Use of elastomeric compounds for seismic protection of the structures

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Seismic design methods

Conventional design (base fixed structures)

⇒Collapse is prevented at design earthquake
⇒Damages are allowed
⇒The resistance is achieved increasing the structural strength

Smart design (isolated structures)

⇒ The resistance is achieved reducing the seismic response
⇒Possible damages are concentrated in the devices
⇒The structure and its content can be protected from damages

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Seismic isolation system goals

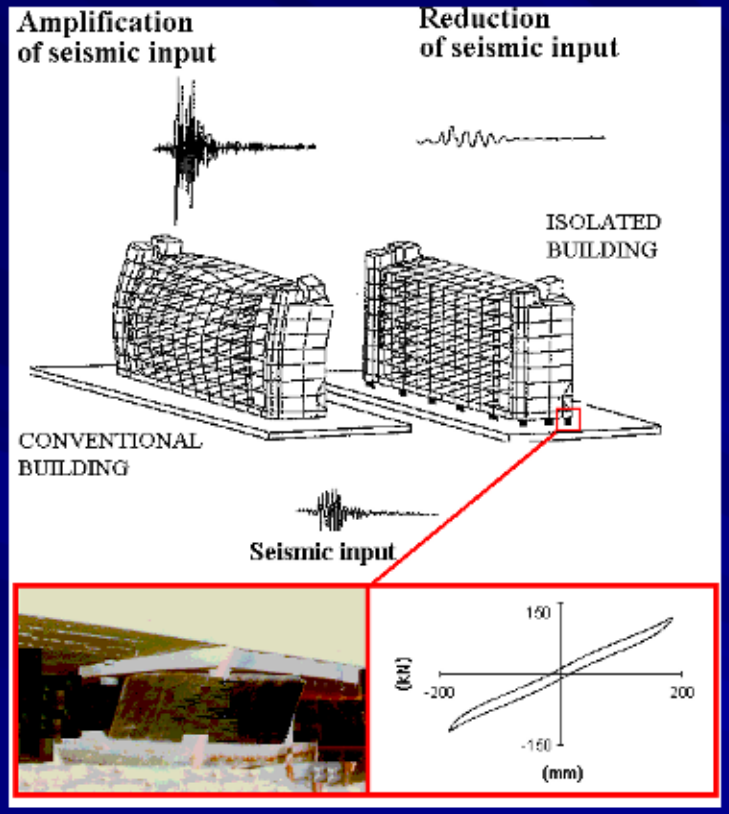
- Support the structure weight
- Allow horizontal movement
- Recentering capability
- Energy dissipation

The seismic isolator is a device that gives the four requirement in a single unit

SEISMIC DEVICES

- E-Safe HDRB High Damping Rubber Bearings
- E-Safe LRB Lead core Rubber Bearings

BASE ISOLATION



MAIN TARGET: SAFETY of PEOPLE, STRUCTURES and EQUIPEMENTS

by a real disengagement between structure and ground behaviors

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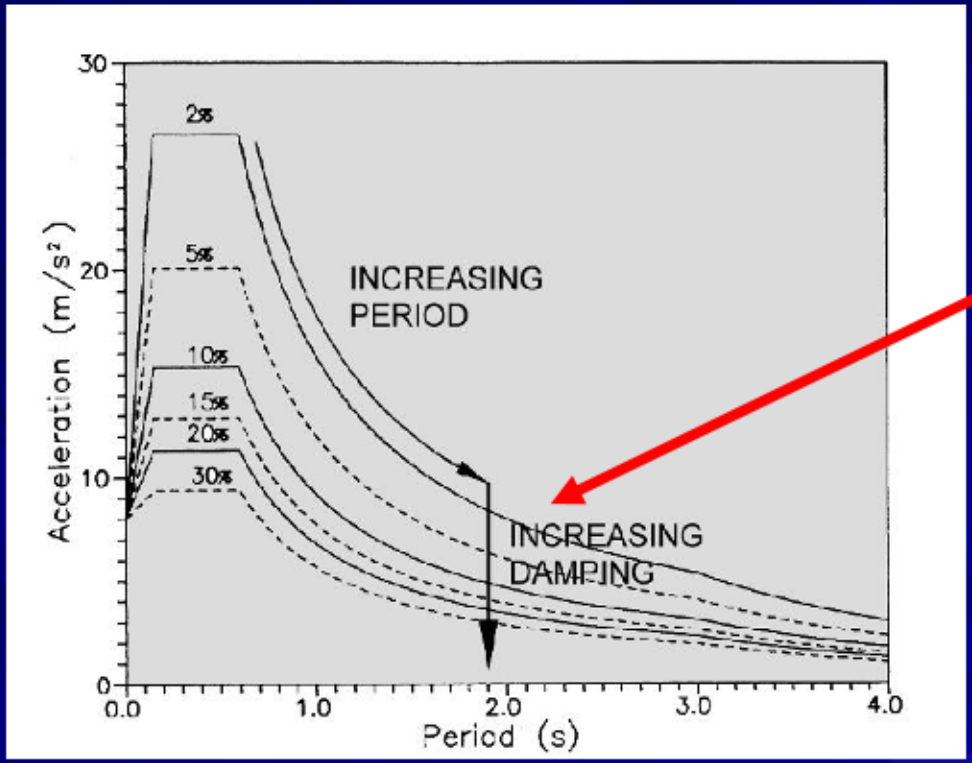
BASE ISOLATION

