NatRisk

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Development of master curricula for natural disasters risk management in Western Balkan countries

Isolation and Dissipation Systems for Seismic Protection of Structures

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Teaching staff training and study visit
Messina, 19th -21st September 2017

Project number: 573806-EPP-1-2016-1-RS-EPPKA2-CBHE-JP

"This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein"

Modern technologies for the building seismic protection

Active control

They are usually hydraulic actuators, electronically controlled, that works when the earthquake exceeds a certain limit, applying to the structure some forces that are opposite to those produced by the earthquake.

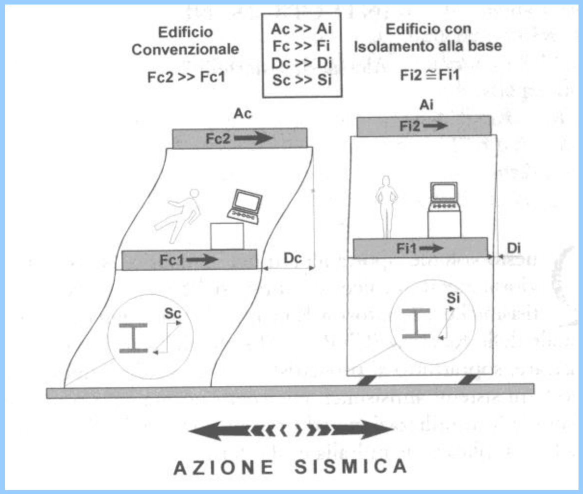
Passive control

Base isolation systems and Energy dissipation systems.

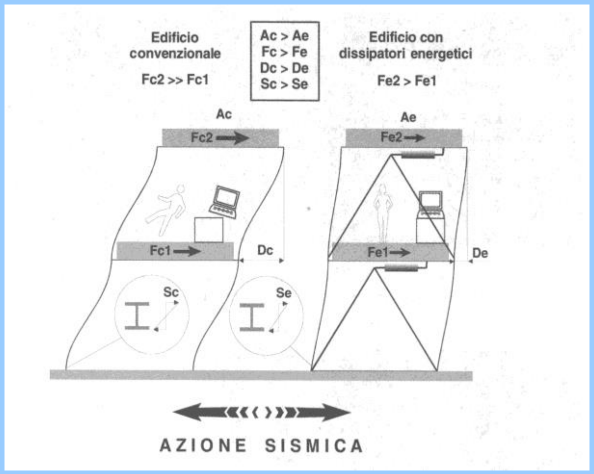
Hybrid control

It is a combination between passive and active control.

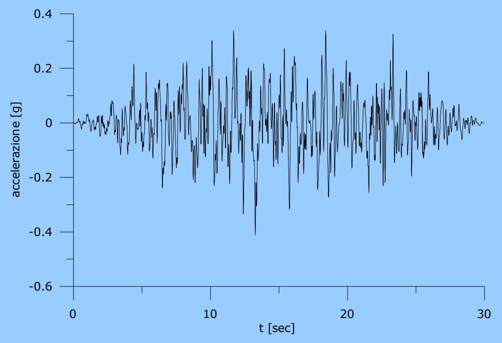
base-isolation

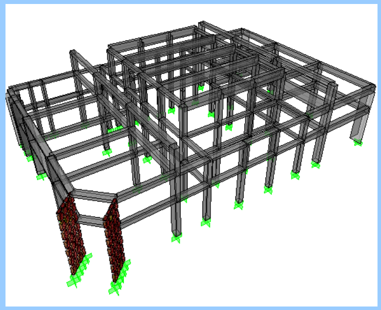


energy dissipation



Energy balance of the structure





Seismic energy E_I = Kinetic energy E_C + Elastic deformation energy, E_E + Dissipated energy, E_D

Base-isolation system $\Rightarrow$ reduces E_I

Energy dissipation system $\Rightarrow$ E_D becomes the sum of the energy , E_{Ds}, dissipated by the structure and of the energy, E_{Dd}, absorbed by the so-called dampers.

$$E_I = E_C + E_E + \left(E_{Ds} + E_{Dd} \right)$$

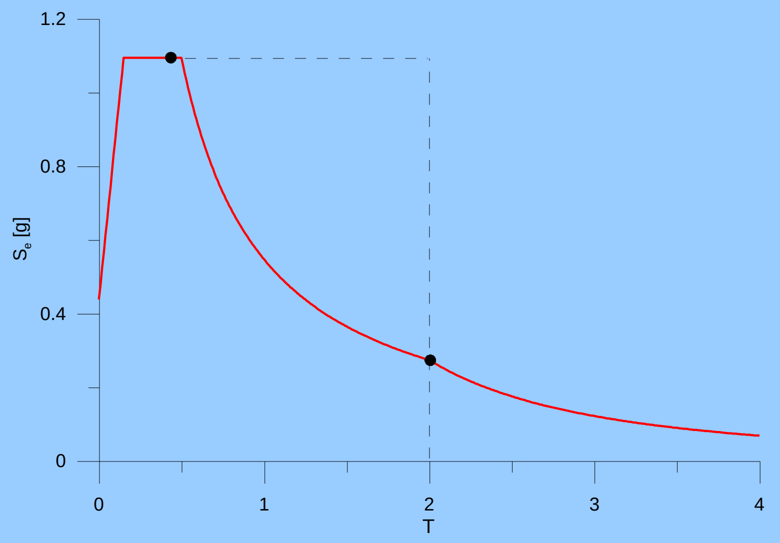
The goal of both these protection systems is the reduction of E_{Ds} that is related to the structural damage.

Fundamentals of the seismic base-isolation

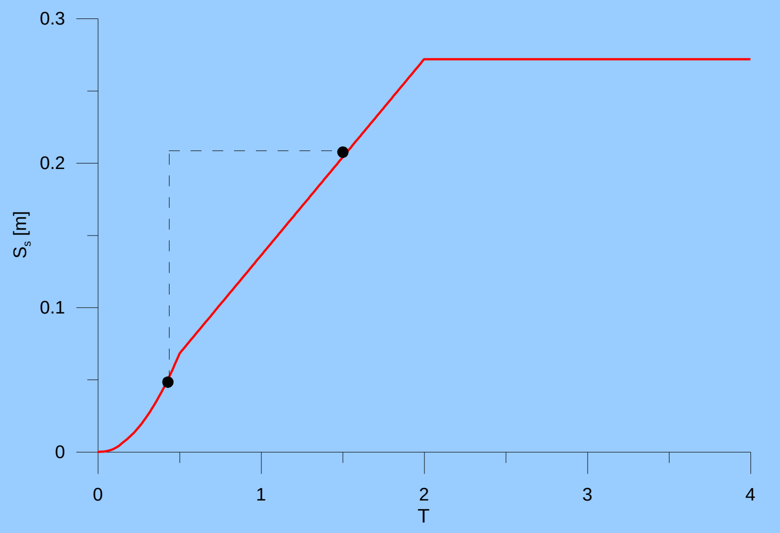
Probably they were known since the ancient Greeks: they put a sand layer between the buildings and the foundation terrain.

The same was made in Persia in the sixth century B.C. for building the Tomb of Cyrus.

The effect of the sand on these buildings is just the goal of the base-isolation, that is the increment of the fundamental period, T_0, of the structure.

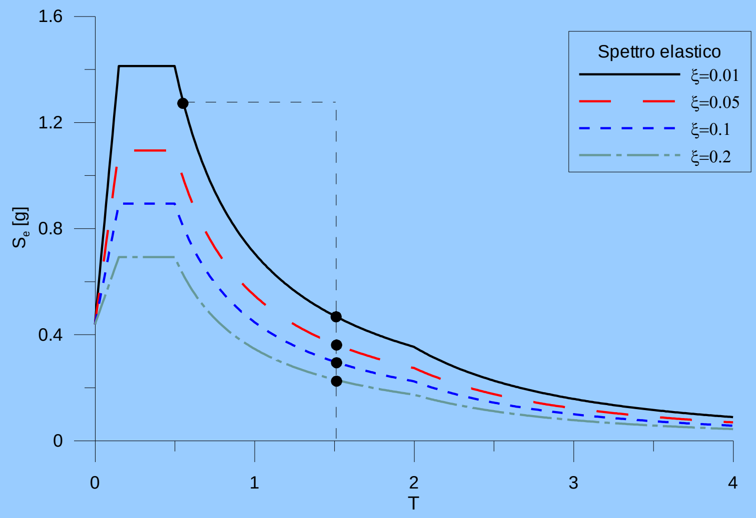


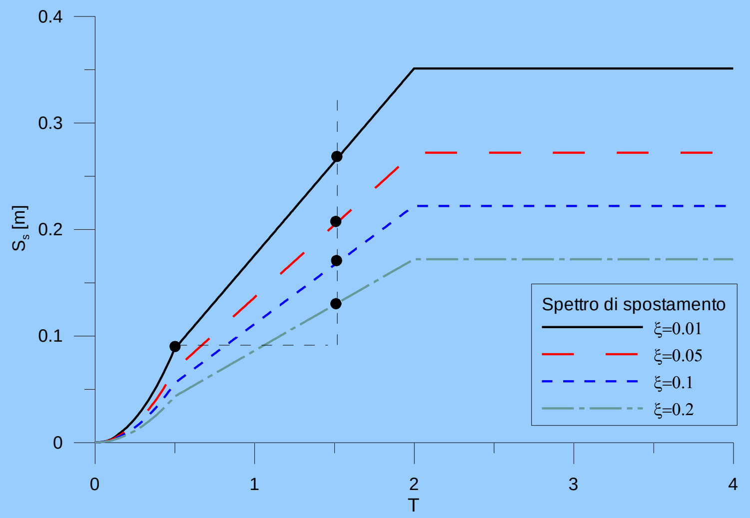
Earthquake pseudo-acceleration spectrum in the Codes.



