PRIN PROJECT

SEISMIC RETROFITTING OF BUILDINGS USING ISOLATION AND/OR ENERGY DISSIPATION TECHNIQUES: DESIGN, MODELLING, IDENTIFICATION

Faculty of engineering - University of Catania

Friday 26th June 2009

Seismic control of base isolated structures: potential of semi-active strategies

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Seismic performances

A multitude of small details in columns, corners or connections decide whether a building will survive or not. Quality control is overwhelmed by this requirement. Its like a game of chance, even for the same type of building in the same location

Seismic performances

Performance / Event	Operational	Immediate Occupancy	Life Safety	Structural Stability
Frequent				
Occasional				
Rare				
Destructive				

Ordinary structures

Relevant structures

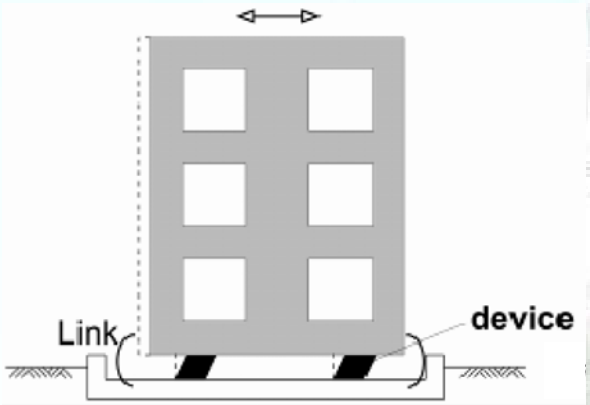
Strategic structures

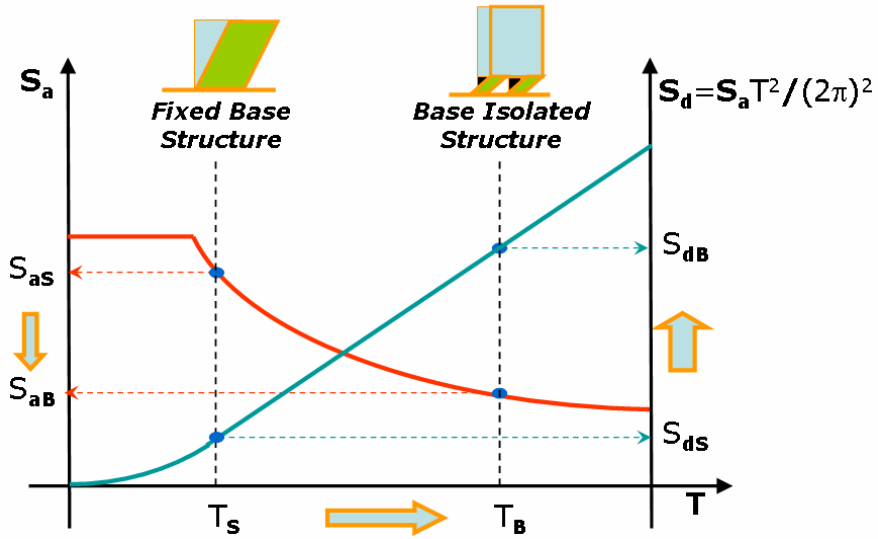
In the case of strategic structures, new design philosophy asks for severe seismic performances. Can we accept small details control the seismic response ?

Structural control

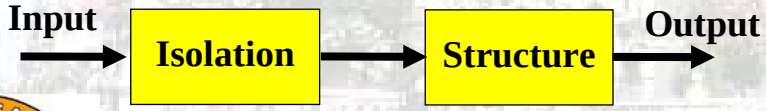
Structural Control is the name given to systems that actively, passively or semi-actively suppress oscillation in structures

Base Isolation





Open Loop Control Scheme



Base isolation is a not robust control system, however isolation provides full controllability to the structural system

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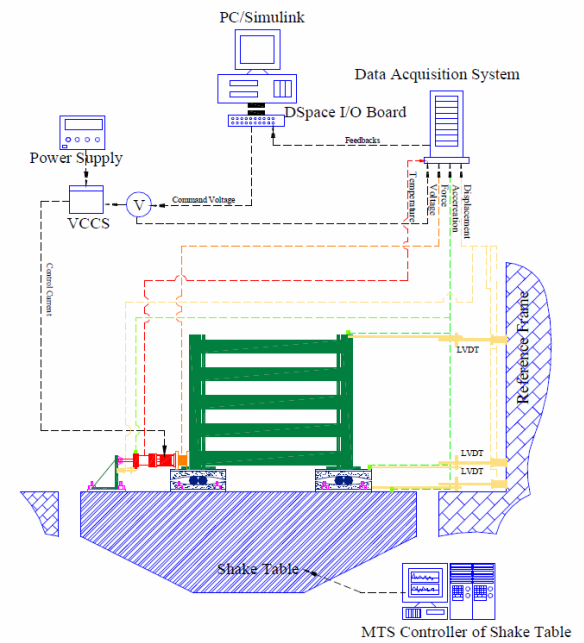
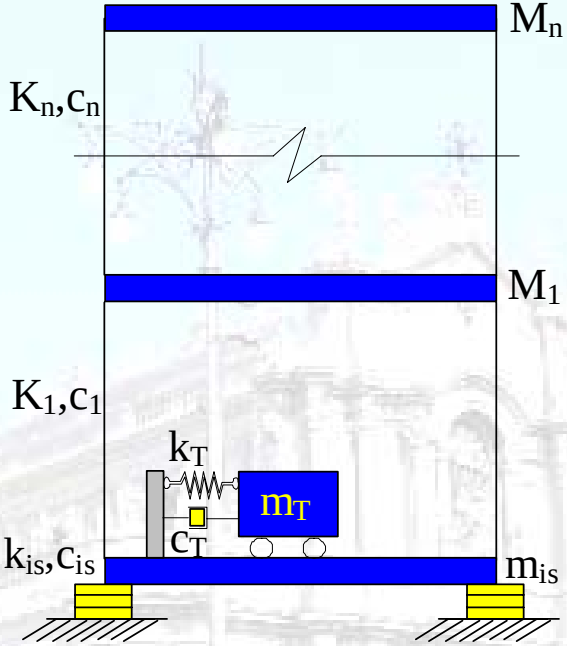
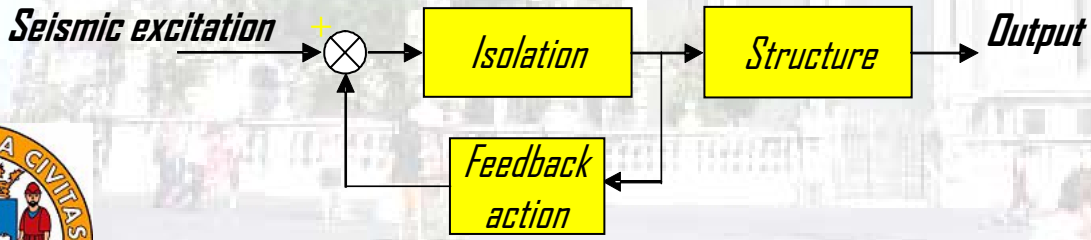
Hybrid control



