ANTI-SEISMIC DEVICES
**INTRODUCTION**

FIP Industriale is proud of its contribution to the development of anti-seismic devices, in particular seismic isolation and energy dissipation devices, in the last 30 years.

In the Seventies FIP Industriale designed and manufactured the anti-seismic devices for the first European seismically isolated bridge structure, the Somplago Viaduct on the Udine-Tarvisio motorway.

Since then, continued research and development led FIP Industriale to a complete range of anti-seismic devices, that are employed to implement either the conventional approach of earthquake engineering or the innovative approach, i.e. passive control of the structural response through seismic isolation and/or energy dissipation.

The advantages of the innovative approach are well known:
- damage to structural elements can be fully avoided or at least strongly reduced;
- seismic isolation is the only technology able to guarantee complete functionality of a structure even after a strong earthquake.

At FIP Industriale flexibility is a must. This makes it possible to work according to the most diversified international standards and project specifications, as well as to develop completely new devices based on customer needs.

Thanks to one of the biggest laboratories in Europe of its type, where equipments comprise of a 8,000 ton test rig and several rigs for dynamic testing employing 680 kW hydraulic power supply system, the devices are full-scale tested at FIP Industriale.

Not only third parties regularly witness testing at FIP Industriale; the devices are also tested at independent international laboratories. For example, both fluid viscous dampers and flat surface sliders with steel hysteretic dampers have been tested in California according to the USA's HITEC protocol.

Worth of note are also the tests carried out on the Caltrans SRMD Test Facility at the University of California San Diego on the fluid viscous dampers for the Rion-Antirion Bridge, tested up to the maximum design velocity of 1.6 m/s, and for the Loureiro Bridge (Portugal). Further to testing at University of California Berkeley, FIP Industriale is the only non- American viscous dampers manufacturing Company pre-qualified for retrofit of the Golden Gate Bridge. Moreover FIP Industriale is approved supplier of viscous dampers for Caltrans. The ever-increasing number of structures worldwide protected by FIP Industriale’s anti-seismic devices, gives conclusive testimony of their technical competence and commitment.

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- TAIWAN, TAIPEI -- Taipei 101 Skyscraper
  viscous dampers for the Tuned Mass Damper

- UAE, ABU DHABI -- Sheikh Zayed Bridge
  seismic isolators, viscous dampers, fuse restraints
FIP Industriale designs and manufactures its devices in accordance with the most widely adopted and stringent international specifications: EN, AASHTO, CNR, British Standards, DIN, NF. At present, FIP Industriale meets the most recent requirements by supplying bearings and anti-seismic devices with CE marking.

The certification ISO 9001, obtained in 1992, guarantees that the same quality level is kept from the design stage through manufacture to installation, while the Certificate OHS 618800 guarantees that FIP Industriale operates an Occupational Health and Safety Management System which complies the requirements of BS OHSAS 18001:2007. FIP Industriale’s quality system is also certified to perform welding activities in accordance with EN ISO 3834-2 and DIN 18800-7.

These prestigious record projects include:

- the **Storebælt Bridge** in Denmark, the *longest suspension bridge in Europe*. Here displacements are controlled by shock transmission units designed for 5000 kN and ±1100 mm;
- the **Taipei 101 Skyscraper** in Taipei - Taiwan, one of the *world’s tallest buildings* (508 m), whose tuned mass damper implements FIP Industriale’s special fluid viscous dampers, designed to have different behaviour to earthquakes and windstorms;
- the **Rion-Antirion Bridge** in Greece, benefits from the *world’s longest fluid viscous dampers* (11.3 m pin-to-pin length);
- the twins **St. Francis Shangri-La Towers** in Manila - Philippines, where viscous dampers are installed into the structure according to an ARUP newly developed and patented configuration;
- the **Stonecutters Bridge** in Hong Kong, 1018 m main span, protected by the *world’s most advanced shock transmission units* (maximum force 8000 kN);
- The **Izmit Bay Bridge** in Turkey, the second longest suspension bridge in Europe, for which FIP Industriale has realized the *biggest hydraulic devices ever built* for similar applications.

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**BIM READY**

The use of shared digital representations to facilitate the design, construction and operation of a structure is the starting point for a reliable and interactive decision-making process which allows municipalities, private clients, contractors and designers to rule all their choices.

FIP Industriale is able to provide BIM models – according to IFC standard – to its Clients in such a way to support the communication, cooperation, simulation and improvement of a project through the whole design life of the built or building structure.
Elastomeric isolators (EIs) are made up of rubber layers alternating with steel laminates joined together through vulcanization. Their behaviour can be modelled as linear, by means of effective stiffness and equivalent viscous damping. Usually they are manufactured with High Damping Rubber compound, i.e. with equivalent viscous damping 10-15% at 100% shear strain (HDRB).

Lead Rubber Bearings (LRBs) are elastomeric isolators with a cylindrical lead plug inserted in their centre, with the aim to increase the damping by hysteretic shear deformations of the lead. The equivalent viscous damping can be up to 30%. Their constitutive behaviour, typically bilinear, can be modelled as linear or non-linear, according to the used code.