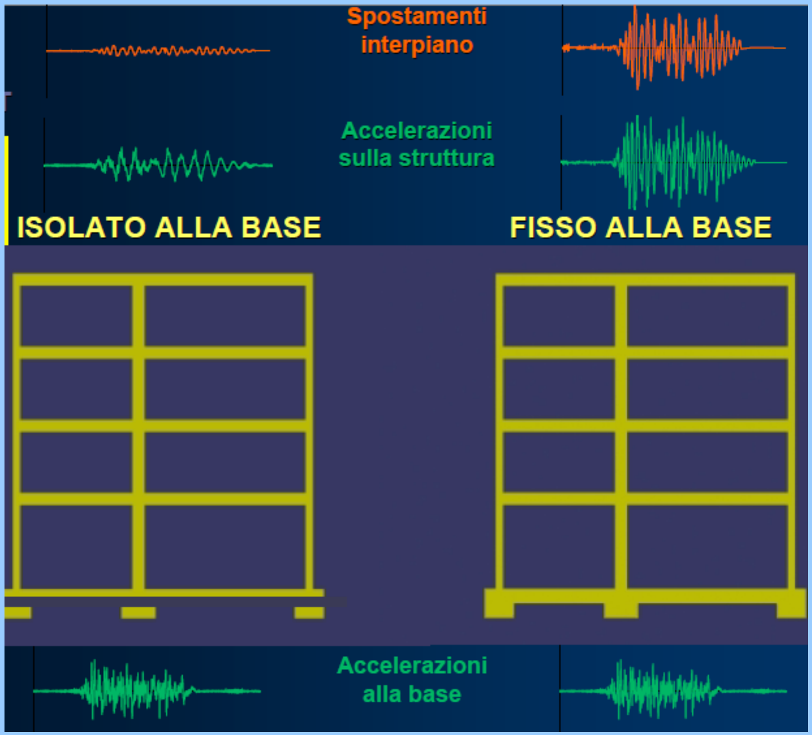
Corresponding earthquake displacement.

Period increment and energy dissipation:





Base-isolation effects on the building



Decreasing of the inertial forces.

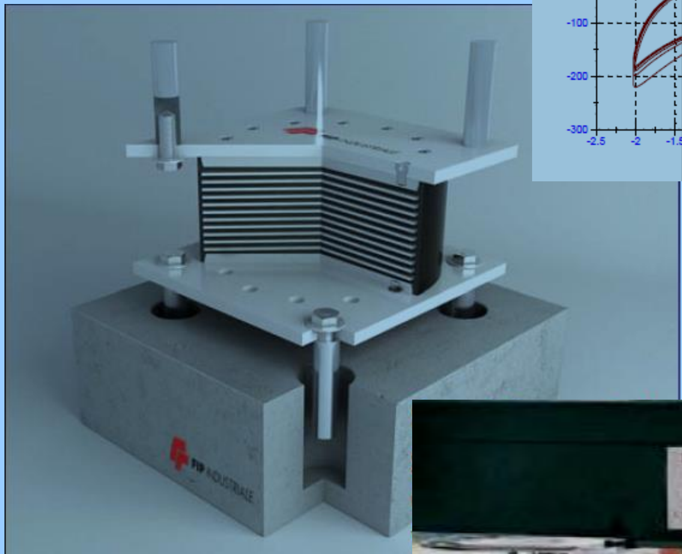
Decreasing of the inter-floors relative displacements having a great influence on the structural safety.

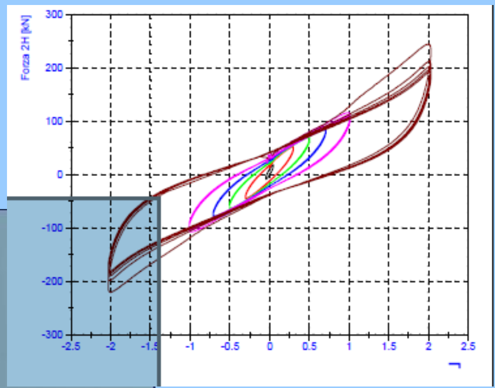
The structure behaves as an unbending system. It is designed in such a way that it remains in the elastic field: all the energy dissipation or ductility must be guaranteed by the isolation system. Then a great attention must be paid in the project and control of these systems.

Most common isolator typologies

RB isolators

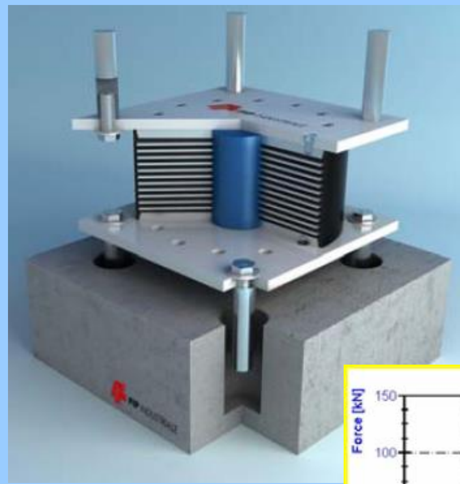
damping factor 10/15%

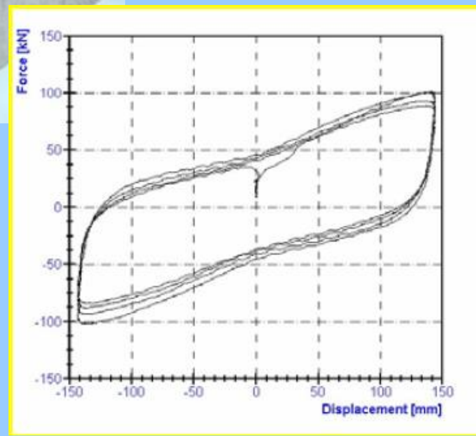




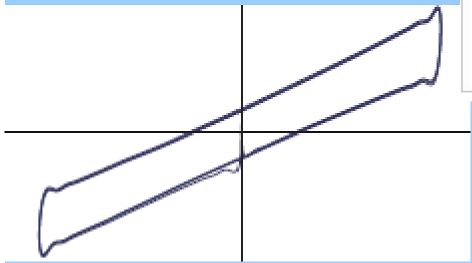
LRB and HDRB isolators

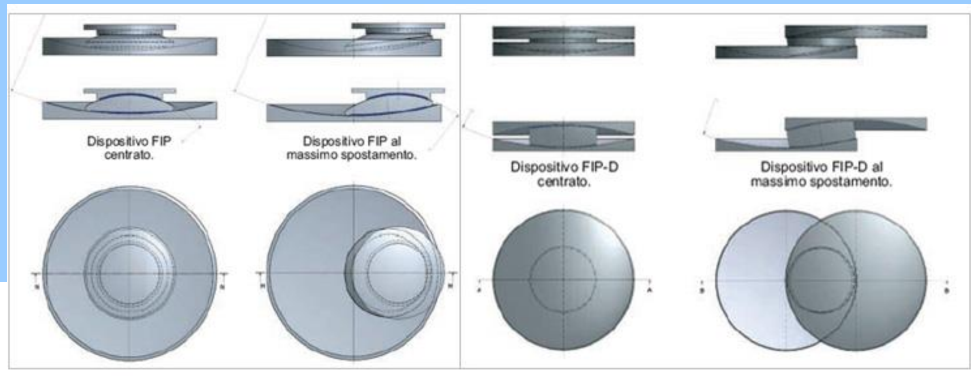
damping factor up to 30%



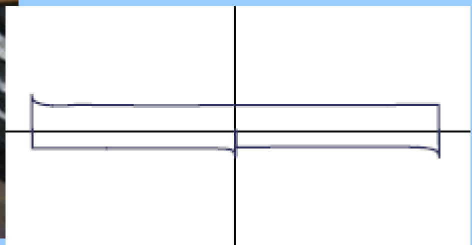


Sliding isolators
(friction pendulum systems)