Base isolation and active control devices



Base isolation and Tuned Mass Damping



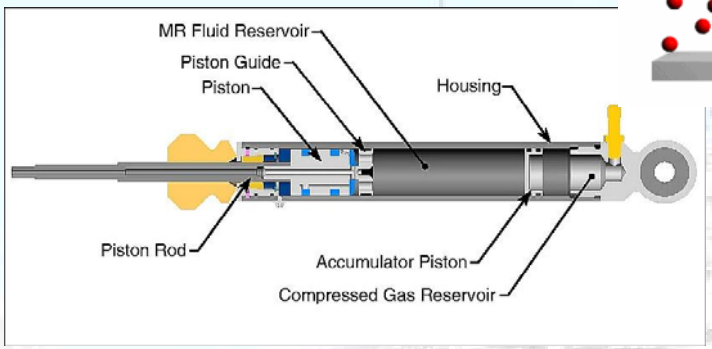
Two issues:

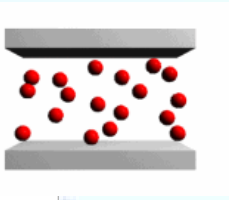
- *Performance*
- *Power supply*

Semi-active control

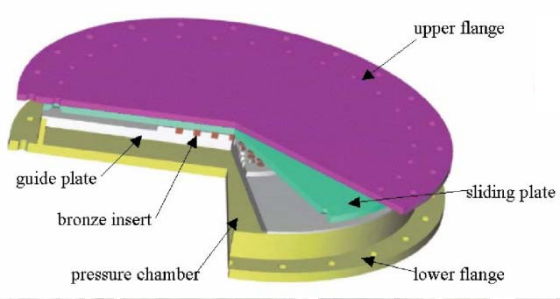
Variable Damping Devices

Magnetorheological Damper

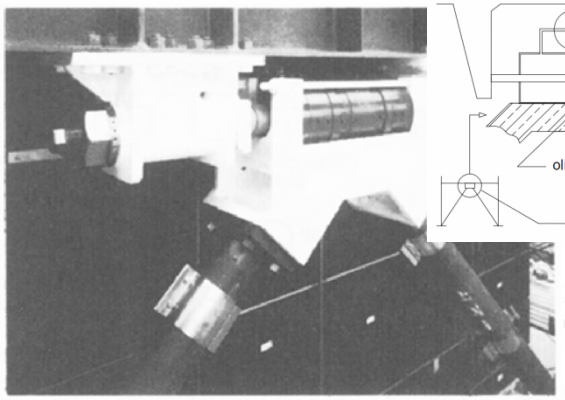


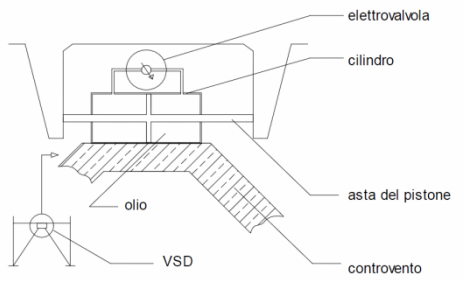


Variable Stiffness Devices



HYDE device

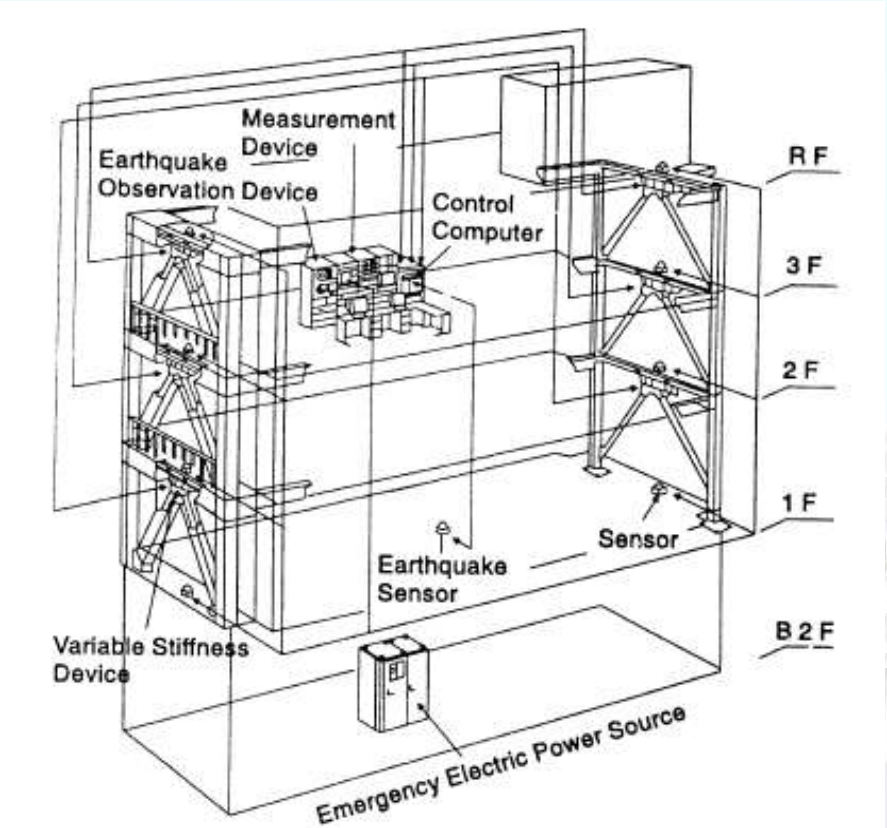




AVS device

These devices need very little power supply to work, moreover they react in milliseconds

