Introduction to Earthquake Engineering

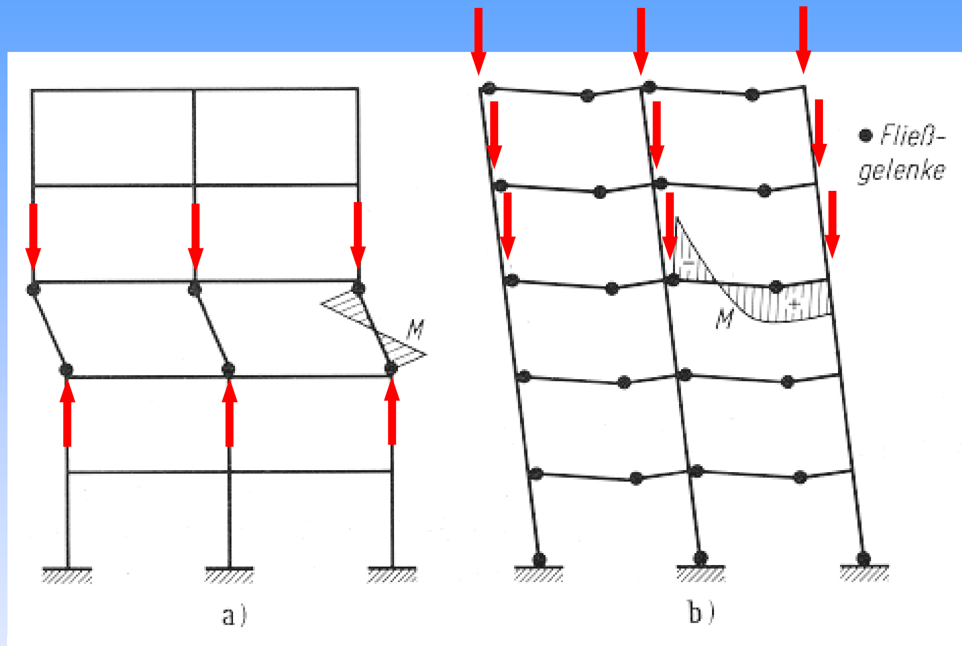
Structures under Earthquakes

UNIKASSEL
VERSITÄT
STAHL- & VERBUNDBAU

Conventional rc-frame structure under Kobe earthquake

Non-linear Cyclic Behavior of Frames

Large overturning moment



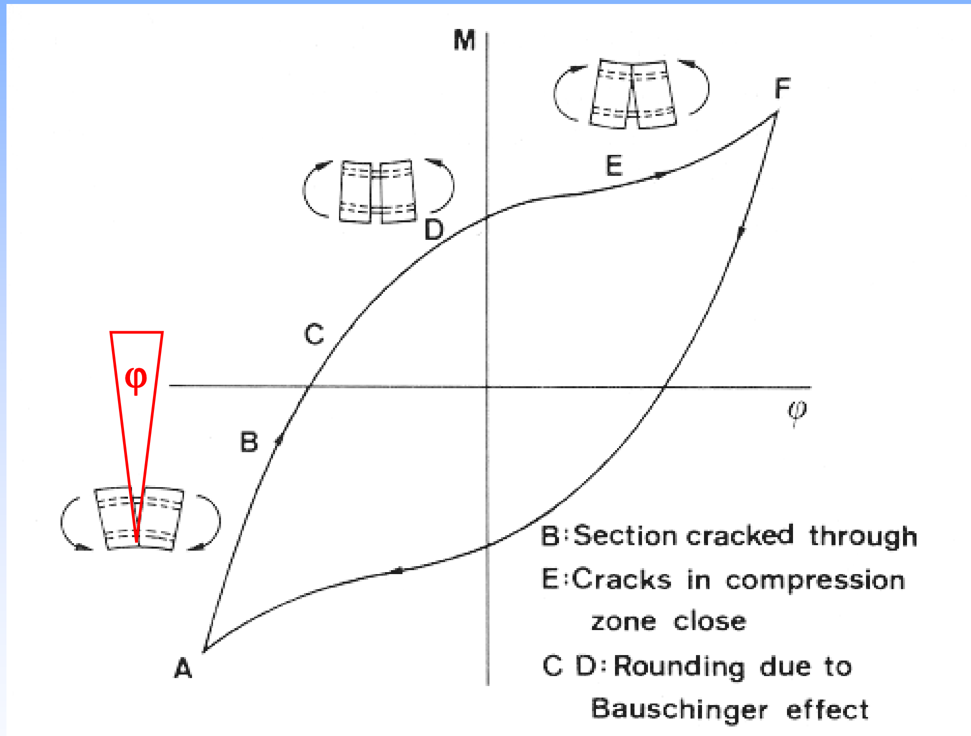
From Müller, Keintzel (2)

Failure in soft storey

Behaviour of Reinforced-Concrete Structures

Flexural cyclic behaviour in plastic hinges

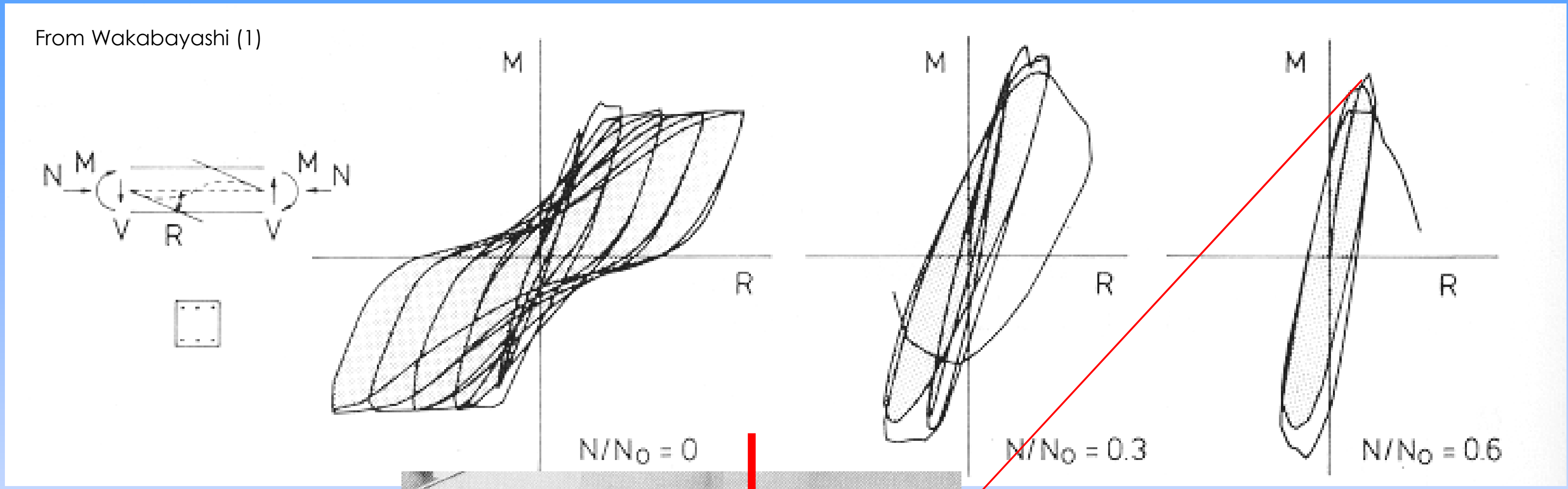
From Earthquake Spectra (10)

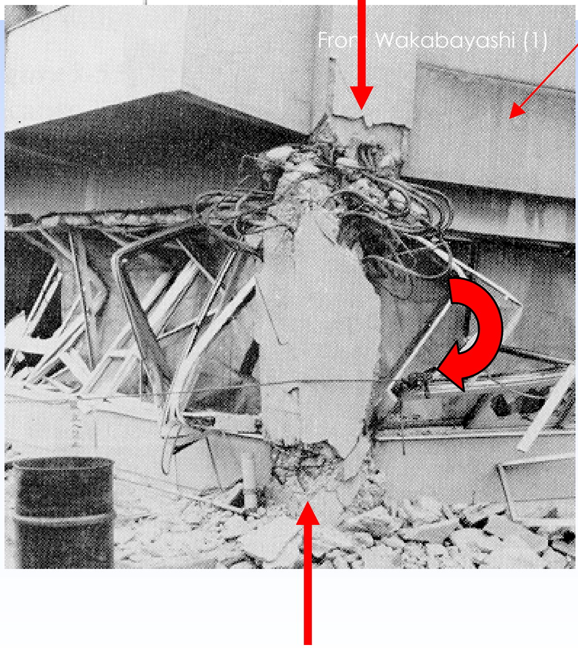


From Wakabayashi (1)

The rc-beam-column:

Behaviour under combined bending (moment and shear) and axial forces:



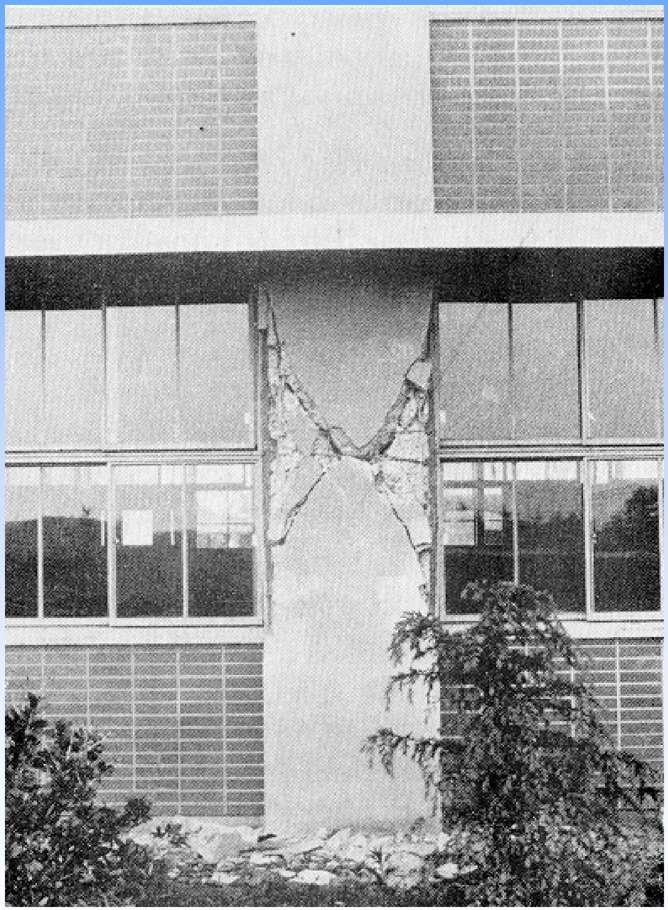


Large overturning moment leads to sudden failure

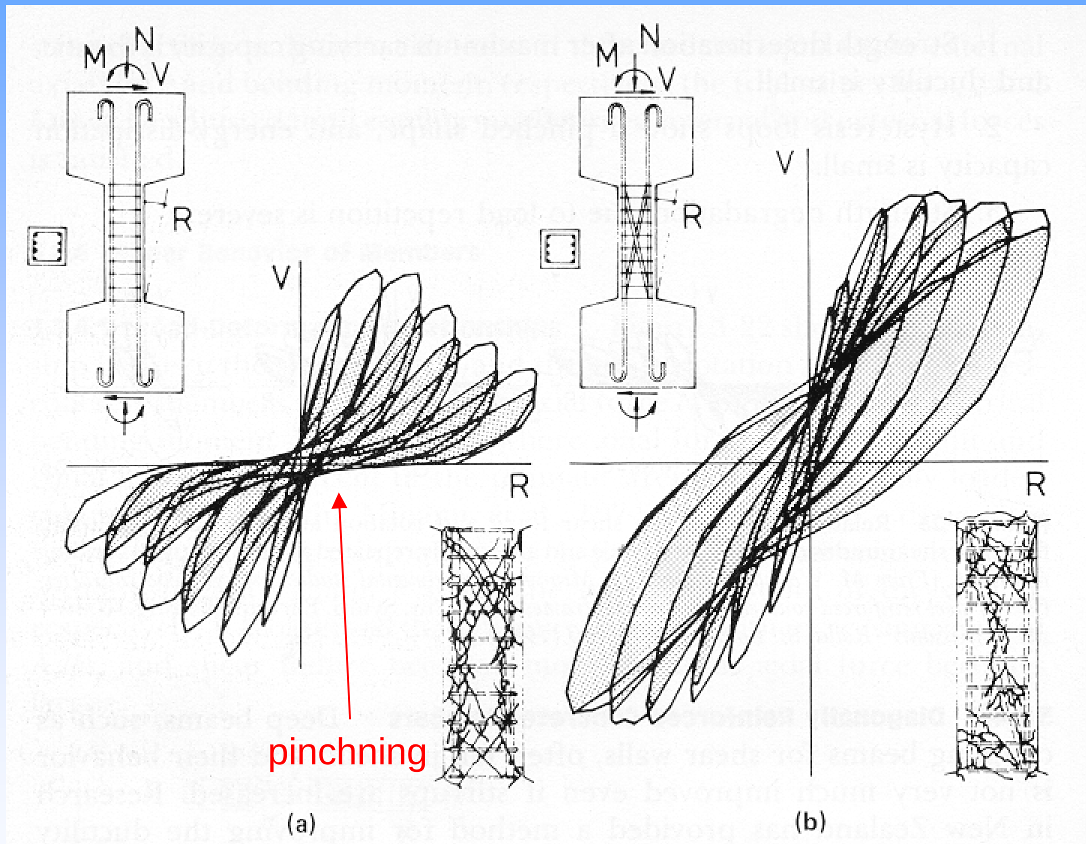
Short column:

