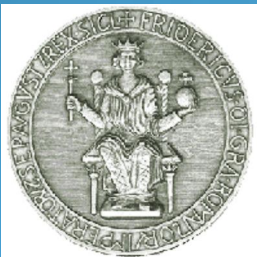


THE USE OF STEEL IN SEISMIC UPGRADING



FEDERICO M. MAZZOLANI

University of Naples – Federico II – Italy

SEISMIC UPGRADING OF EXISTING R.C AND MASONRY STRUCTURES BY MEANS OF METAL SYSTEMS

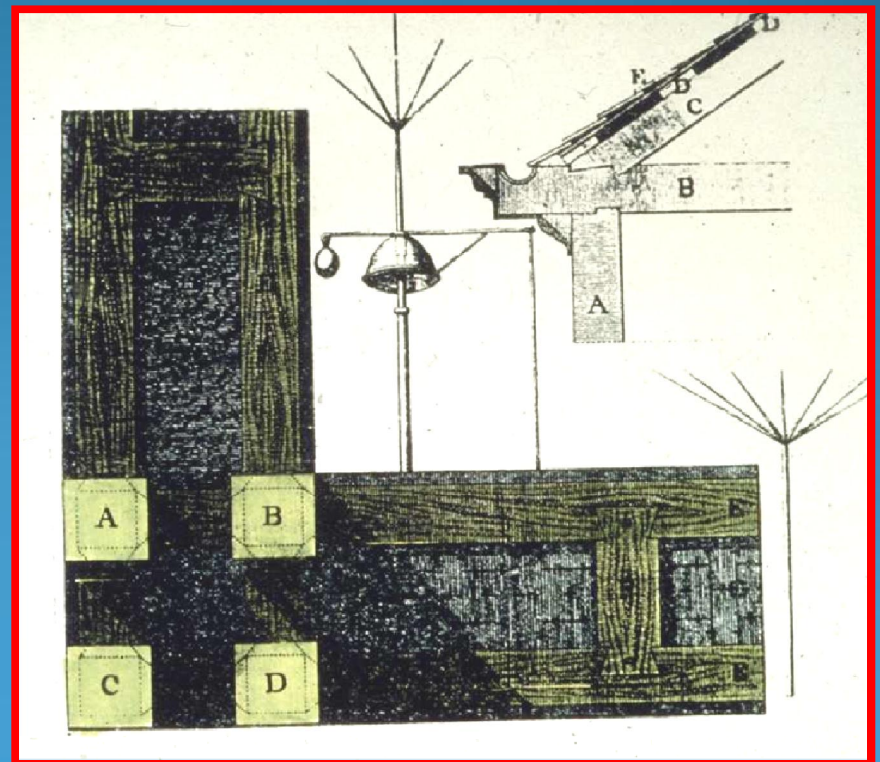
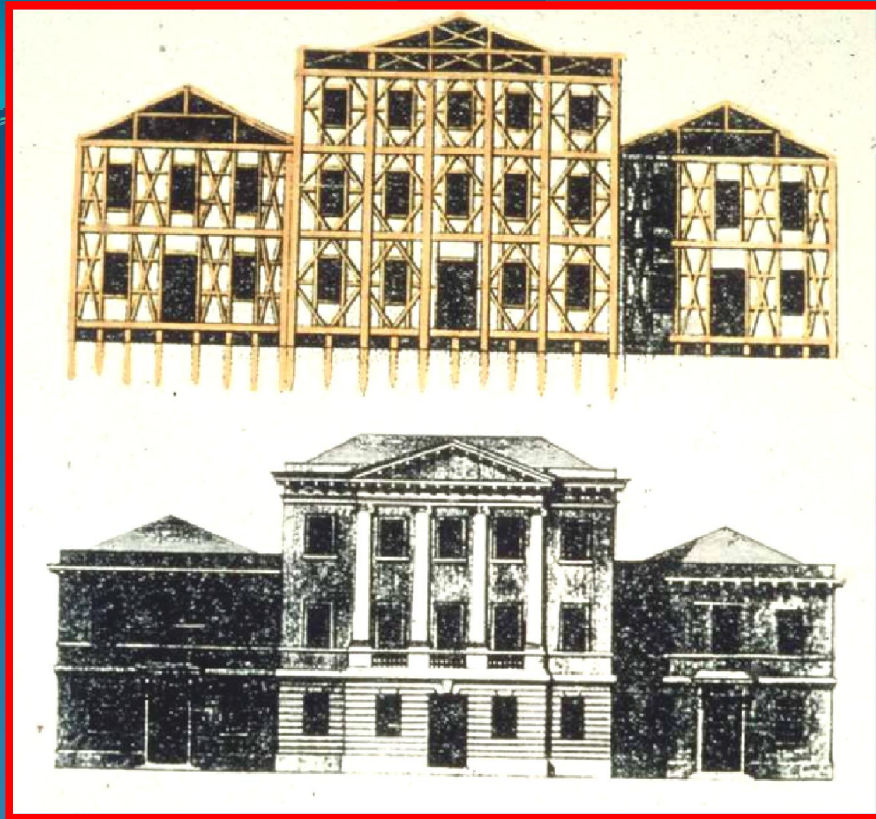
ÅBRACING SYSTEMS

ÅSHEAR PANELS

ÅAPPLICATIONS TO HISTORICAL BUILDINGS

ÅFULL SCALE TESTS

BRACING SYSTEMS

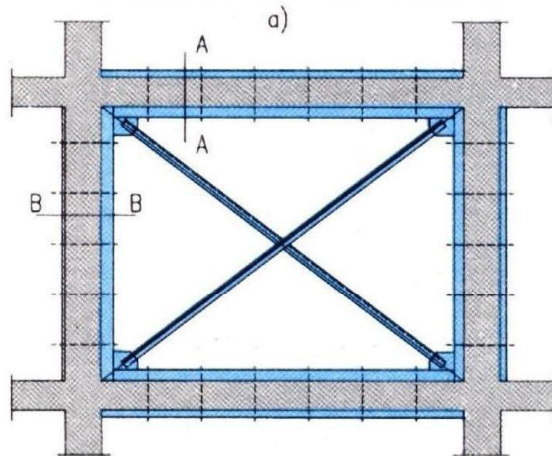


“Case Baraccate”(Calabria, Italy)

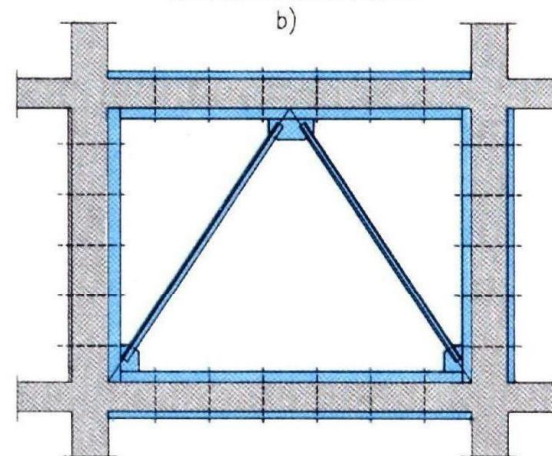
Old and new bracing systems



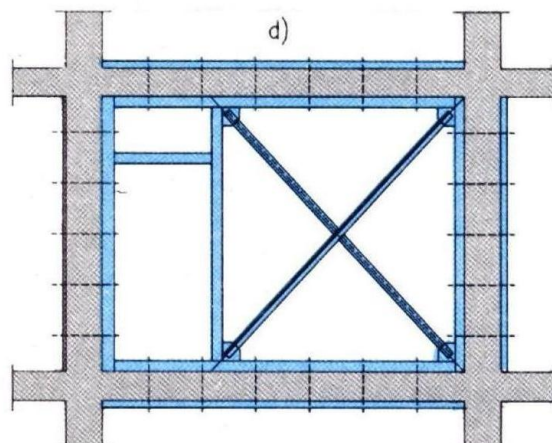
Contr. a croce di S. Andrea



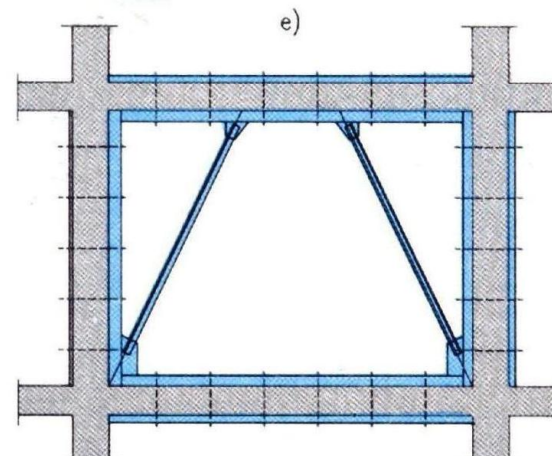
Controvento a K



Controventi con aperture



Controventi eccentrici

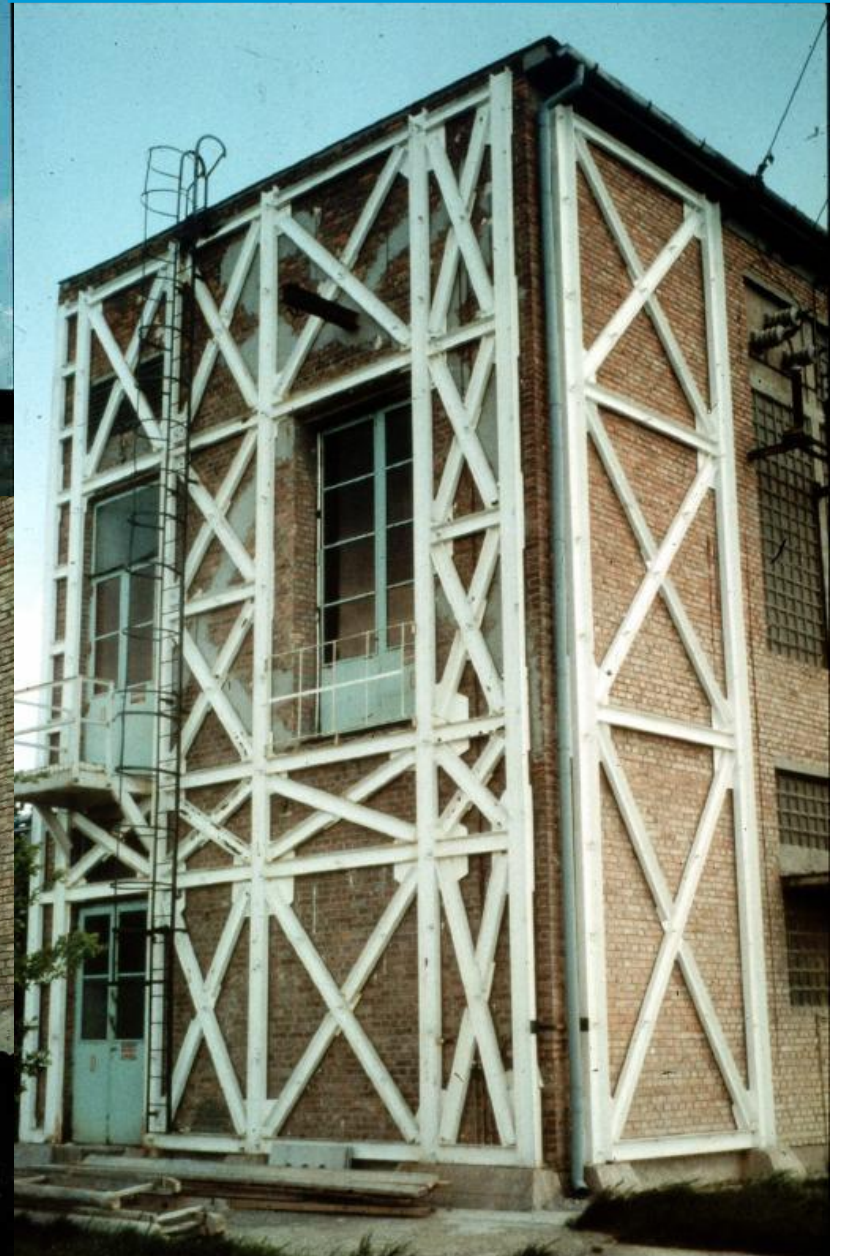
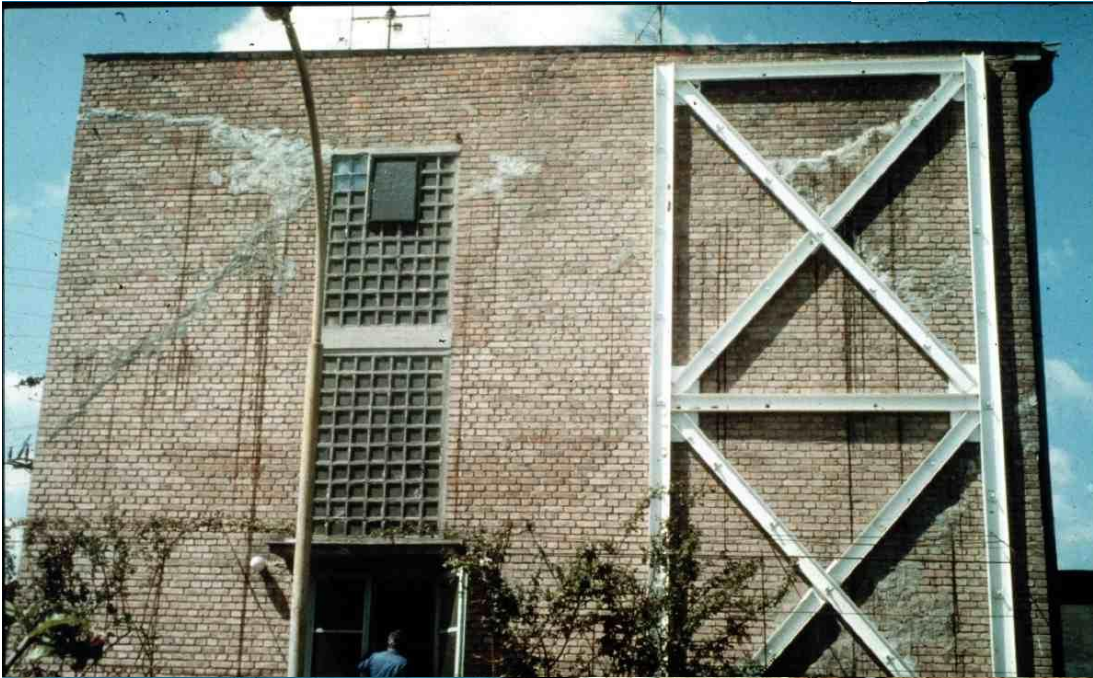


Bracing systems for masonry structures



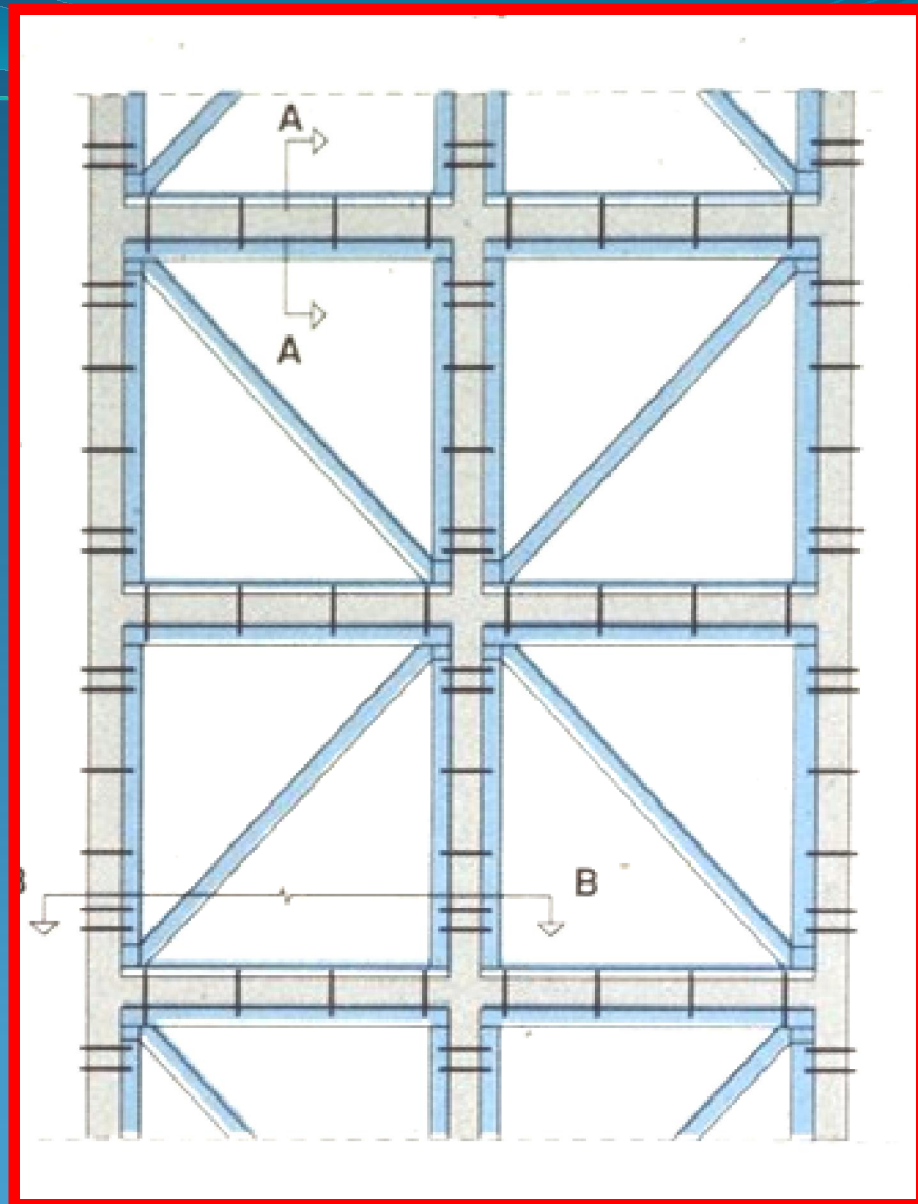
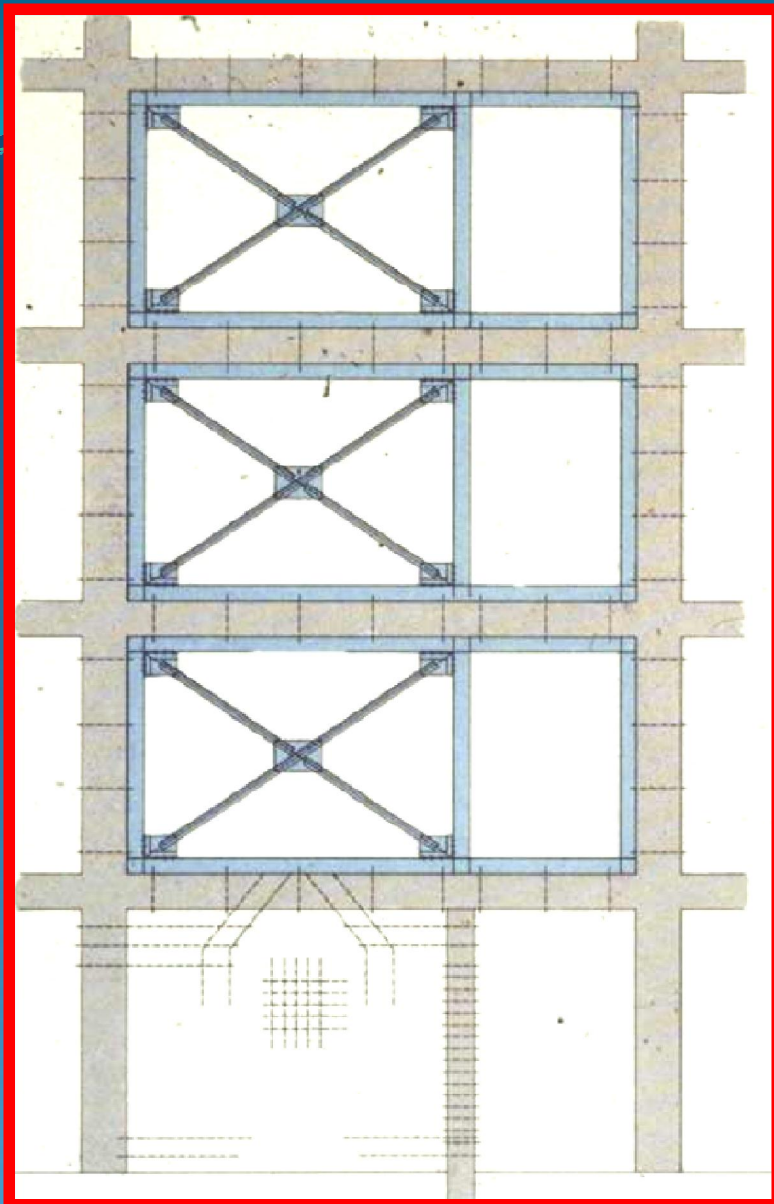
Montemarano Church (Avellino, Italy)

Electrical power station
(Hungary)



