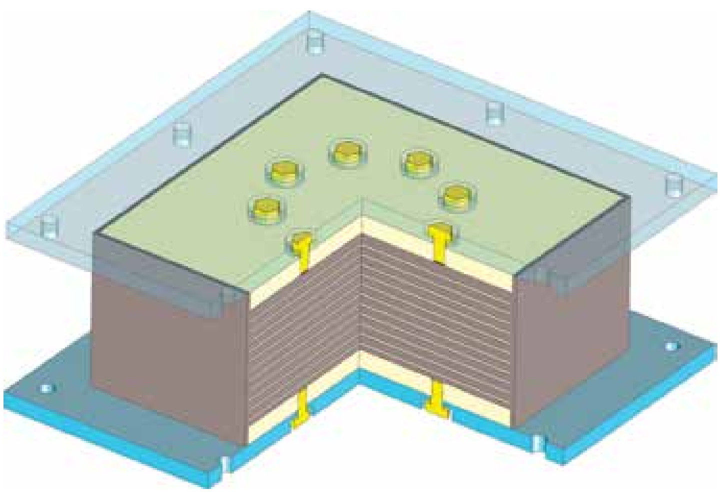


Figure 3: Elastomeric laminated bearing pads can be used to provide low damping for some projects. These bearing pads generally have a greater number of relatively thin internal layers compared to standard laminated bearing pads. They can be fabricated in a square or round shape. High-damping rubber bearings are constructed in the same manner.

LEAD-RUBBER BEARINGS

Lead-rubber bearings are another type of laminated elastomeric isolators. Here, a perfectly circular hole is made in the middle of a laminated bearing and filled with a lead core, which provides damping. This type of isolator provides more damping than high-damping rubber, typically up to 30%. However, as with all laminated elastomeric isolators, their vertical load-carrying capacity is limited.

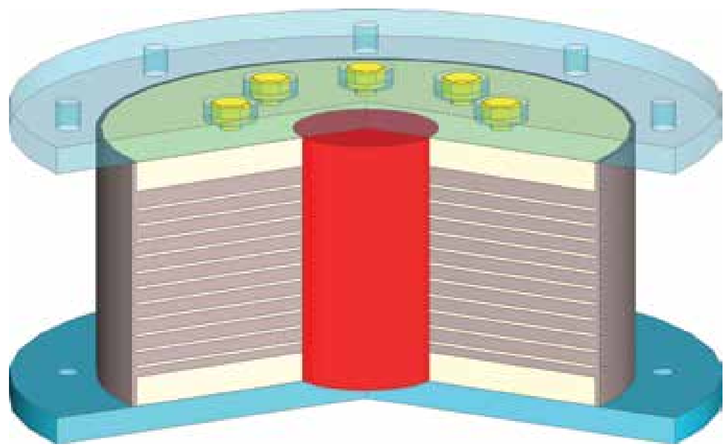


Figure 4: Lead-rubber bearings have a lead core that provides damping. Lead behaves as an elastic-plastic solid at room temperature and will regain its shape after deformation.

Product: Izolatech system

Project: Nicolet River on Highway 20 – Saint-Léonard-d'Aston, Quebec
Special product characteristics: The isolator has fuses to limit movement under non-seismic loads and has an equivalent damping capacity of more than 30%.

IZOLATECH SYSTEM (ZTS)

The Izolatech system (ZTS) can resist higher gravity loads due to a confined elastomeric disc. Energy is dissipated by the sliding interface and the spring elements, which deform. ZTS can be adapted to a wide range of damping values by changing the spring characteristics.

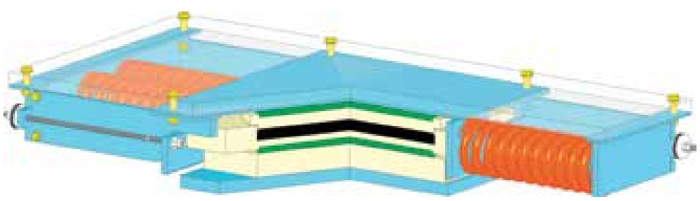


Figure 5: ZTS have high vertical load-carrying capacity and they can be designed with a wide range of damping values. The combination of the sliding interface and the spring elements provides a reliable energy dissipation system.