Short Columns

Extreme **pinching** of hysteresis loop and failure in shear

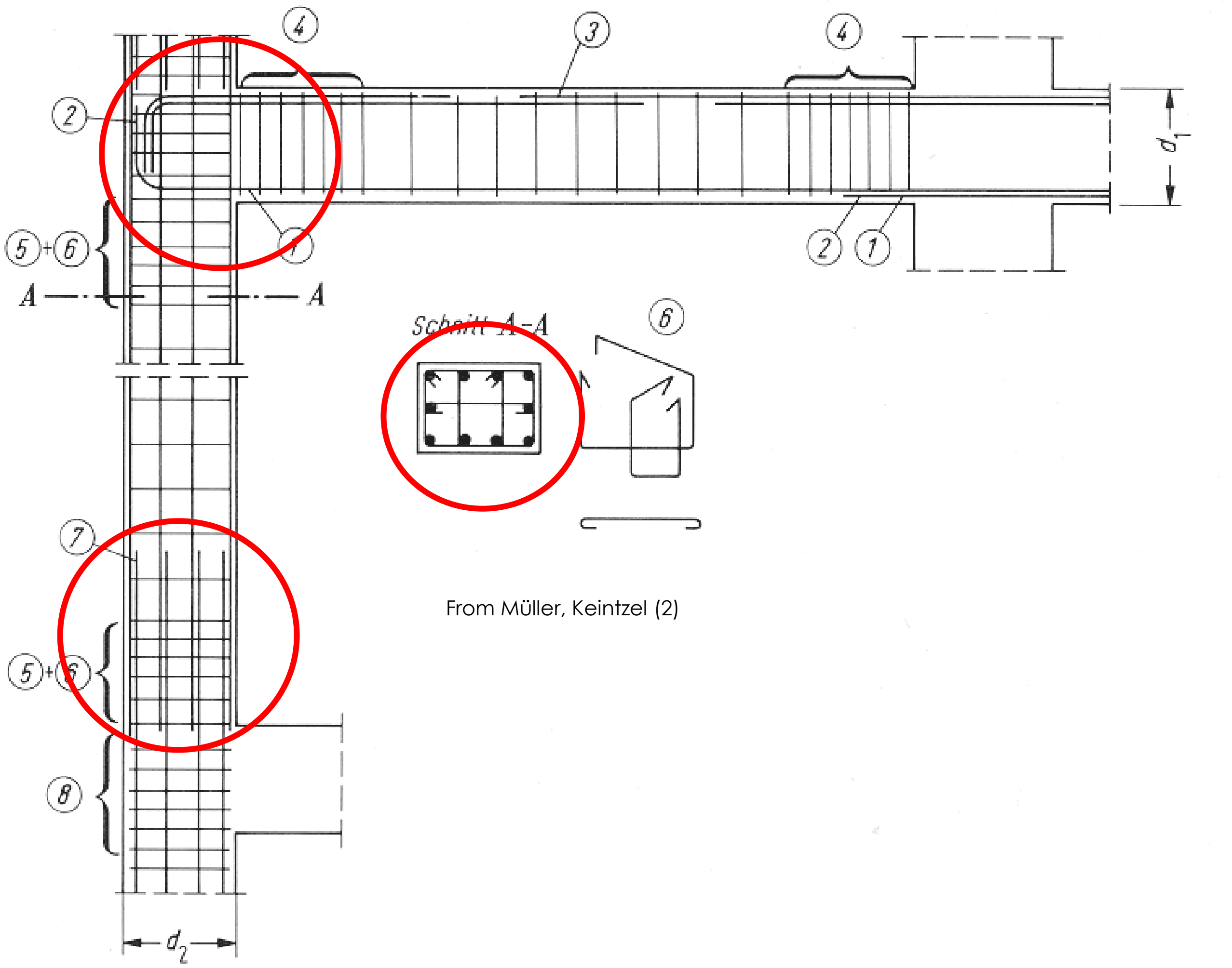


From Wakabayashi (1)



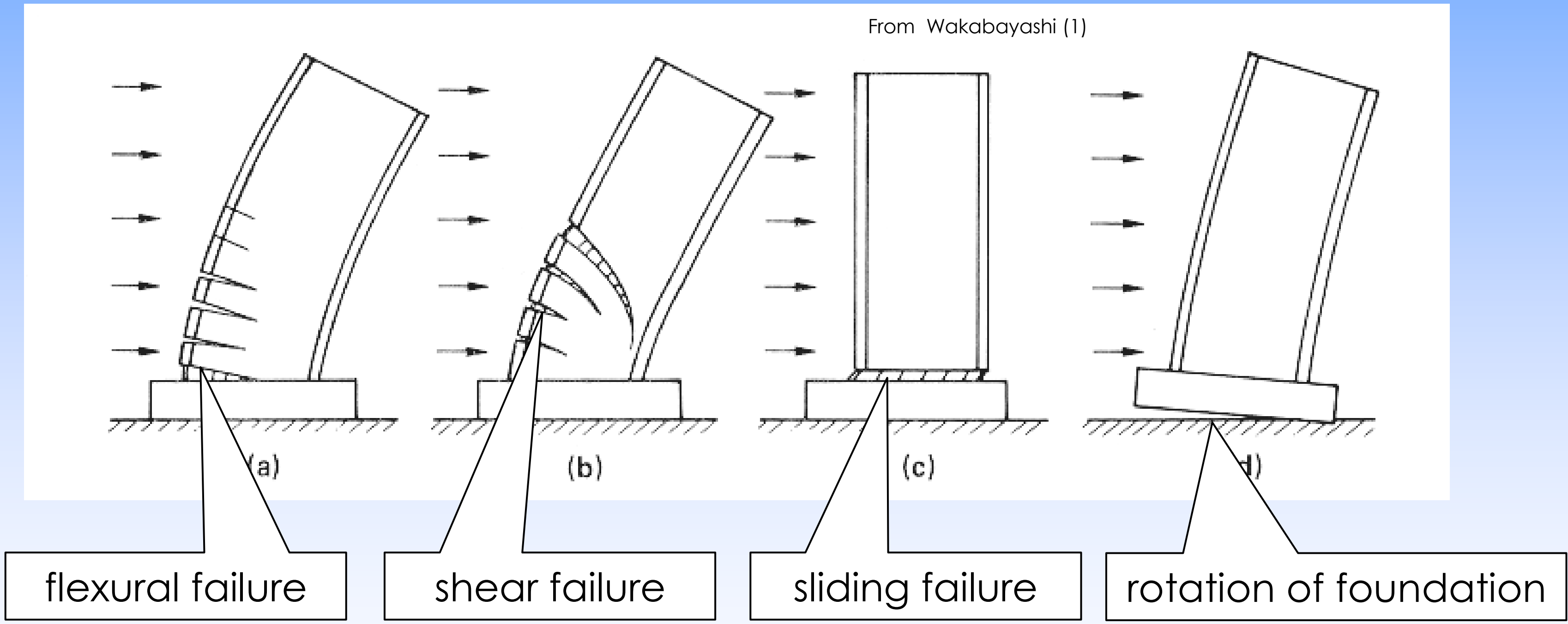
From Wakabayashi (1)

Complicated details in rc-frames:



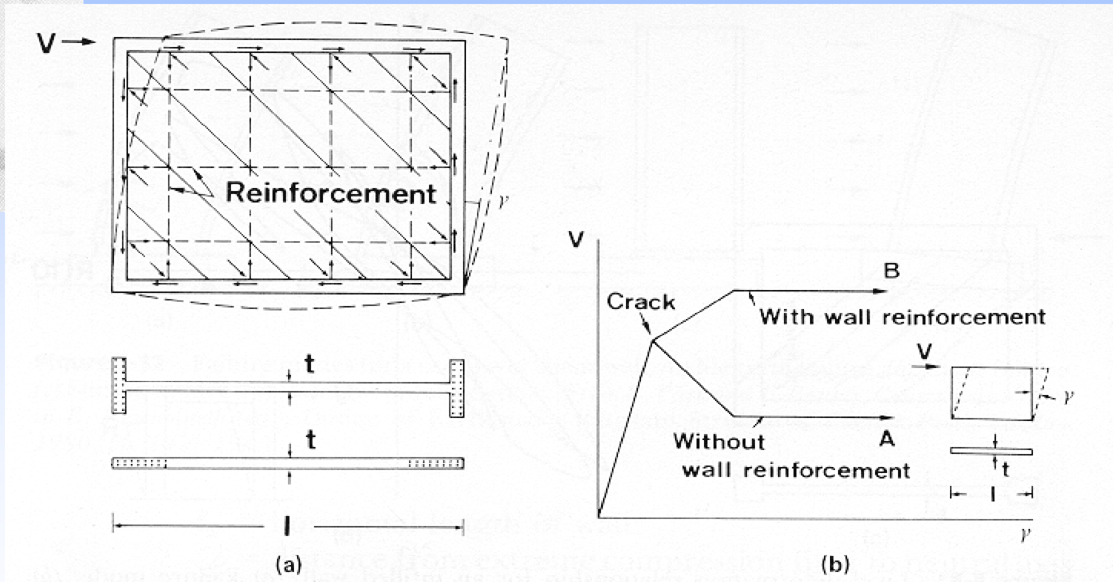
From Müller, Keintzel (2)

Non-linear Cyclic Behavior of Walls



Shear walls

From Wakabayashi (1)



From Wakabayashi (1)

Pre-cast connections

From Wakabayashi (1)

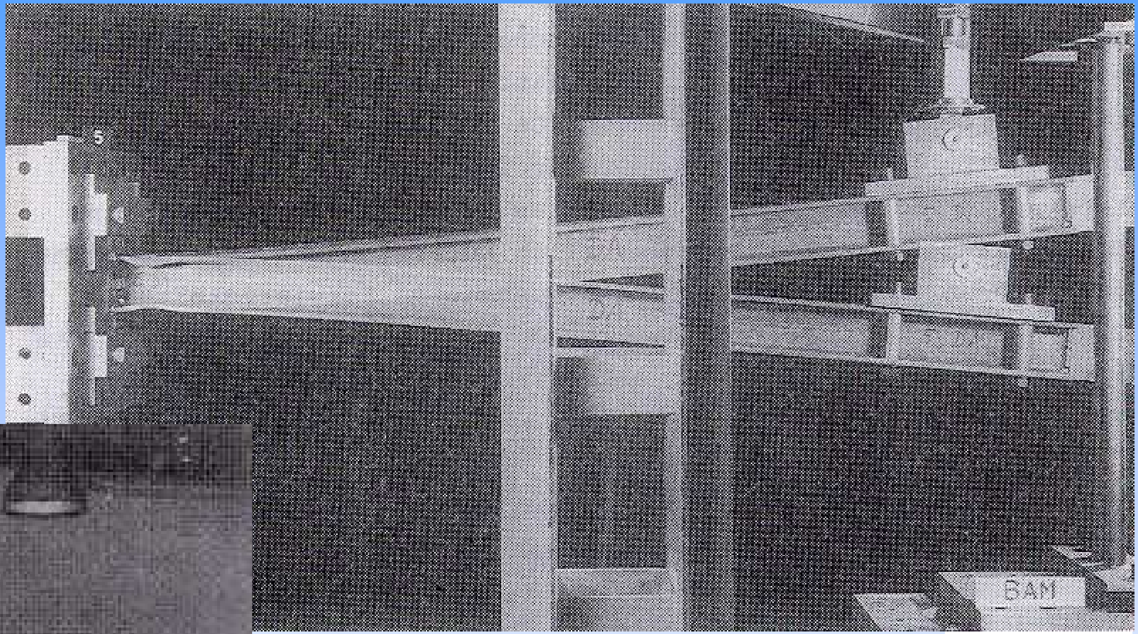
From Earthquake Spectra (10)