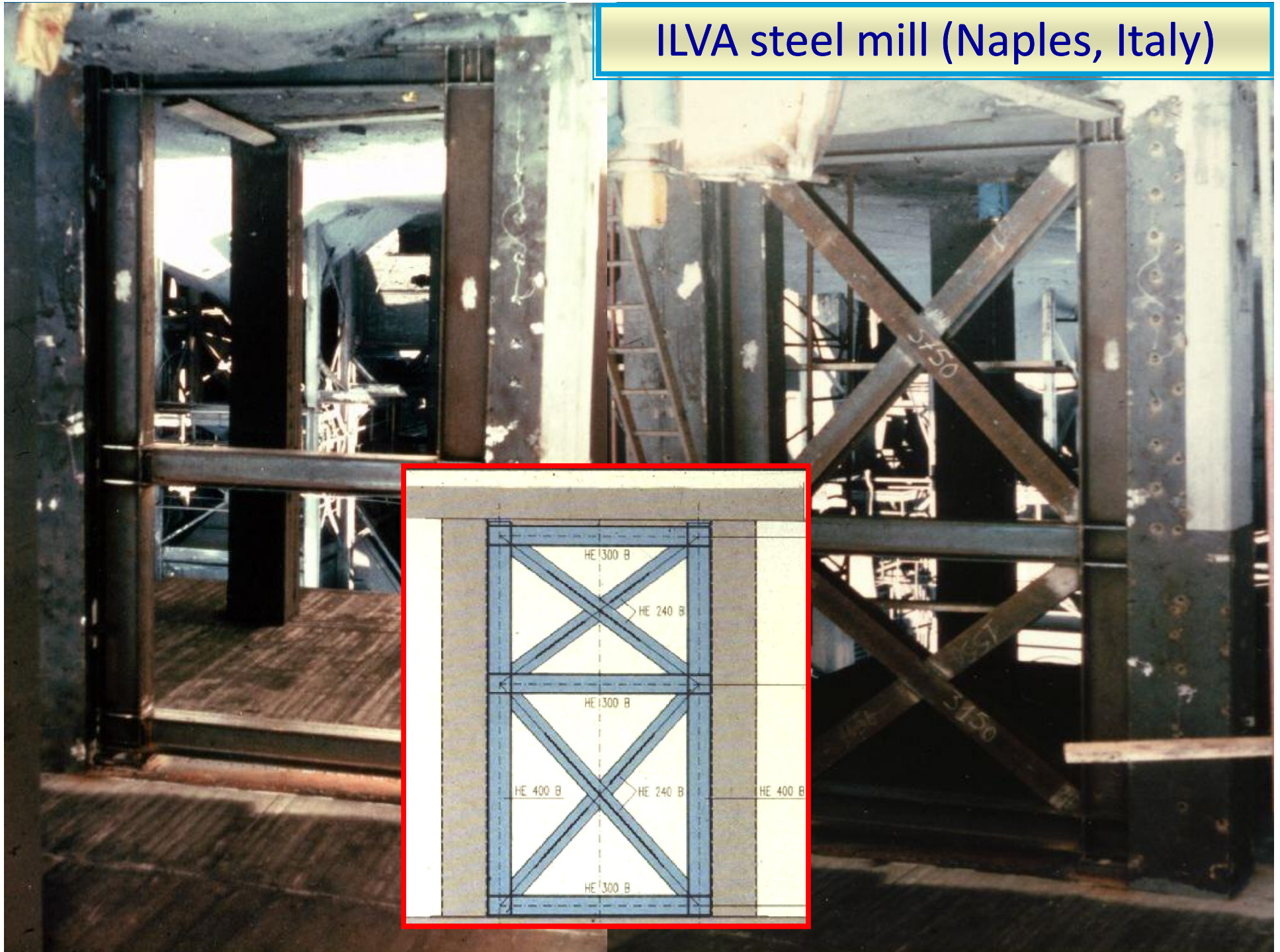
“Rione terra” in Pozzuoli (Italy)

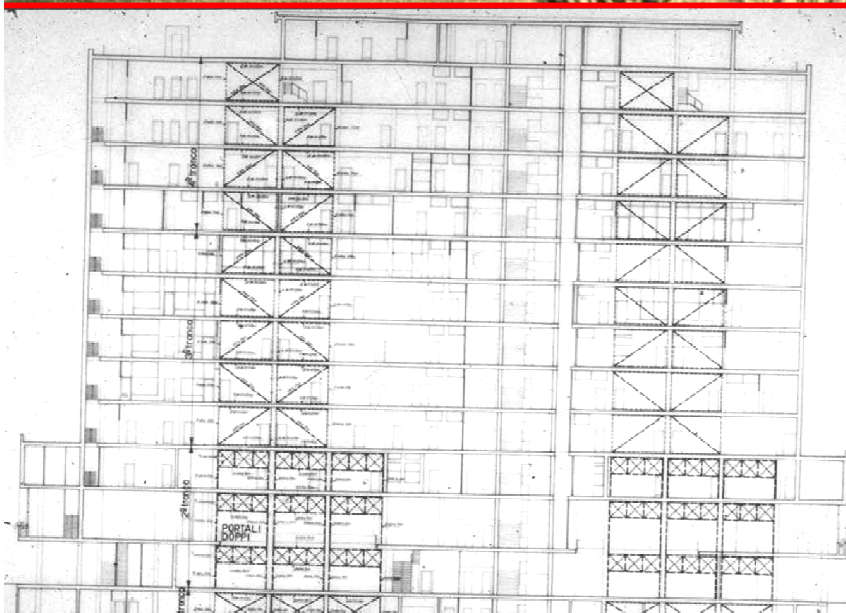
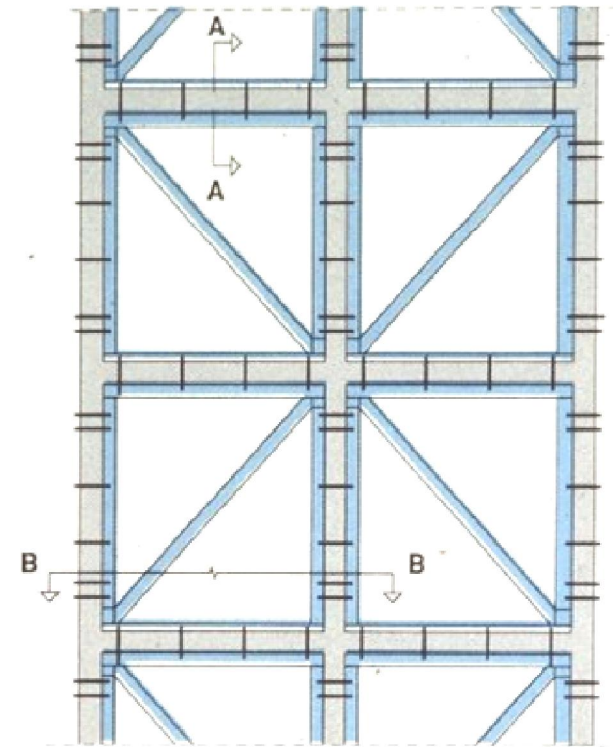




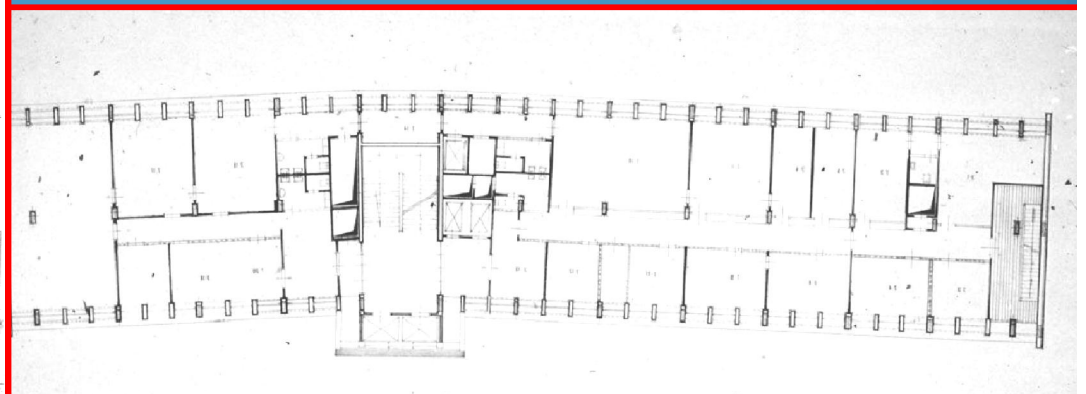
Steel bracing schemes

ILVA steel mill (Naples, Italy)





Engineering Faculty (Naples, Italy)



Mexico City, 1992

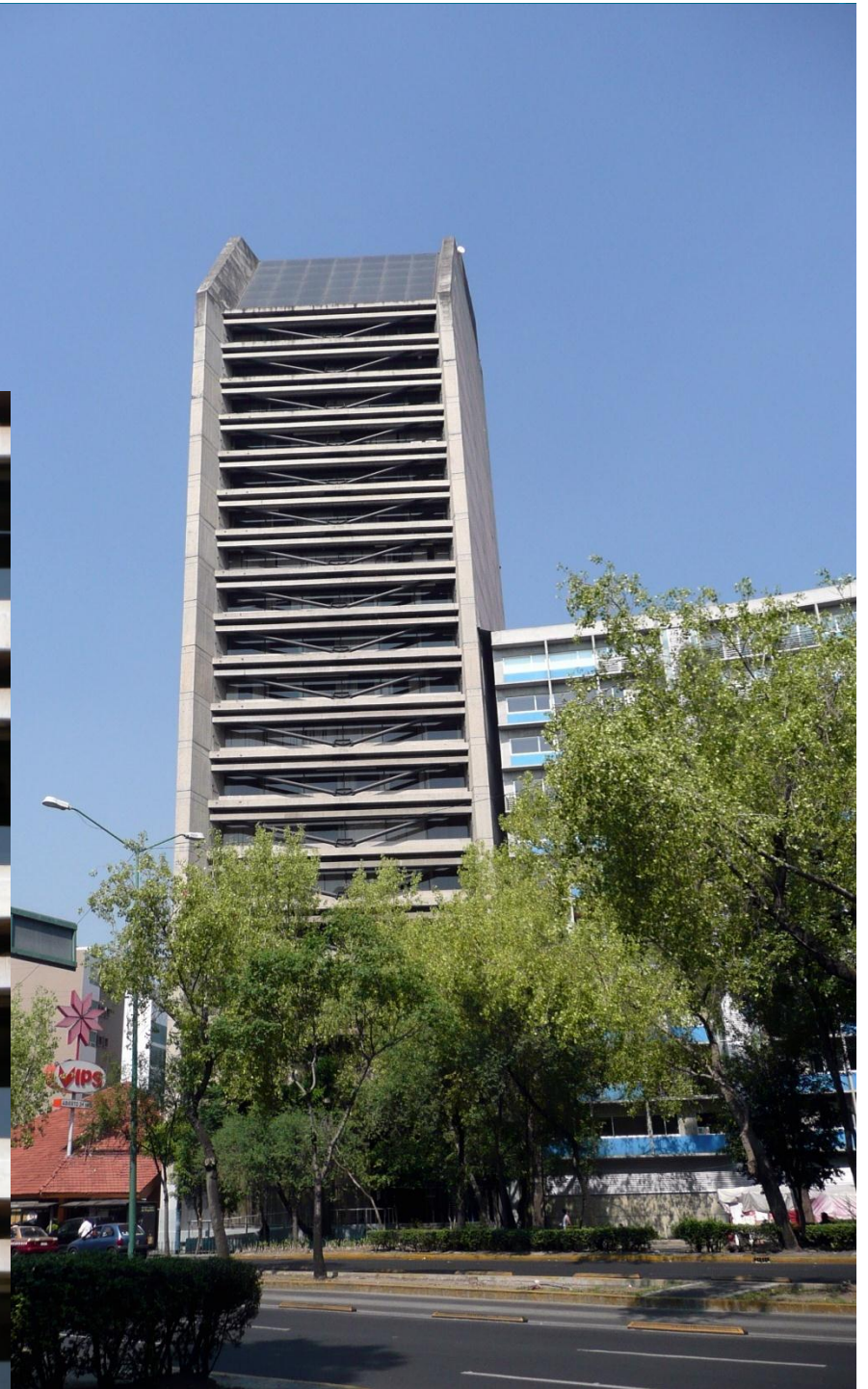
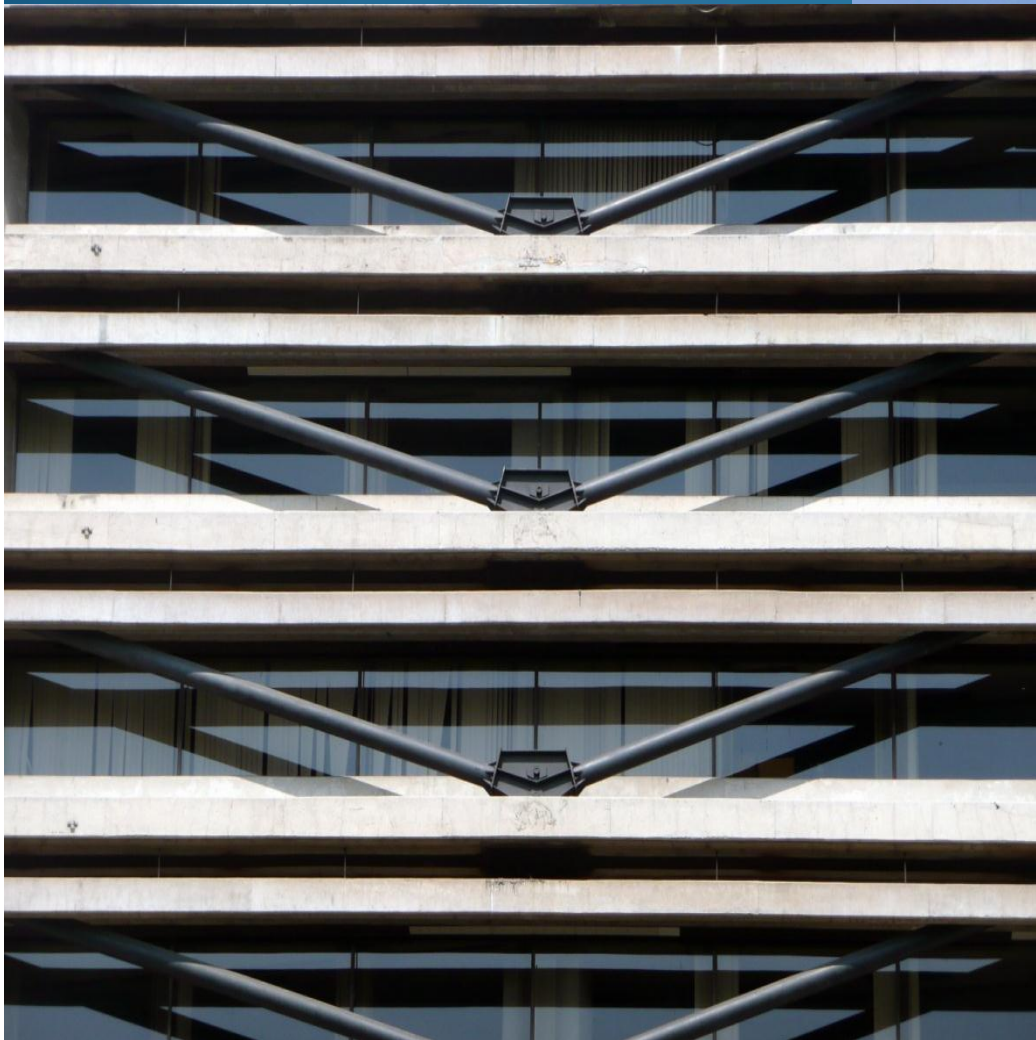




Mexico City, 2011

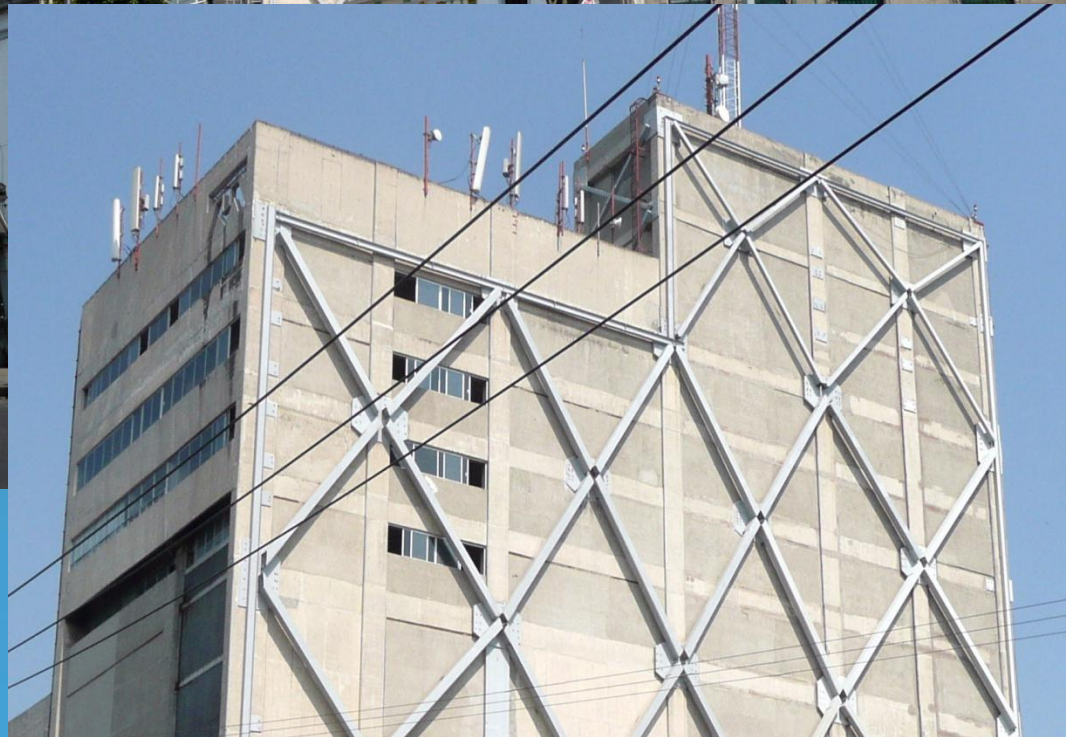
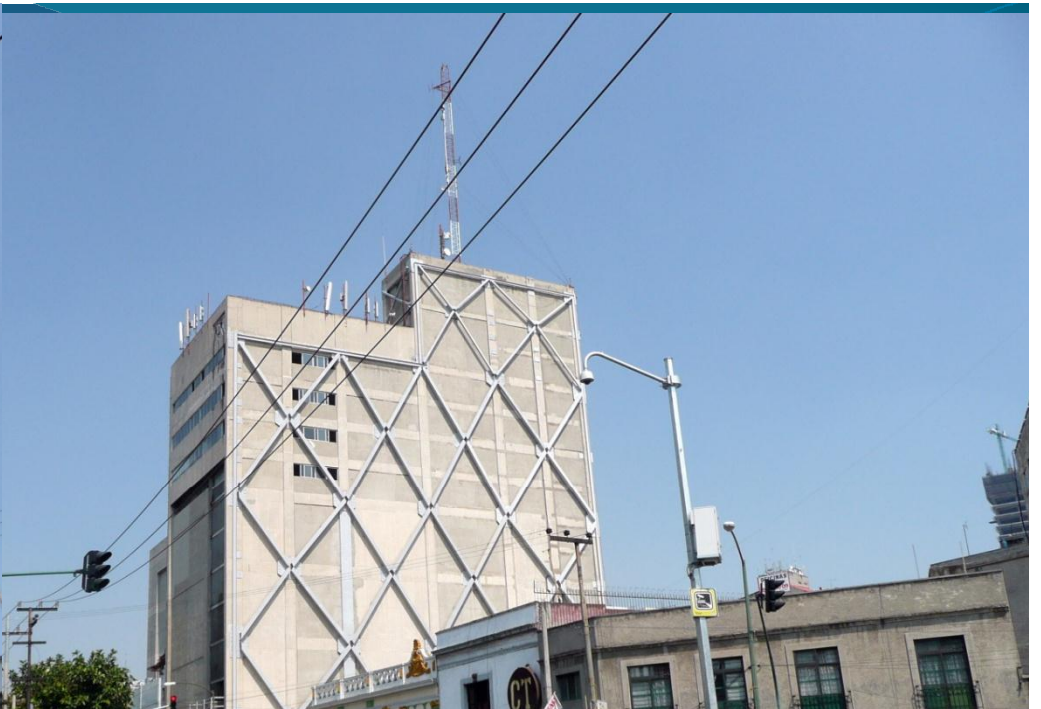