Experimental hysteresis loops of an EI at frequency 0.5 Hz, shear strain ±100%.

Experimental hysteresis loops of an LRB at frequency 0.5 Hz, shear strain ±100%.

Setting up for testing of two 1150 mm diameter EIs at FIP laboratory.

LRB under shaking table testing at the National Technical University of Athens, Greece.

EIs as installed in the "Da Luz" Hospital, Lisbon, Portugal.

LRBs as installed in an office building in Italy.
The Curved Surface Sliders (CSSs) or Friction Isolation Pendula (FIP®) use gravity as the restoring force. Energy dissipation is provided by friction in the main sliding surface. The parameters of the bilinear constitutive law depend on the radius of curvature and friction coefficient. For very large displacements CSSs may be substituted by Double Concave Curved Surface Sliders (DCCSSs).

These isolators combine in a single device a slider and dampers, that typically are steel hysteretic and/or fluid viscous dampers. Thus, the resulting behaviour is characterised by a very high energy dissipation capacity. The slider can be free-sliding or guided, as required. The isolator can also combine STUs or mechanical fuse restraints.
GREECE – Rion Antirion Bridge
fluid viscous dampers, 3500 kN ± 2600 mm

TURKEY – Izmit Bay Bridge
viscous dampers
Fluid Viscous Dampers (FVDs) are cylinder/piston devices that exploit the reaction force of silicon fluid forced to flow through an orifice and/or valve system. The typical force-velocity law of FIP’s FVDs is non-linear, i.e. $F=Cv^\alpha$, where $\alpha=0.15$, $F$ is the force, $C$ is the damping constant and $v$ is the velocity. Different values of the exponent $\alpha$ can be provided on request.

The reaction force $F$ of Fluid Spring Dampers (FSDs) depend on both imposed velocity $v$ and displacement $x$ according to the law $F=F_0+Kx+Cv^\alpha$, where $F_0$ is the pre-load force, $K$ is the stiffness, $C$ is the damping constant and $\alpha=0.15$. The pre-load force can be useful to avoid displacements under service horizontal loads (e.g. braking forces in a bridge).

Classification and graphic representation (plan view) according to the European standard EN 15129 “anti-seismic devices”
**DISPLACEMENT DEPENDENT DEVICES**

**STEEL HYSTERETIC DAMPERS**

Steel Hysteretic Dampers (SHDs) use as a source of energy dissipation the hysteretic yielding of steel elements of various shapes, developed to guarantee many stable hysteresis loops.

The most used elements are the crescent moon and the tapered pin (single or double). SHDs can be combined with STUs, when necessary to handle significant thermal movements.

![Experimental hysteresis loops of a SHD with crescent moon elements.](image)

**SHAPE MEMORY ALLOY DEVICES**

Shape Memory Alloy Devices (SMADs) are axial restraint devices exploiting the superelastic properties of shape memory alloys in the austenitic state.

Their force-displacement curve exhibiting one or more “plateaux” enables SMADs to limit the maximum load transmitted to the structure to which they are connected. They have a strong recentring capability.

![Experimental force vs displacement curve of a SMAD.](image)

**BUFFERS**

Buffers are double-acting axial devices comprising a certain number of elastomeric discs, each of them vulcanized to two steel plates.

A particular arrangement of steel rods allows the discs to always be compressed, regardless of the direction of the movement.

Buffers are used in bridges at abutments and/or between adjacent decks where expansion joints are located.

![Experimental force vs displacement curve of a buffer.](image)

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Elastomeric Viscoelastic Dampers (EVEDs) are made of one or several layers of elastomer which are strained in shear, connecting the relatively moving parts of a structure. Usually they are installed in bracings in framed buildings. The elastomer compound used is high damping, with equivalent viscous damping 15÷20% at 100% shear strain.

Experimental hysteresis loops of an EVED at frequency 0.5 Hz, shear strain ±100%.

Classification and graphic representation (plan view) according to the European standard EN 15129 "anti-seismic devices"
CHINA, HONG KONG -- Stonecutters Bridge shock transmission units, 8000 kN ± 400 mm
Shock Transmission Units (STUs) provide a very stiff dynamic connection, whilst their reaction to low velocity applied displacements, e.g. due to thermal changes, is negligible. STUs find valid application whenever the structure is requested to change its behaviour in the event of earthquakes or other dynamic actions. Sometimes STUs are also referred to as lock-up devices.

Guide bearings and restraint bearings are devices which provide steady restraint in one or two horizontal directions, respectively, accommodate rotations and vertical displacements, i.e. do not transmit bending moments and vertical loads. Guide bearings are also referred to as Moveable Connection Devices, and restrained bearings as Fixed Connection Devices.

Mechanical Fuse Restraints (MFRs) below a pre-established force threshold prevent relative movement between connected parts, whilst they permit movements after the aforementioned threshold has been exceeded, provoking the breakaway of sacrificial components. Movements can be in one or any direction; i.e. a MFR can be designed to become a guide bearing after breakaway.

Classification and graphic representation (plan view) according to the European standard EN 15129 "anti-seismic devices"