Behaviour of Steel Structures

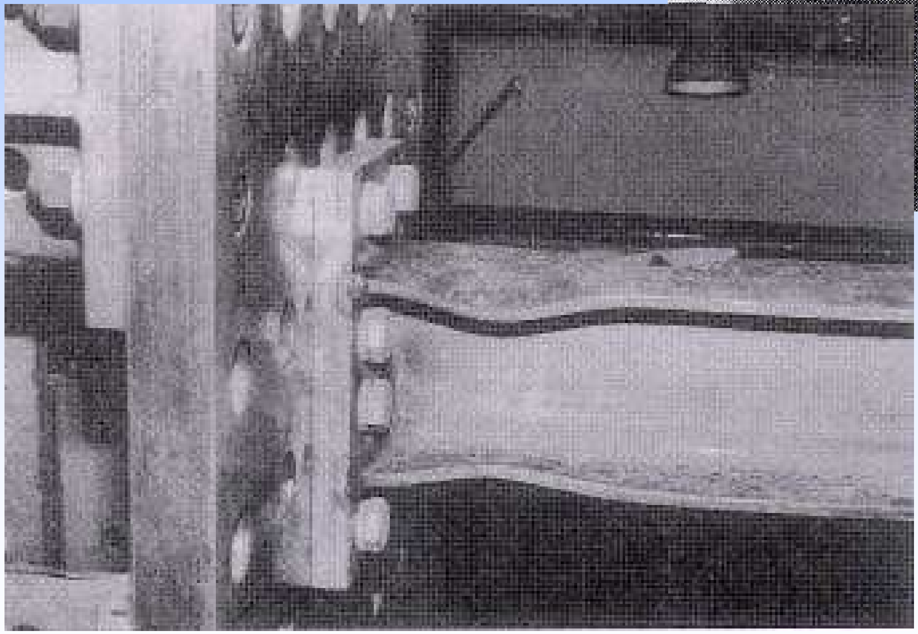
Conventional steel structure under Kobe earthquake: Soft storey

Behaviour of Steel Structures

Plastic hinges

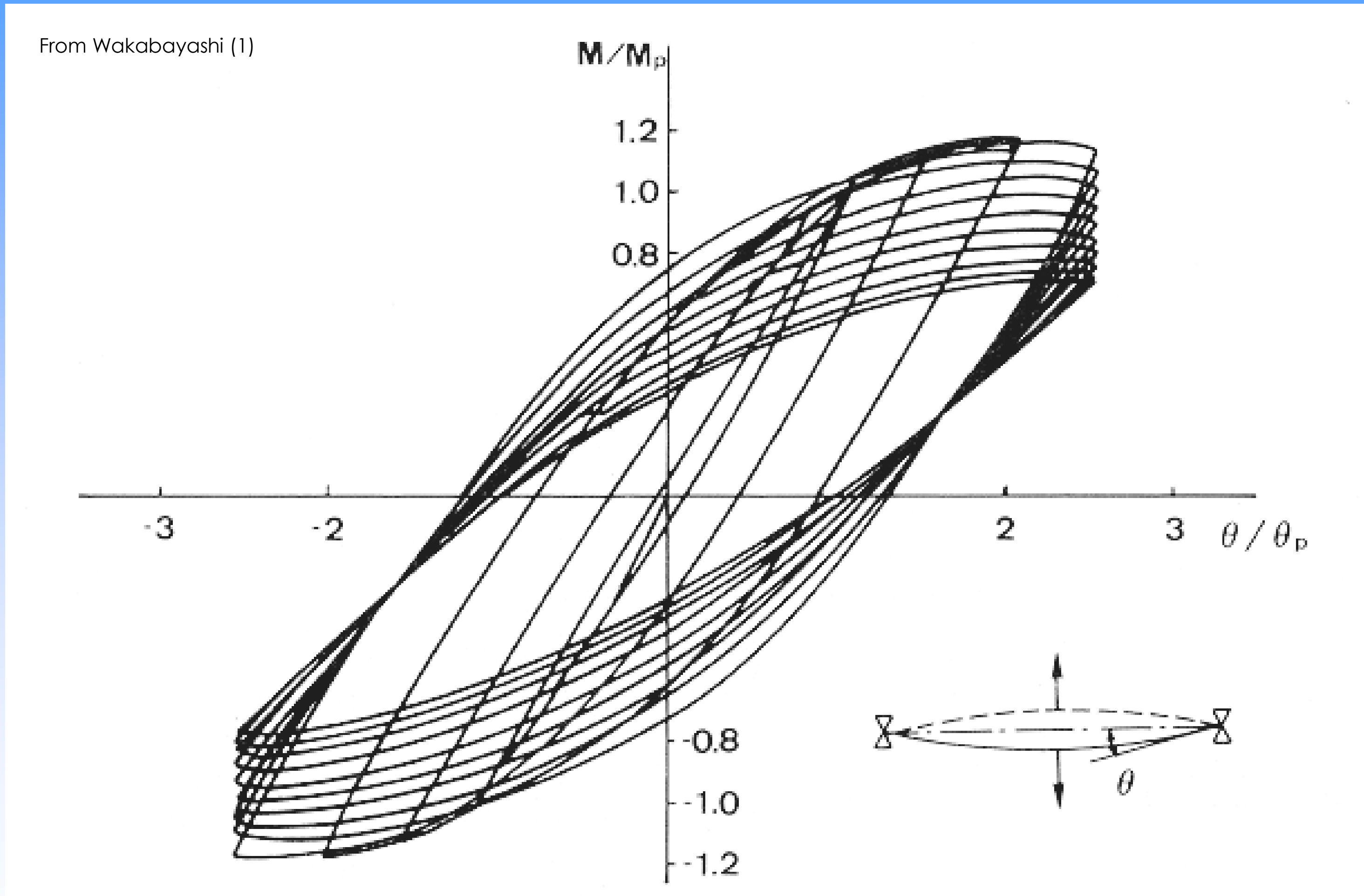


From DGEB (8)



Local Buckling under Cyclic Loading

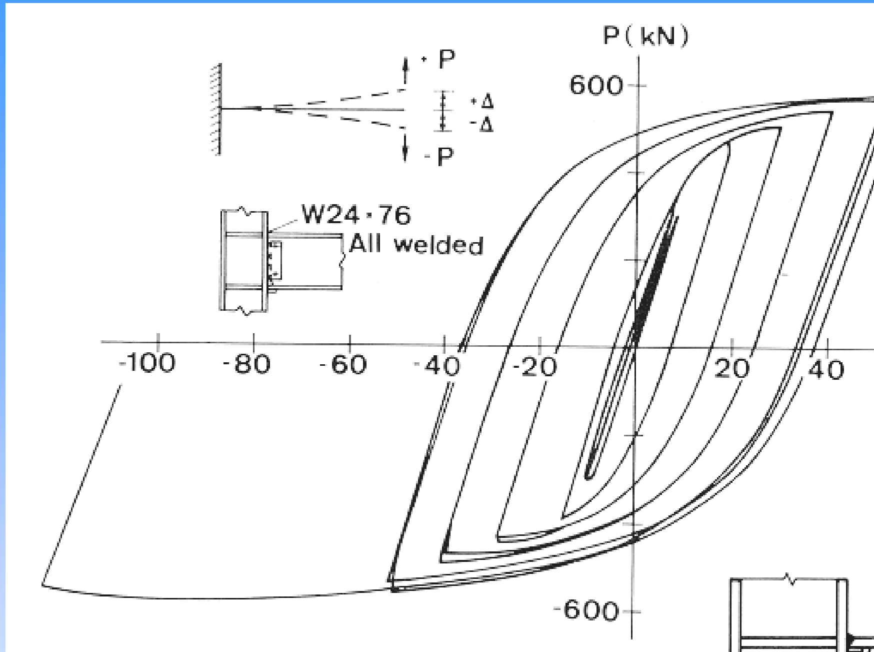
Relationship between moment and rotation angle for a beam under cyclic loading



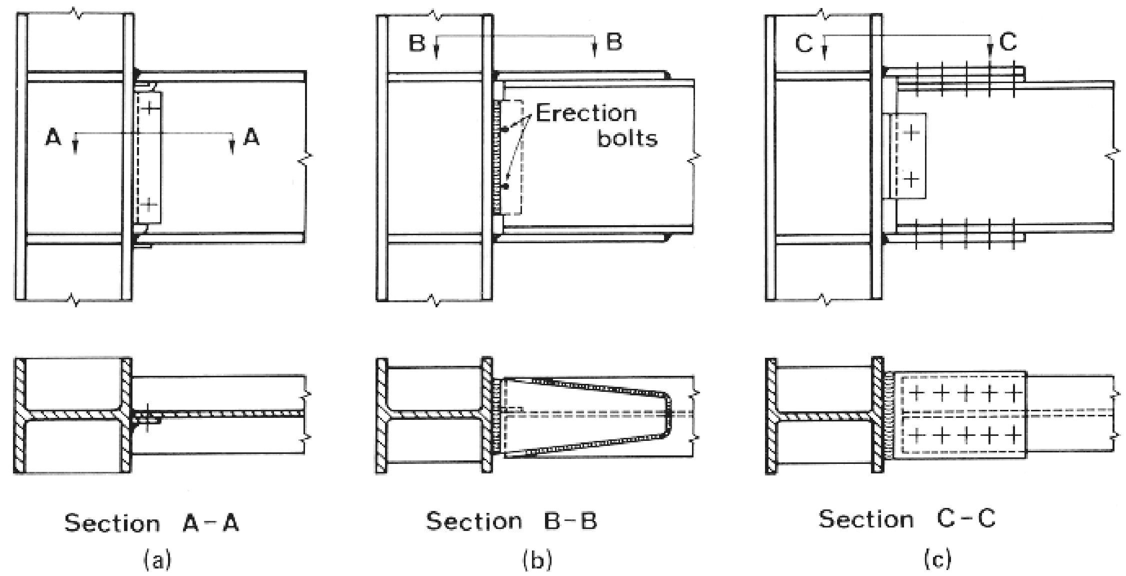
Fracture in connections

Both Pictures from earthquake Spectra (10)