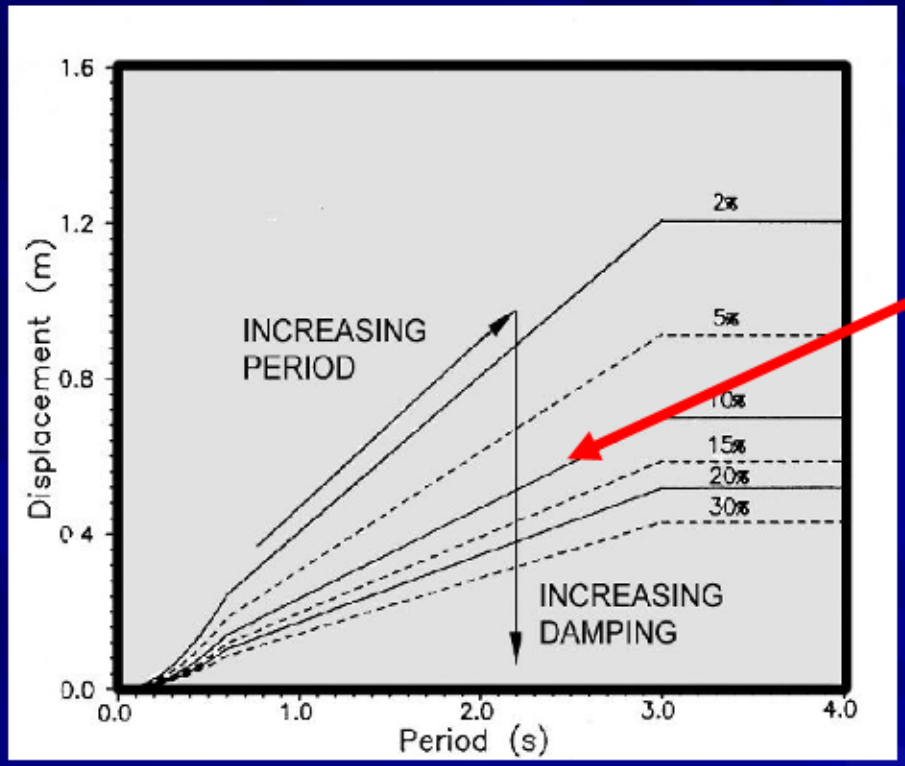


Isolated structure

Effects of period shift on the acceleration

In order to minimize the acceleration of the structure is it possible to design a specific isolator with a defined value of damping

BASE ISOLATION



Isolated structure

Effects of damping on displacement

Increasing the damping the period of vibration moves to the higher values: it means slow movement of the structure and higher levels of safety for people and equipments

Isolation system design

M = structure mass

T = target isolation period

$$K = M\frac{4\pi^2}{T^2}$$

K = total isolators stiffness

Isolator stiffness

$$K_i = \frac{GA}{h}$$

G = rubber shear modulus

A = rubber isolator plan area

h = isolator total rubber thickness

Isolation system design

Isolator damping

η = acceleration reduction factor

$$\eta = \sqrt{\frac{10}{5+\xi}} \geq 0{,}55$$

Examples

For ξ = 10% η = 0,82

For ξ = 16% η = 0,69

$$a_{design} = \eta a(T)$$

Design codes

- European EN15129 / EN 1337-3
- American AASHTO Guide Specificaiton for Seismic Isolation Design