Semiactive control full-scale application

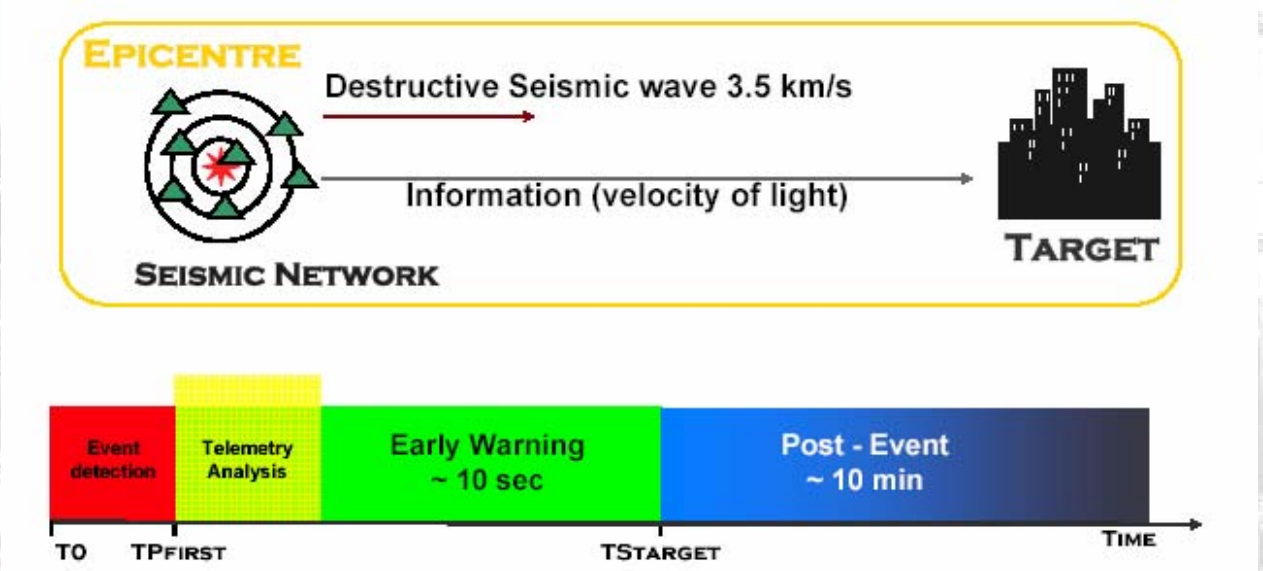


Kajima Research Lab.# 21

A control computer analyses the signal from sensors located in different buildings' positions and through suitable algorithms commands the semiactive devices

Real-time seismology

Real-time seismology normally refers to a practice in which seismic data are collected and analyzed quickly after a significant seismic event so that the results can be effectively used for post earthquake emergency response and, under favorable circumstances, early warning.



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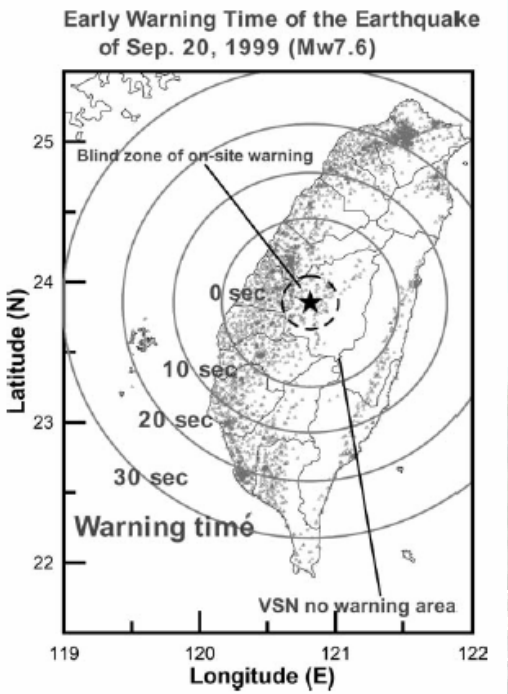
Early warning Systems

Two approaches to earthquake early warning are possible:



- ***Regional warning***:

The traditional seismological method is used to locate an earthquake, determine the magnitude, and estimate the ground motion at other sites.

These information are used to reduce seismic risk related to the incoming event (evacuate schools, shut down vulnerable segments of power grid…)

The Taiwan regional network warning is able to estimate the magnitude of a seismic event in less than 5 sec. The alarm is sent to the coastal cities 20 sec before the arrival of P waves

Early warning Systems

- On site (or site-specific) warning:

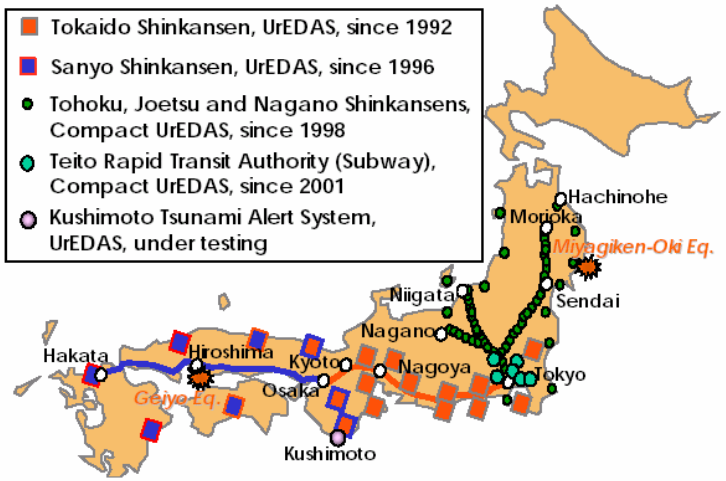


Figure1 The distribution of UrEDAS and Compact UrEDAS in Japan

The "Uredas" system in Japan goes along the Shinkansen rail track.