SERVICE OFFER

Goodco Z-Tech will provide technical support and prepare proposal drawings without any obligation on the part of the design engineer. In addition, we will supply any other information required for seismic isolators. Contact Goodco Z-Tech experts to identify which type of seismic isolator is best suited to your project.

FRICTION PENDULUMS

Friction pendulums are a different kind of isolator. They rely on the movement of two elements relative to one another to permit the lateral movement of the structure and dissipate energy. They can be used for light and heavy structures, as their period depends only on the radius of curvature. They can also carry a high vertical load and can provide more than 30% damping. However, contrary to the previous types of isolators described, friction pendulums must be used at all locations in a structure.

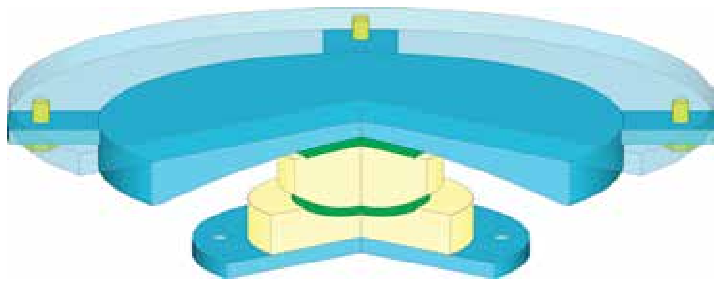


Figure 6: Friction pendulums rely on gravity to provide the restoring force. Since their lateral movement also creates a vertical movement, they must be installed throughout the structure. However, their period is a function of the radius of curvature radius only, which makes them a good alternative for light and heavy structures.

Product: lead-rubber bearings

Project: Highway 20/73 Interchange – Lévis, Quebec
Special product characteristics: The isolators were used to provide approximately 25% damping in the longitudinal direction. Transversal movement is impeded by guide bars that are welded to the upper and lower bearing plates. These guide bars also feature a unique sliding system that has a low coefficient of friction to allow longitudinal movement.

FEATURES

PERFORMANCE AT LOW TEMPERATURES

Goodco Z-Tech isolators are especially designed to withstand low temperatures and to meet the low-temperature testing criteria of the Canadian Highway Bridge Design Code or individual project specifications. Moreover, all of Goodco Z-Tech isolators satisfy the requirements of the AASHTO Guide Specifications for Seismic Isolation Design.

ISOLATOR TESTING

Goodco Z-Tech hires independent laboratories to perform full-scale dynamic tests on its isolators during their initial design stages. For each project, the seismic devices undergo qualification and quality control tests performed by independent laboratories in accordance with current Codes and Standards. Once prototype testing has shown that Goodco Z-Tech isolators meet project specifications, quality control testing is performed on each isolator before installation.

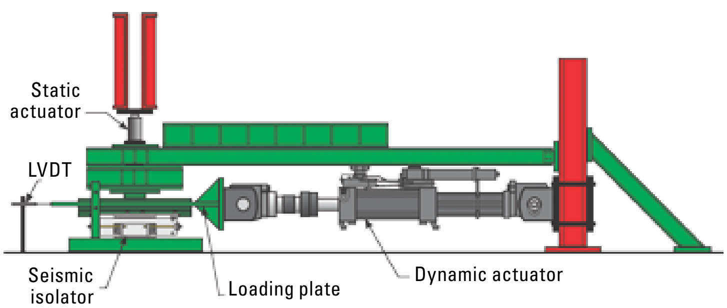


Figure 7: The test set-up at independant laboratory.