Low damping rubber compound

Table 10 — Mechanical and physical properties of low damping elastomers

Property	Requirement			Test Method
Shear modulus[a] (MPa)	$0,3 \le G \le 0,7$	$0,7 < G \le 1,1$	$1,1 < G \le 1,5$	
Tensile strength (MPa), min. Moulded test piece Test piece from isolator [b]		16 14		ISO 37 Type 2
Elongation at break (%), min. Moulded test piece Test piece from isolator [b]	 450 400	 425 375	 350 300	 "
Tear resistance[c] (kN/m), min.	5	8	10	ISO 34[g] Method A
Compression set[d] 70 °C, 24 h, max.	30	30	30	ISO 815 Type A 25% compression
Ozone resistance[e] Elongation 30 % - 96 h 40 °C ± 2 °C	no cracks	no cracks	no cracks	ISO 1431-1
Accelerated air oven ageing[f] Maximum change from unaged value Hardness (IRHD) Tensile strength (%) Elongation at break (%)	 -5, +8 ± 15 ± 25	 -5, +8 ± 15 ± 25	 -5, +8 ± 15 ± 25	ISO 188, Method A ISO 48 ISO 37 Type2 "

NOTE Because the ozone and ageing tests are checks that appropriate antidegradants have been included, not tests related to service performance, their effectiveness necessitates that the conditions should be appropriate to the elastomer

High damping rubber compound

Table 11 — Mechanical and physical properties of high damping elastomers

Property	Requirement		Test Method
	Moulded Sample	Test piece from device[d]	
Tensile strength (MPa), min.	12	10	ISO 37 Type 2
Elongation at break (%), min.	400	350	"
Tear resistance (kN/m), min.	7		ISO 34[c] Method A
Compression set 70 °C, 24 h, max.	60		ISO 815 Type A 25% compression
Ozone resistance[a] Elongation 30 % - 96 h 40 °C ± 2 °C	no cracks		ISO 1431-1
Accelerated air oven ageing[b] Maximum change from unaged value			ISO 188, Method A
Hardness (IRHD)	-5, +8		ISO 48
Tensile strength (%)	± 15		ISO 37 Type 2
Elongation at break (%)	± 25		"

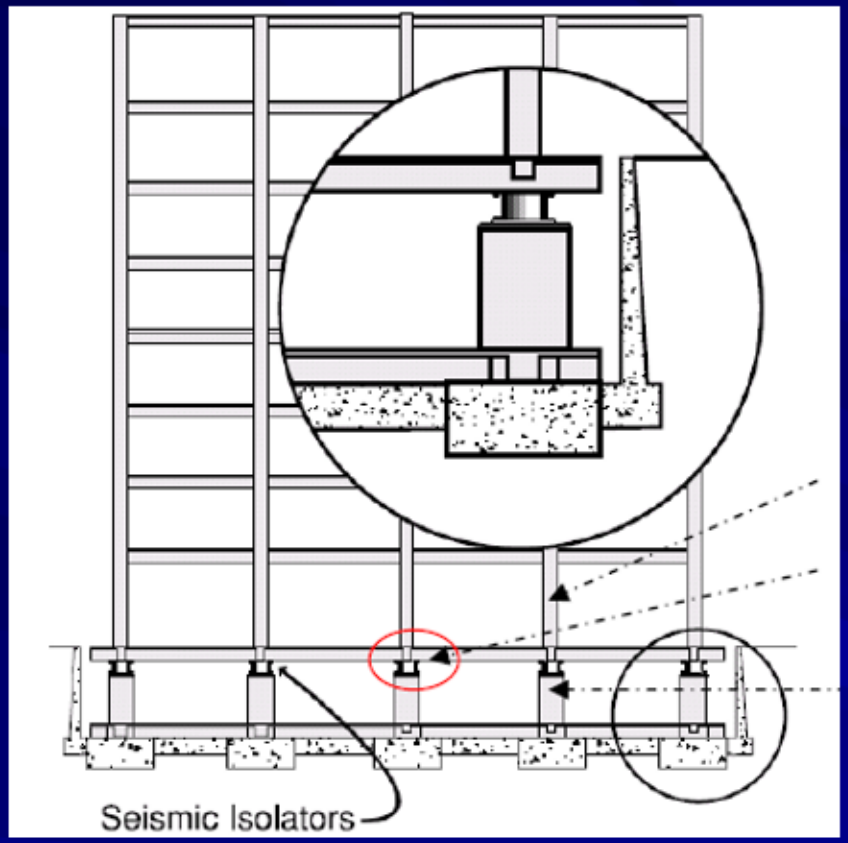
NOTE Because the ozone and ageing tests are checks that appropriate antidegradants have been included, not tests related to service performance, their effectiveness necessitates that the conditions should be appropriate to the elastomer used in manufacture of the devices.