The beginning of the ground motion (mainly P wave) observed at a site is used to predict the ensuing ground motion (mainly by S and surface waves) at the same or different site; no attempt is necessarily made to locate the event and estimate the magnitude.

A rapid estimation of the nature of the progressing earthquake or the ground motions at an early stage of its rupture process is necessary

Potential use of EW network info

Individual actions:

Protective action at home, at school, at job sites

Immediate run out from chemical devices, dangerous installation, unstable infrastructures

Automatic actions:

Activation of transportation systems slowing/stop mechanism in Industrial areas

Cancellation of aircraft landing

Traffic stop in correspondence of bridges

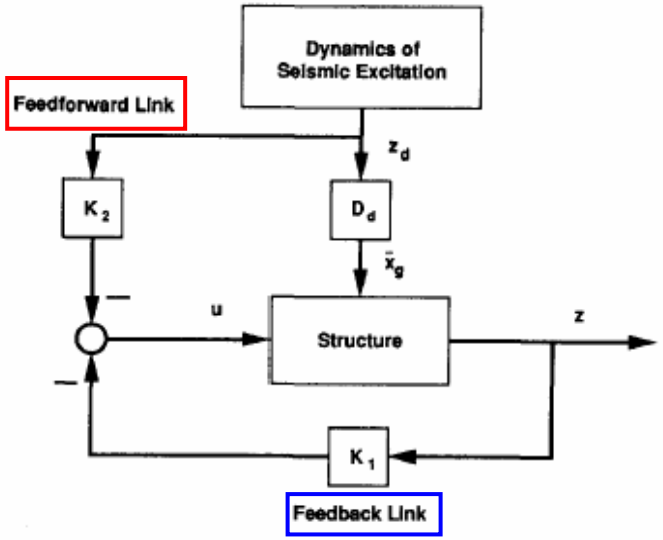
Deactivation of chemical industrial systems

Protection, control and temporary deactivation of gas and power supply network

Activation of semi-active control devices to reduce the seismic response of buildings

Data back-up and power off for relevant informatics systems

Site warning and seismic control strategies

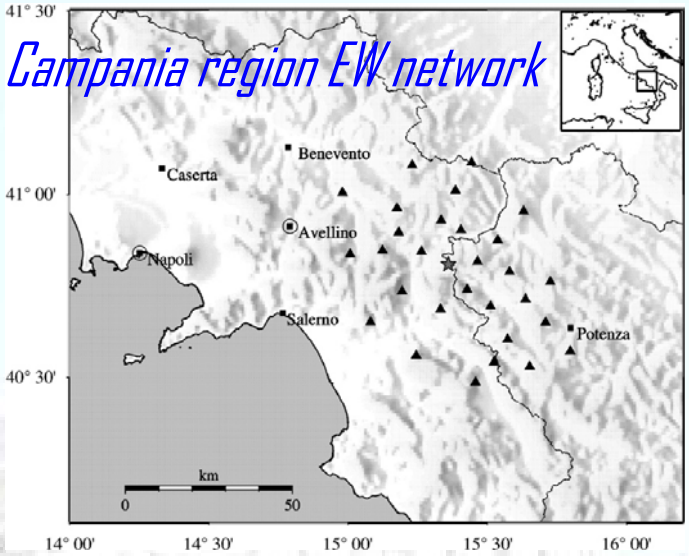


In the last few years, the possibility of using information from an early warning network to drive active or semi-active control systems has arisen as a new and fascinating issue in seismic engineering.

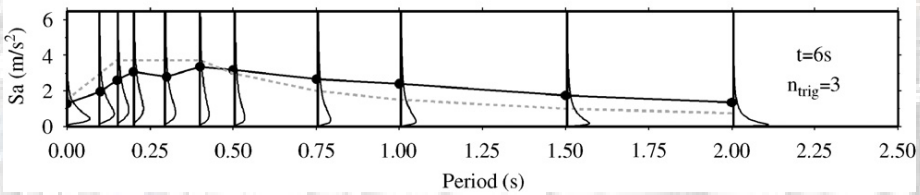
Nevertheless, few studies has been carried out in order to understand ***what's the minimal information "quantity and quality" to allow a control system to work properly***

Seismological available info

Nowadays EW network are able to provide reliable information about the magnitude and spectral seismic demand by analyzing the first few seconds of the incoming earthquake accelerometric recording



In the case of "in situ" approach the ground motion at the site can be estimated with relative high accuracy

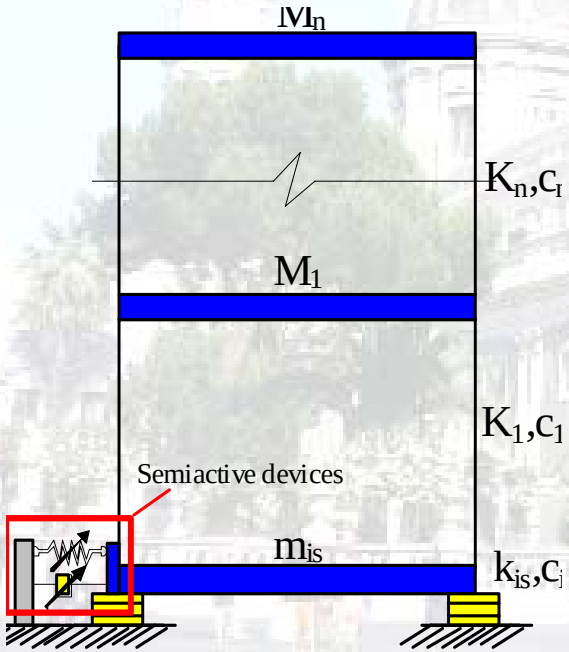


V. Convertito, I. Iervolino, A. Zollo, G. Manfredi
Prediction of response spectra via real-time earthquake measurements
Soil Dyn. and Earthq. Eng., doi:10.1016/j.soildyn.2007.07.006, 2007

Semi-active strategy on BI system

With a reliable estimation of the incoming signal and/or the spectral demand at the base isolation fundamental period a very simple protection strategy has been investigated.