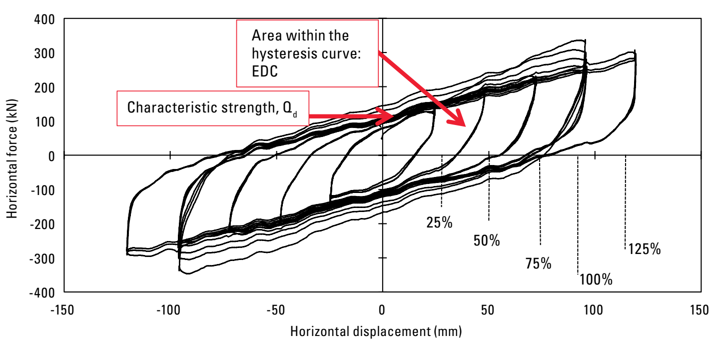


Figure 9: Force displacement curve during prototype tests of a lead-rubber bearing performed at room temperature, as specified in CAN/CSA-S6-06, section 4.10.11.2 c) ii).

Figure 8: ZTS in a testing facility at independant laboratory.

TERMS AND SYMBOLS

Hysteresis curve		The force-displacement relationship describing the behaviour of the isolator. Isolators are generally idealized with bi-linear hysteresis curves.
Yielding displacement	Δ_{Fy}	The displacement at which the isolation system yields. It is the transition point between the initial and secondary stiffness of the isolator.
Maximum displacement	Δ_{max}	The maximum displacement of the isolator.
Characteristic strength	Q_d	The force at which the hysteresis curve intersects with the axis.
Yield force	F_y	The force at which the isolation systems yields. It is the transition point between initial and secondary stiffness of the isolator.
Maximum force	F_{max}	The force at maximum displacement.
Elastic stiffness	K_y	The initial stiffness of the isolator. For lead-rubber isolators, this stiffness depends on the lead core. For friction isolators, this stiffness occurs before the initial slip.
Yielded stiffness	K_d	The secondary stiffness of the isolator. In the case of lead-rubber isolators, this stiffness occurs after the lead core has yielded and depends on the rubber. For friction isolators, this stiffness occurs after the initial slip and depends on the restoring force (spring rigidity or radius of curvature).
Effective stiffness	K_{eff}	Maximum force divided by maximum displacement.
Energy dissipated per cycle	EDC	The area under the hysteresis loop. The total energy dissipated by one cycle of the isolator.
Damping	ß	The equivalent viscous damping ratio of the isolator.

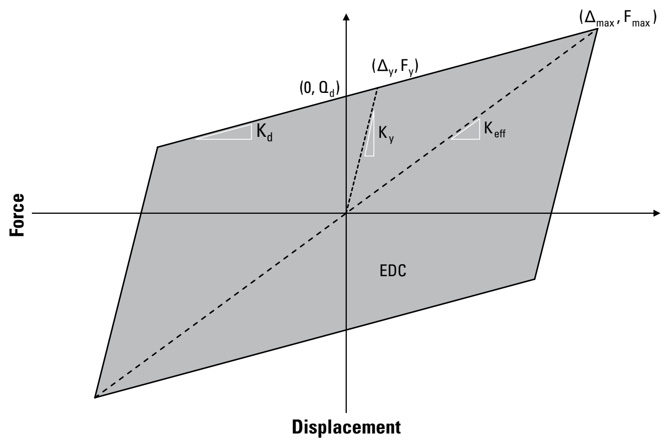


Figure 10: An idealized bi-linear hysteresis curve for a seismic isolator.

Product: laminated bearings

Project: Highway 10 at the Richelieu River – Carignan, Quebec
Special product characteristics: Standard laminated bearings were used to provide damping of approximately 5%. The use of standard laminated bearing pads can be a cost-effective method to isolate a bridge where only low damping is necessary.

BUILDING BETTER BRIDGES

With more than 60 years of experience, Goodco Z-Tech is the leading Canadian fabricator of structural bearings and expansion joints. Relying on the knowhow of our highly skilled team and state-of-the-art equipment, Goodco Z-Tech designs and fabricates a broad range of products for highway and railway bridges, and other structures. Goodco Z-Tech works in close collaboration with Canam-Bridges, a North American leader in the design, fabrication and construction of steel bridges.

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