Mexico City, 2011





Mexico City, 2011



Mexico City, 2011

Mexico City, 2011





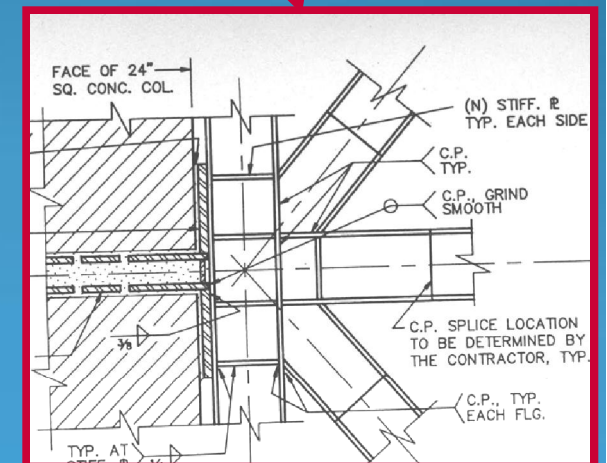
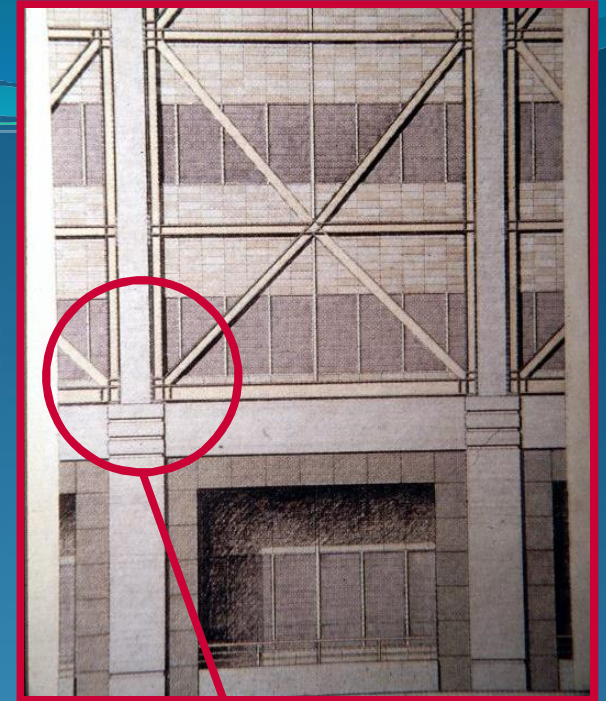
TESSALONIKI (GREECE)

SANTA MONICA (California-USA)



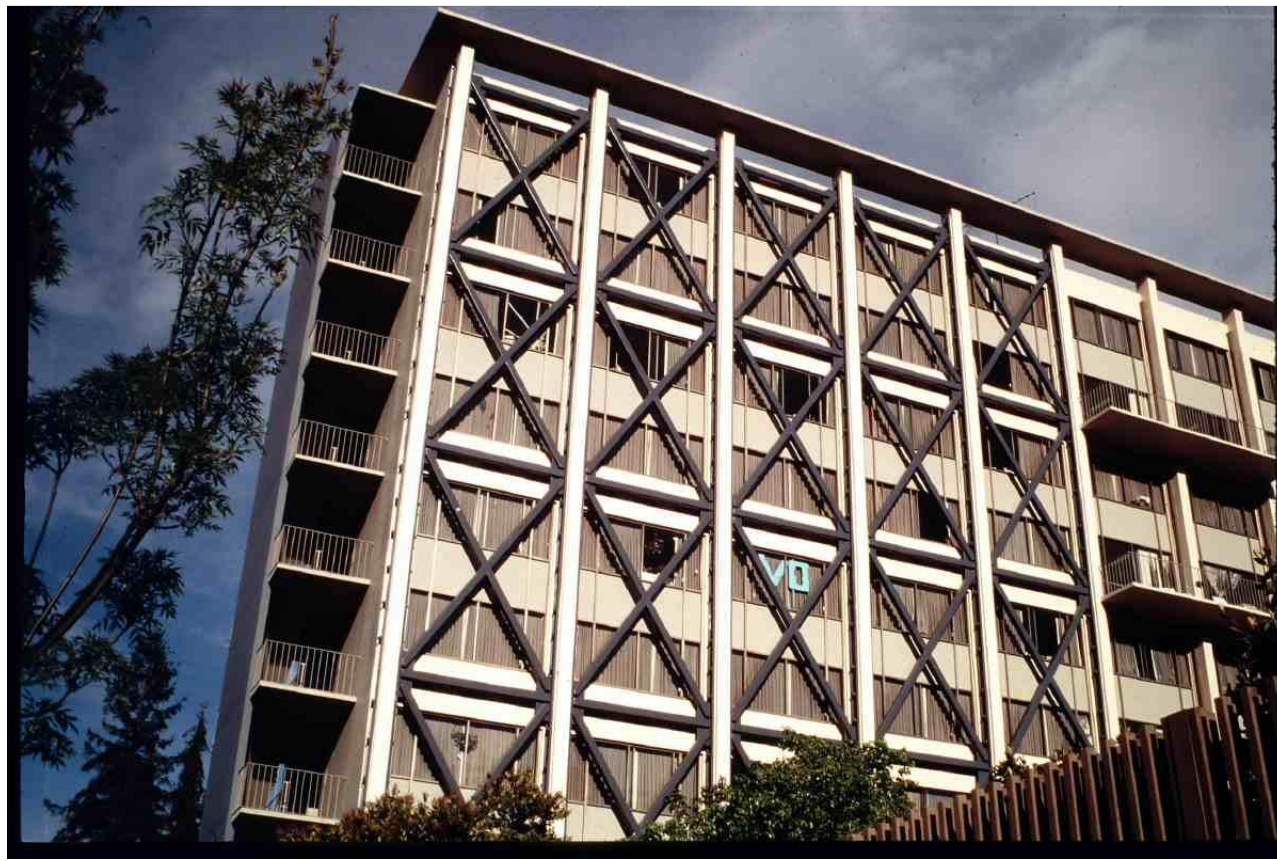


University Hall (Berkeley, California)





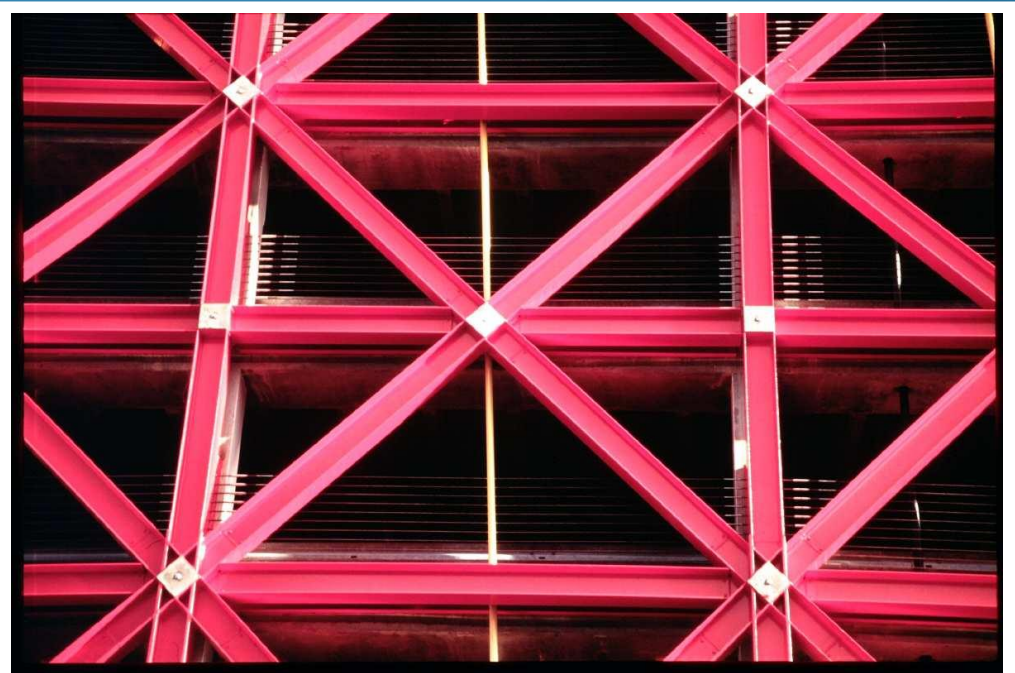
University Hall (Berkeley, California)

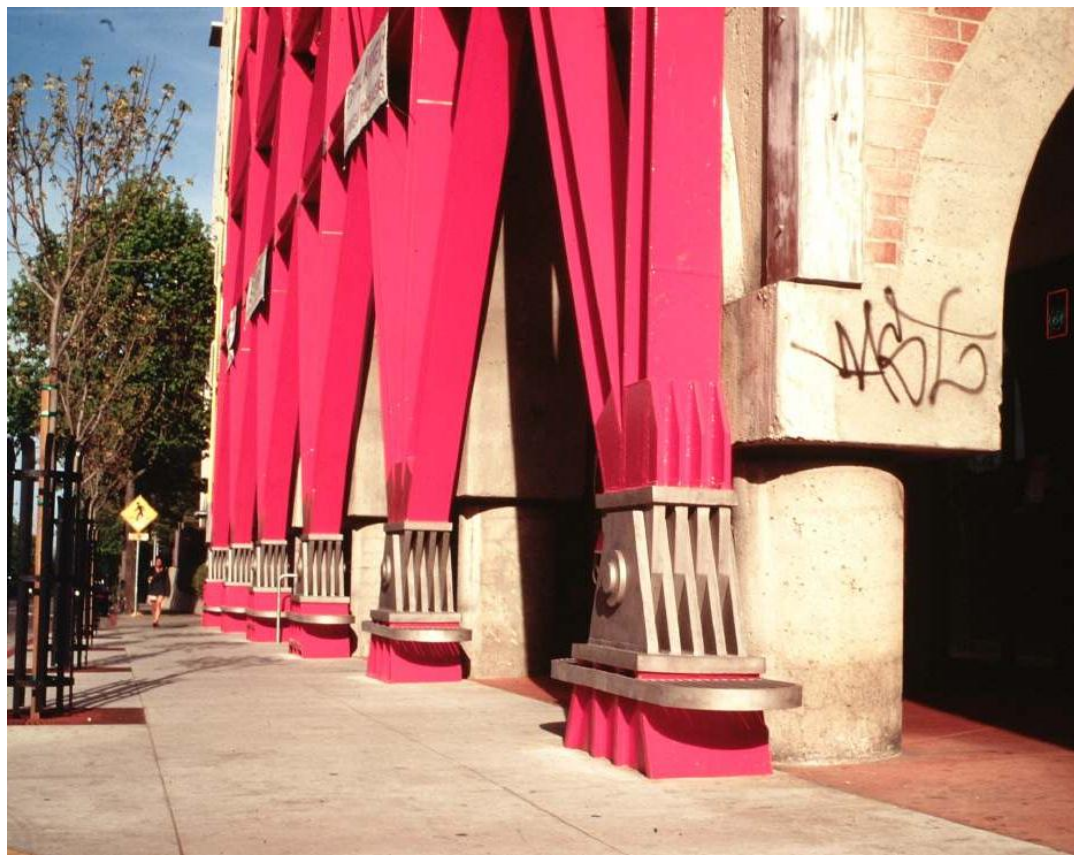


Apartment building (Berkeley, California)



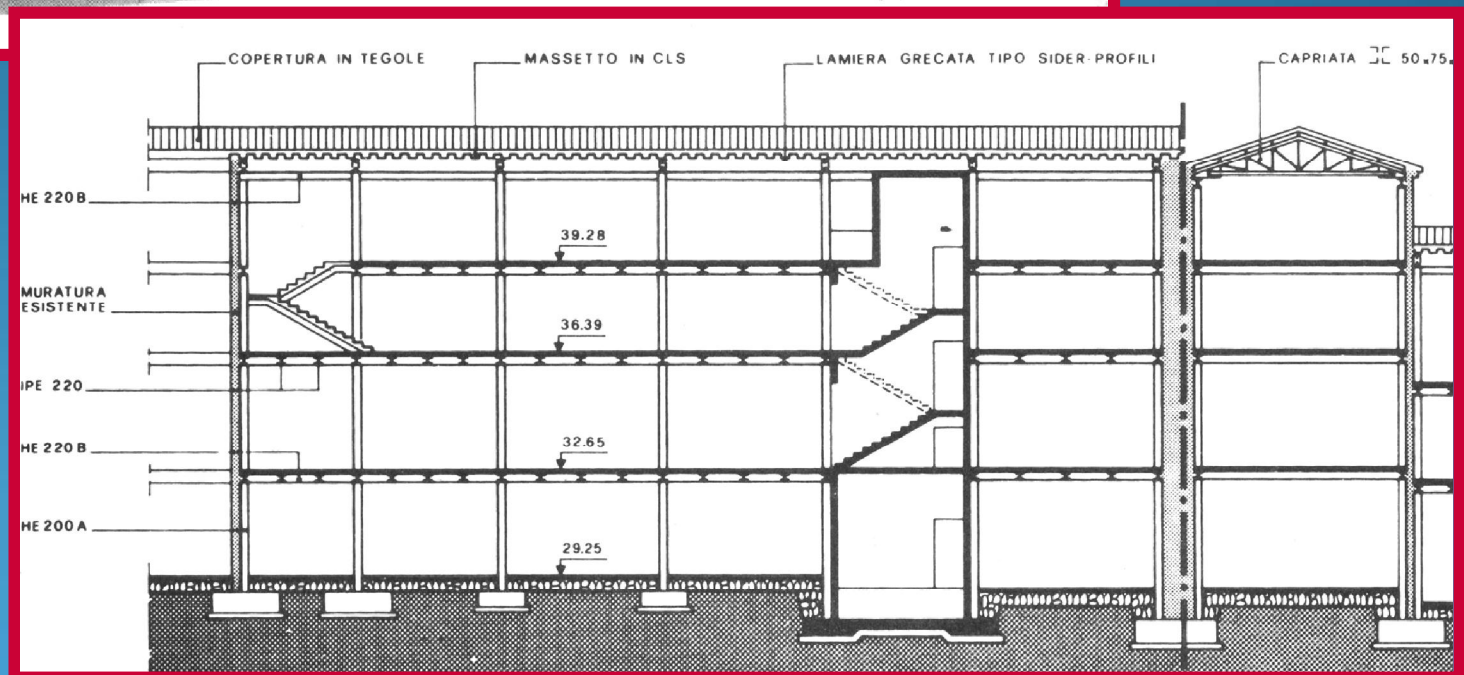
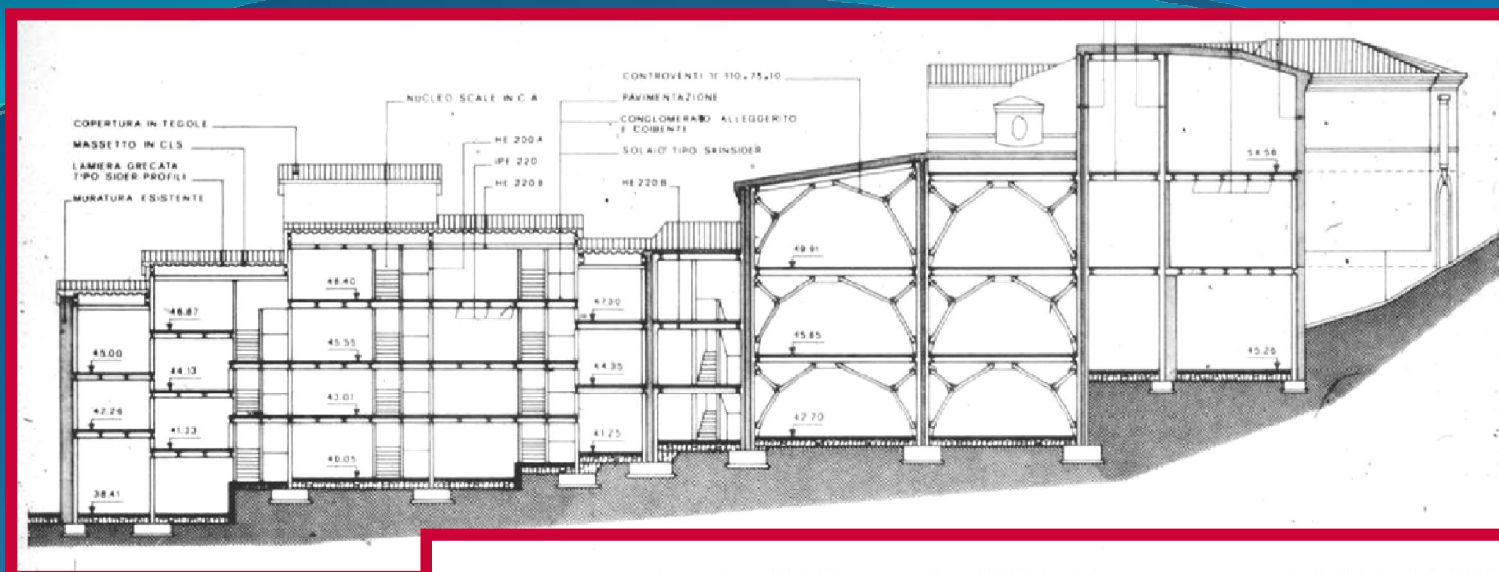
Autoshelos (Berkeley, California)



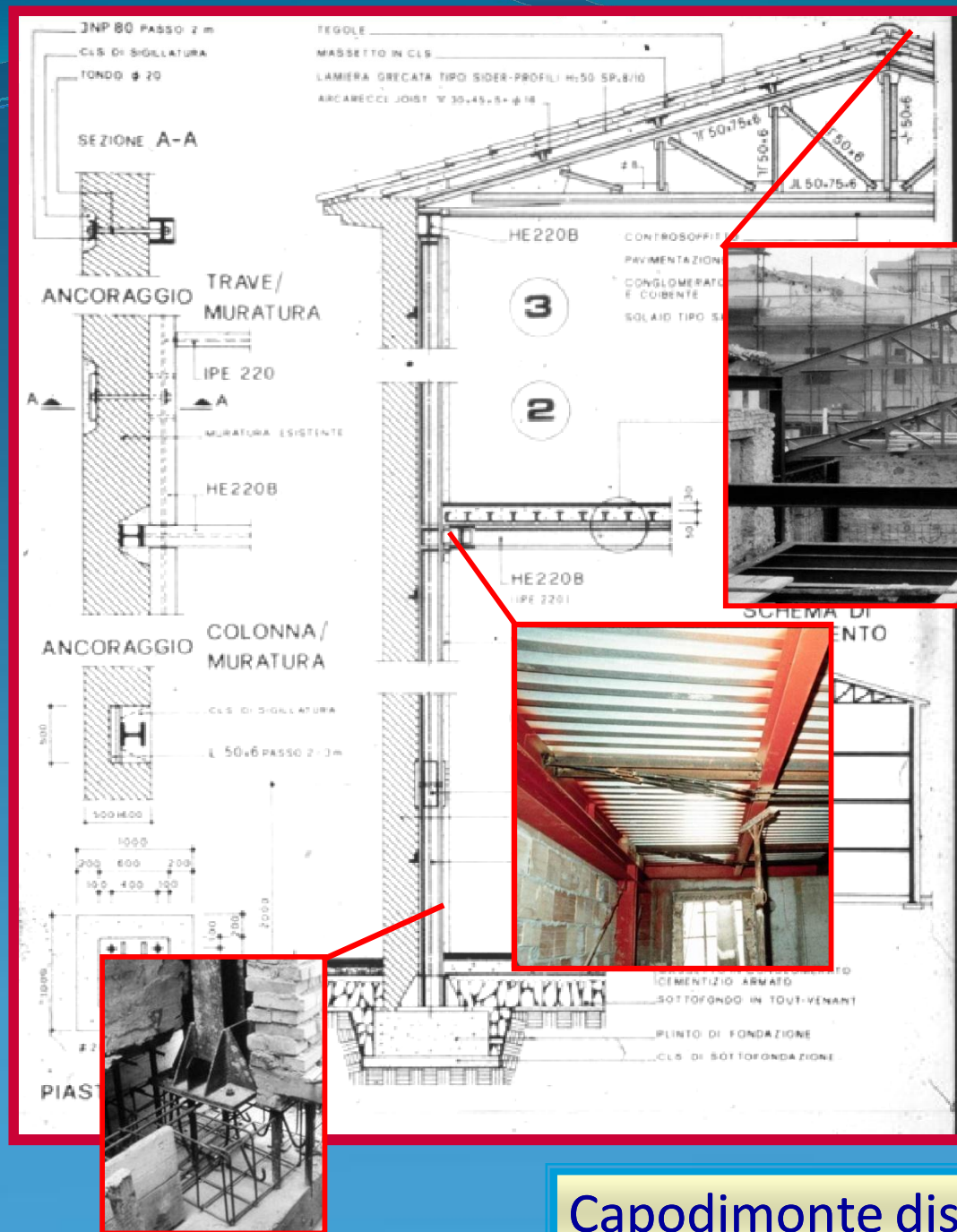


Autosylos (Berkeley, California)

Capodimonte district (Ancona, Italy)