In particular additional stiffness and damping can be applied at the isolation layer when a seismic response threshold is overcome



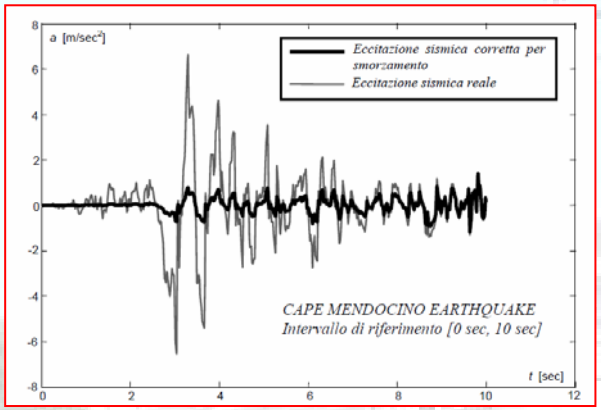
Hyphotesis:

- *Deterministic knowledge of the incoming signal*
- T_0=2 sec **AVS** → T_1=1 sec
- ξ_0=0.05 **AVD** → ξ_1=0.10
- $X_{s,max}$=0.30 m
- *BI model by Kelly et al. (1988)*

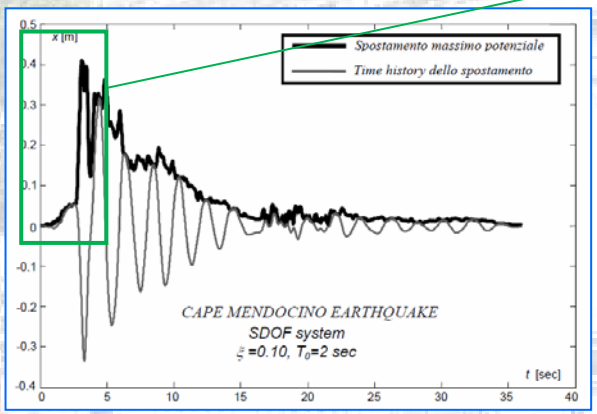
Estimation of seismic demand

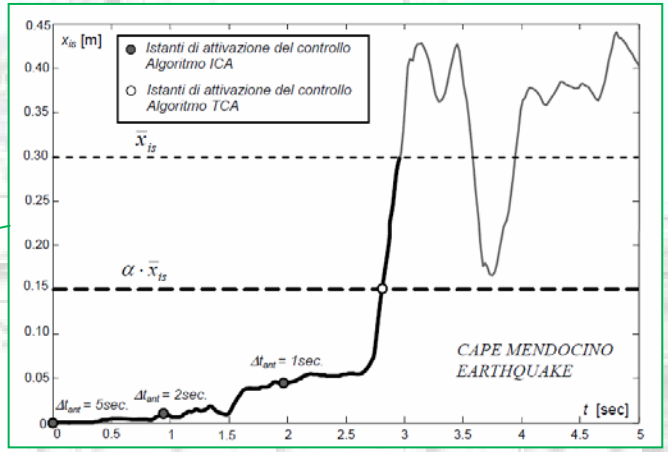
By using the Fast Fourier transform and a corrected signal to taken into account the effect of damping, the alarm time has been evaluated for each considered seismic event

$$\ddot{y}_{corr}(\tau,t) = \ddot{y}(\tau)\cdot e^{-\xi\omega_0(t-\tau)}$$



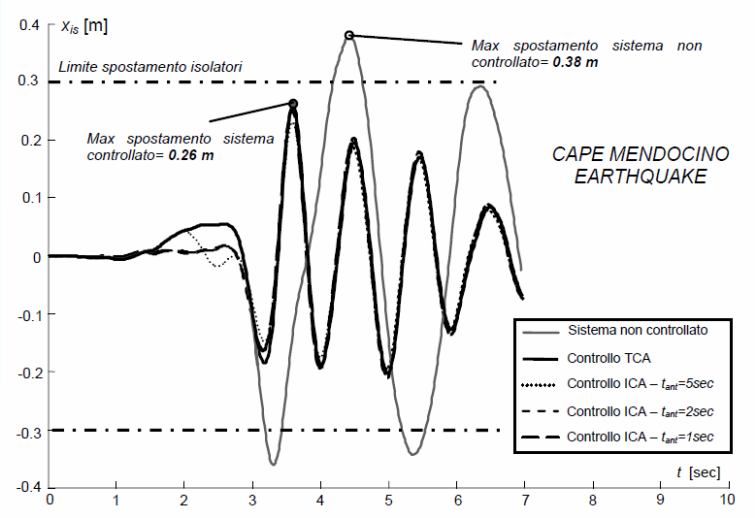
$$x_{\max}(t) = \frac{1}{\omega_d}\cdot F_{corr}(\omega_d)$$



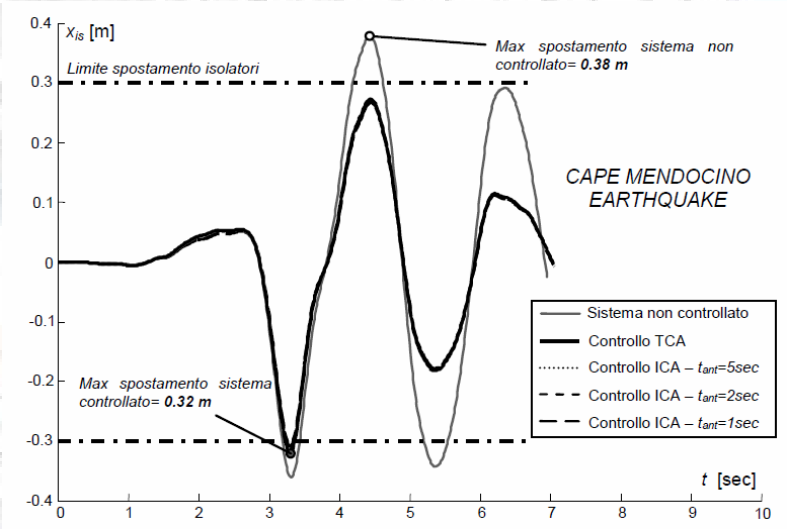


Strategy Effectiveness

Results highlights activation of AVS system is more effective and less sensitive to the available anticipation time