[a] The ozone concentration shall be appropriate to the elastomer used. For natural rubber based vulcanisates, 25 pphm shall be used and for polychloroprene based vulcanisates 100 pphm. For other elastomers, the values shall be given in the relevant EADs. For elastomers with no unsaturated carbon-carbon bonds, an ozone test need

Isolators design parameters

- Maximum vertical load in static condition
- Maximum vertical load in seismic condition
- Minimum vertical load in seismic condition
- Device horizontal stiffness
- Device design displacement (seismic, thermal, irreversible movements)
- Device equivalent viscous damping

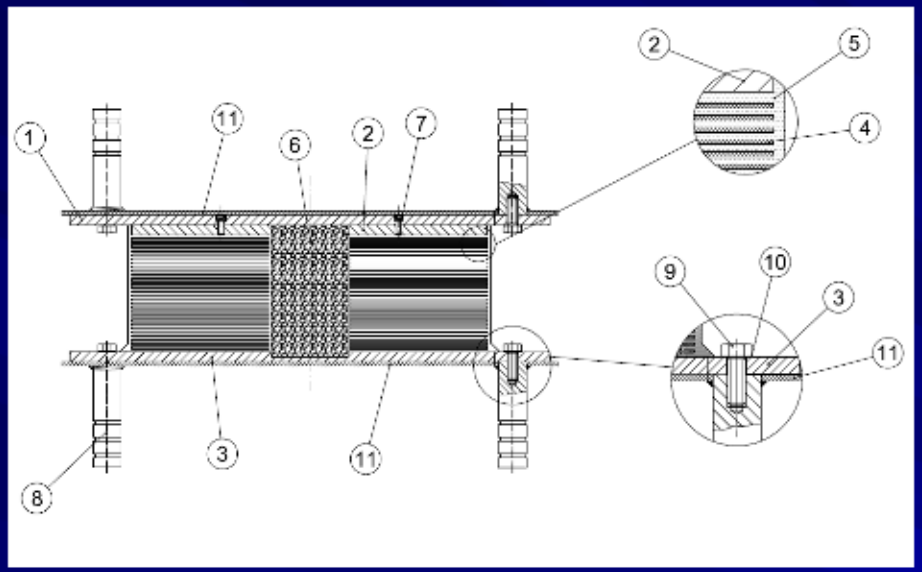
BASE ISOLATION

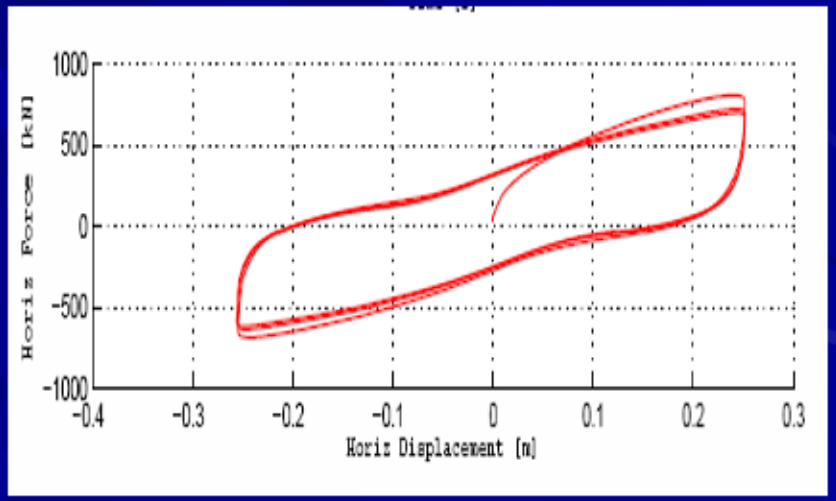


- This application is based on a special elastomeric bearing named “ISOLATORS” made of special rubber compounds.
- The main features of this kind of rubber are: excellent elongation, tensile strength and bond, high damping, resistance to the ageing agents.
- The isolation system disconnect the structure from the ground.
- The structure moves like a rigid body during the seismic event.