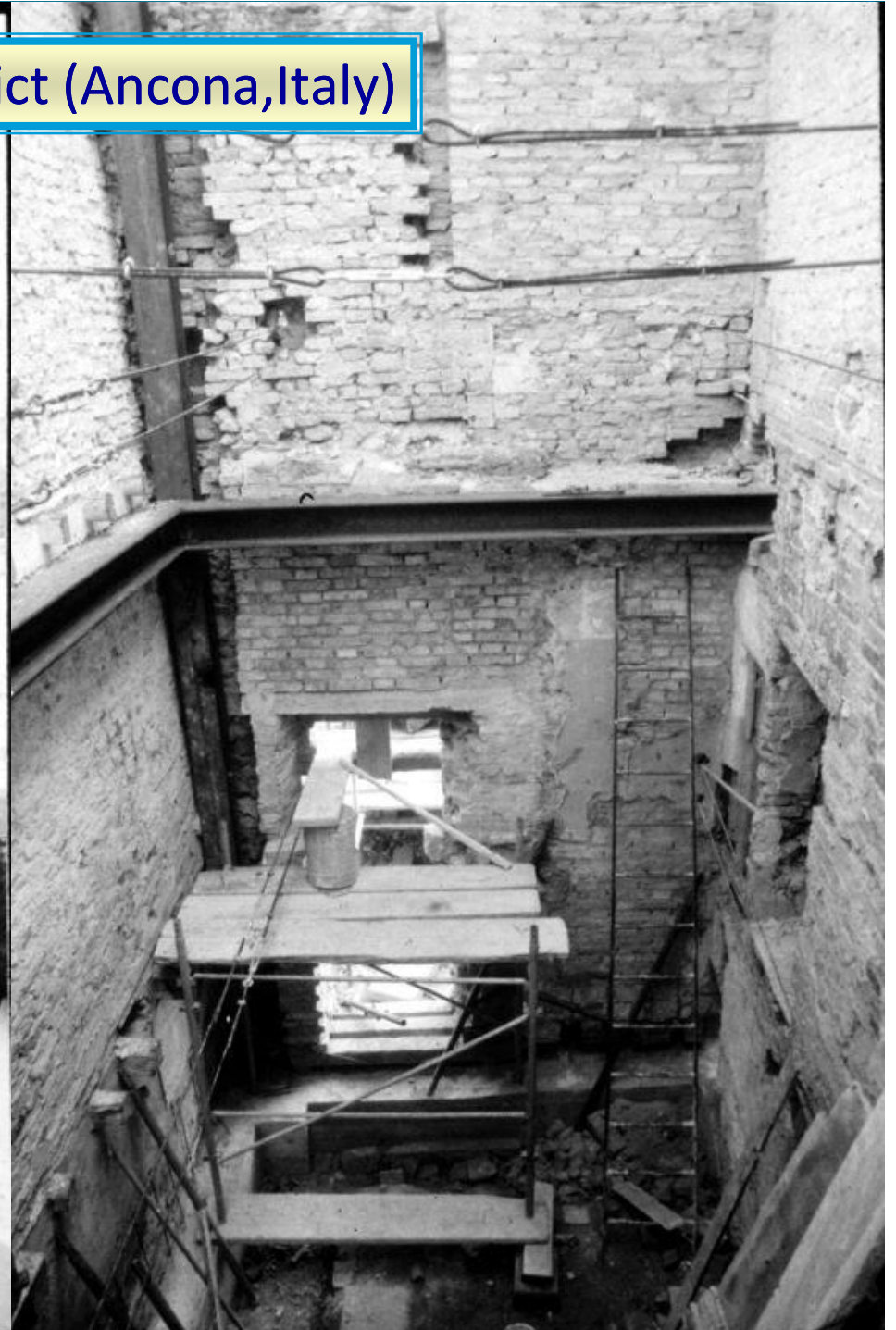
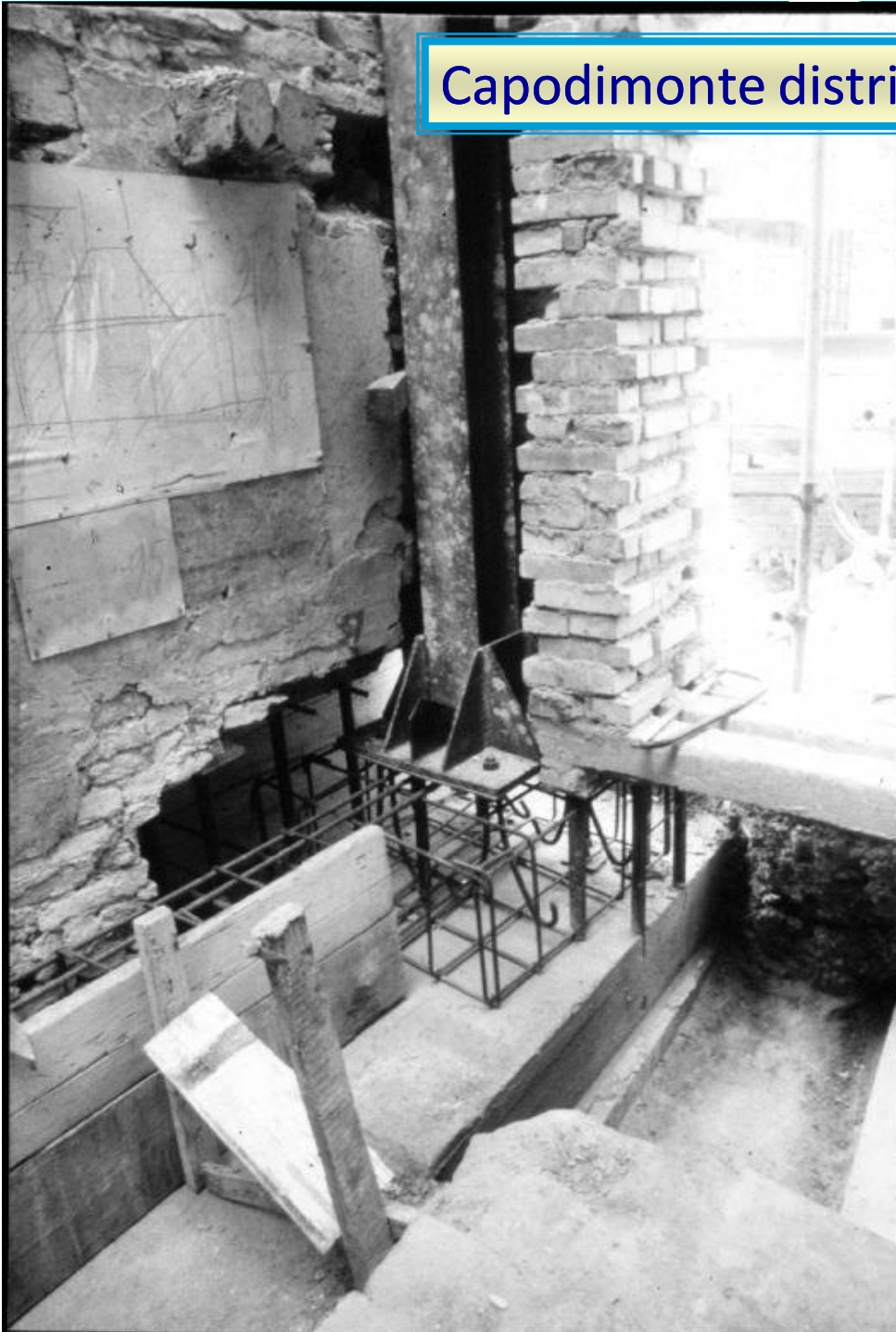


Capodimonte district (Ancona, Italy)



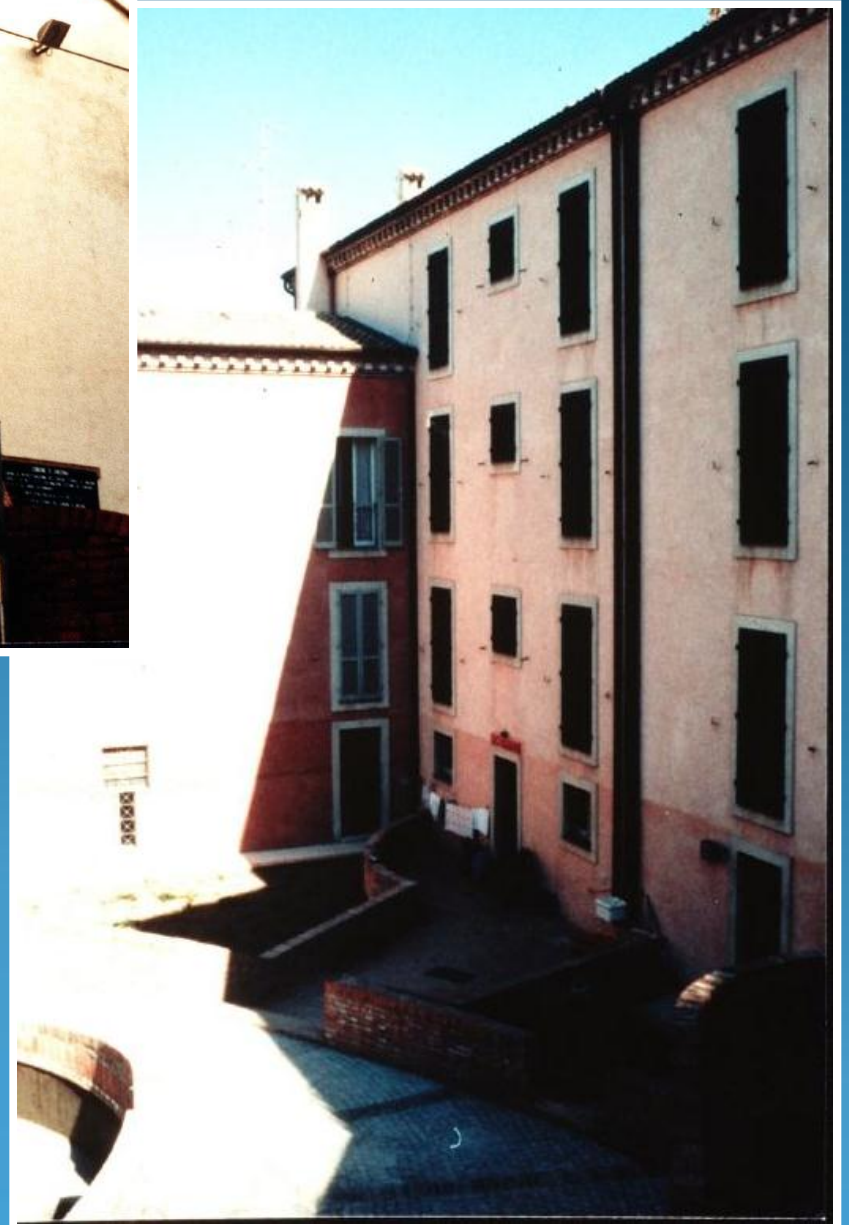
Capodimonte district (Ancona, Italy)

Capodimonte district (Ancona, Italy)



Capodimonte district (Ancona, Italy)

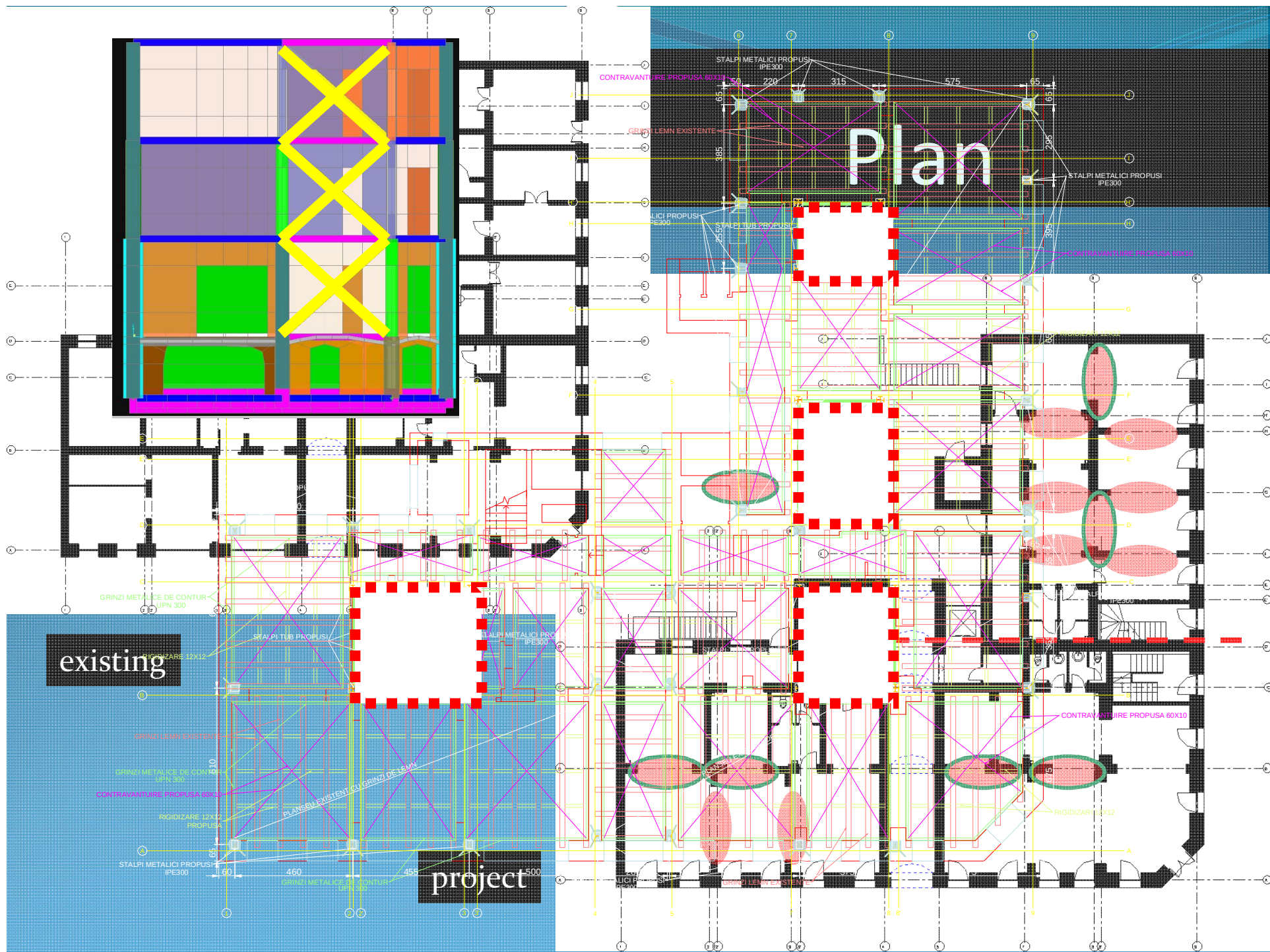


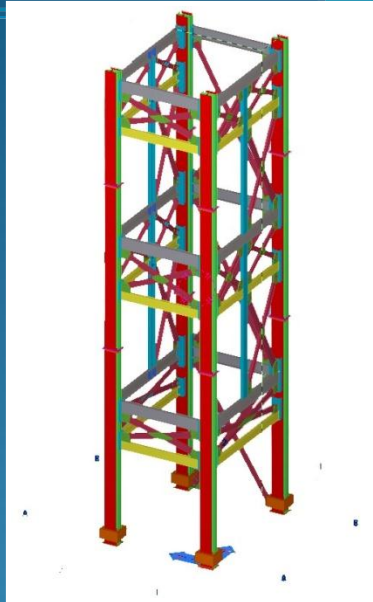


Capodimonte district (Ancona, Italy)