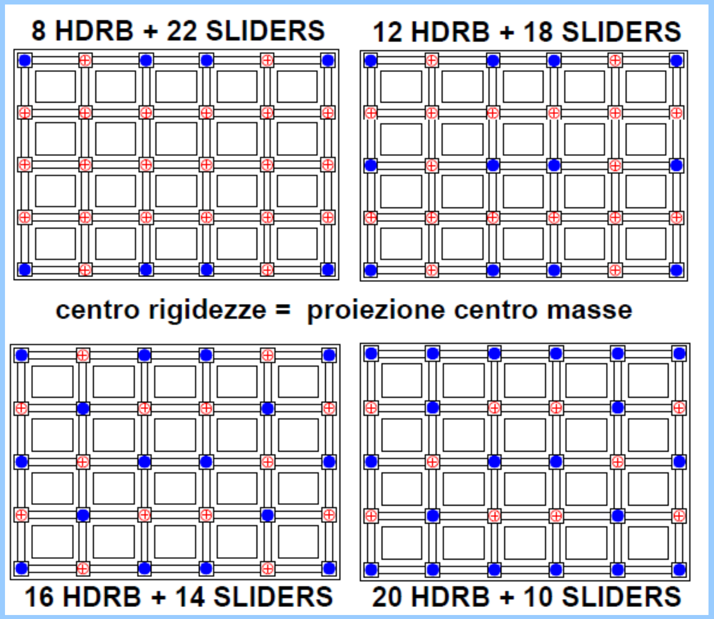
pure sliding



Some tools for the design of base-isolated buildings

The building must work in the elastic field.

The projection of the floor mass centres and the stiffness centre of the isolation-building system must be as closer as possible.



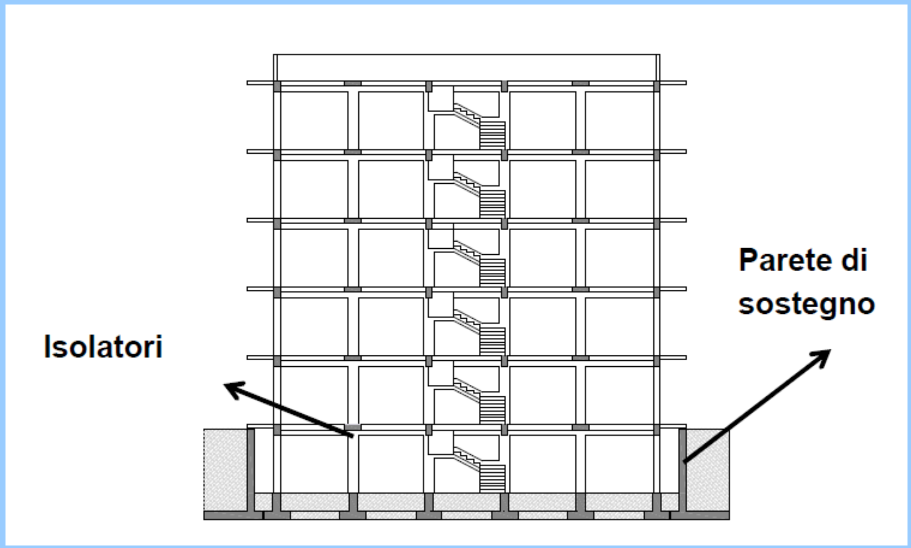
If few dissipating and re-centring bearings are in the isolation system, these must be positioned along the building perimeter.

The bearings must be subjected to almost uniform compression loads.

During the earthquake the vertical load on a bearing must be always a compression, never a traction.

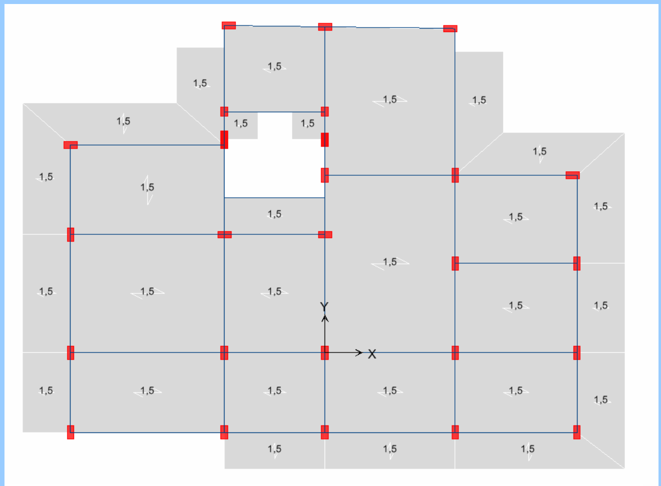
The structural elements that are on the plane immediately below and immediately over the isolation system must be such that these plains have a very stiff behaviour.

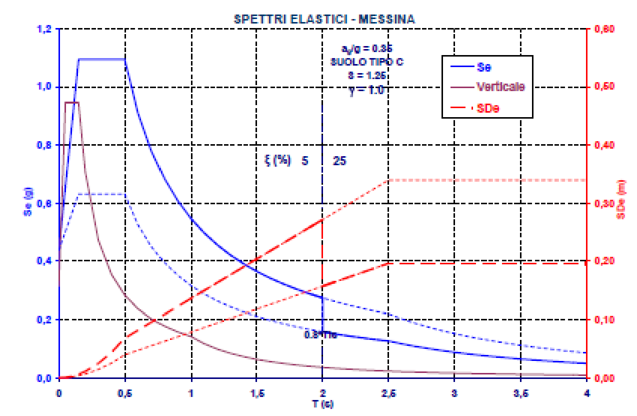
The connections of the isolated structure with any other non-isolated element must be studied for allowing the structural displacements during the earthquake, that may reach even some tens of cm.