Application of AVS dampers



Application of AVD dampers

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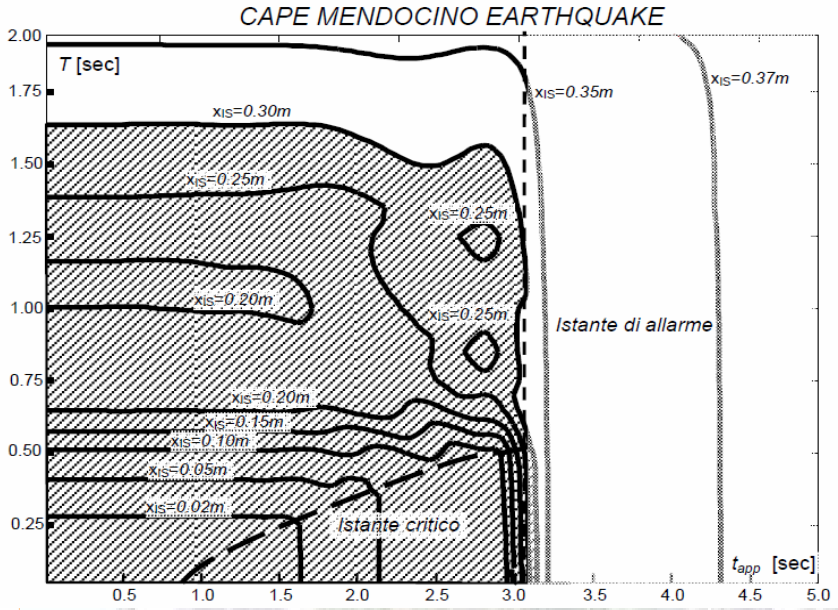
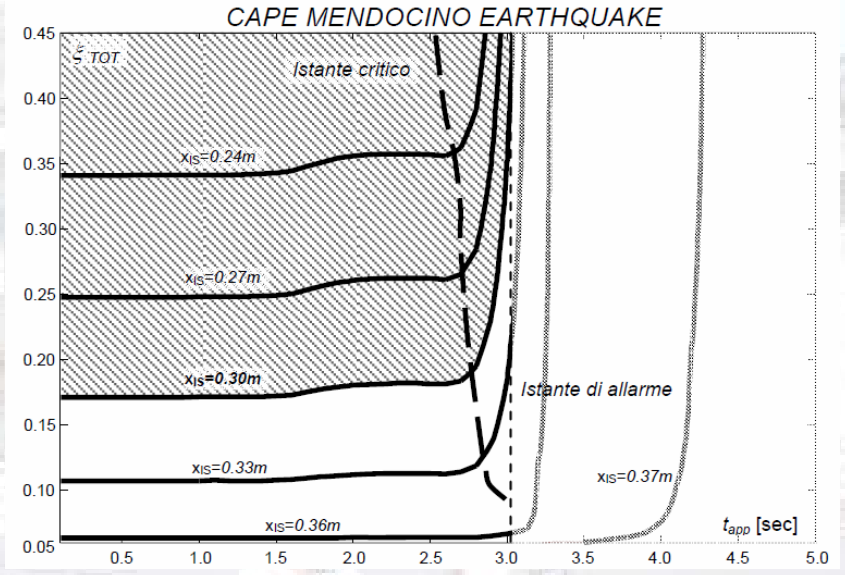
It's a matter of time and resources

The numerical analysis focused on the evaluation of semiactive control performance on varying the anticipation time and the dampers' capacity



Application of AVS dampers



Application of AVD dampers

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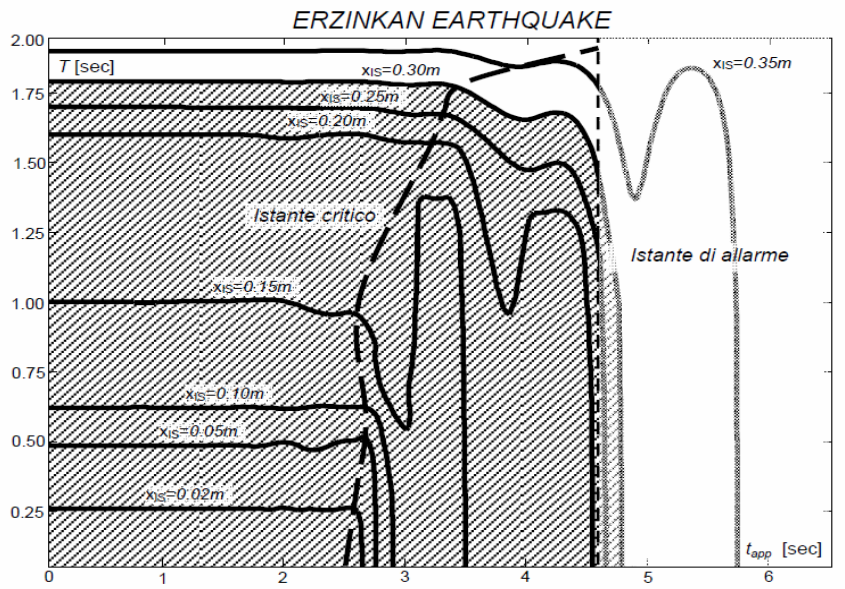
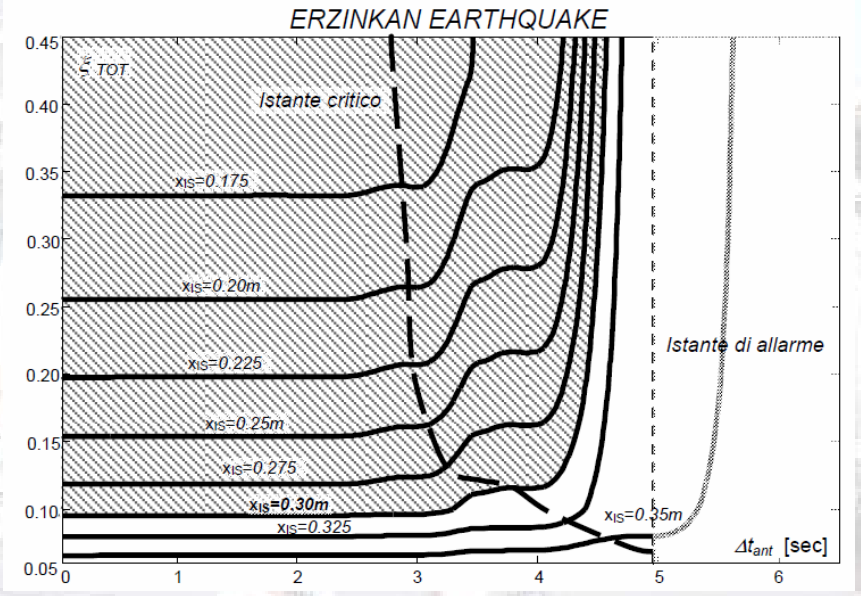