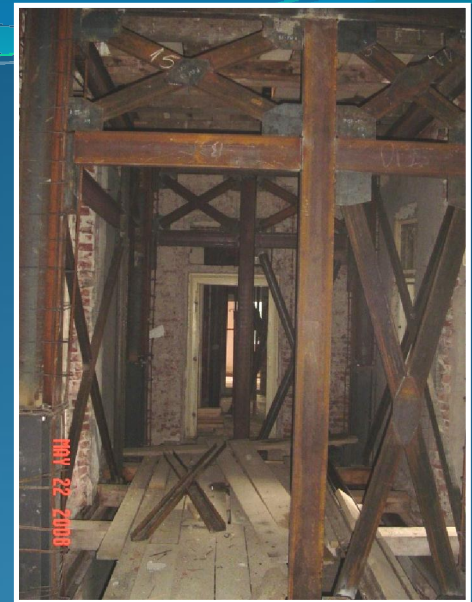
BUILDING IN Str. MOCIONI nr.8 TIMISOARA



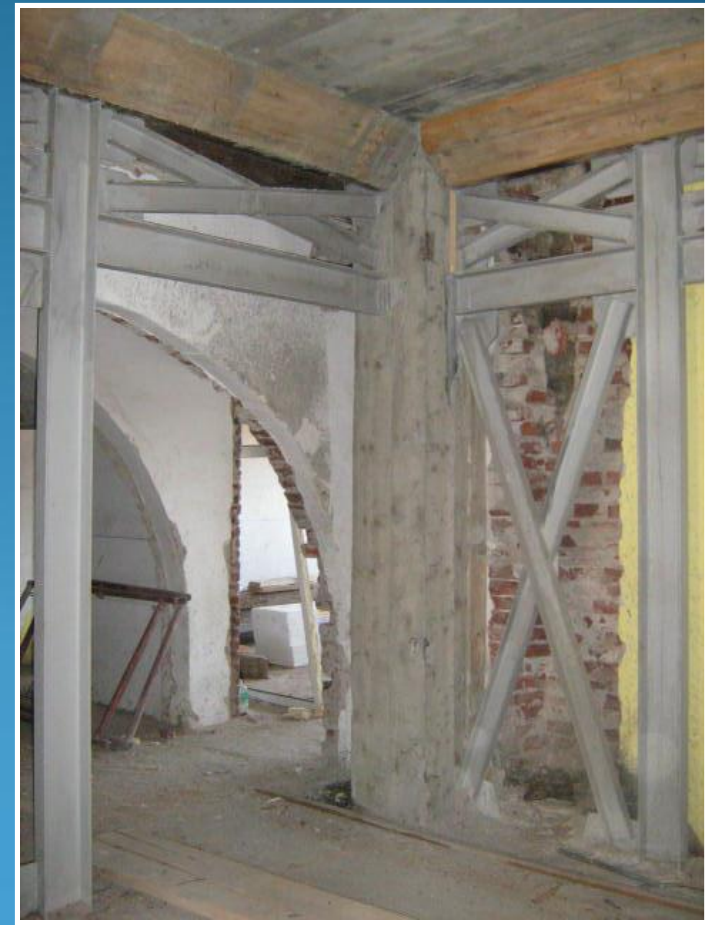




Steel bracing types

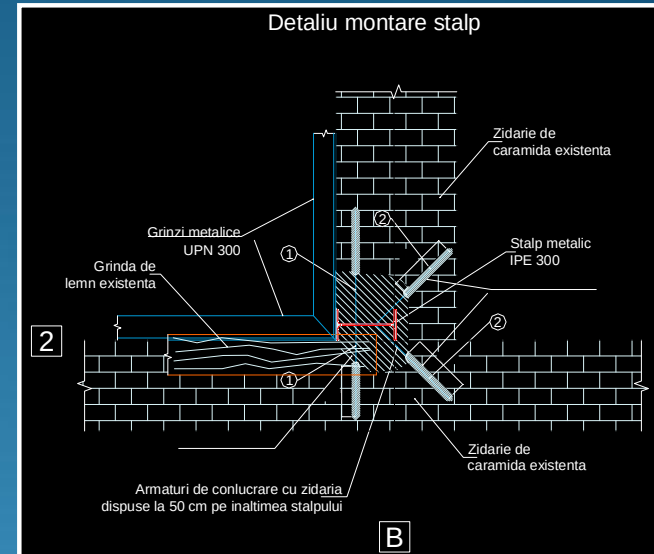


Bracing in the arches



Details of connections





**Details of
connections**

Horizontal braces



**Beam
reinforcement**

**Perimetral
frame**



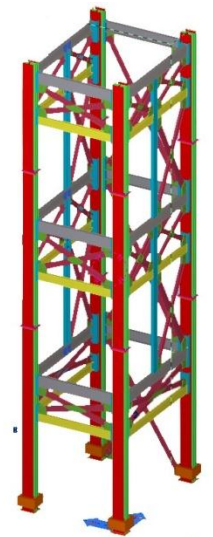
**Steel
columns**



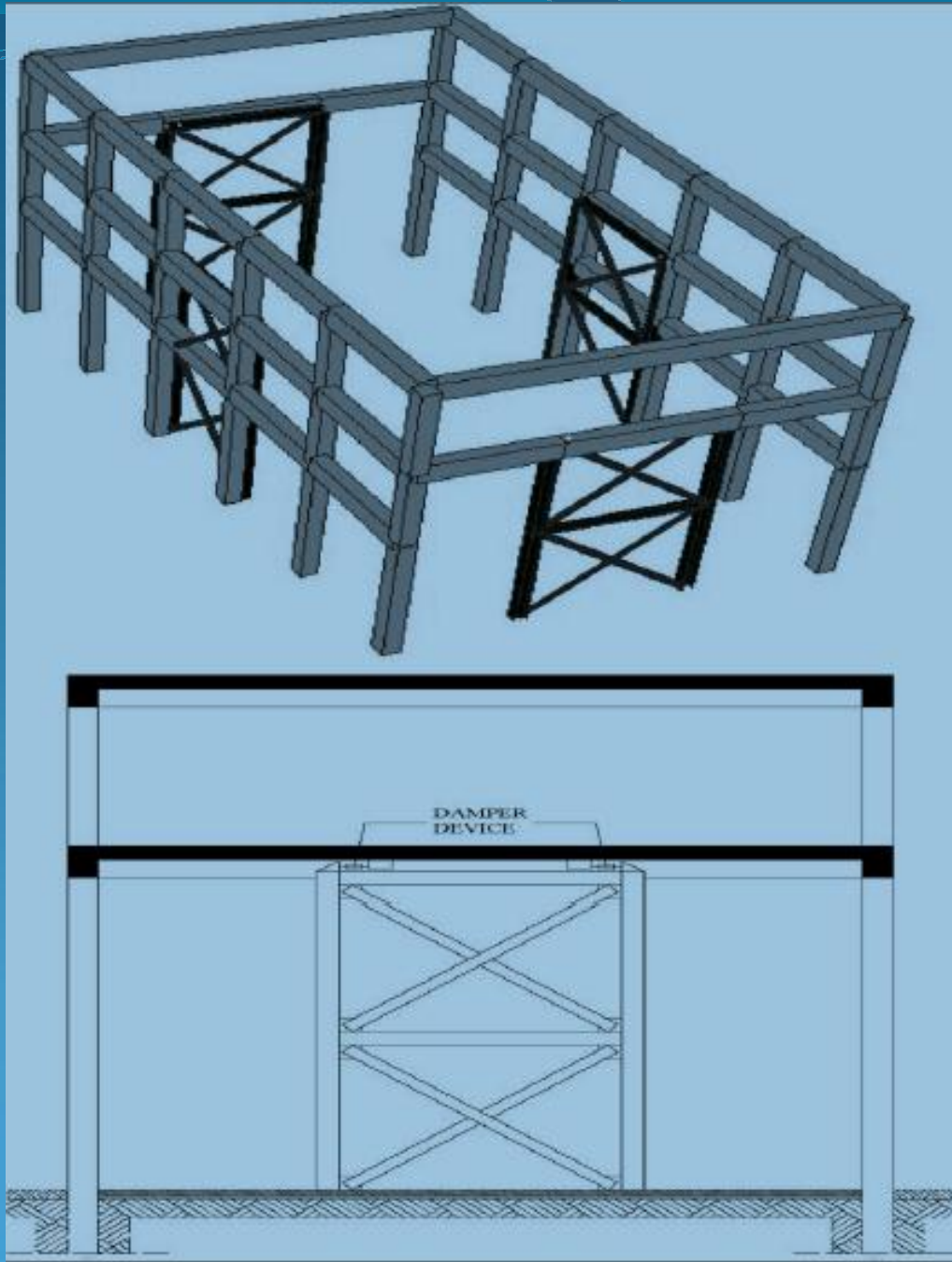
Roof structures

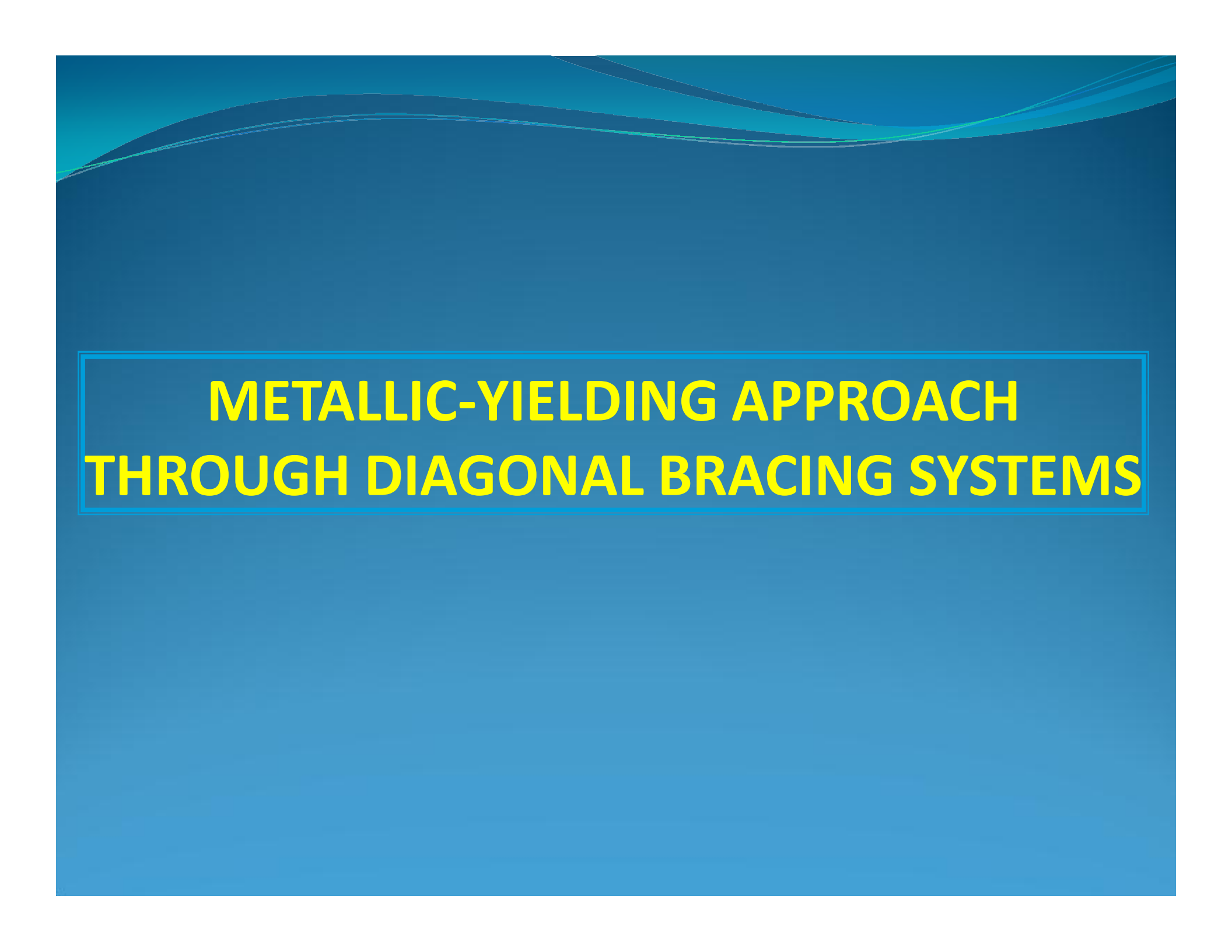


**Steel cores:
details of
connections**



DISSIPATIVE BRACING SYSTEMS

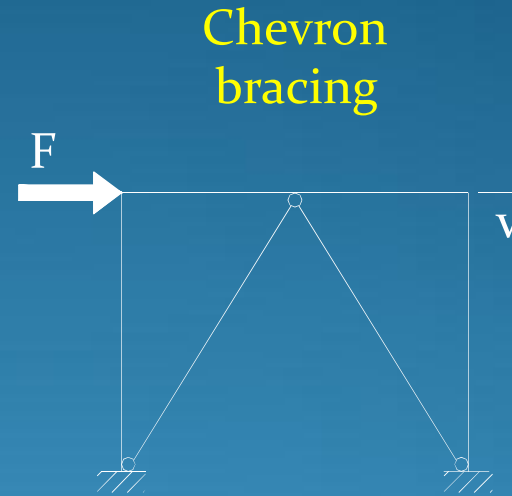
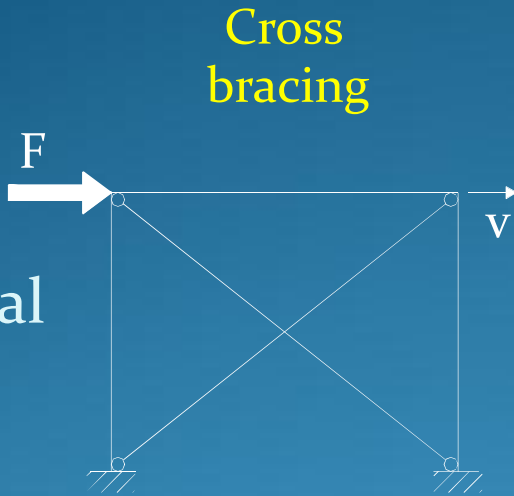


The background is a solid blue color with a gradient. At the top, there are several thin, wavy lines in shades of blue and teal, creating a sense of movement or a stylized horizon. The main text is centered in the middle of the slide.

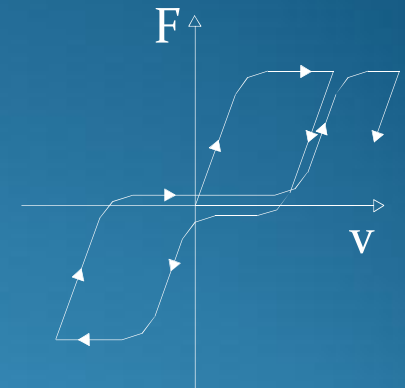
METALLIC-YIELDING APPROACH THROUGH DIAGONAL BRACING SYSTEMS

METALLIC-YIELDING APPROACH THROUGH DIAGONAL BRACING SYSTEMS

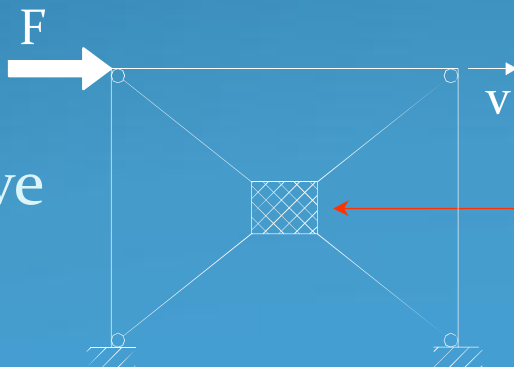
Traditional
bracing



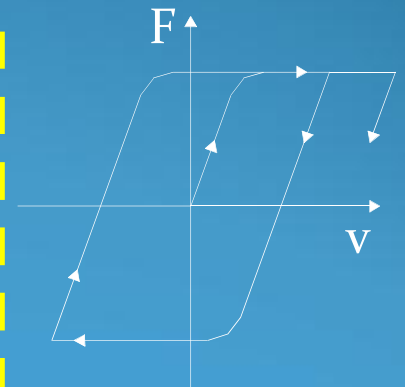
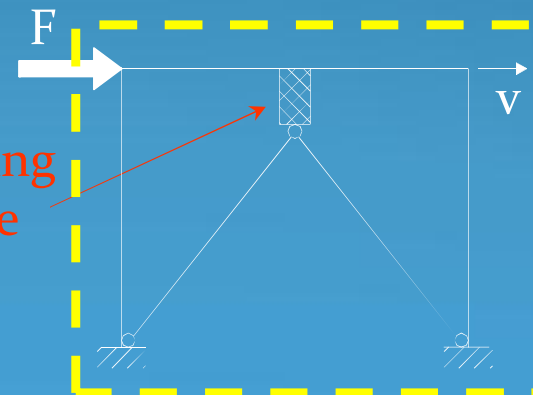
Cyclic behaviour



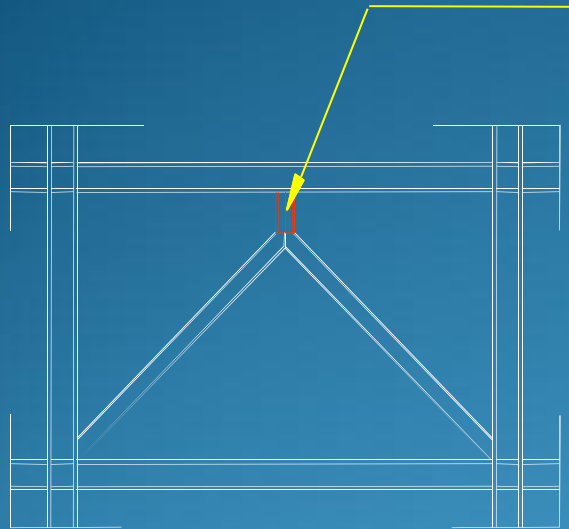
Dissipative
bracing



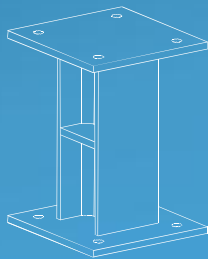
Damping
device



DIAGONAL BRACING SYSTEMS BASED ON METALLIC-YIELDING

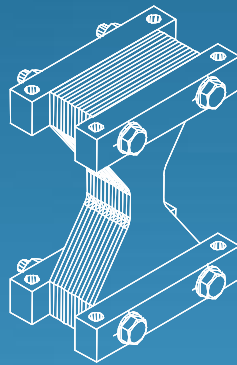


Y-braced eccentric braces

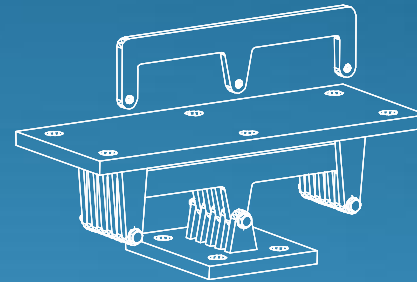


Conventional steel link

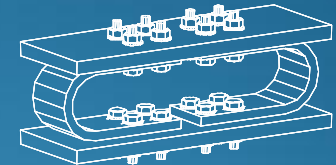
Added Damping And Stiffness elements (ADAS)



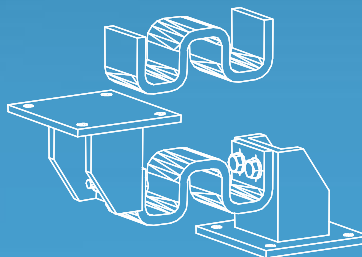
X-shaped



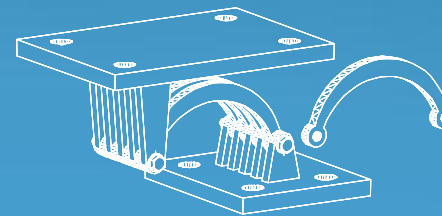
E-shaped



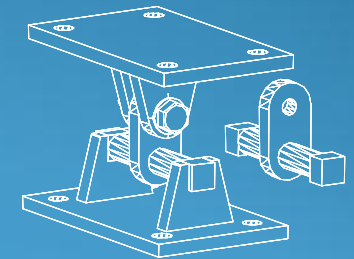
U-shaped



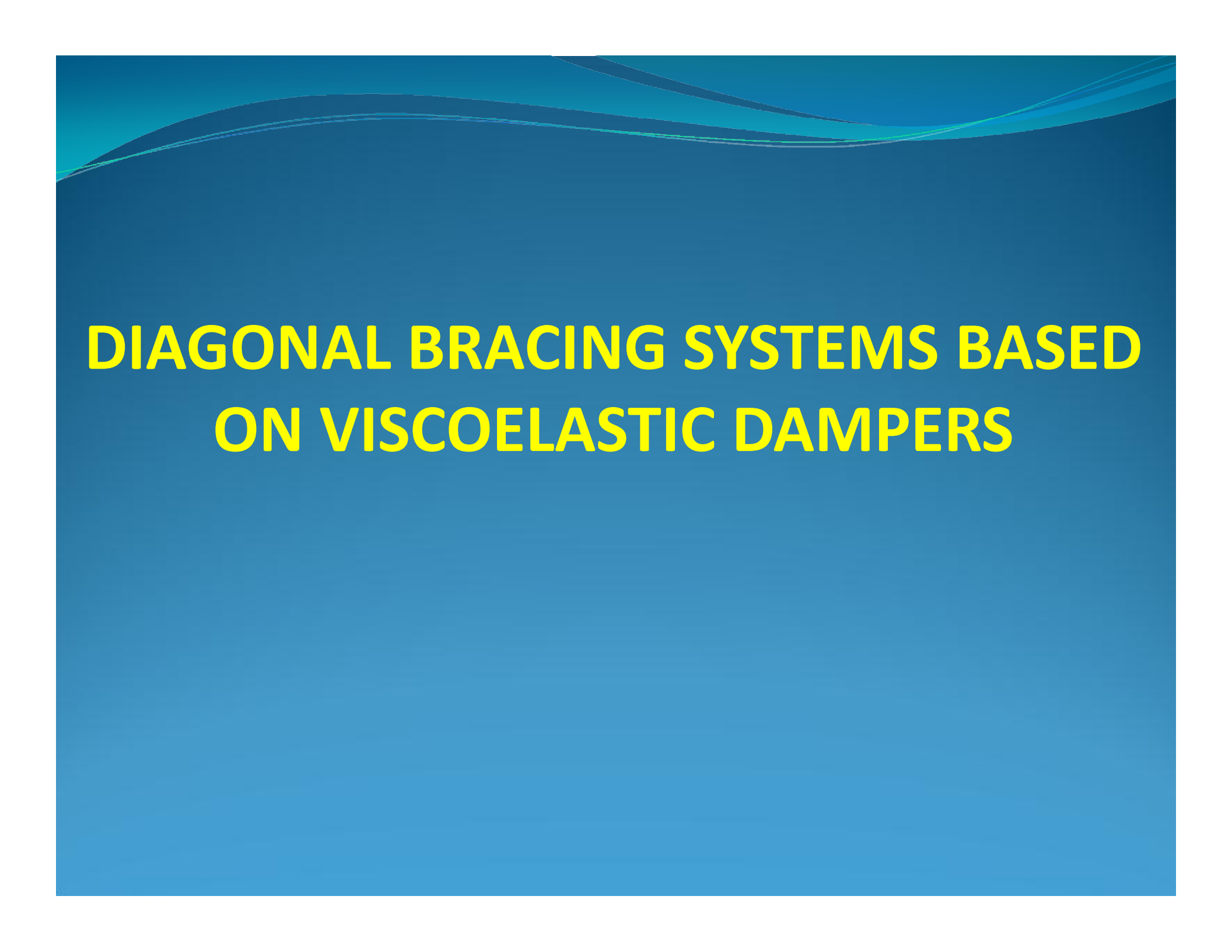
Ω-shaped



honeycomb-shaped



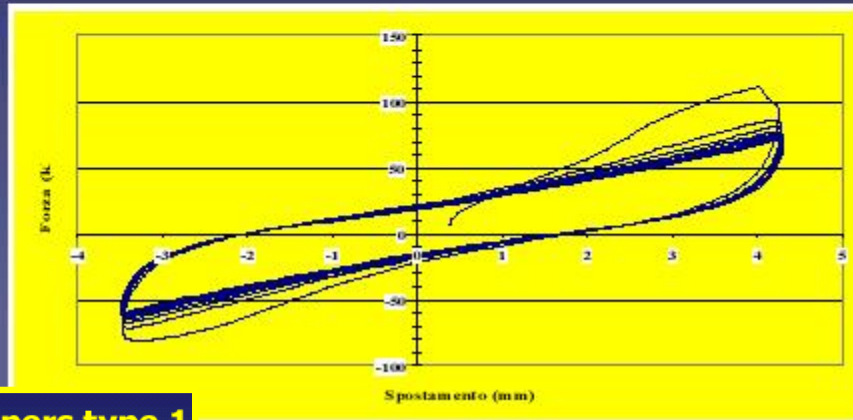
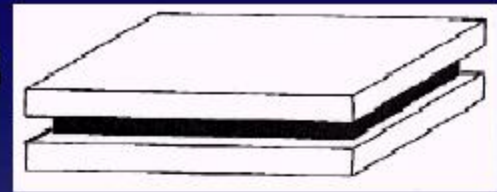
Torsional device

The background is a solid blue color with a gradient. At the top, there are several thin, wavy lines in shades of blue and teal, creating a sense of movement or a stylized horizon. The main title is centered in the upper half of the image.