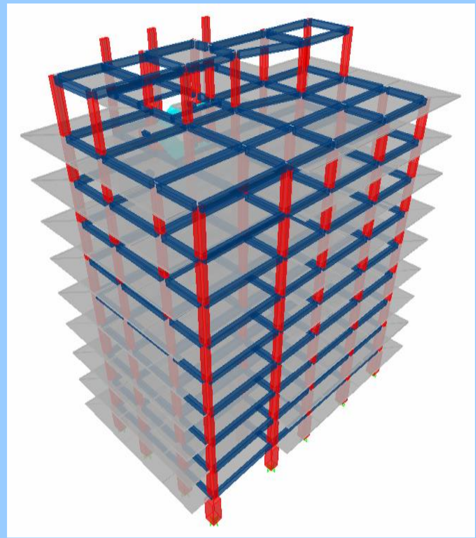


Building in viale Europa – Messina

Structural Engineering: ing. Marino Manlio





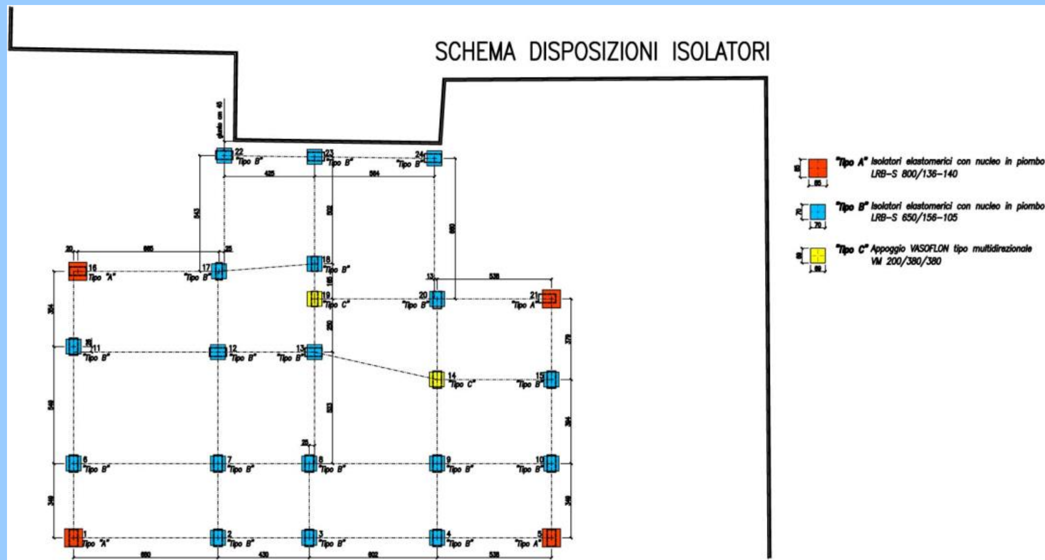


8 floors
volume = 6655 mc
mass M=4318 tonn

$$T_{is} = 2.5 \sec$$

$$K_{esi} = (2\pi T_{is})^2 \cdot M$$

$$K_{is} = K_{esi} / (n.col.)$$

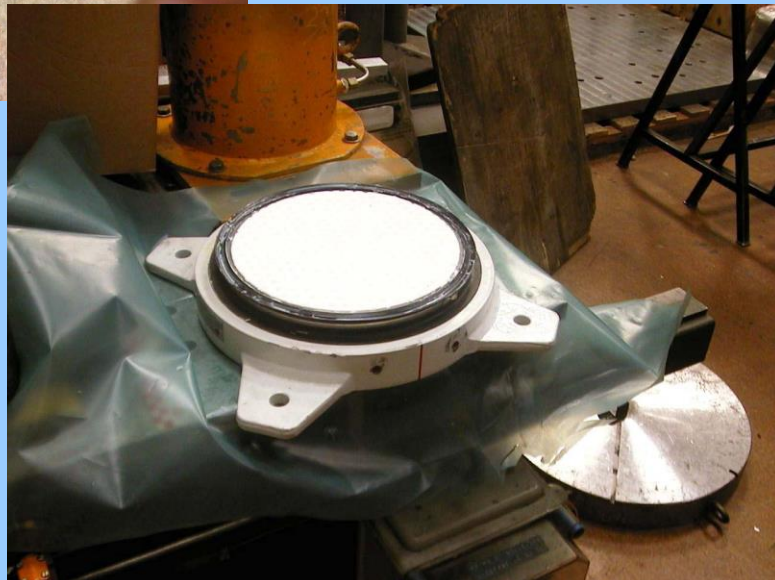


Final design choice:

4 bearings LRB-S 800/136-140
18 bearings LRB-S 650/156-105
2 sliders VM 200/380/380


LRB-S 800/136-140


2PRH
D & D

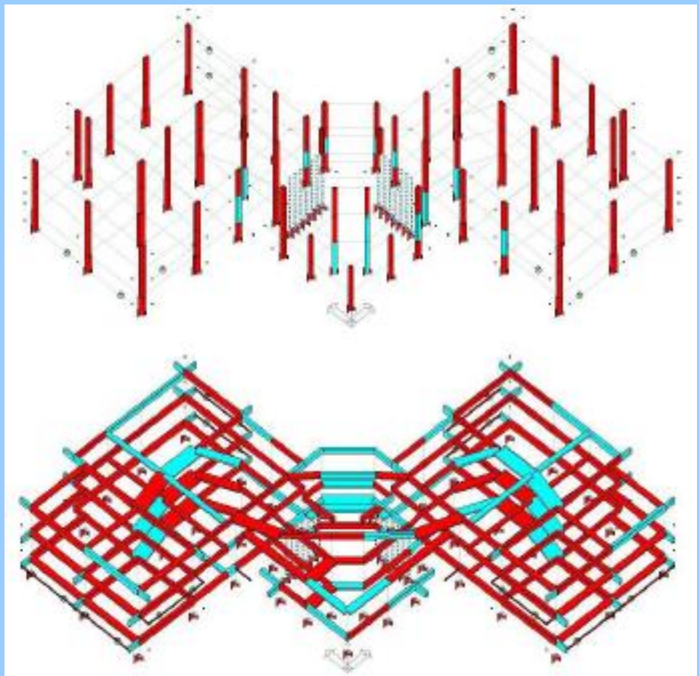


School building Quasimodo in Riposto (CT)

Retrofitting design:
prof. ing. Neri Fabio.

construction age: 1978-80.

After the Santa Venerina earthquake (october 22, 2002) (MR=4,5), the school was condemned.

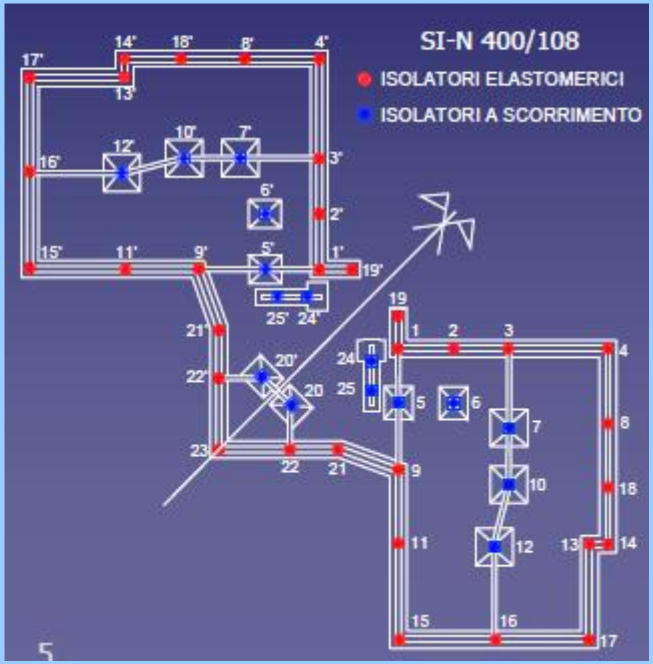


2 - Analisi Non Lineare

$$\alpha_u = mim\left(\frac{PGA_{CO}}{PGA_{2\%}};\frac{PGA_{DS}}{PGA_{10\%}}\right) = 0.25$$

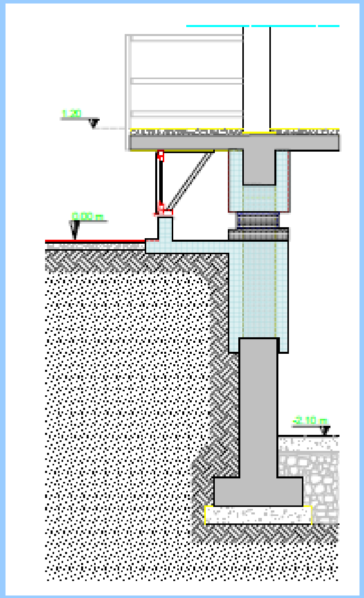
Design choice

$$T_{bf} = 0.38\,\text{sec},\;\; T_{is} = 1.71\,\text{sec}$$



33 bearing isolators
FIP SI-N 400/108

16 sliders FIP VM 175/500/500



Demolition of internal and external stairs. Column retrofitting.



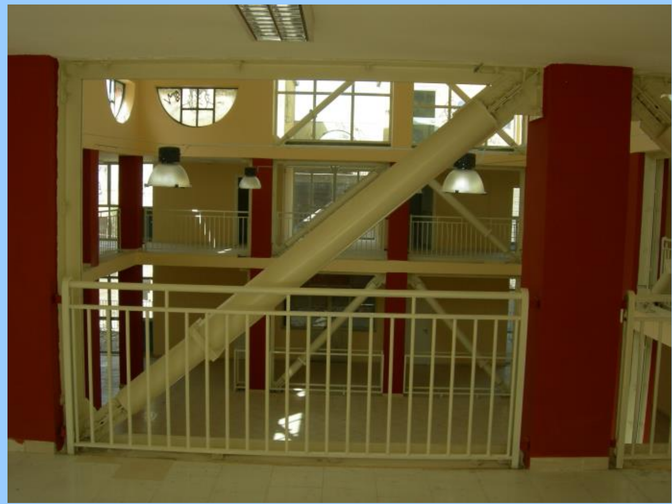


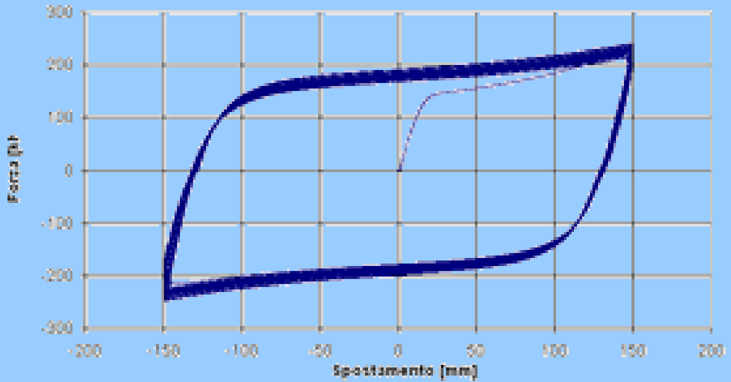

Reinforcement of some structural elements. Columns cutting.