Base Isolation:

LEAD RUBBER BEARINGS with Lead Core as dissipating device





E-Safe LRB

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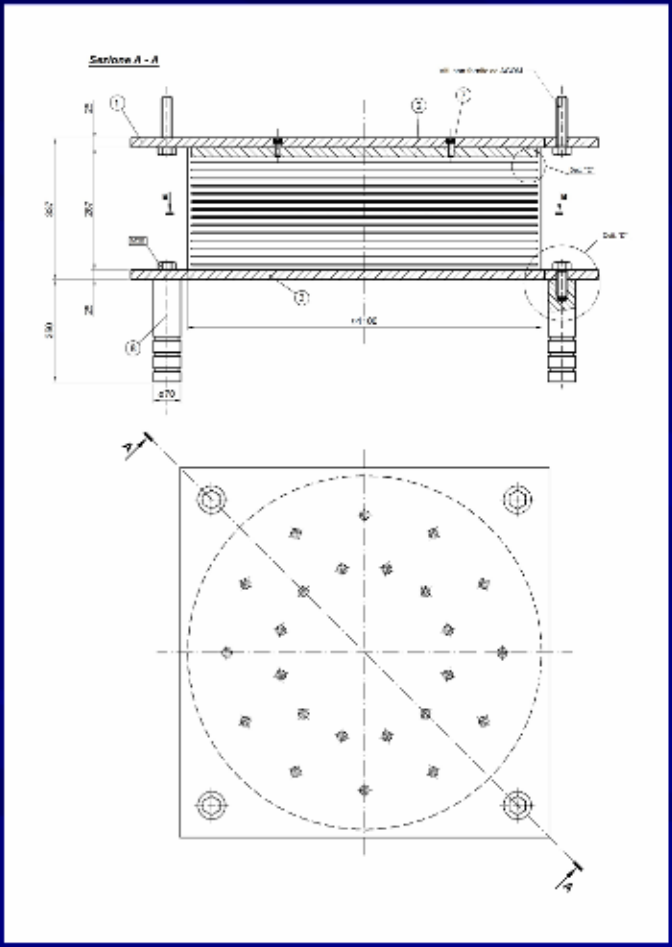
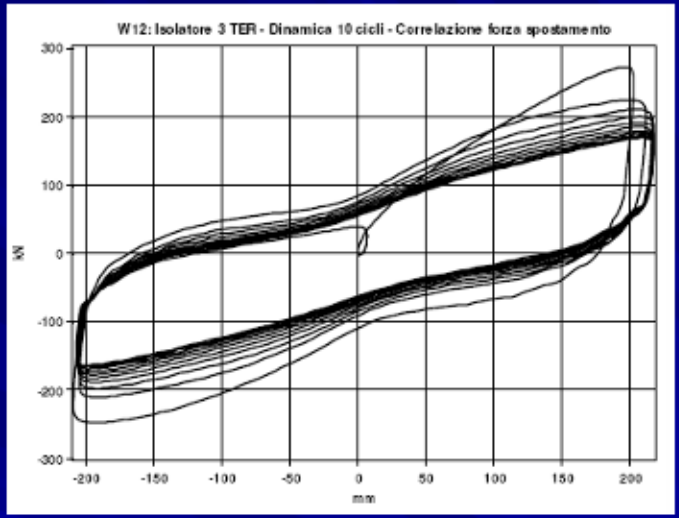
Base Isolation:

HIGH DAMPING RUBBER BEARINGS
made of high damping rubber compound





E-Safe HDRB

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BASE ISOLATORS *E-Safe*

Tested at independent and certified laboratories according to the most important seismic standards

- Top quality materials
- Certified behavior
- Easy installation
- Practically free of maintenance

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AGOM BASE ISOLATORS *E-Safe*

Very severe vertical load test: 3 times the design value is applied:

- Vertical load of 8700 kN on 500 mm isolator diameter

- Resultant 45 N/mm^2 rubber pressure

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AGOM BASE ISOLATORS *E-Safe*

Testing according to International standard (example european EN1529):