DIAGONAL BRACING SYSTEMS BASED ON VISCOELASTIC DAMPERS

DIAGONAL BRACING SYSTEMS BASED ON VISCOELASTIC DAMPERS

damping is provided by shear deformation of a special rubber compound ($\xi \approx 20\%$), induced by the interstory drift



Retrofit of Gentile-Fermi school building (Italy)

- 18 viscoelastic dampers type 1
 $F \approx 80 \text{ kN}$
 $K = 19.8 \text{ kN/mm}$ (s.s. 100%)
- 7 viscoelastic dampers type 2
 $F \approx 60 \text{ kN}$
 $K = 14.8 \text{ kN/mm}$ (s.s. 100%)
- 8 viscoelastic dampers type 3
 $F \approx 30 \text{ kN}$
 $K = 7.4 \text{ kN/mm}$ (s.s. 100%)



Dissipative braces in one school in Fabriano



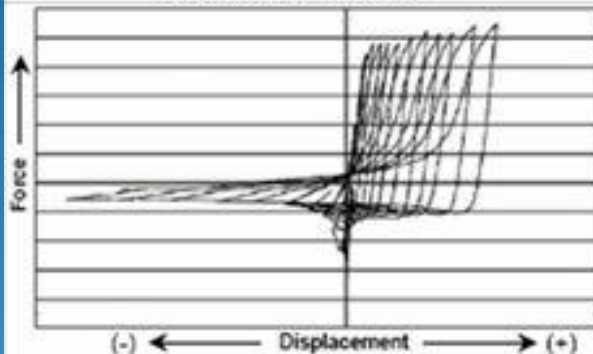
Dissipative braces in two schools in Potenza

Buckling Restrained Braces (BRBs)

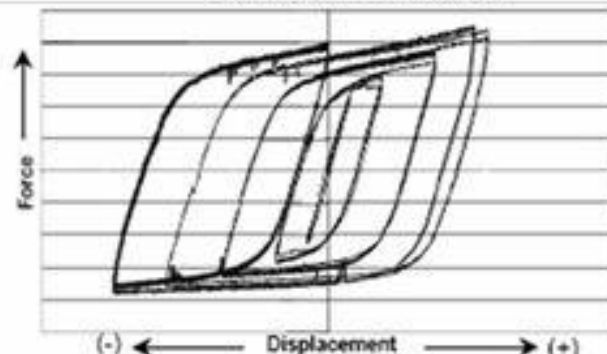
Buckling Restrained Braces (BRBs)



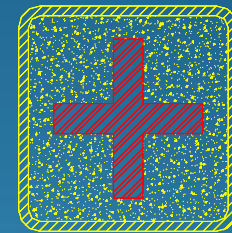
- Buckled out
- Poor nonlinear behaviour



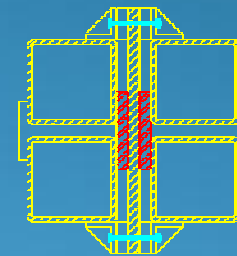
- Unbuckled
- Excellent nonlinear behaviour



Unbonded BRBs



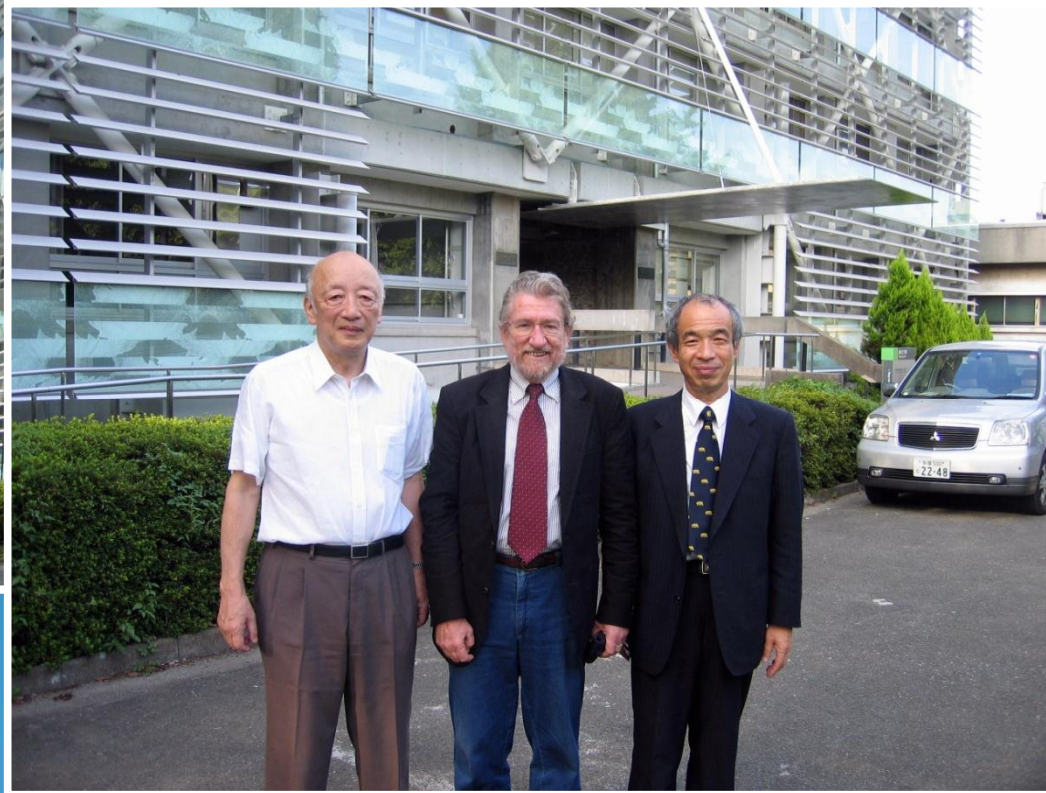
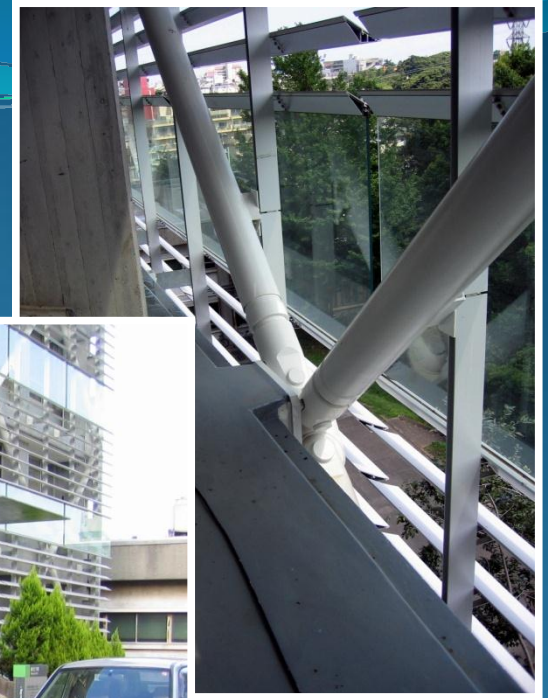
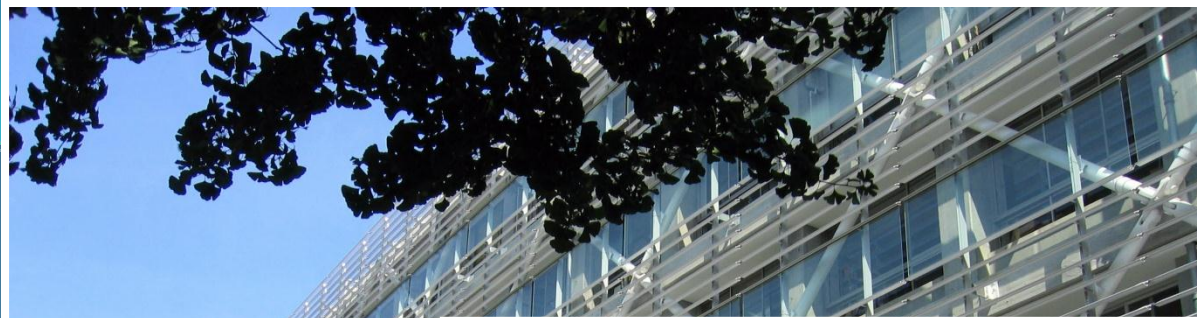
All-steel BRBs



BRBs are special advanced braces, which exhibit the same response in tension and compression with stable hysteresis loops and large energy absorption capacity



Unbonded BRB bracings



The Tokyo Institute of Technology
(Japan)

Seismic upgrading by Buckling Restrained Braces (BRBs): the University of Ancona



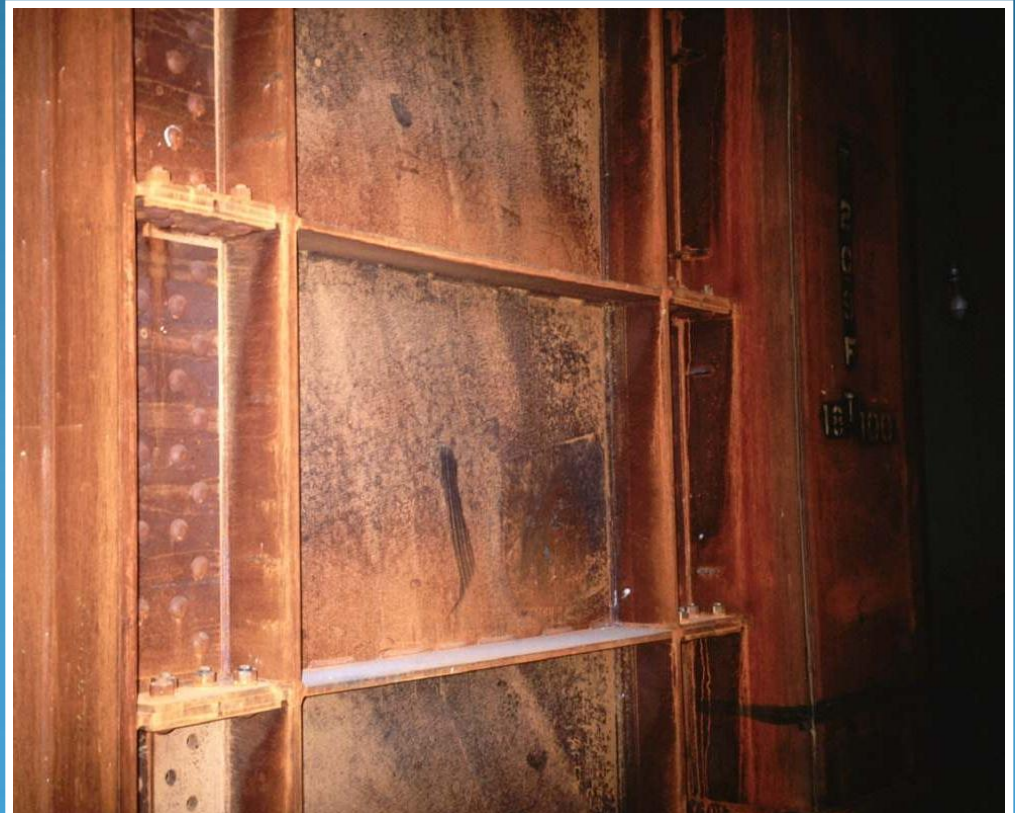
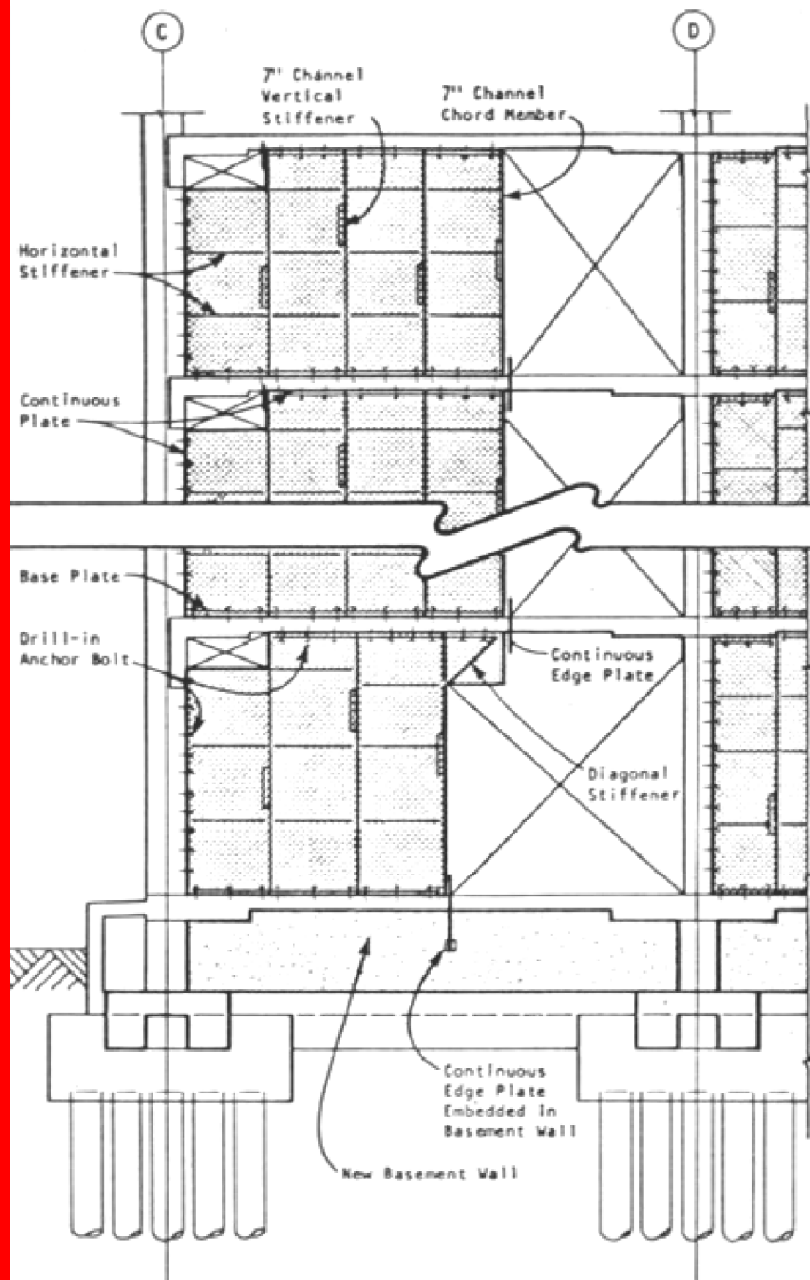
Buckling Restrained Braces (BRBs)



Five full-scale tests on two RC buildings equipped with novel “all-steel” BRB prototypes have been carried out by DIST.

METAL PANELS

Metal shear panels



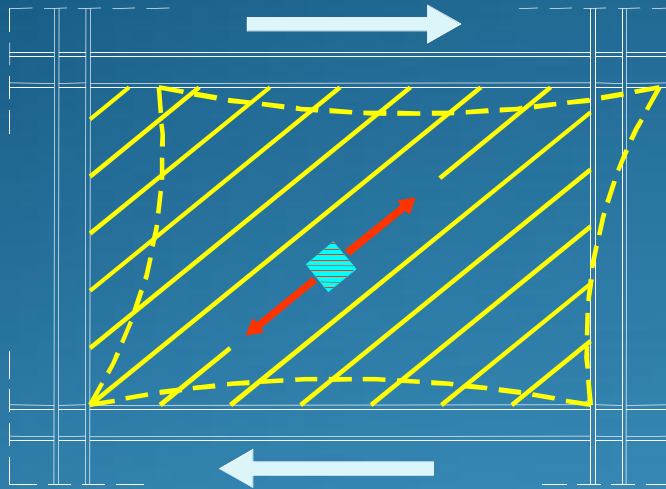


Tokyo bay

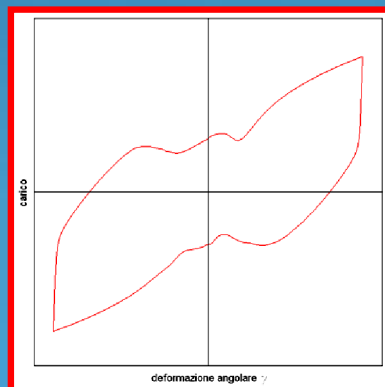




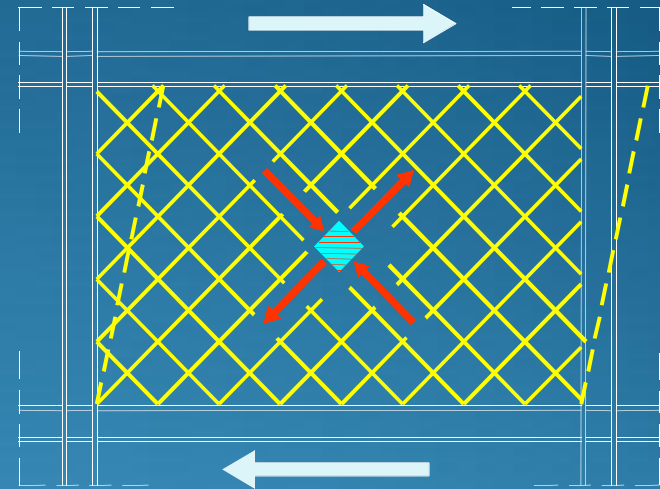
BASIC ENERGY DISSIPATION MECHANISMS FOR SHEAR PANELS



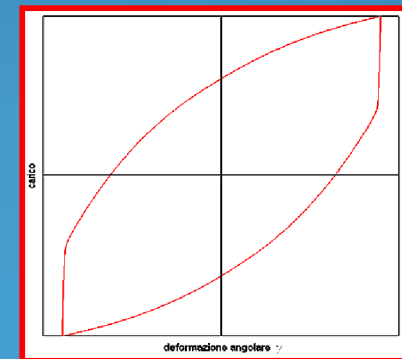
Tension field mechanism
(elastic buckling)



SLENDER PANELS



Pure shear mechanism
(no-buckling)



COMPACT PANELS

TWO PRACTICAL WAYS OF USING METAL SHEAR PANELS

Unstiffened steel shear panels

May be used also as façade walls of the building

May provide a significant stiffening and strengthening contribution

Have a poor dissipative behaviour

SLENDER PANELS

Low-strength metal shear panels

Mainly conceived as damping devices

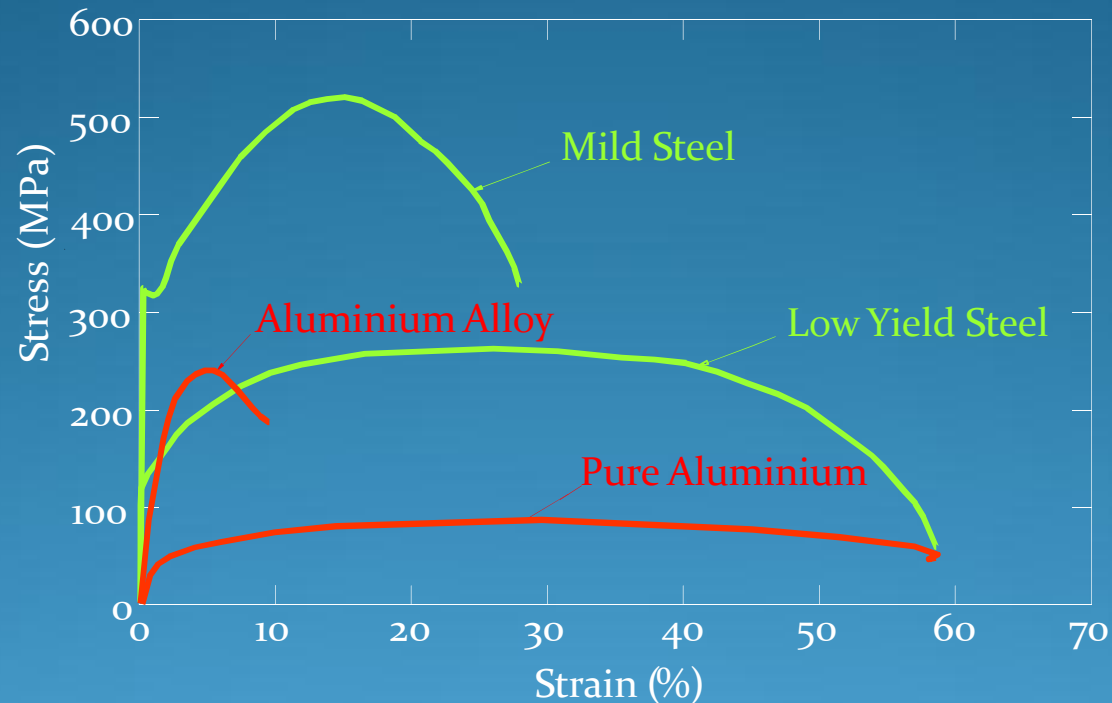
Provide an excellent hysteretic behaviour

Have a very low yield strength and relevant initial stiffness
(useful for damage control)