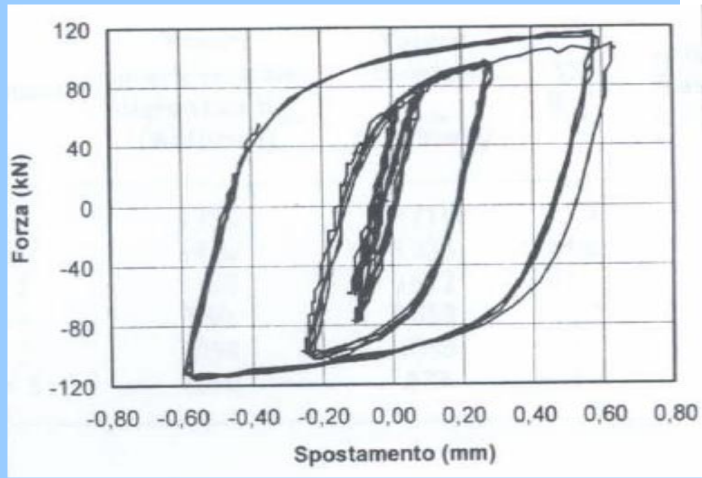
Placement of isolators

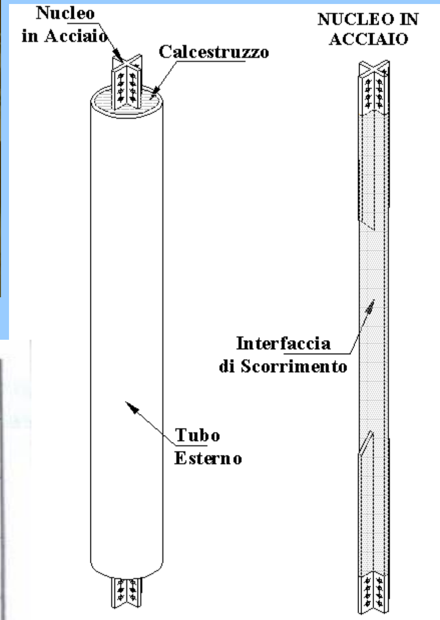
Technologies for Energy Dissipation

Hysteretic devices



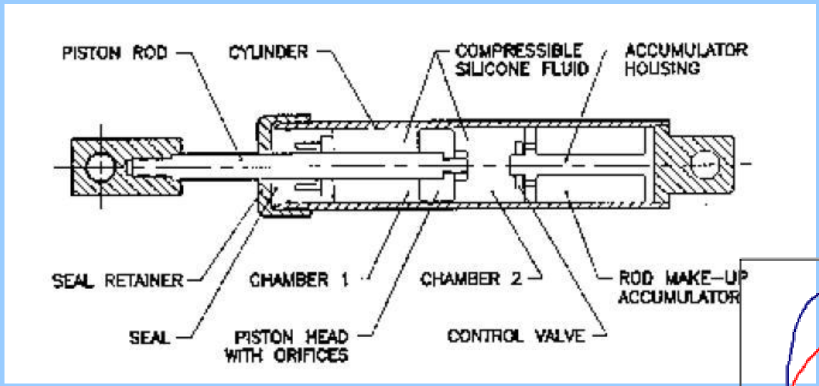




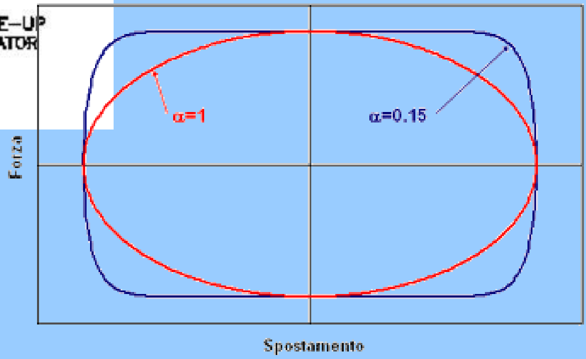


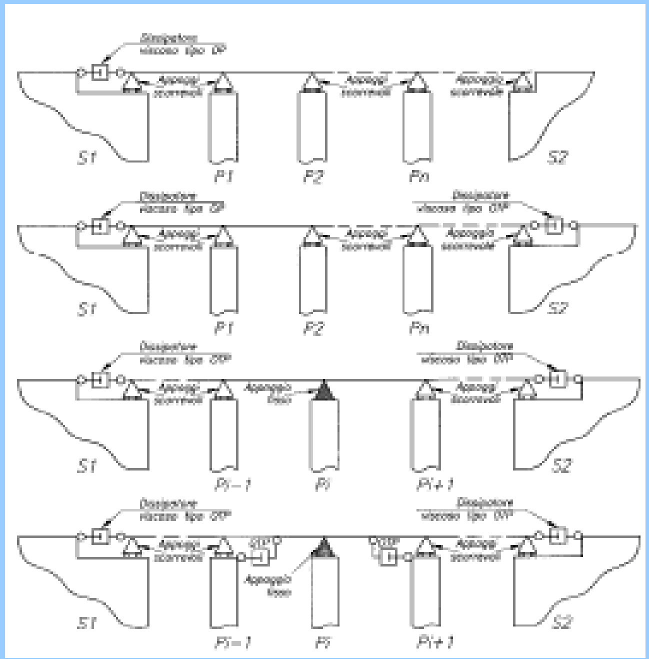
Buckling restrained axial devices (BRAD)

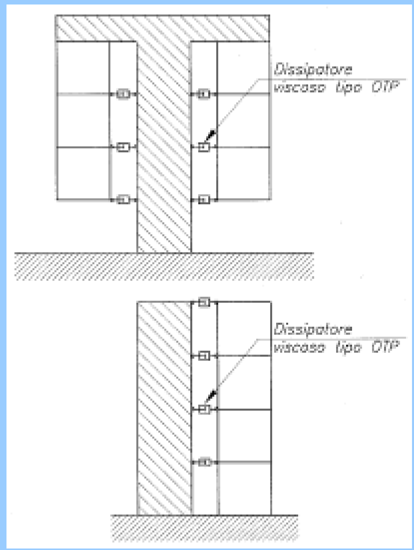
Viscous devices

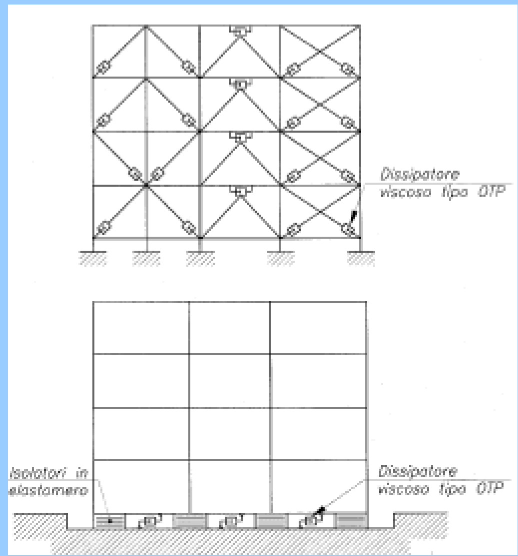


$$F = cv^{\alpha}$$



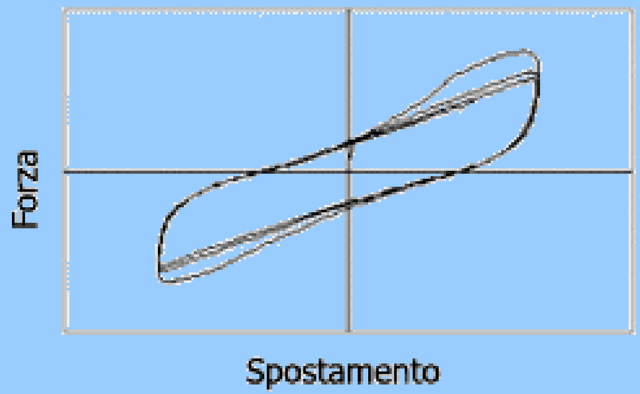






Elastomer Visco-Elastic Devices (EVED)

The dissipation is due to the shear behaviour of the elastomer material that shows high damping.



Scuola media Gentile-Fermi di Fabriano.

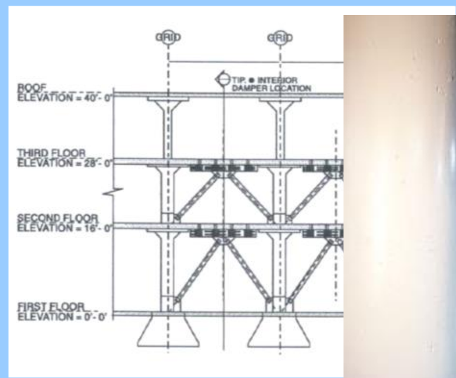
Using damper devices for seismic retrofitting of buildings.

Woodland Hotel –
San Francisco

Liceo Perticari -
Senigallia

Istituto D. Viola -
Piacenza

Scuola dei Cappuccini -
Ramacca (CT)



Building 116 -
San Diego

Design parameters.

The placement of the devices inside the building structure is always made through braces placed in the frames that have been chosen to contain the devices.