Seismically sound connections

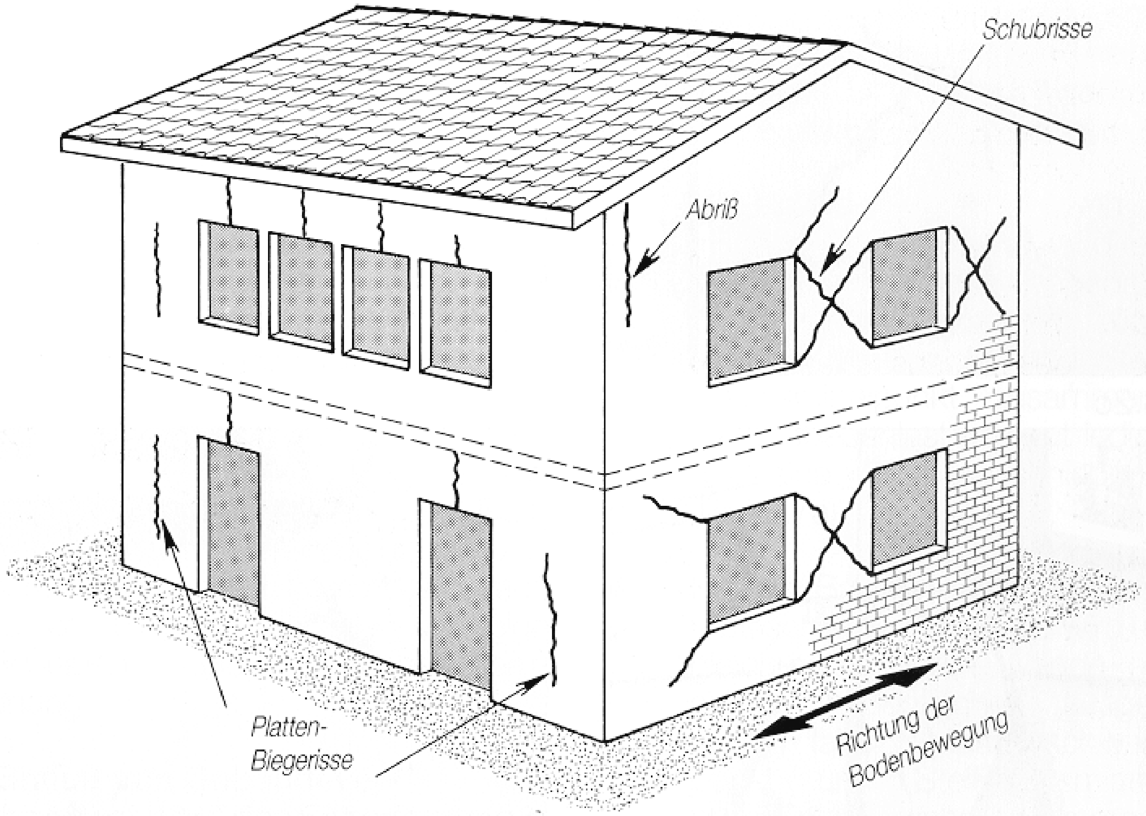


From Wakabayashi (1)

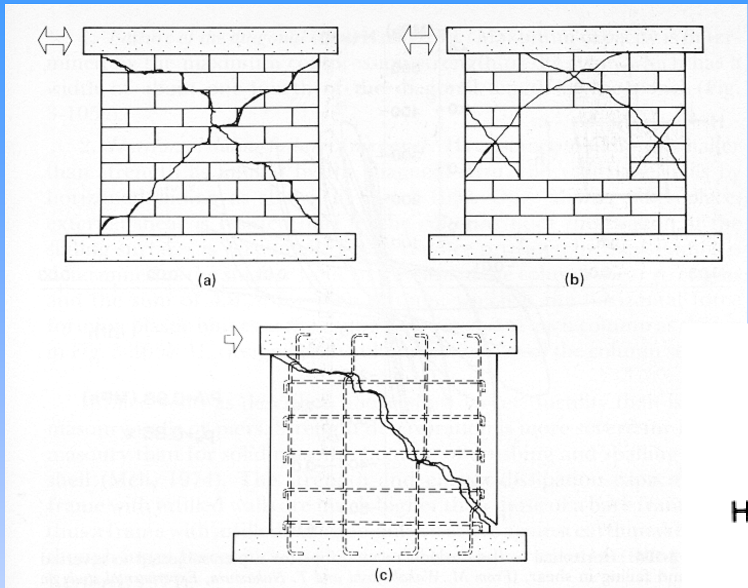


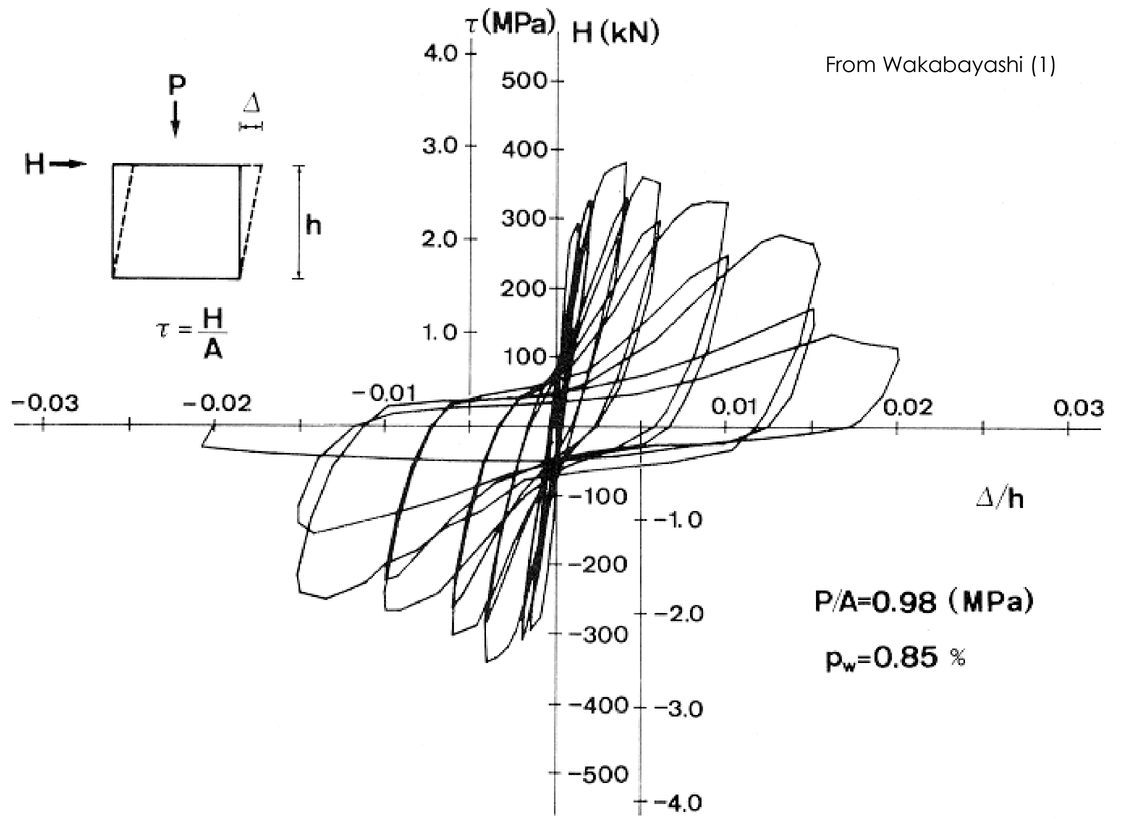
Masonry Structures

From Wakabayashi (1)


Schubrisse
Abriß
Platten-
Biegerisse
Richtung der
Bodenbewegung

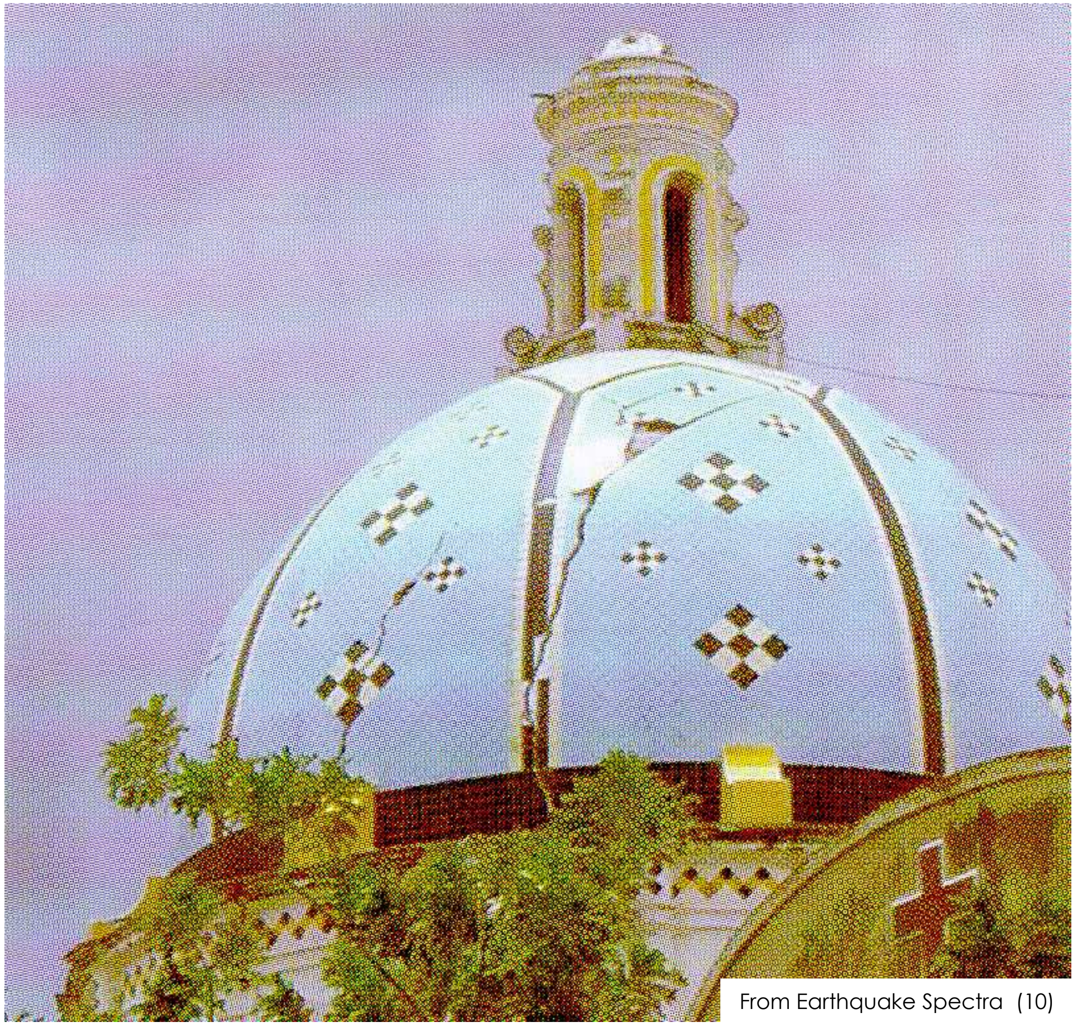
Horizontal load-deflection relationships for a pier subjected to reversed shear and failing in shear





Historic Structures

Historic Structures



From Earthquake Spectra (10)

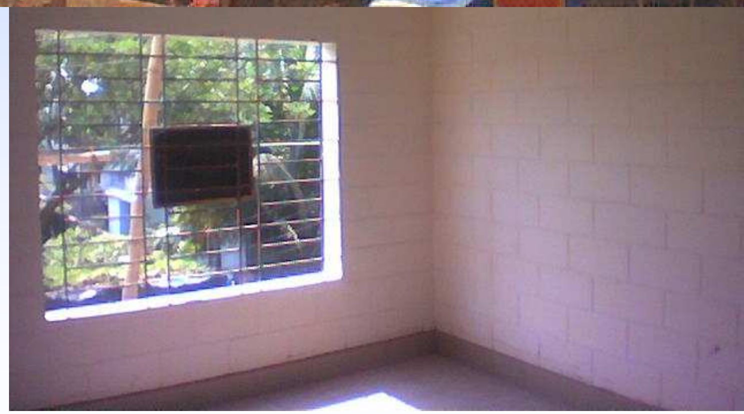
Historic Structures

Historic Structures

Seismically Robust Structures

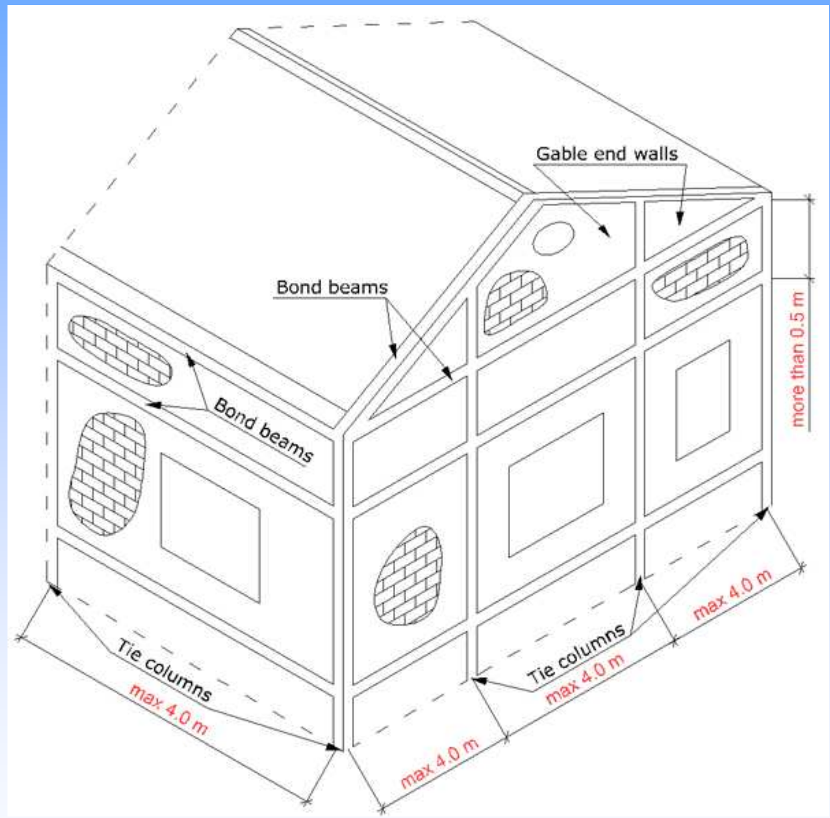
Reinforced masonry:

- simple
- inexpensive
- easy quality control
- architectural freedom



Seismically Robust Structures

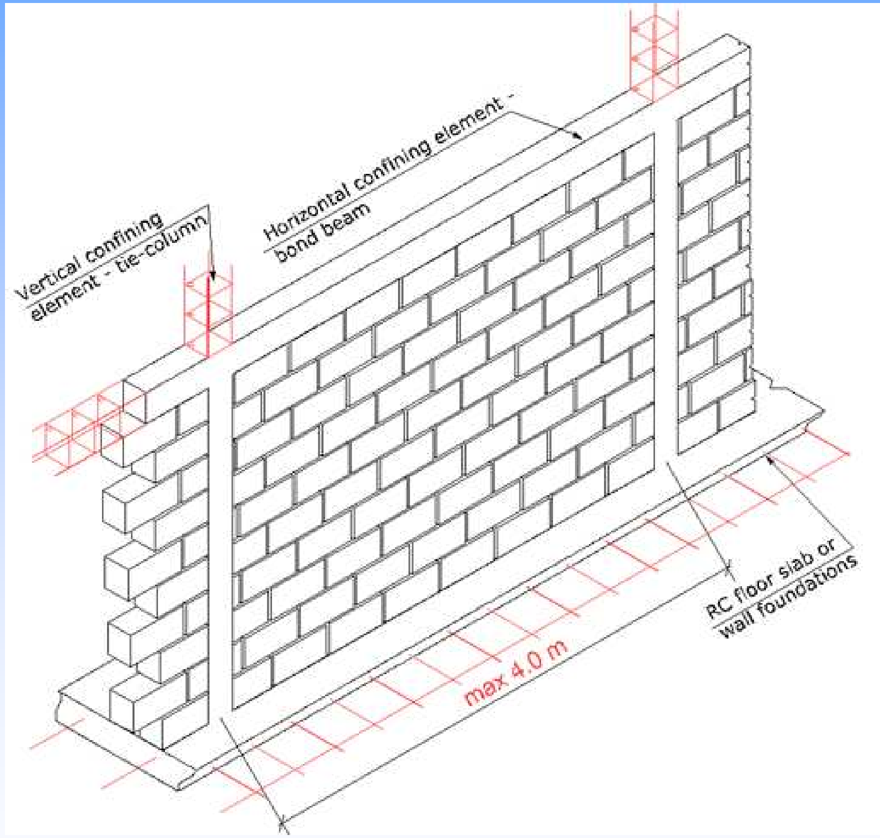
Confined masonry:

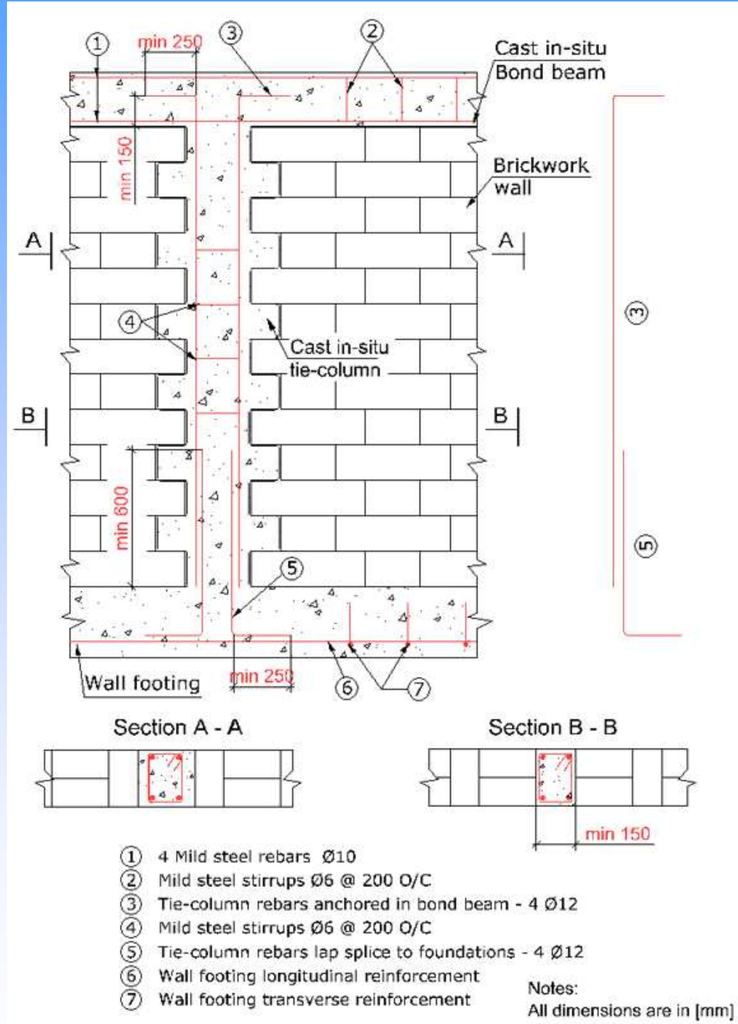


From WHE Report Peru

Seismically Robust Structures

Confined masonry:

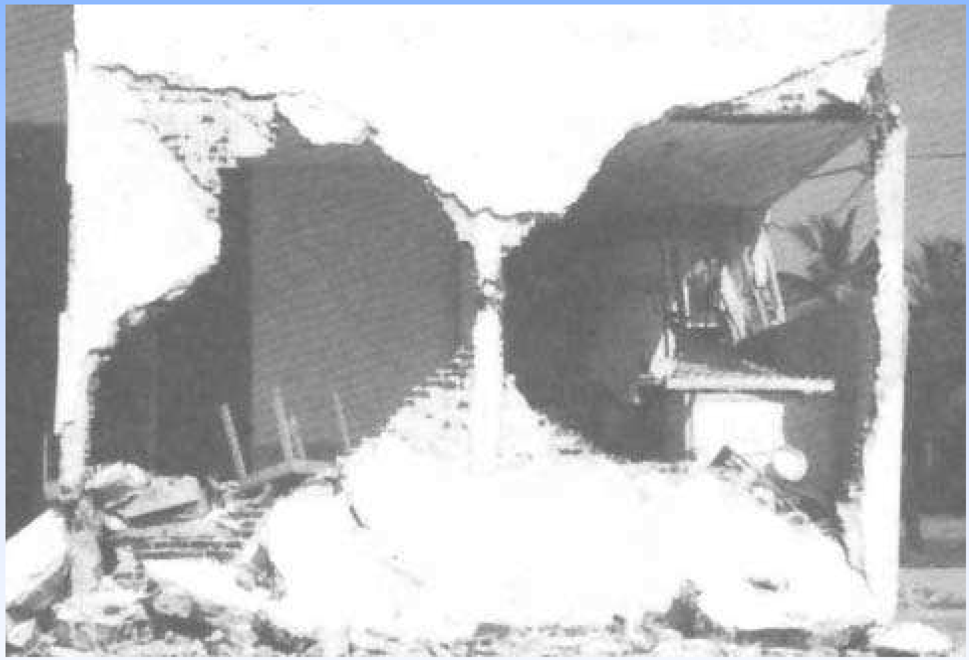




Seismically Robust Structures

Confined masonry:

Damages when structural rules are not strictly observed

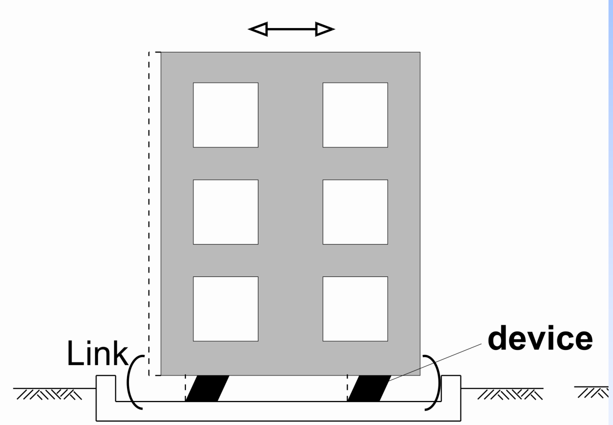


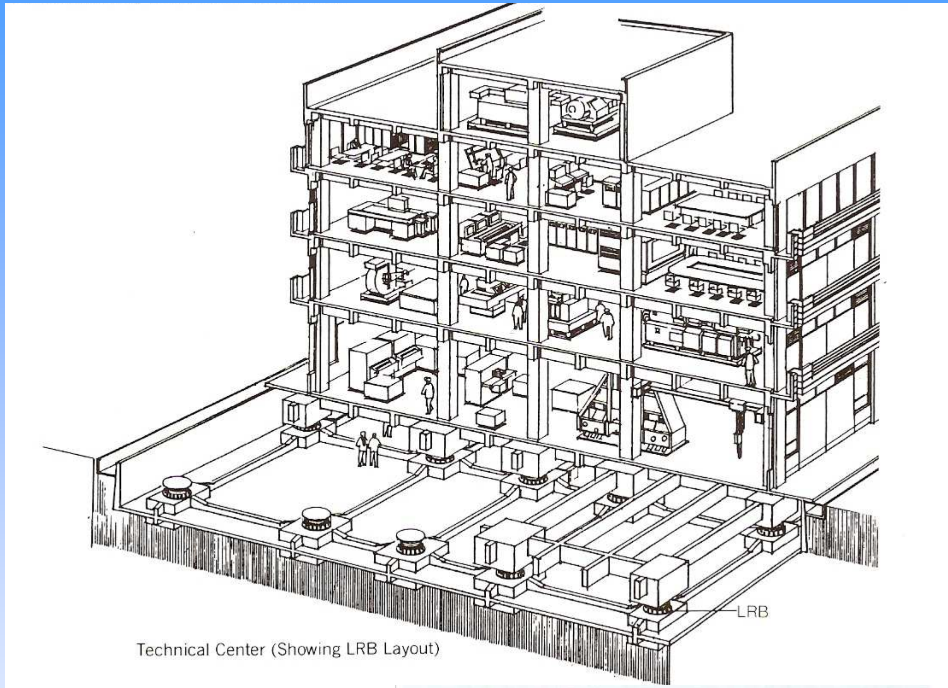
From WHE Report Chile

Control concepts for earthquake protection

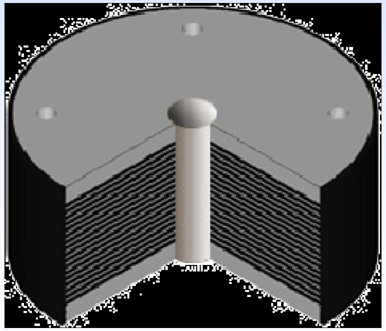
Base Isolation:

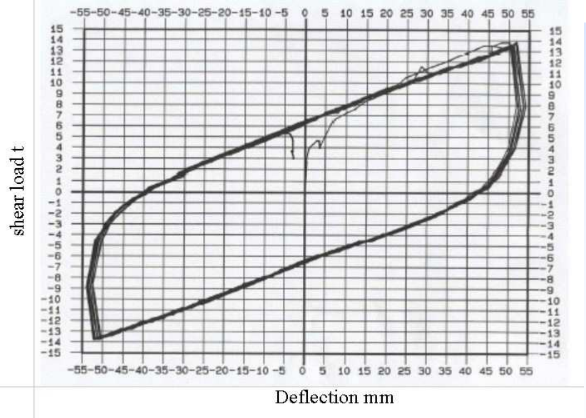
- A rigid body mechanism de-coupled from the base and controlled by soft passive or semi-active devices





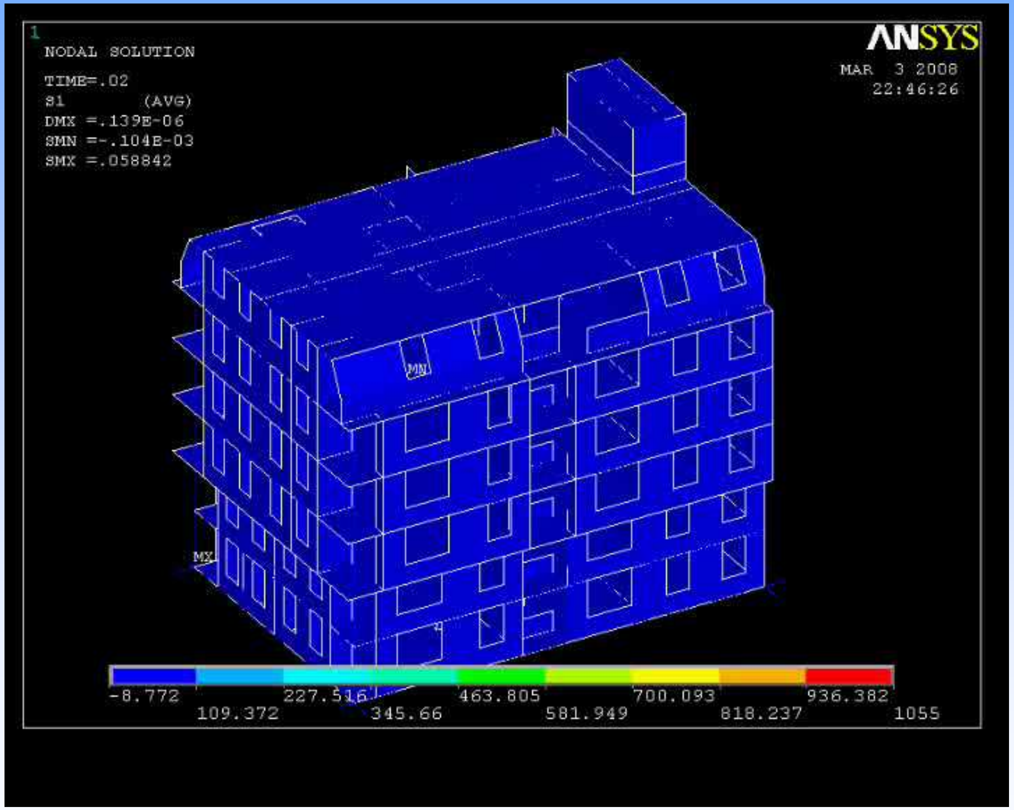
Lead-rubber bearing:





Control concepts for earthquake protection

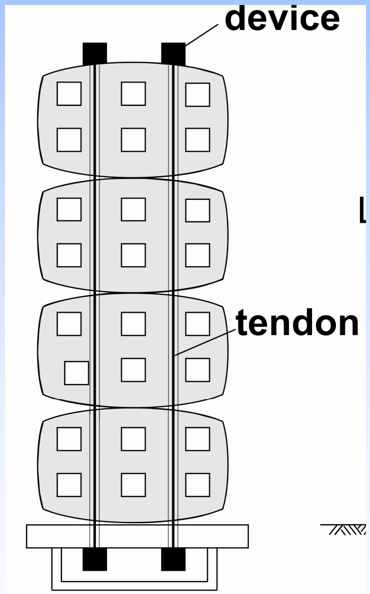
Base Isolation:



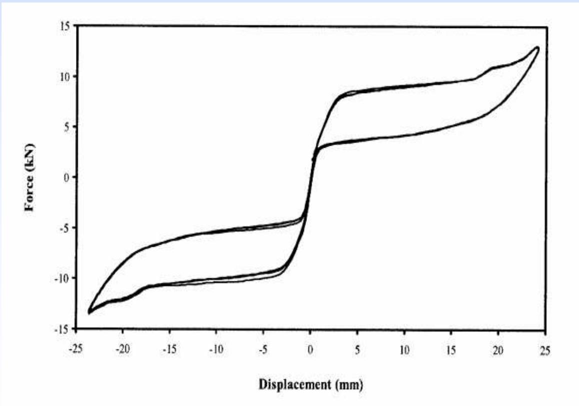
Control concepts for earthquake protection

Tendon System:

- Tendons with passive or semi-active devices control the motion of rigid bodies

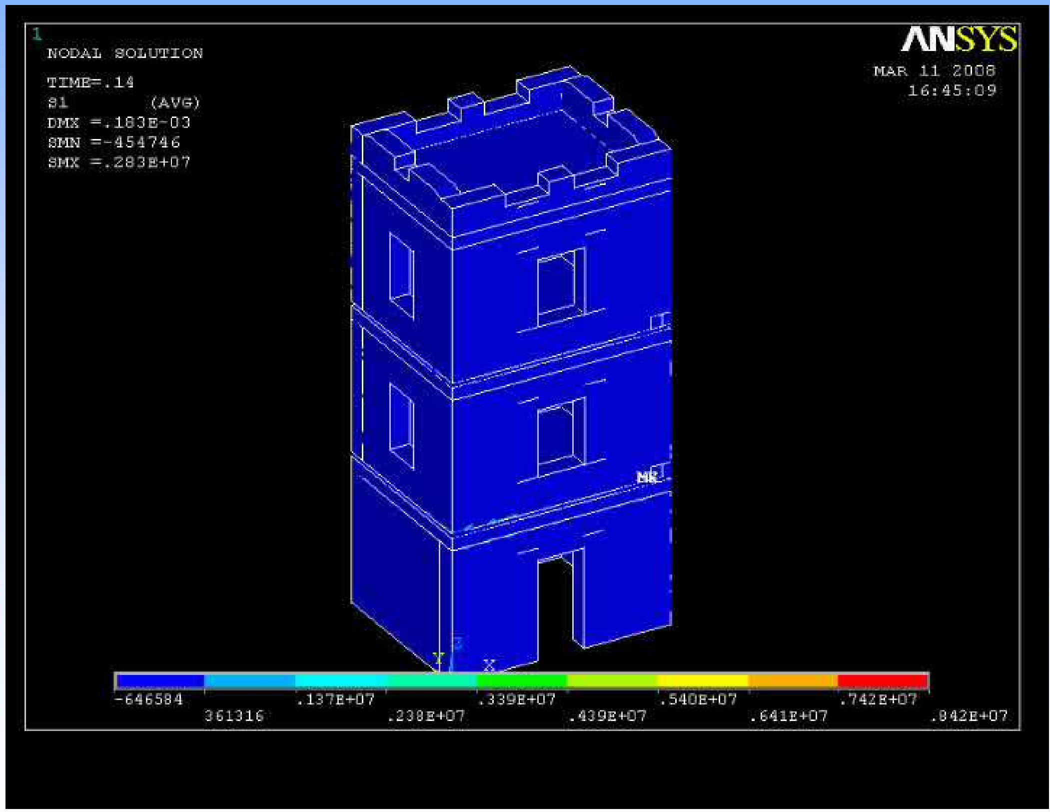


Shape memory alloy device:



Control concepts for earthquake protection

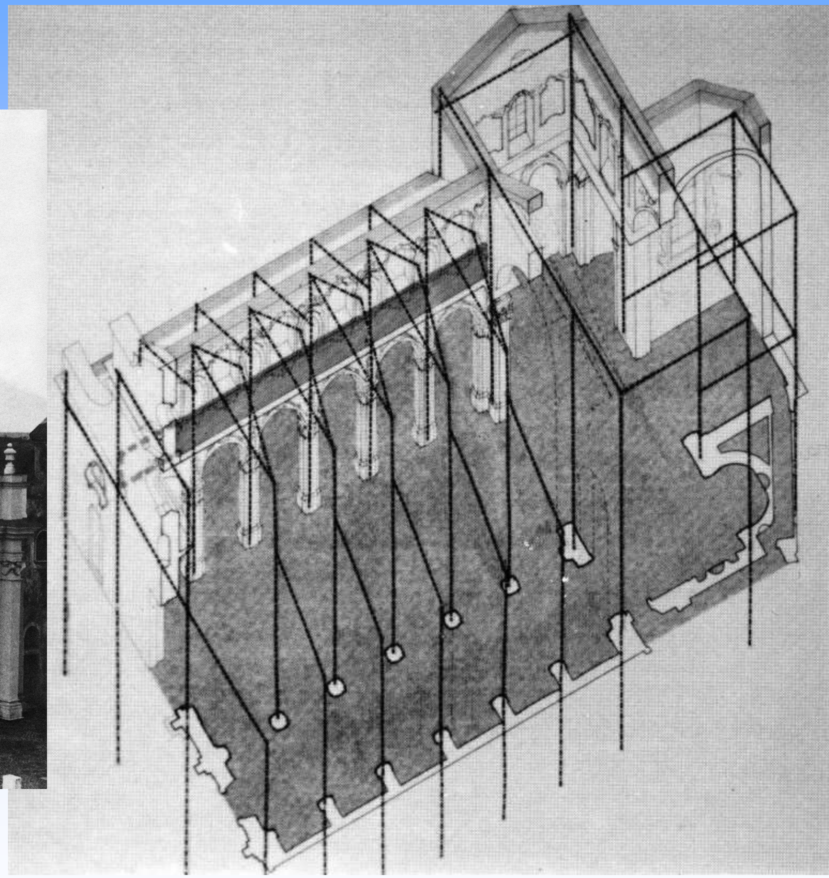
Tendon System:



Control concepts for earthquake protection

Tendon System:

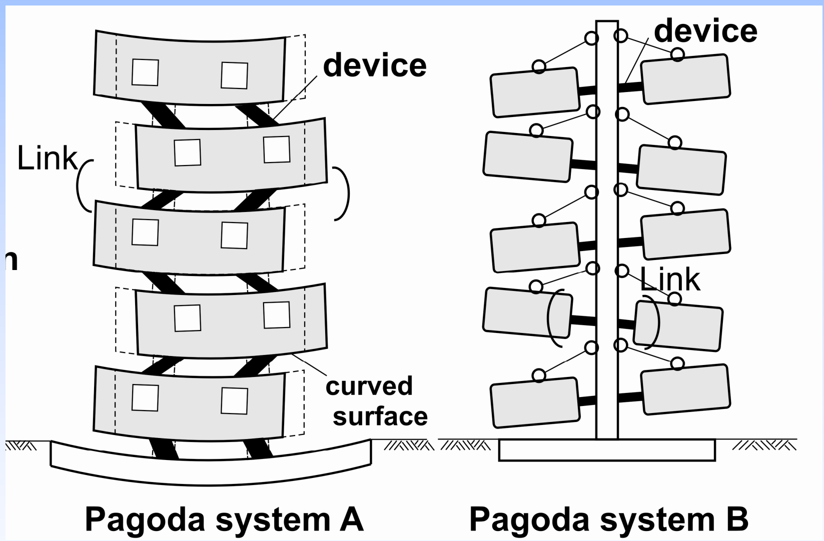
- Retrofitting of historic structures



Control concepts for earthquake protection

Pagoda System:

- A “snake dance” rigid body mechanism controlled by friction “devices” that is proven for over 1200 years



Control concepts for earthquake protection

Pagoda System:

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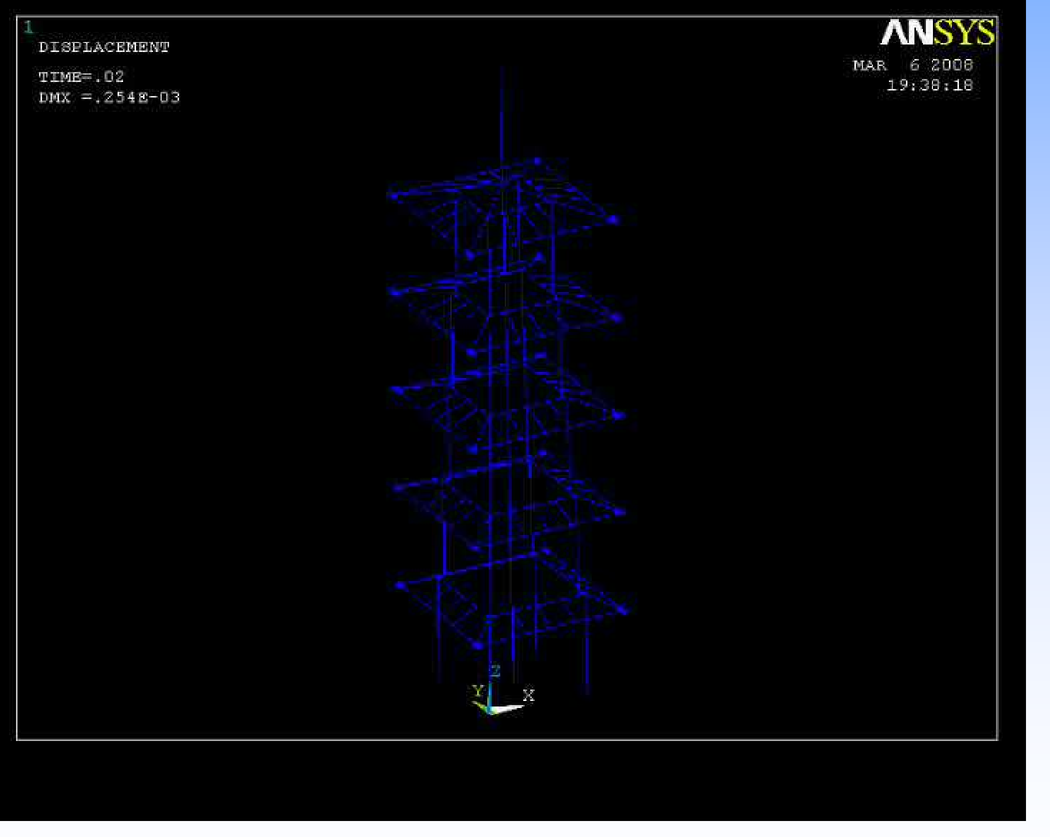
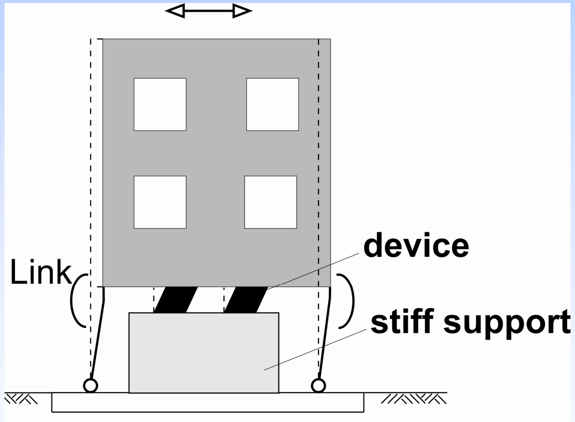
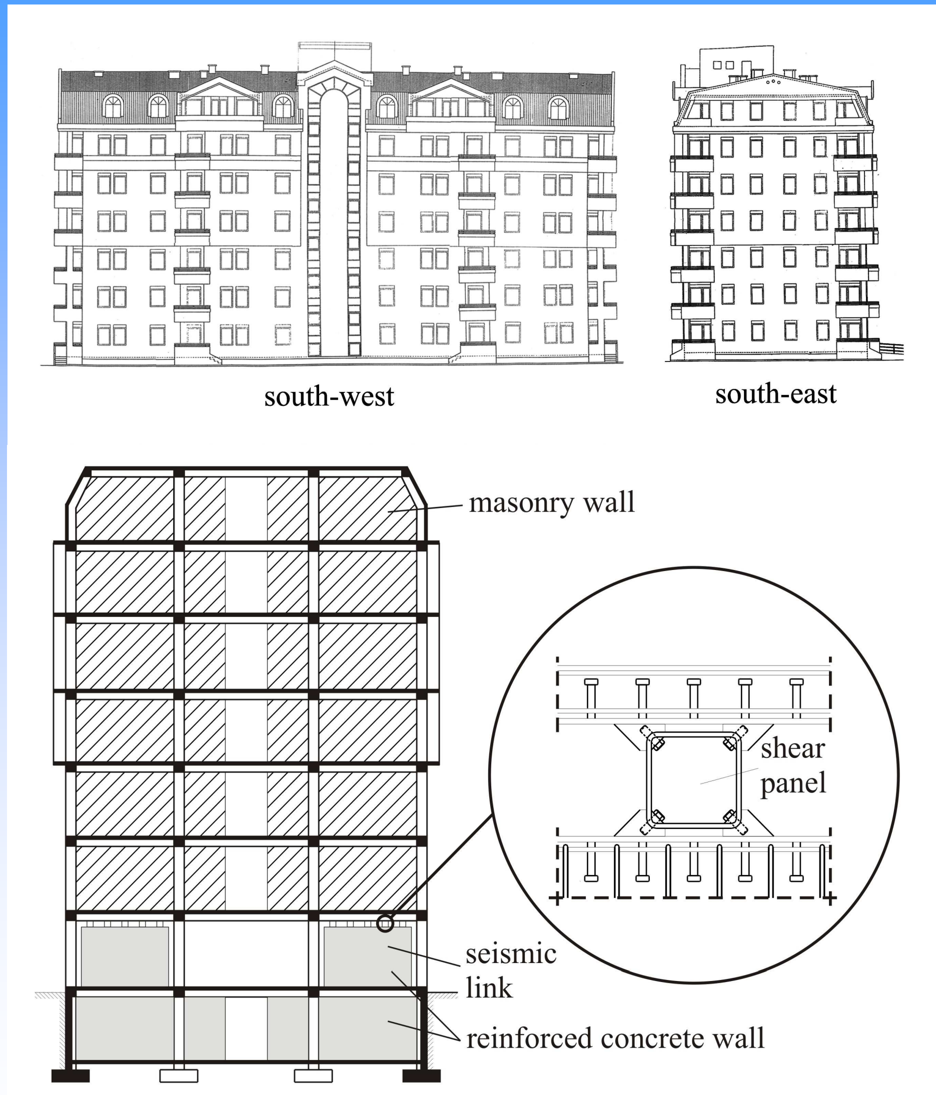


Control concepts for earthquake protection

Hyde System:

- A plastic rigid body motion in a seismic link controlled by stiff-plastic devices
- Suitable for retrofitting **soft-storey structures!**

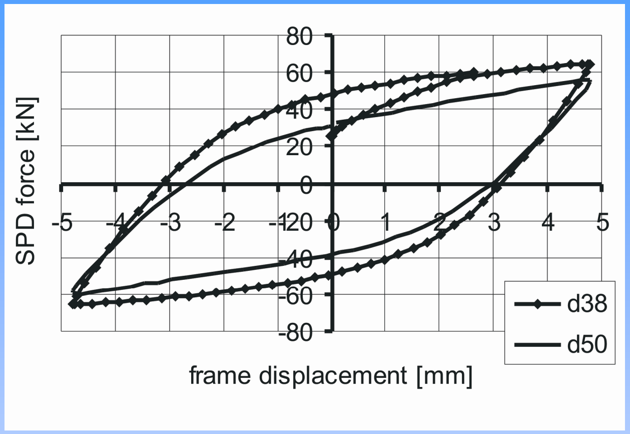




Control concepts for earthquake protection

Hyde System:

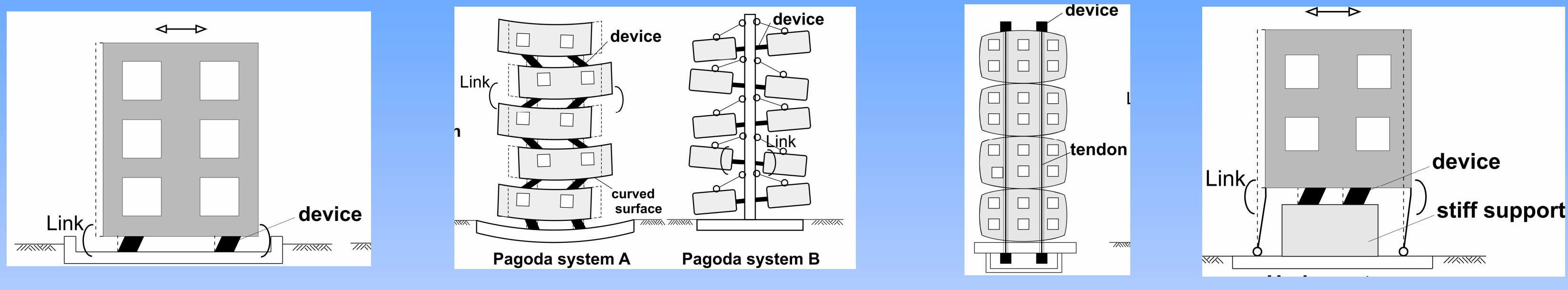
- has been verified with large-scale pseudo-dynamic tests at JRC-Ispra on a 1/2-scale steel frame with shear-panels



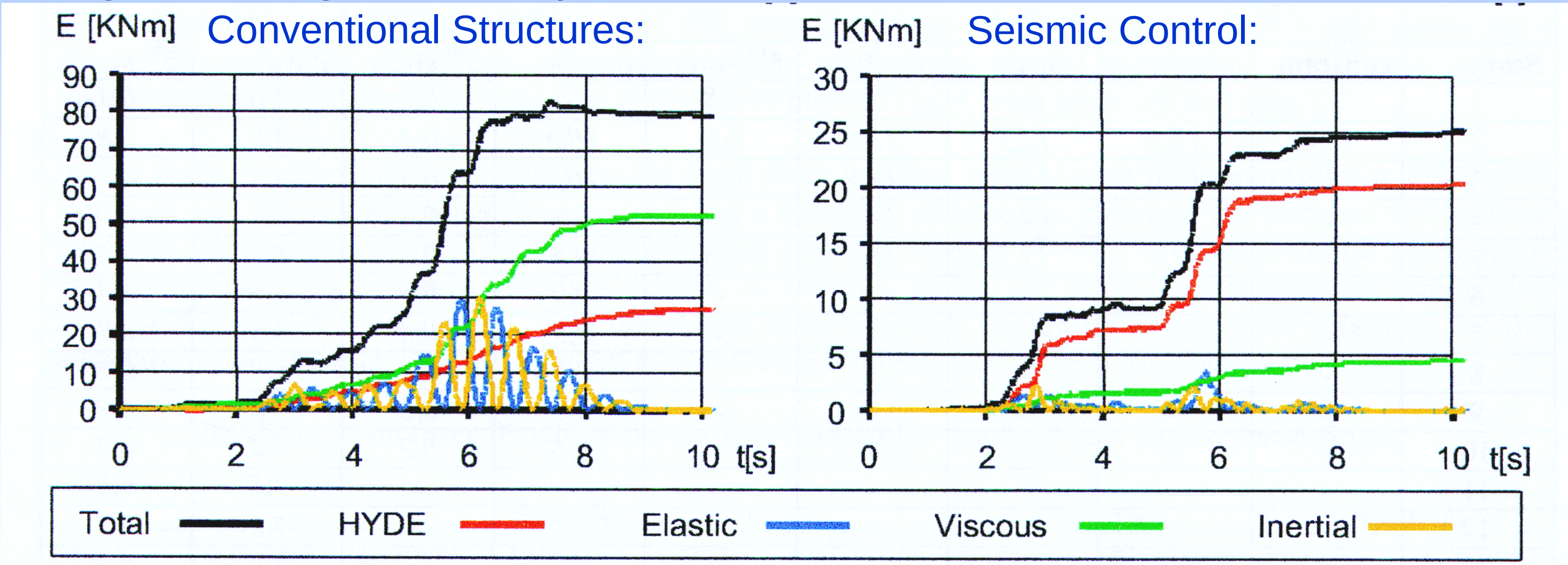
Control concepts for earthquake protection