COMPACT PANELS

THE USE OF PURE ALUMINIUM FOR METAL SHEAR PANELS

Comparison of Stress-Strain Relationship
between Steel and Aluminium

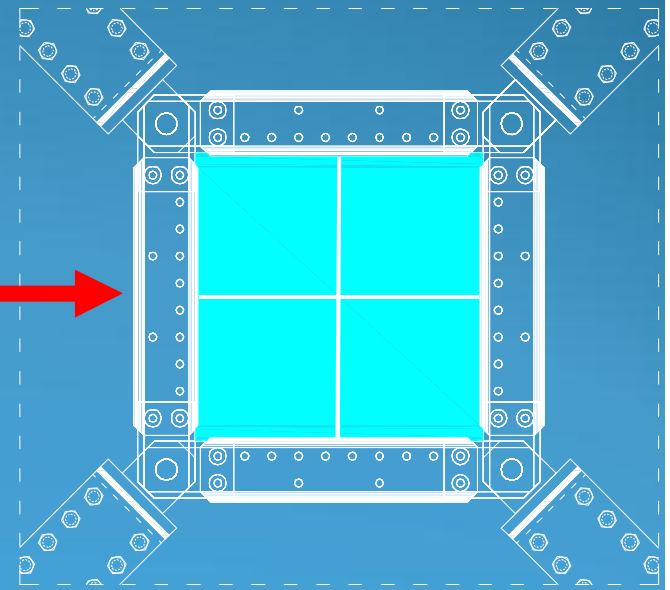
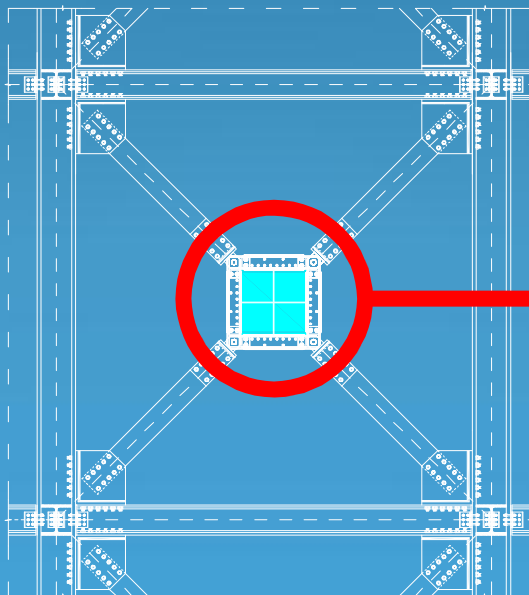
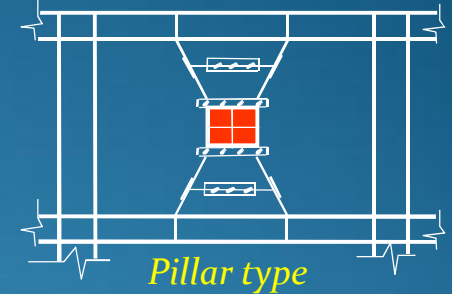
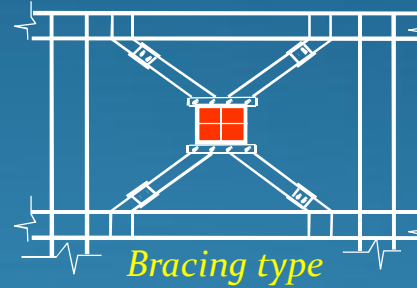
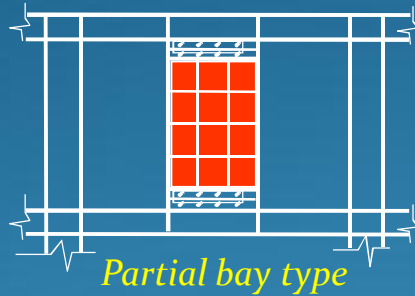
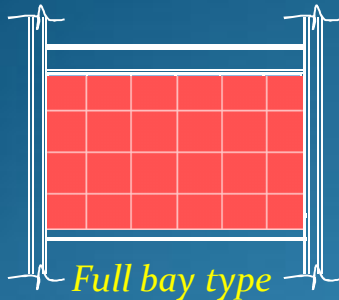


Tensile properties of pure aluminium

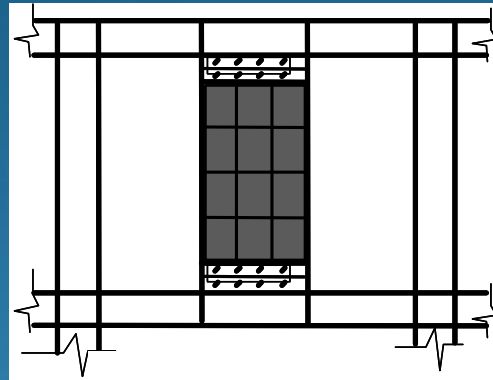
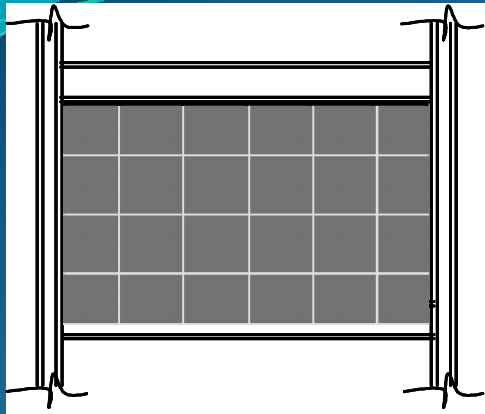
Tensile strength, f_u (MPa)	Yield strength, f_y (MPa)	hardening ratio, f_u/f_y	Elongation (%)
40-50	15-20	2-3,3	50-70

BRACING TYPE PURE ALUMINIUM SHEAR PANELS

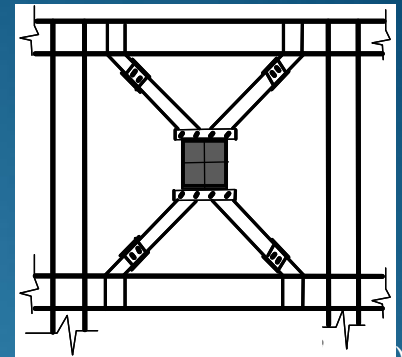
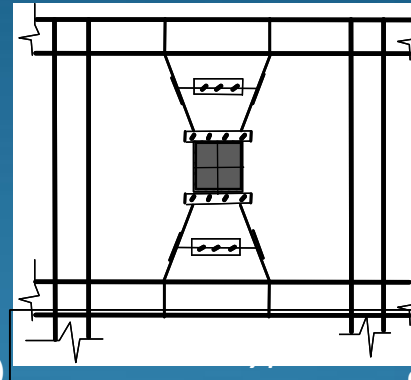
DIFFERENT ARRANGEMENTS IN THE FRAMEWORK



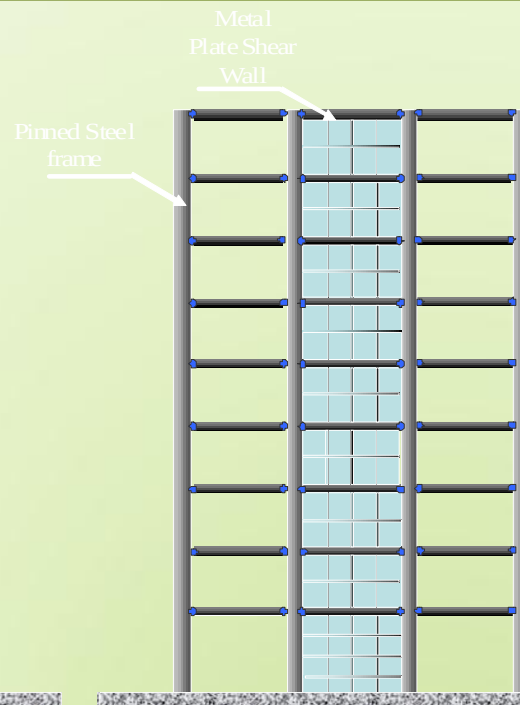
PANELS ARRANGEMENT IN FRAMES



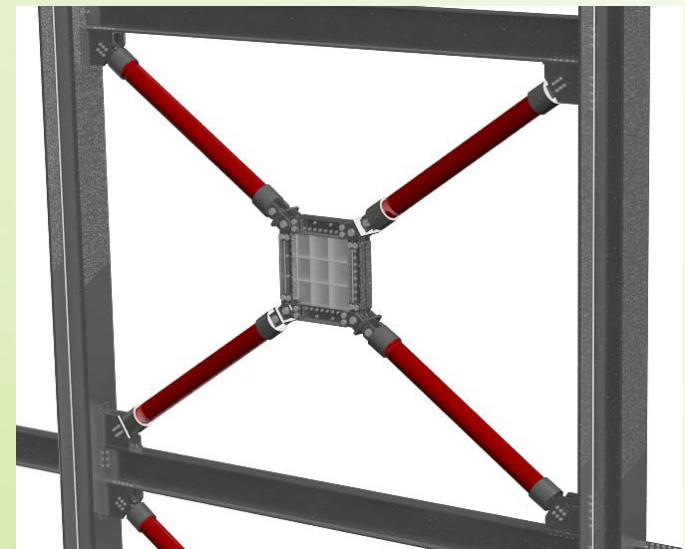
Partial bay type



*MRF+Shear Panels
(Dual Structural System)*



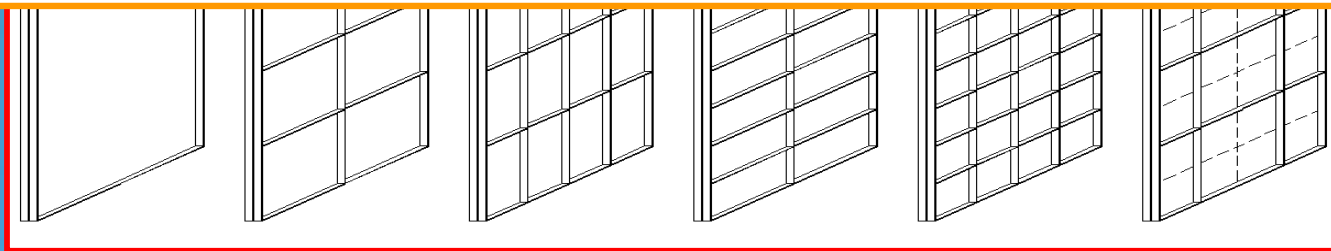
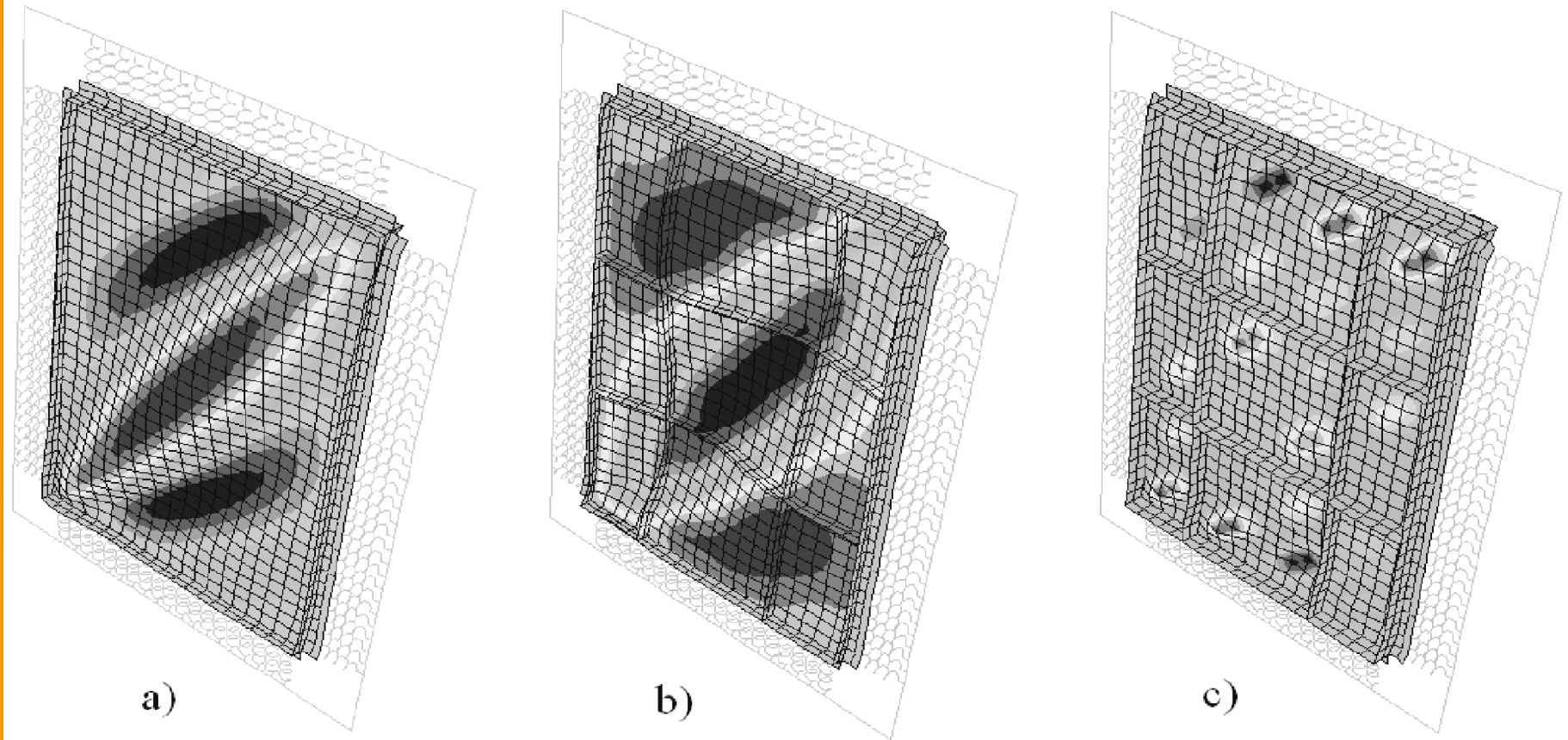
*Pinned frame+Shear Panels
(Standard Structural System)*



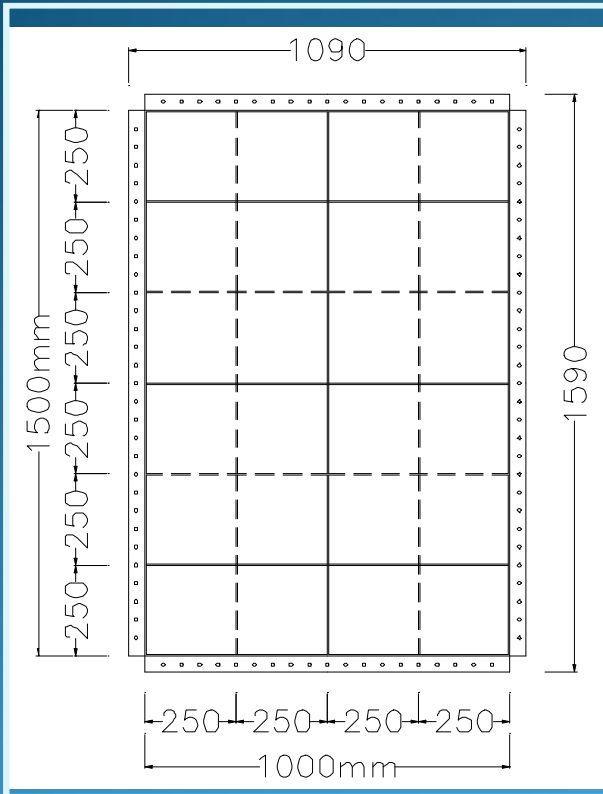
*Shear Panels as dissipative
bracing system*

FEM MODELLING

Collapse mechanism



TEST ON ALUMINIUM SHEAR PANEL

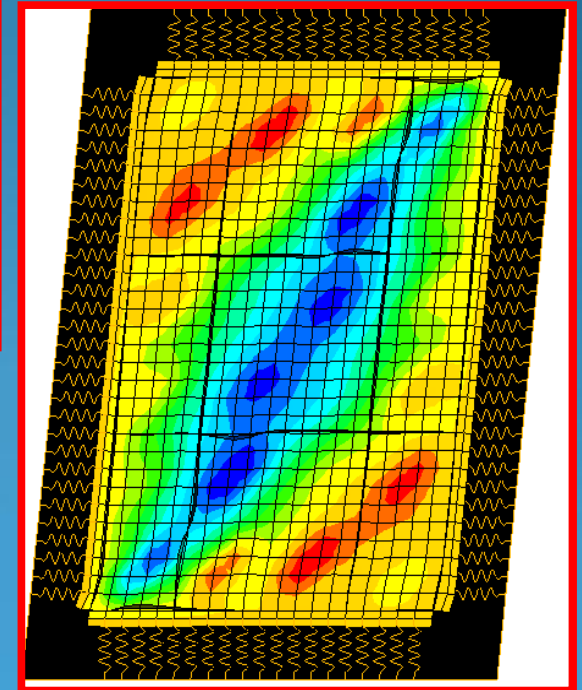
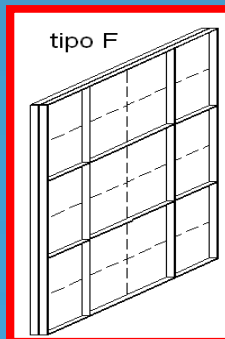
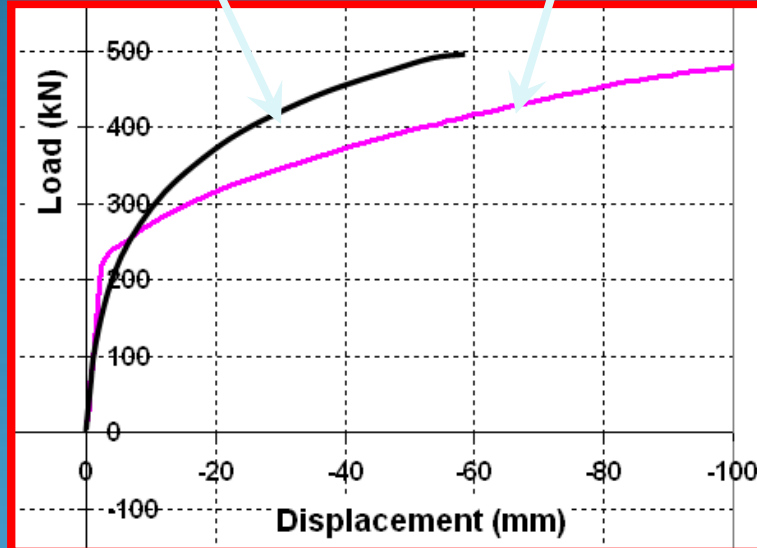


TEST ON ALUMINIUM SHEAR PANEL

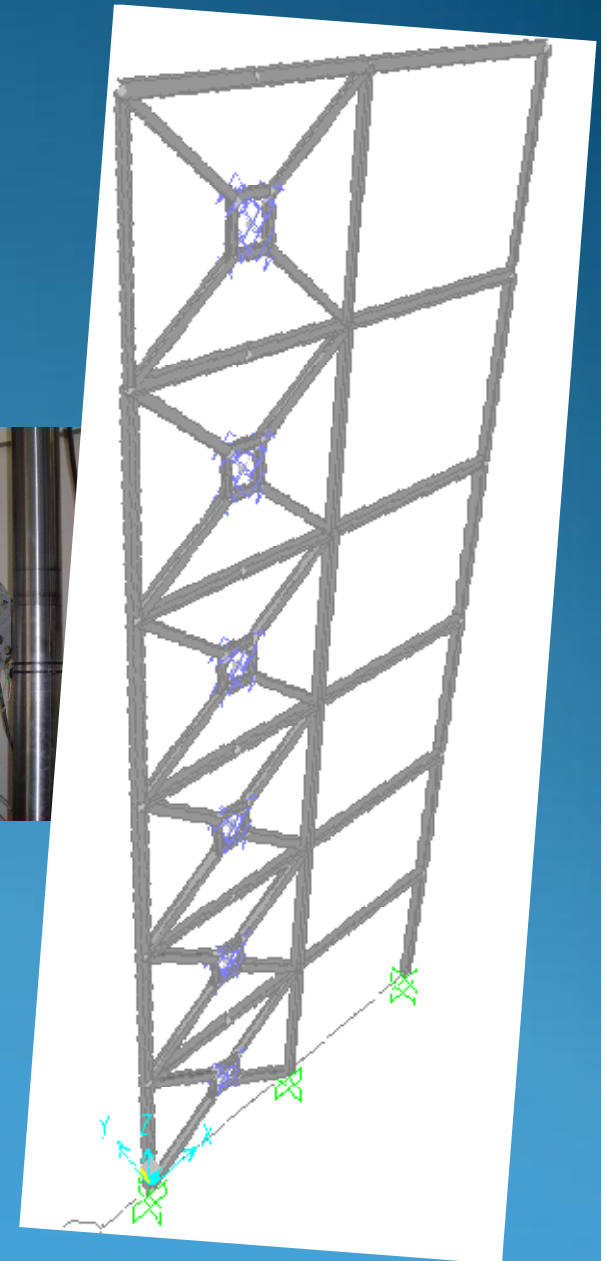
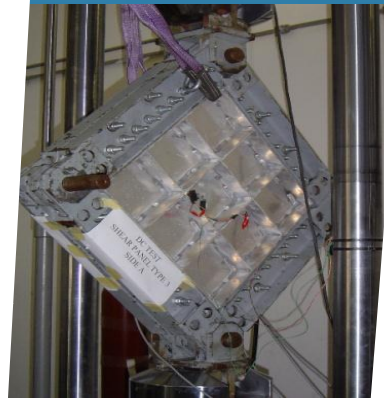
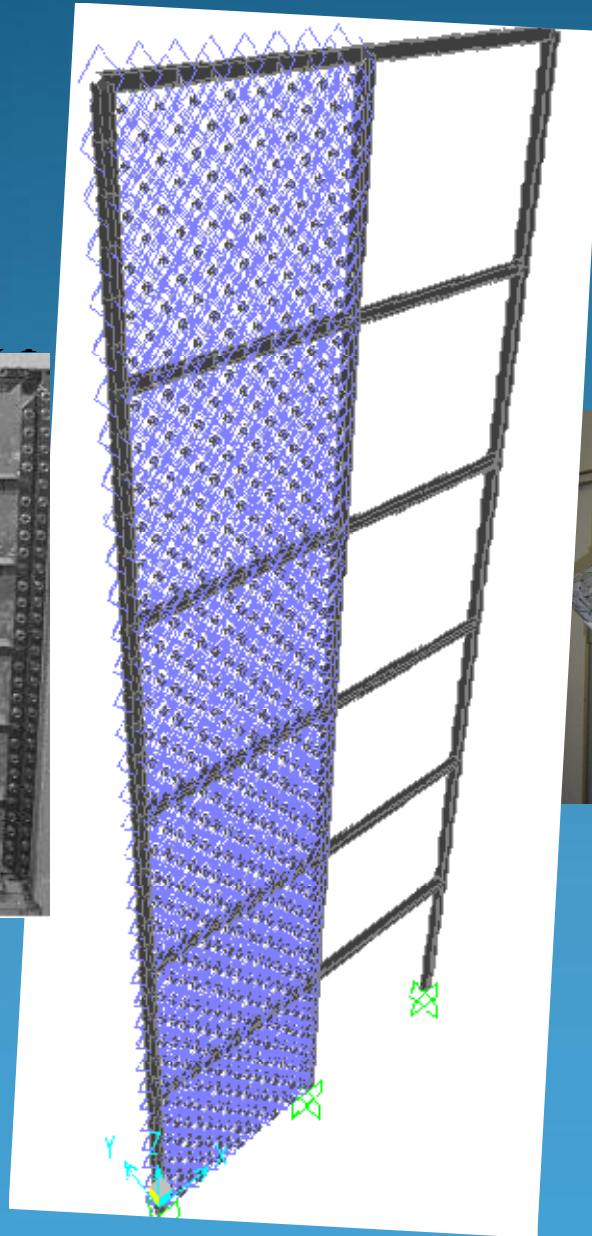
COMPARISON BETWEEN EXPERIMENTAL AND NUMERICAL RESULTS