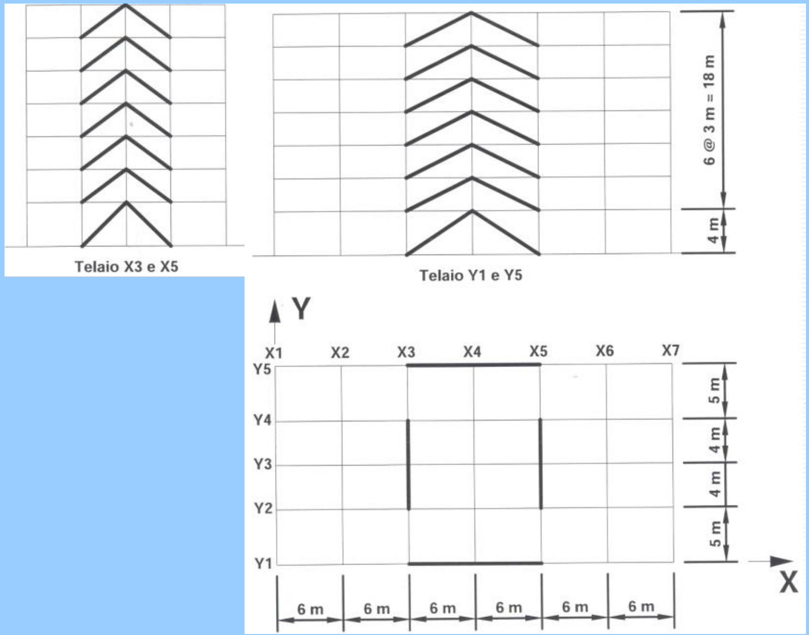


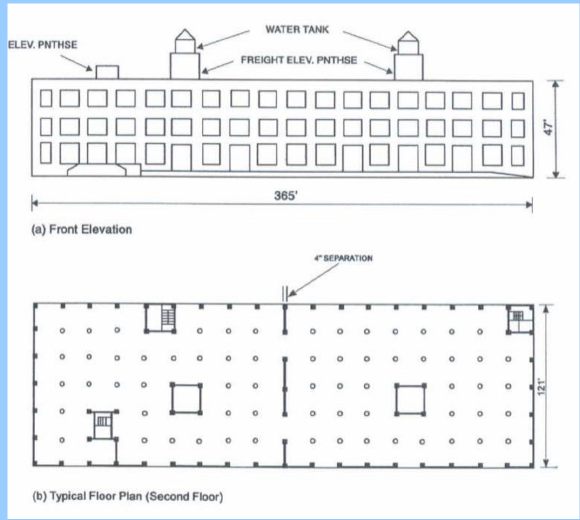
The design of a damper device system is usually a complex iterative process that depends on many decisions:

- brace position in horizontal and in vertical directions
- brace shape
- brace stiffness
- damper properties

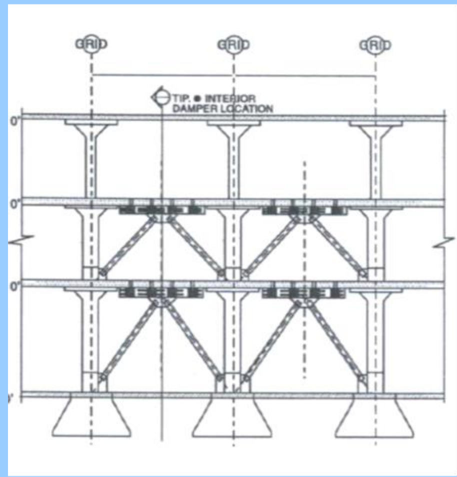


The brace position must guarantee the building regularity in elevation and an adequate torsion stiffness in plant.

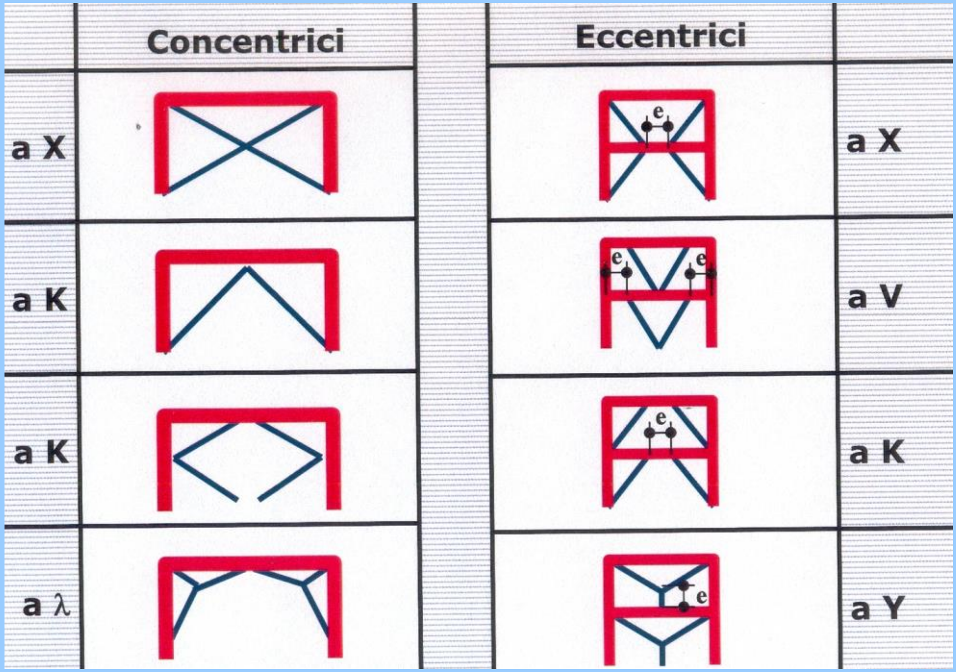




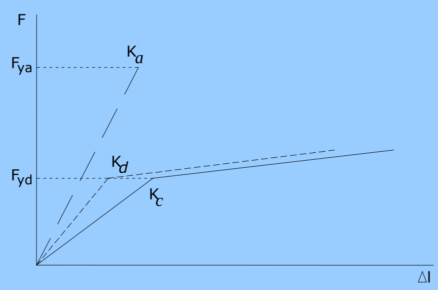
Building 116 – San Diego

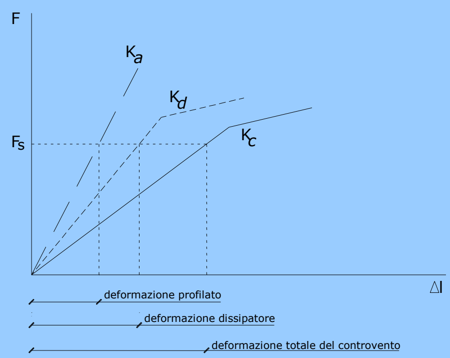


Moreover, it must respect some restrains of architectural, distributive and, if possible, aesthetic type.

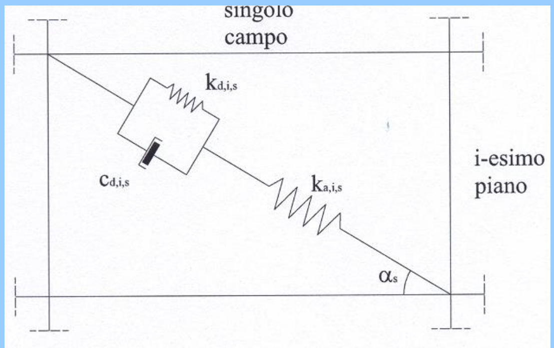


The braces may have many shapes. They depend on the eventual presence of doors or windows and by the damper device chosen.





The braces change the frame stiffness



k_d = device stiffness

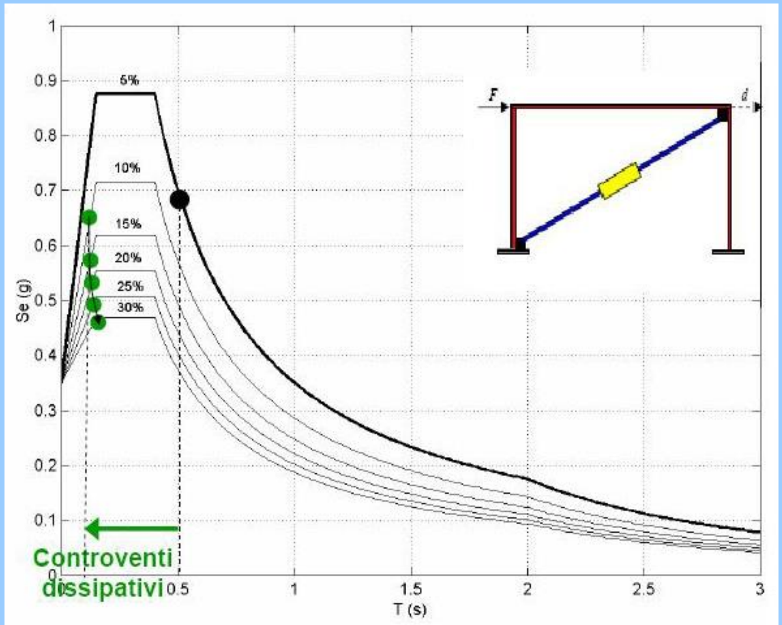
k_a = brace stiffness

k_C = damper system stiffness

$$k_C = \frac{1}{\frac{1}{k_d} + \frac{1}{k_a}}$$

$$k_{TOT} = k_C + k_S$$

Usually, the braces have a relatively high stiffness in order to concentrate many energy in the damper devices. Consequently, the devices must be able to guarantee a relatively high energy dissipation for small displacements.