Rigid body motion control: No vibrations, small forces and displacements

Base isolation | Pagoda System | Tendon System | Hyde System



Energies during an earthquake:



Conventional Bridges

Deck failure by
dropping off supports

Both Pictures from Earthquake Spectra (10)

Conventional Bridges

Sudden column failure
in brittle shear

Both Pictures from Earthquake Spectra (10)

Conventional Bridges

Failure due to excessive drift and large overturning caused by vertical loads

Both Pictures from Earthquake Spectra (10)

Conventional Bridges

Bearing failure

Both Pictures from Earthquake Spectra (10)

Conventional Bridges

Failed inadequate seismic retrofitting

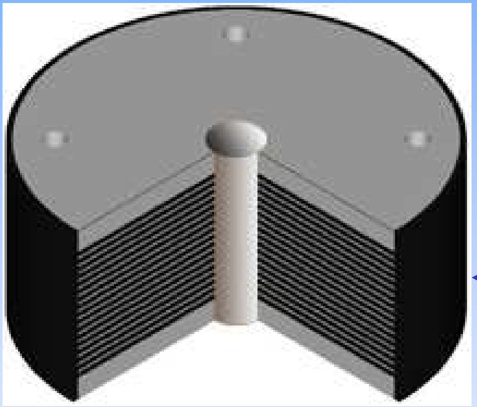
Both Pictures from Earthquake Spectra (10)

Seismic Control in Bridges

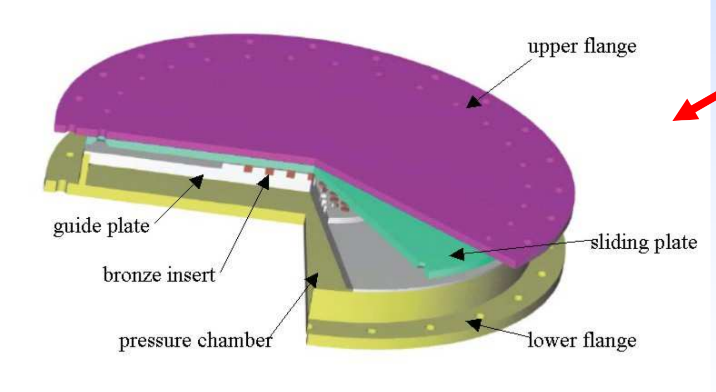
An elevated rail track:

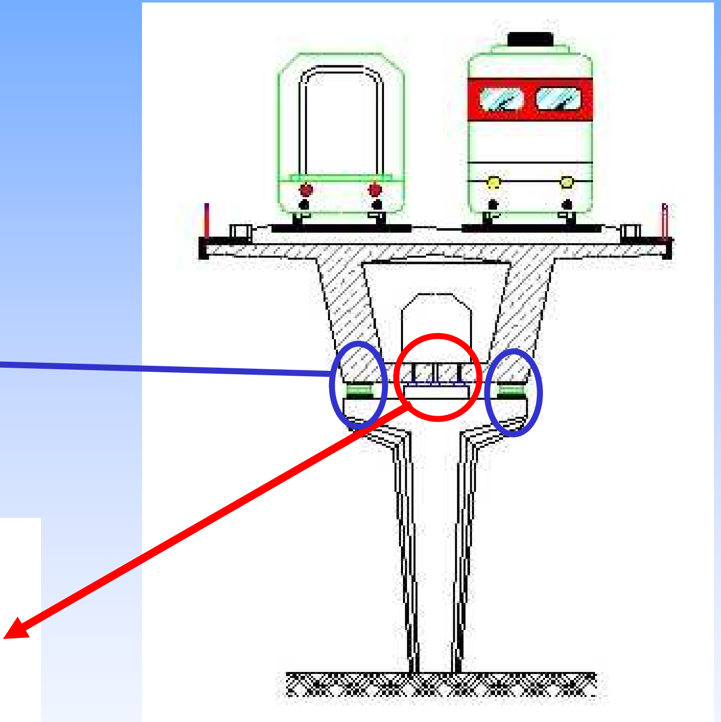
- Equipped with Base Isolation or Hysteretic Device (Hydes) in a seismic link

LRB



UHYDE-fbr

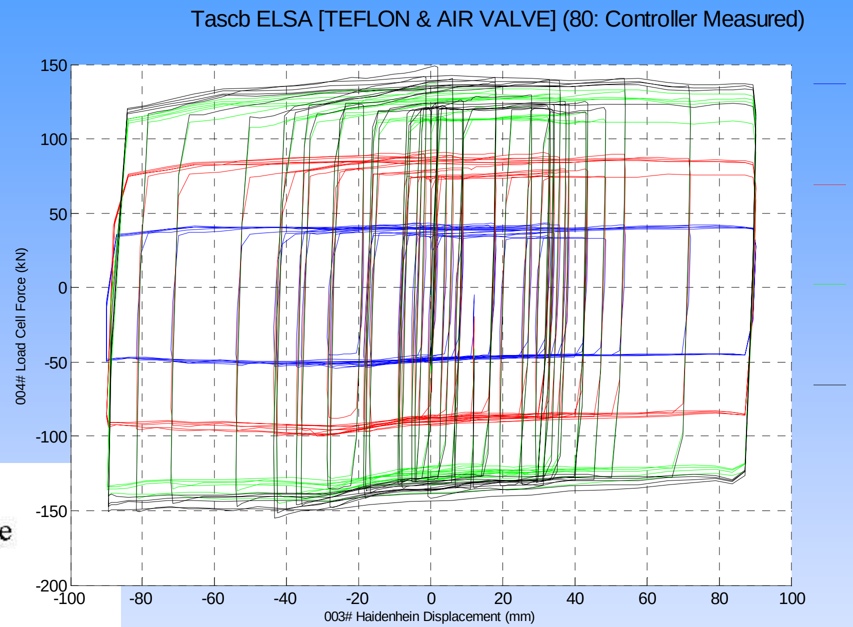


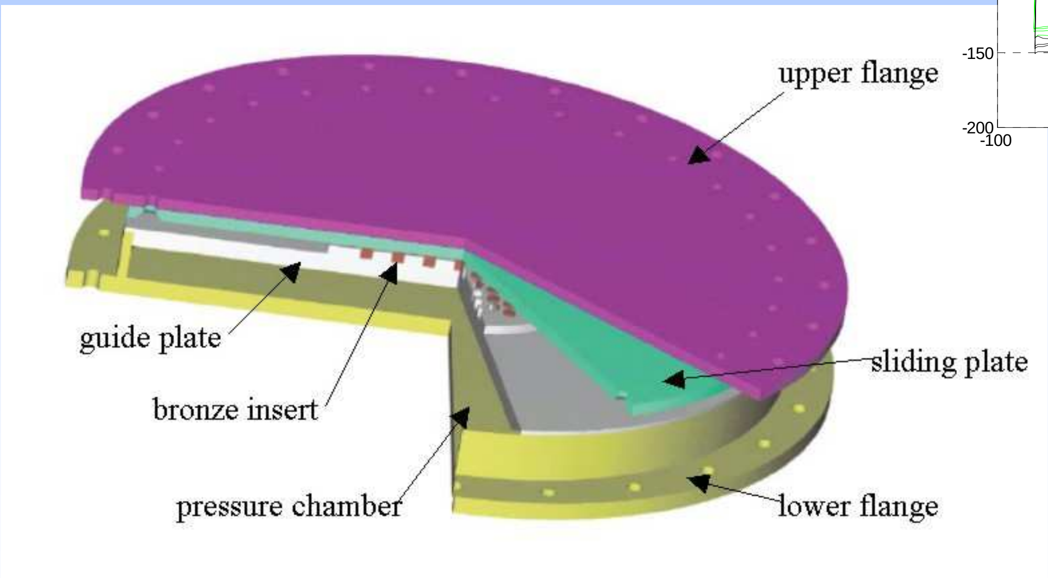


Seismic Control in Bridges

Uhyde-*fbr*

- Example for a semi-active device
- Friction is controlled by air pressure and produced between bronze inserts and a rough steel plate
- Very stable hysteresis loop even after many cycles





Conclusions

- Conventional structures cannot be produced with the quality required for earthquake safety of large numbers of buildings due to a multitude of critical details: Too much can and will go wrong
- “Wall systems with integrity”, like reinforced masonry or confined masonry are more robust, less expensive, easy to build and require only common quality control
- Structural control systems are superior in performance, reliability and price and have become a viable alternative
- Most suitable for seismic control are rigid body mechanisms
- Base Isolation, Tendon Systems, Pagoda Systems and Hyde Systems use passive or semi-active control and may be used in new structures as well as in structural rehab
- Because of its stiff-ductile links, the Hyde system is of particular advantage providing a better performance and price for low to medium high buildings and it is the best control concept to retrofit soft storey buildings

References

[1] M.C. Constantinou, M.D. Symans – Experimental study of seismic response of buildings with supplemental fluid dampers. Struct. Design Tall Bldgs. 2 (1993).

[2] U.E. Dorka, A. Ji, E. Flygare – A hysteretic device system for earthquake retrofit of large panel buildings. 11*th* European Conf. Earthq. Eng. (1998).

[3] U.E. Dorka, V. Bayer – Distribution of Seismic Links in Hysteretic Device Systems. *12th World Conf. Earthq. Eng*. (2000).

[4] U.E. Dorka – Erdbebensicherung durch Structural Control. Stahlbau 73 (2004), Heft 9. Ernst & Sohn Verlag.

[5] U.E. Dorka, S. Gleim – HYDE-systems for earthquake protection of residential buildings. NATO International Workshop - Advances in Earthquake Engineering for urban risk reduction, Subproject 4 of NATO Project SfP 977231, Istanbul (2005).

[6] U.E. Dorka – Hysteretic device system for earthquake protection of buildings. *5th US Nat. Conf. Earthq. Eng.* (1994). [7]

[7] U.E. Dorka, K. Schmidt – Retrofitting of buildings with masonry infill using HYDE concept. *12th European Conf. Earthq. Eng*. (2002).

[8] U.E. Dorka, G.A. Conversano – Seismic retrofit of Allstate Building. IABSE Symp., San Francisco (1995).

[9] A. Filiatrault, R. Trembley, A. Wanitkorkul – Performance Evaluation of Passive Damping Systems for the Seismic Retrofit of Steel Moment-Resisting Frames Subjected to Near-Field Ground Motions. Earthquake Spectra, Vol. 17, No. 3 (2001).

[10] FIP Industriale web site – Technical Note: Isolation Devices.

[11] J. Garcia, U.E. Dorka, G. Magonette, J. Rodellar, N. Luo – Testing of Algorithms for Semi-Active Control of Bridges, EU-ECOLEADER TASCB Report.

[12] G. Magonette, F. Marazzi – Active Control Experiment of a large scale cable-stayed bridge mock-up.Third International Symposium on Cable Dynamics, Trondheim, Svezia (1999).

[13] Preumont – Vibration Control of Active Structures. Kluwer Academic Puplishers.

[14] K. Schmidt, U.E. Dorka – Comparative studies of steel frame retrofitted with HYDE system and added damping system subjected to near-field earthquakes. 40SEEE, Skopje (2003).

[15] K. Schmidt, U.E. Dorka, G.E. Magonette, F. Taucer – Retrofitting of a steel frame and a rc frame with HYDE systems. Report EUR21180EN, European Commission, Ispra (2004).

[16] Soong, Dargush – Passive Energy Dissipation Systems in Structural Engineering. John Wiley & Sons

[17] B.F. Spencer, S.J. Dyke, M.K. Sain, J.D. Carlson – Phenomenological model of a magneto-rheological damper. Engineering Mechanics 123-3 (1997).

[18] www.staff.city.ac.uk/earthquake/MasonryBrick/ConfinedBrickMasonry/

[19] C. Loaiza, M. Blondet – EERI World Housing Encyclopedia (WHE), Peru

[20] – EERI World Housing Encyclopedia (WHE), Chile