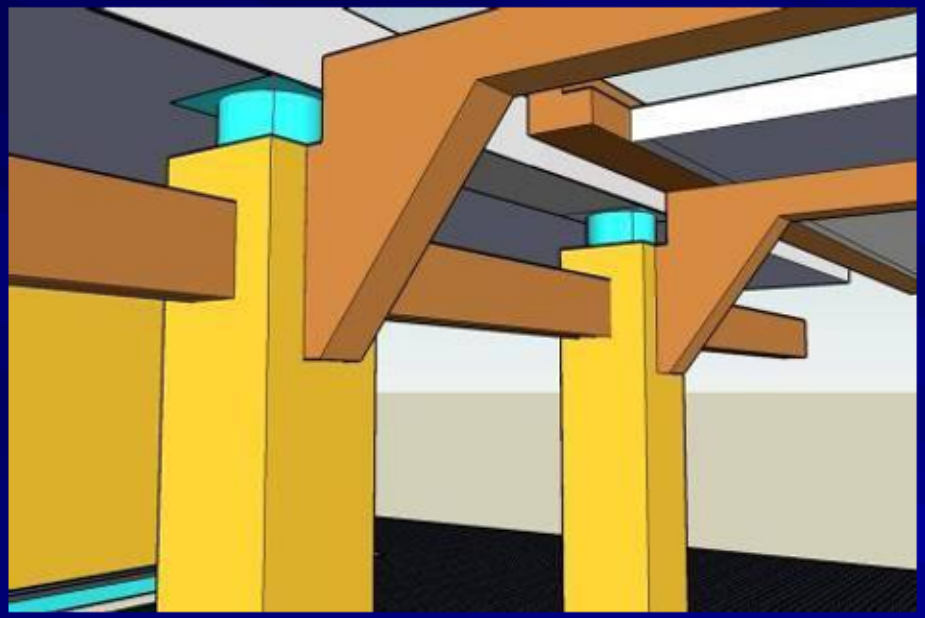
- Compression stiffness
- Dynamic tests: lateral stiffness and damping
- Compression capacity
- Lateral capacity
- creep