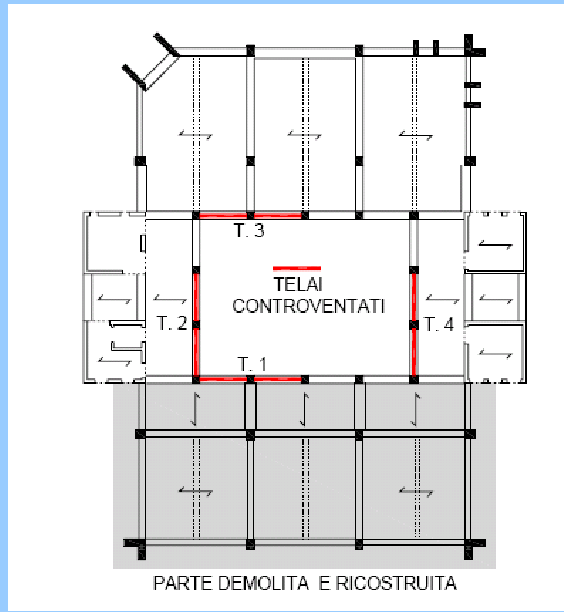
The increase of the frame stiffness determines a decrease of the structural natural period that may not be a benefit for the seismic behaviour of the structure. However, this must be always compensated for by the corresponding increment of the damping.

The definition of the methods for the optimal design of the damper device system is an open argument of the international scientific community.

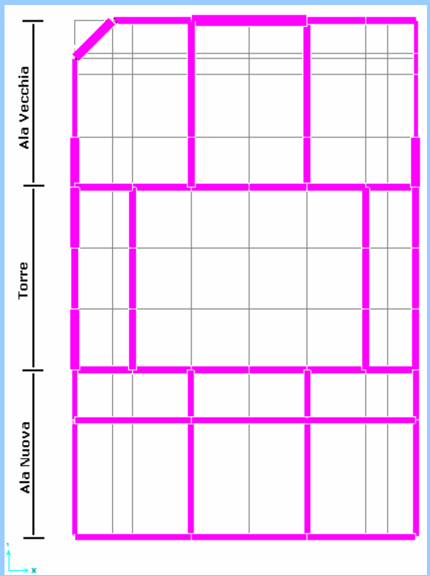
U. Alibrandi, G. Falsone, Optimal design of dampers in seismic excited structures by the Expected value of the stochastic Dissipated Power, *Probabilistic Engineering Mechanics*, vol. 41, 2015, 129-138.

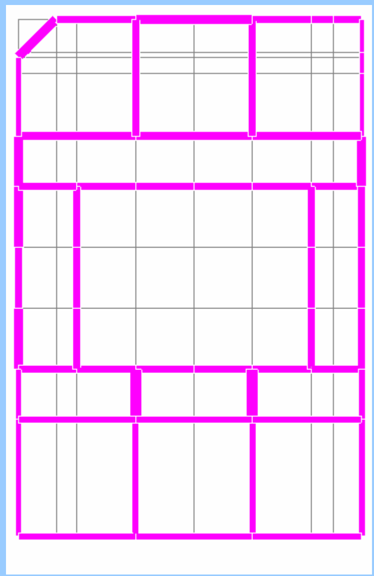
Seismic retrofitting by damper device systems for the school building "Cappuccini" in Ramacca (CT)

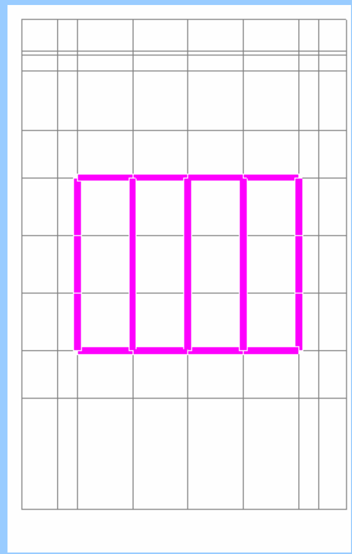
Structural engineering**: prof. ing. Neri Fabio**
dissipation system Consulent: **prof. ing. Falsone Giovanni**



Costruction age: 1970 (no seismic codes)
Volume: 6500 mc

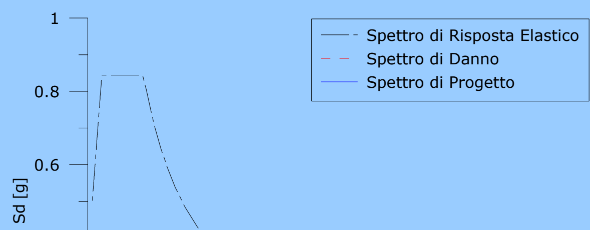




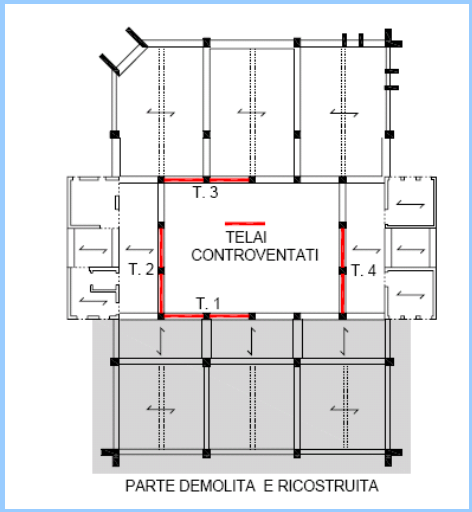


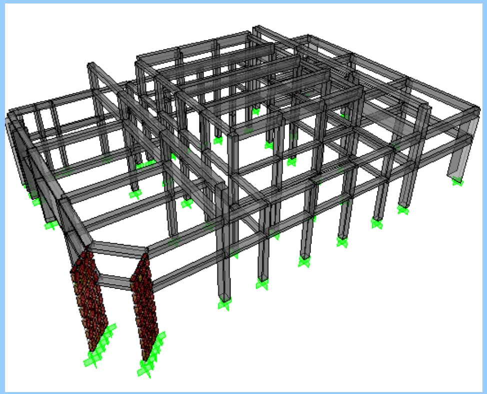
After the Santa Venerina earthquake (2002), the scholl was condemned for the great amount of cracks. The first tests and analyses revealed very low ductility and stiffness and a quality of the concrete lesser than that declared in the design.

Design of the damper device system



The brace placement has been made for concentrating the most part of the stiffness in the central zone of the building, where the best frames where. This choice was due also to the absence of the first two floors in this central part, that has allowed a more comfortable collocation the damper device systems.



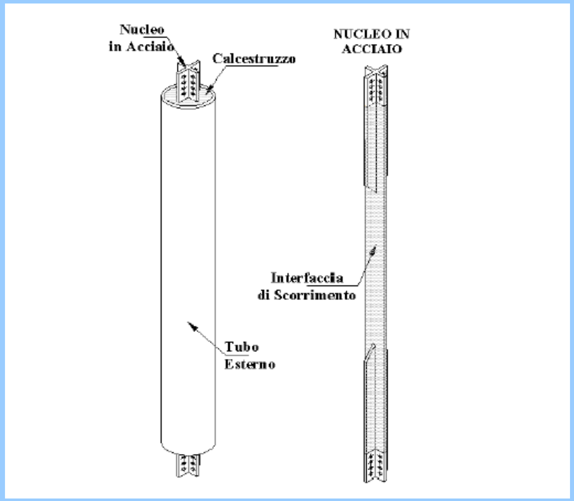


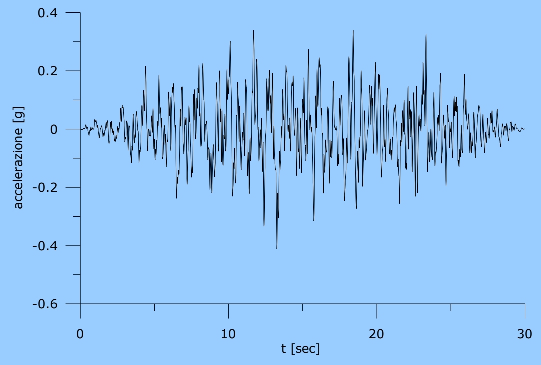
The damper type chosen is the BRAD.