Application of AVS dampers



Application of AVD dampers

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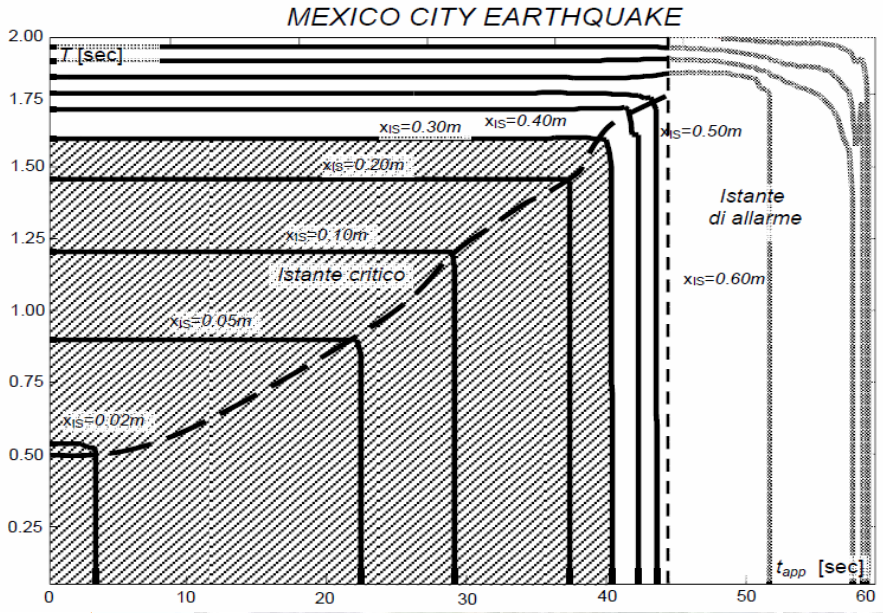
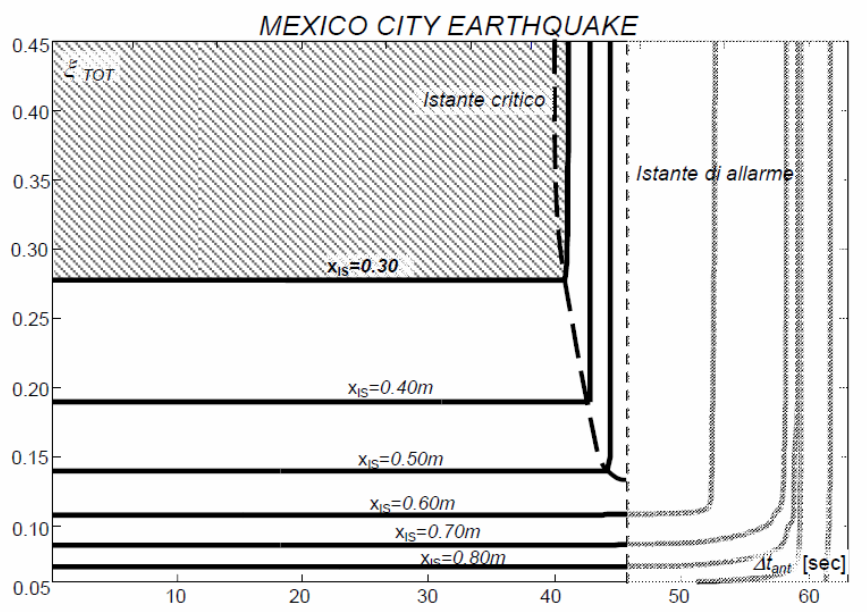