ISOLATORS – Wide Range

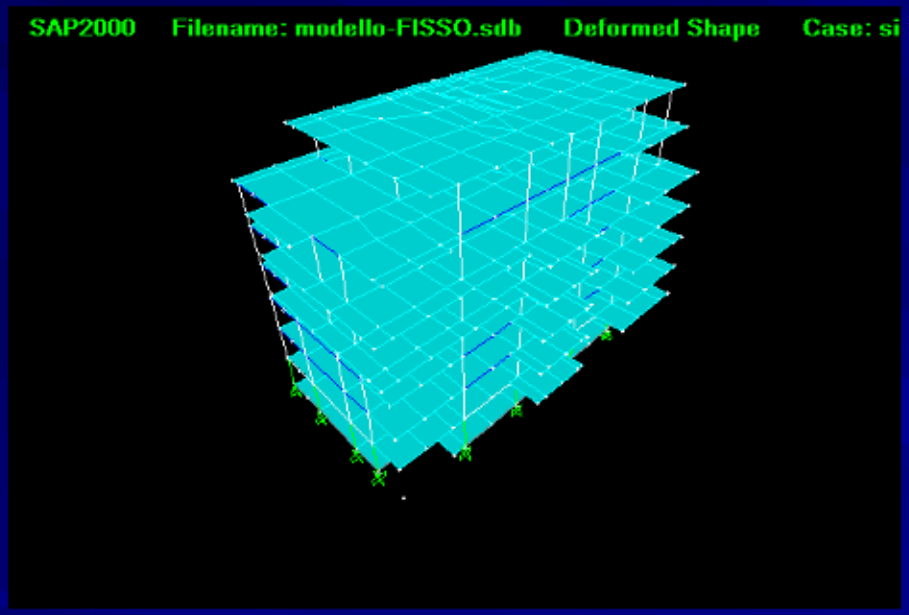
Diameters from 80 to 1400 mm

Seismic isolated building in Milano

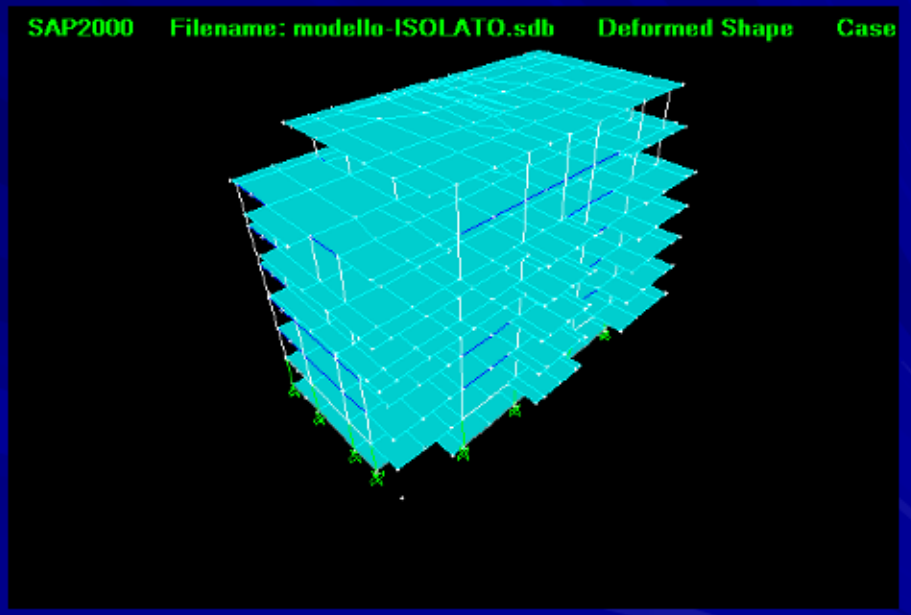
Isolator positioning



Building seismic dynamic analysis

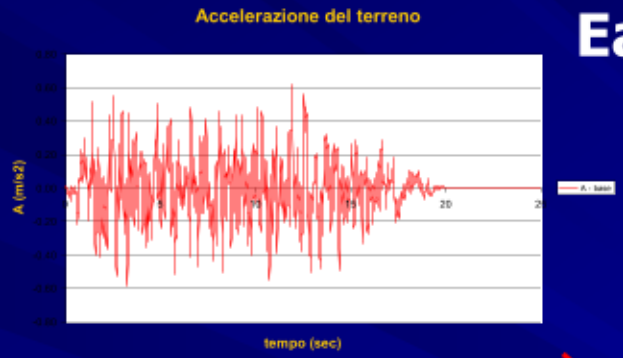


Fixed base building

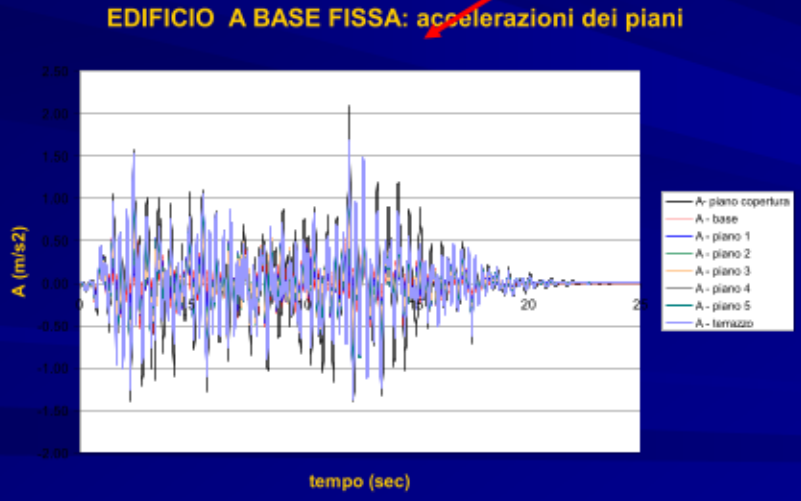


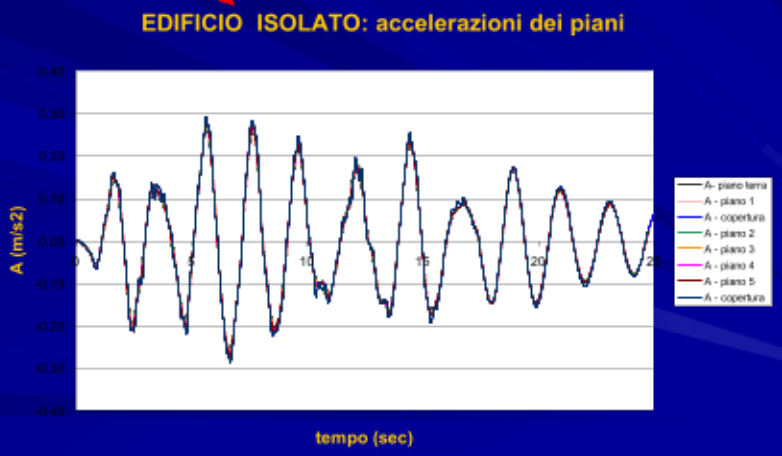
Isolated building

Isolated building dynamic response



Earthquake signal





Fixed base building

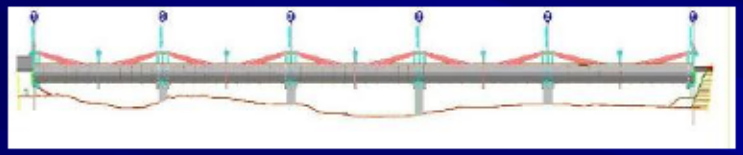
Isolated building

E-Safe HDRB
AGFLEX

ULULONE BRIDGE

Interchange S.S. 43 Fai della Paganella

Location: Mezzolombardo, Trento, Italy
Owner: Regione Trentino
Contractor: Impresa Collini S.p.A.
Consultant: In.Co.
Total length: 227 m
Date: 2006÷2007



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PONTE DI FRONTIERA TIENDITAS

Location: Colombia/Venezuela border
Owner: Instituto Nacional de Vías (Colombia) / Fondo Nacional de desarrollo (Venezuela)
Contractor: Conconcreto (Colombia) / Pilperca (Venezuela)
Consultant: Santander y Asociados (Colombia) and
Diseño y Construcciones Integrados (Venezuela)
Total length: 280 m
Date: 2015

n.36 elastomeric seismic isolators with lead core with diameter up to 1400 mm

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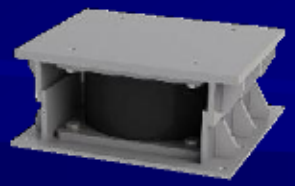
PONTE METÁLICA DE ABRANTES

Location: Abrantes, Portugal
Owner: Estradas de Portugal S.A.
Contractor: Domingo da Silva Teixeira S.A
Consultant: Betar Consultores
Total length: 330 m
Date: 2015÷2016



n.24 high damping elastomeric seismic isolators

"SANTO CHIODO" STORE OF CULTURAL GOODS

Location: Spoleto, Italy
Owner: Regione Umbria