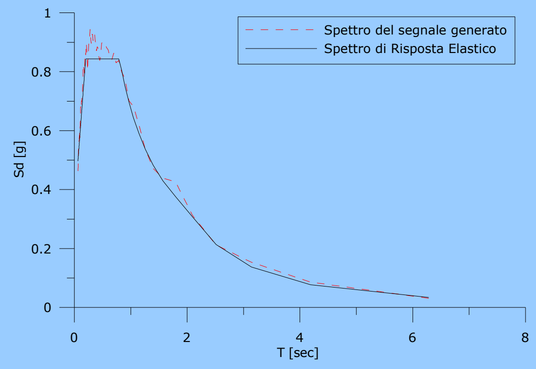
These devices may replace an entire brace or may be a part of this one.

The optimal design of the damper device system has been realized for obtaining the $\max\left(E_{D_d}\right)$.

This result has been obtained by nonlinear dynamical analyses where the inputs were spectrum-compatible accelerograms.

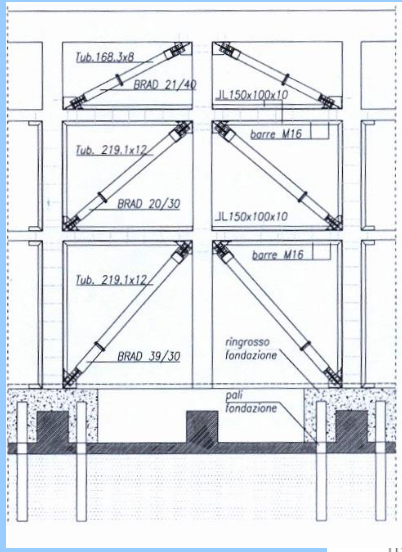


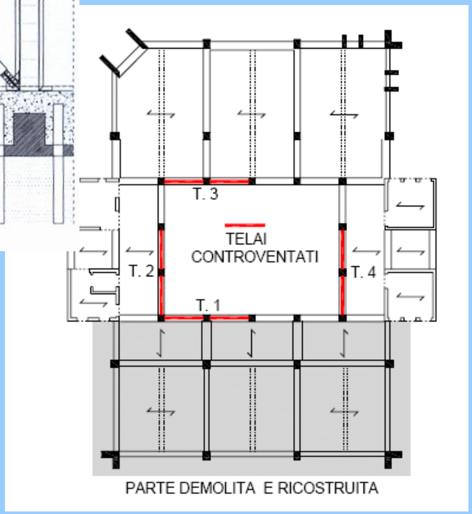


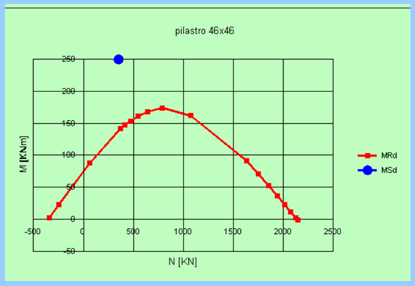


In this way, the brace position, the brace dimension and the damper type have been chosen.

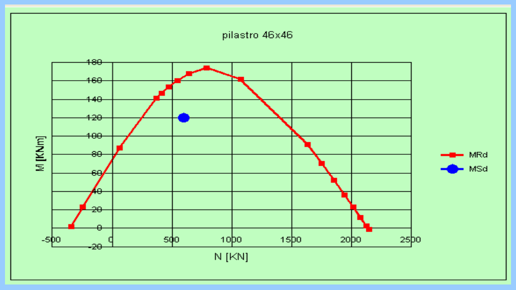
	Massimi spostamenti di interpiano [m]			
	Direzione x		Direzione y	
Quota	Libero	Controventato	Libero	Controventato
1° Impalcato	$5.86\ 10^{-2}$	$1.58\ 10^{-2}$	$10.58\ 10^{-2}$	$1.66\ 10^{-2}$
2° Impalcato	$4.62\ 10^{-2}$	$1.33\ 10^{-2}$	$7.76\ 10^{-2}$	$1.42\ 10^{-2}$
3° Impalcato	$5.83\ 10^{-2}$	$8.56\ 10^{-3}$	$4.38\ 10^{-2}$	$7.66\ 10^{-3}$



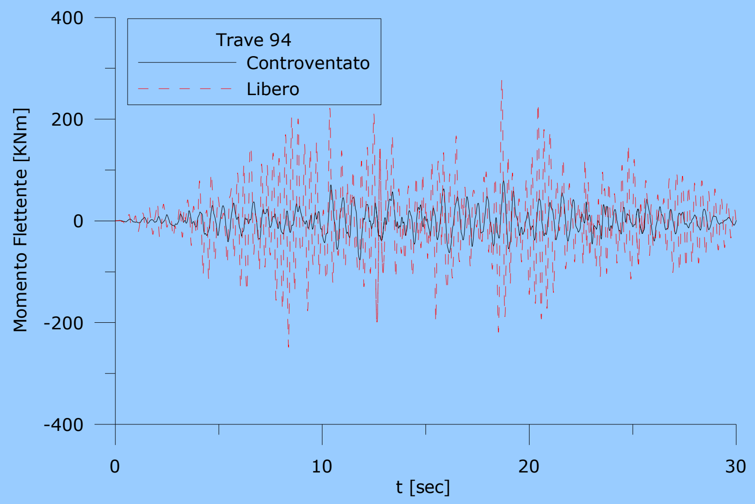


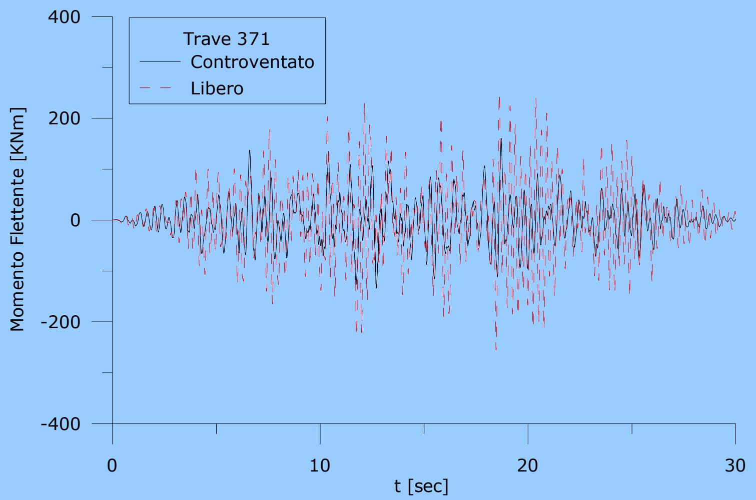


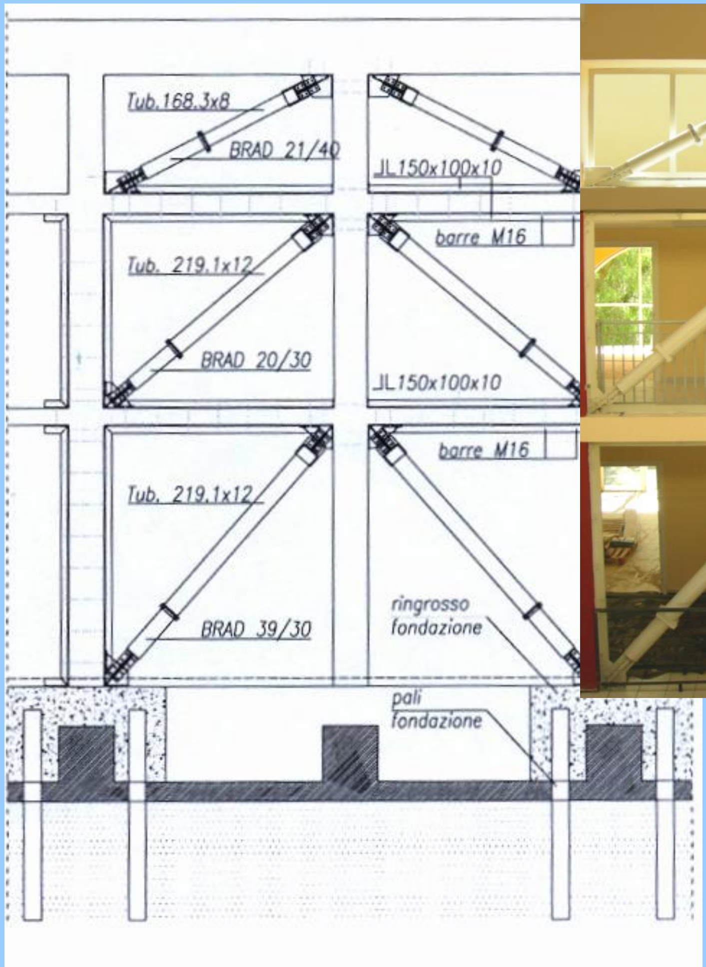
without damper device



with damper device






Tub.168.3x8
BRAD 21/40
L150x100x10
barre M16
Tub. 219.1x12
BRAD 20/30
L150x100x10
barre M16
Tub. 219.1x12
BRAD 39/30
ringrosso
fondazione
pali
fondazione

Thank You Very Much