Application of AVS dampers



Application of AVD dampers

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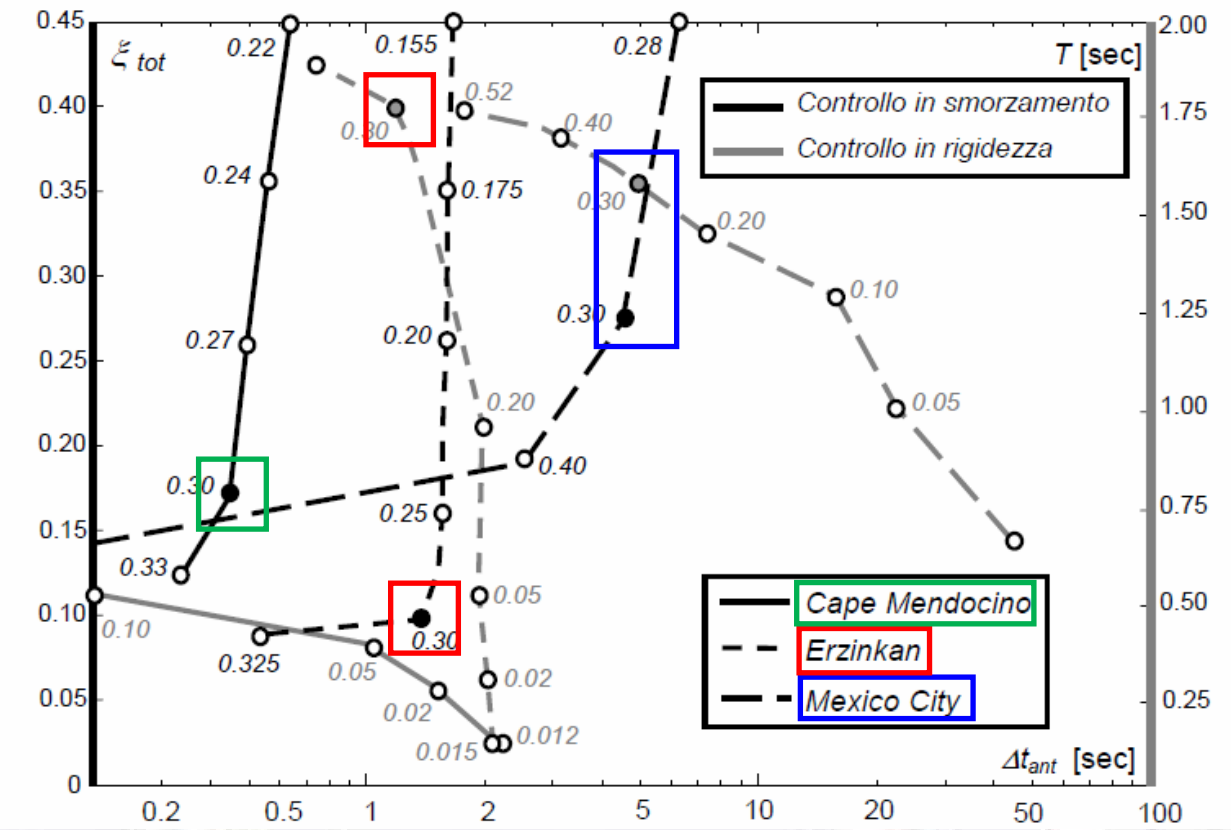
It's a matter of time and resources

Little anticipation time generally allows to stay within the performance limits, dampers capacity to reach the pre-assigned performance strongly depend from the dynamical characteristics of the incoming event



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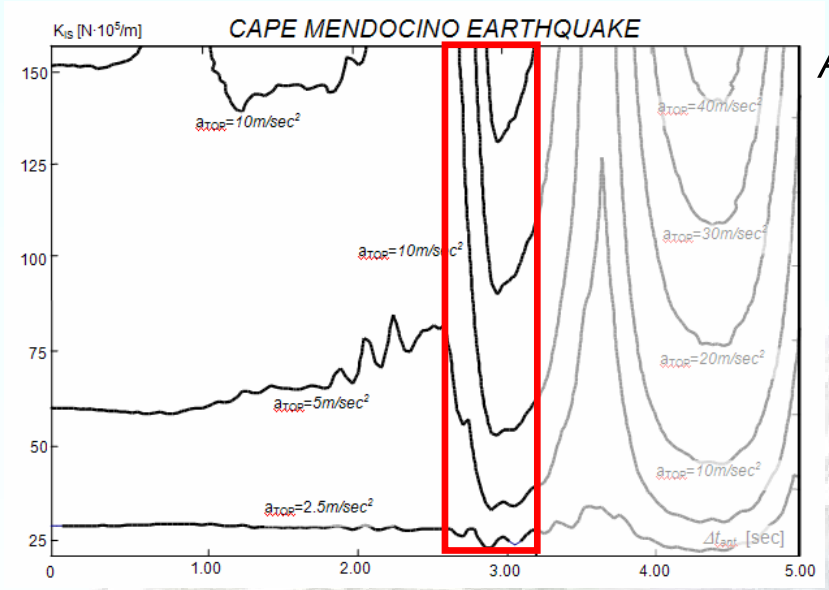
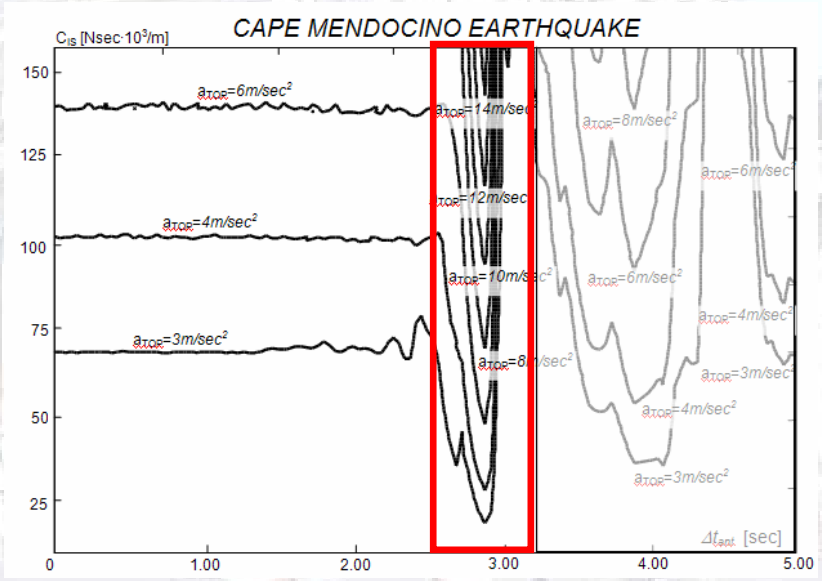
Superstructure performances

The effect of the anticipation time variable on the superstructure seismic response has to be carefully considered



Application of AVS dampers



Application of AVD dampers

Open issues

- *Algorithm effectiveness for non-deterministic signal (in progress)*
- *More complex and efficient control algorithm (in progress)*
- *Extension of the approach to non-fully controllable system (fixed base frame system)*
- *Effectiveness comparison between the EW strategy and classical semiactive control scheme (results available for some algorithm)*

Thanks for Your attention

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