Contractor: Torelli Dottori S.p.A.
Consultant: RA Consulting
Function: conservation, maintenance and development of historical and artistic goods
Date: 2006÷2007

n.32 elastomeric seismic isolators with lead core
n.17 free sliding pot bearings

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SHACOLAS SHOPPING MALL

Location: Nicosia, Cyprus
Owner: ITTL Trade Tourist & Leisure Park Ltd
Contractor: Vert & Blanc Enterprise Ltd
Consultant: Redesco s.r.l.
Date: 2007

n.22 high damping elastomeric seismic isolators
n.48 free sliding pot bearings

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AXPO NUCLEAR POWER PLANT

Location: Leibstadt, Switzerland
Owner: Kernkraftwerk Leibstadt AG
Operational Manager: Axpo Power
Designer: Studio Ingegneria Sciarini SA
Total installed performance: 1,220 MW
Date: 2013

n.10 elastomeric seismic isolators with lead core

HIGH SCHOOL SEISMIC BASE ISOLATION

E-Safe LRB
V-Max

Location: Ipseoa "Caterina De' Medici", Gardone Riviera, Italy
Owner: School Administration – Province of Brescia
Contractor: Biserni Costruzioni
Consultant: Studio INARGEO
Total building floors: 3
Date: 2015÷2016

n.62 elastomeric seismic isolators with lead core
n.26 free sliding pot bearings

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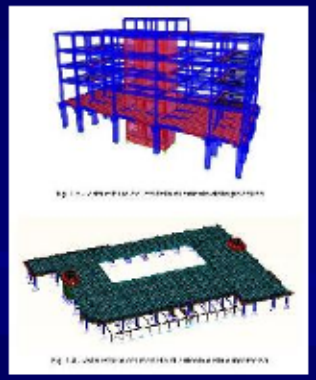
HEADQUARTERS OF FIREFIGHTERS IN ANCONA

Location: Ancona, Italy
Owner: Ministry of Infrastructure and Transportation
Contractor: Torelli Dottori S.p.A.
Designer: ALL Ingegneria
Date: 2016



n.20 high damping elastomeric seismic isolators
n.14 free sliding pot bearings

Thank you for the attention

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