Experimental
response

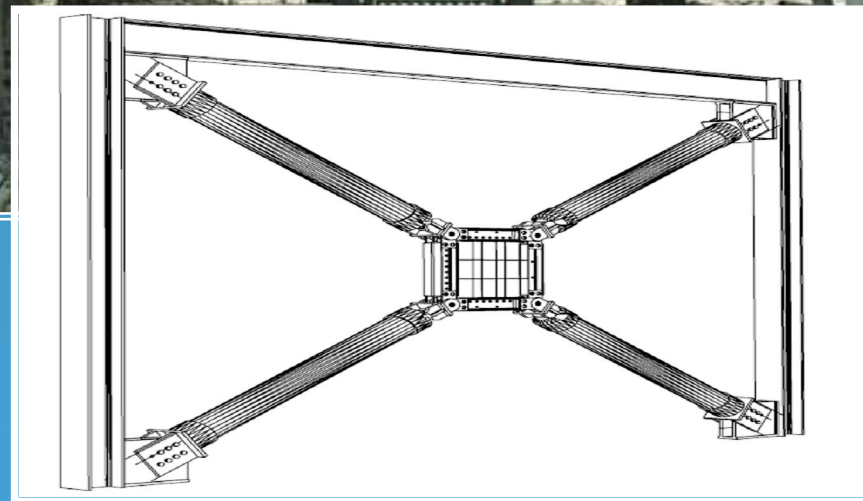
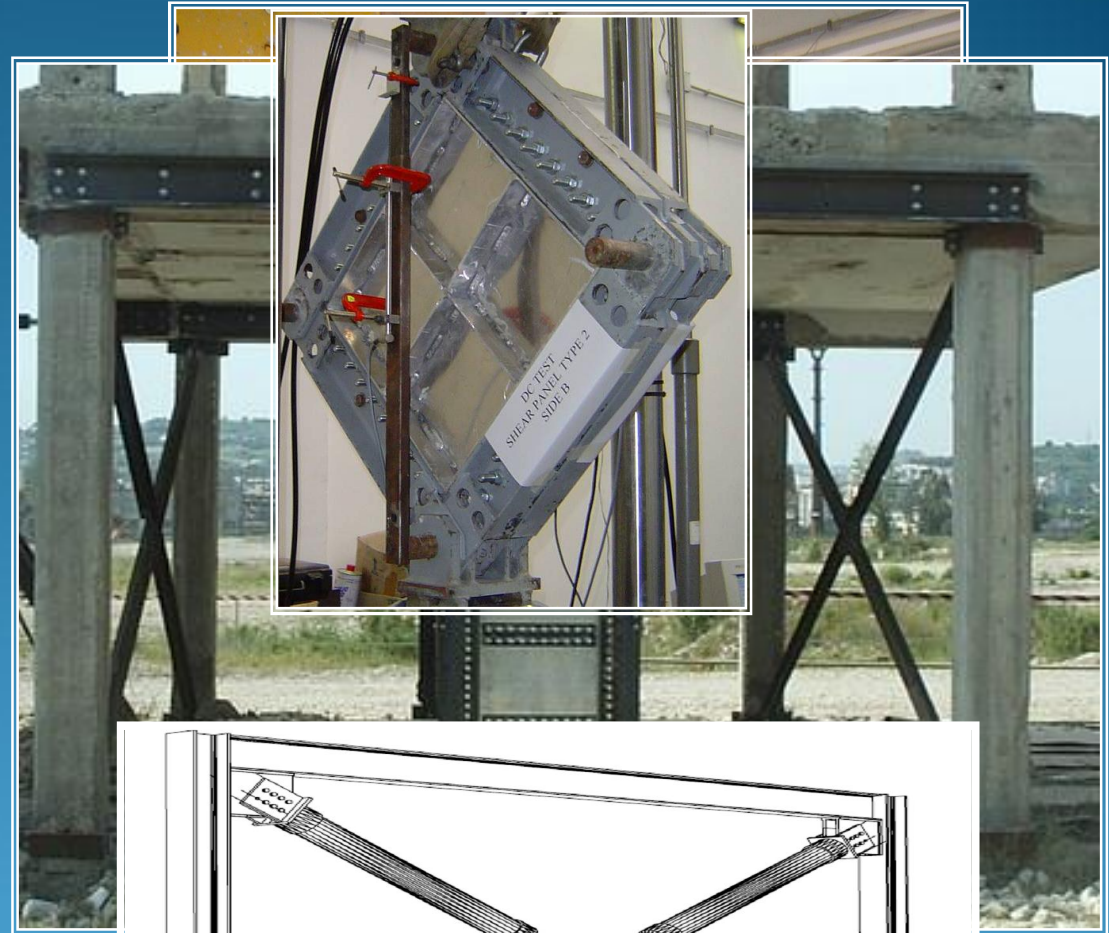
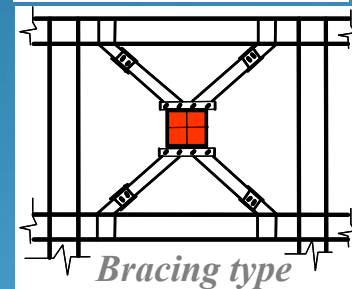
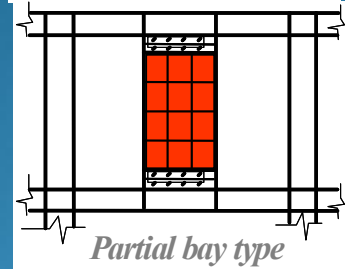
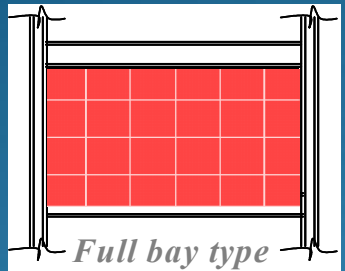
Preliminary numerical
response



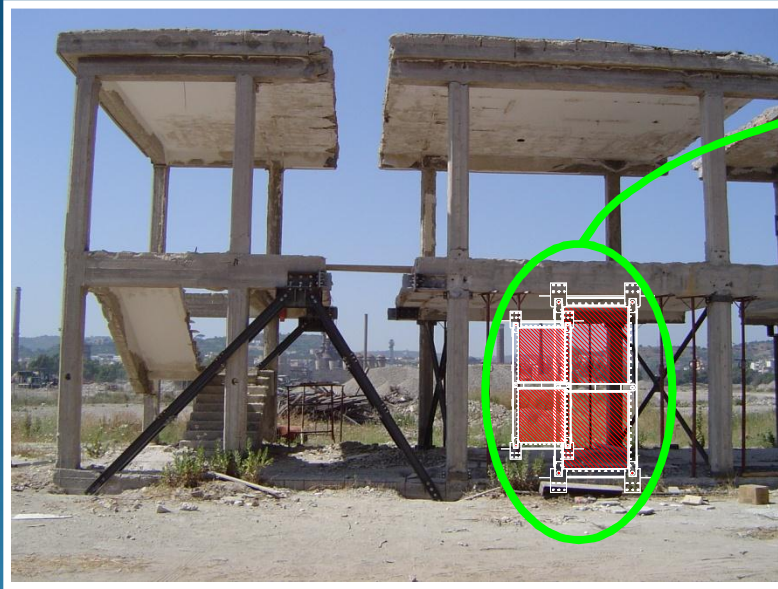
SOME EXAMPLES: FULL BAY TYPE AND BRACING TYPE PURE ALUMINIUM SHEAR PANELS



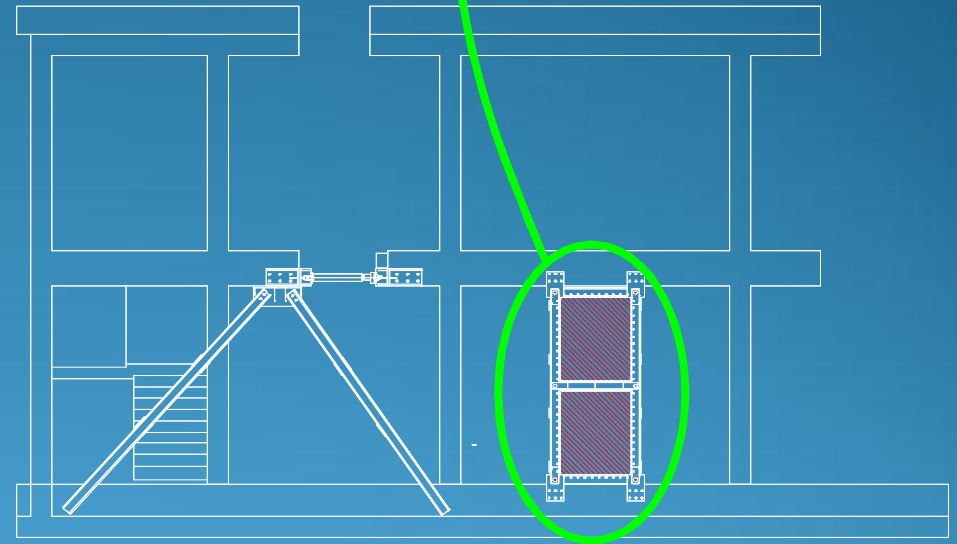
Dissipative Pure Aluminium Shear Panels



SEISMIC RETROFITTING OF R.C. FRAMES BY MEANS OF SHEAR PANELS : THE "ILVA-IDEM" PROJECT

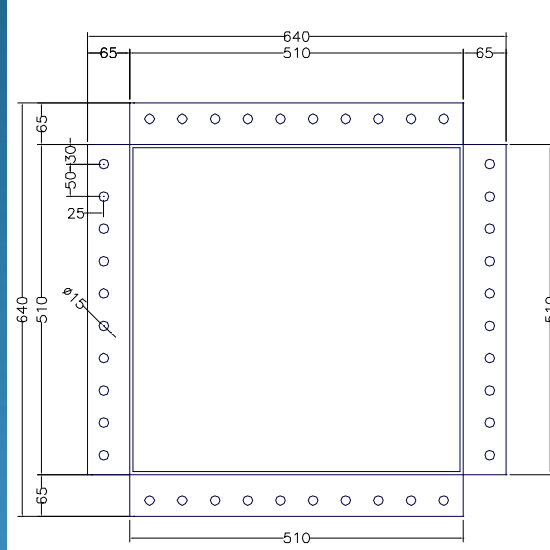
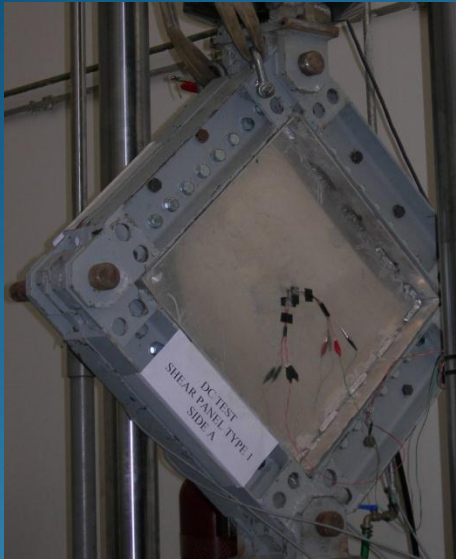


METAL SHEAR PANELS



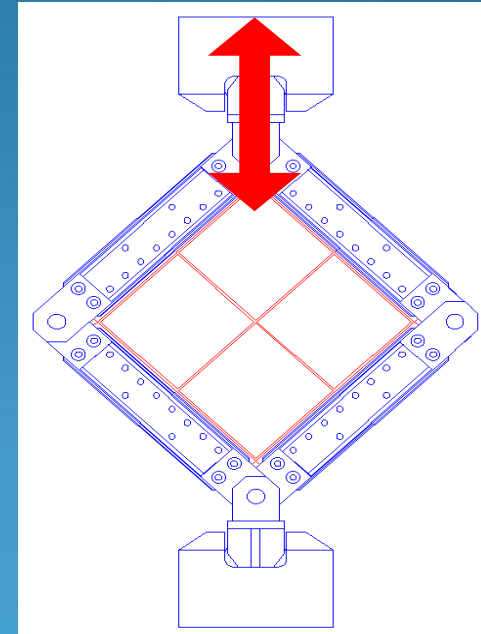
BRACING TYPE PURE ALUMINIUM SHEAR PANELS

Geometrical configurations

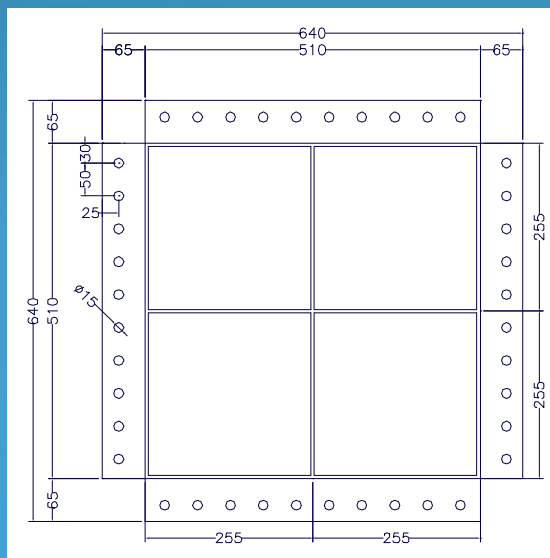
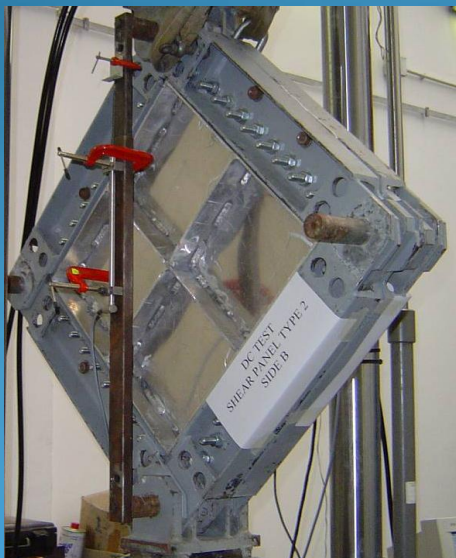


BTPASP configuration 1
($b/t=100$)

SHEAR CYCLIC TESTS BY
DIAGONAL COMPRESSION

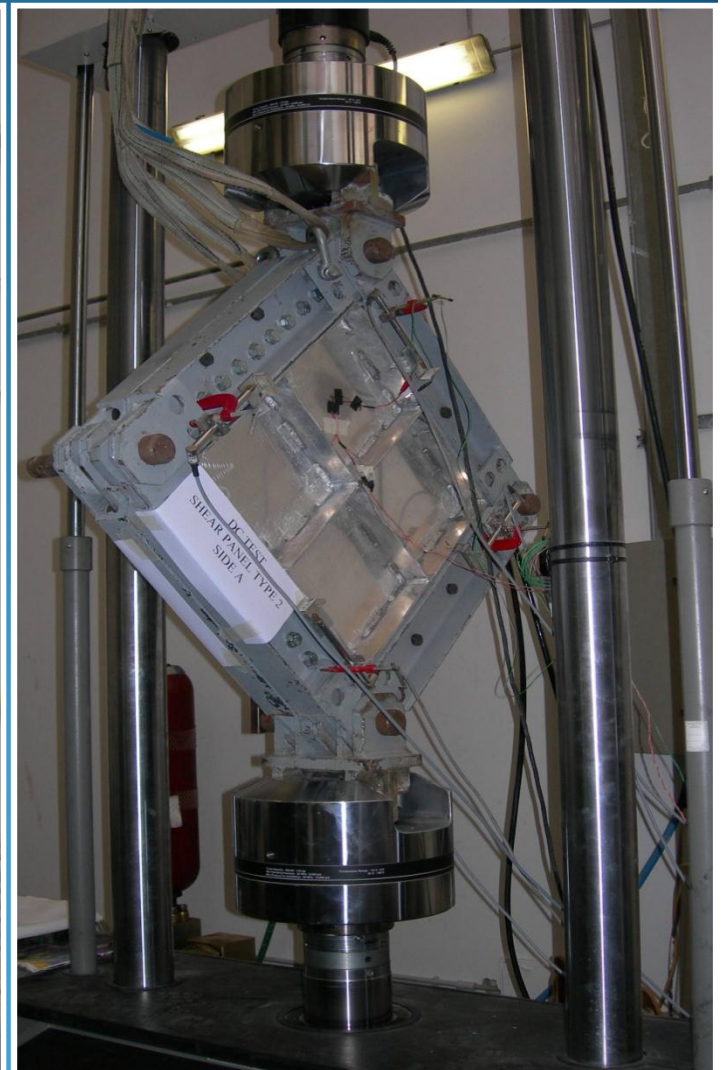
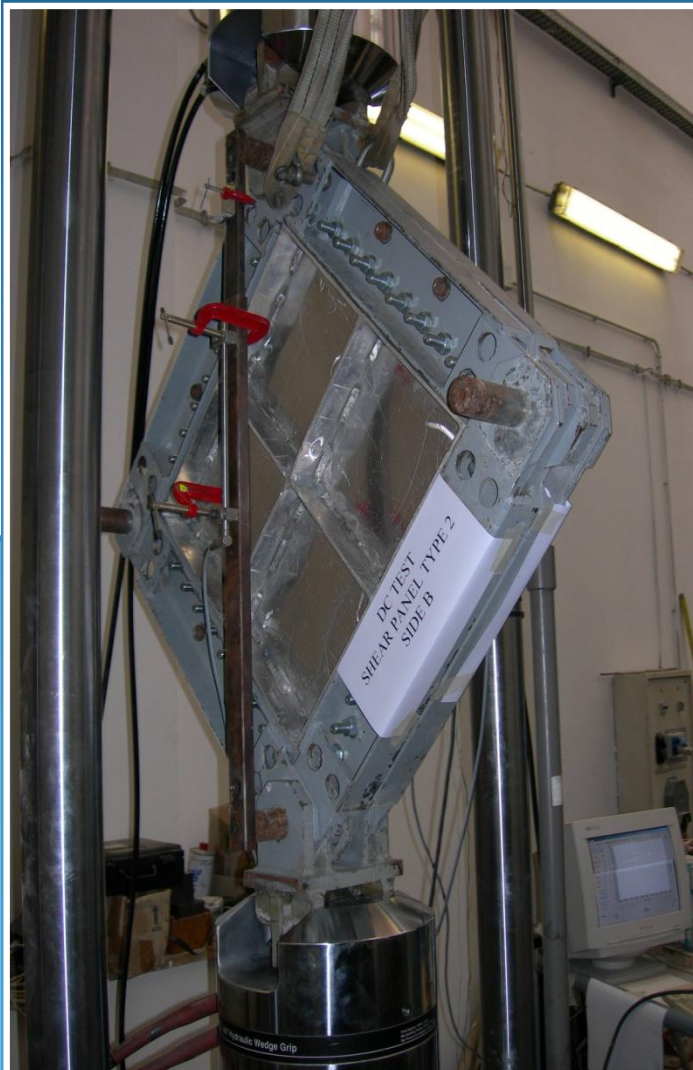
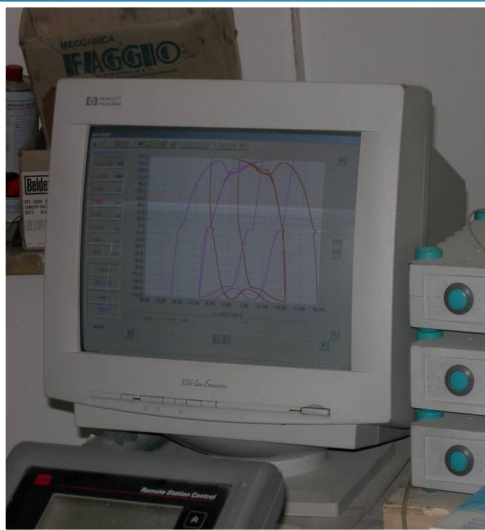


BTPASP configuration 2
($b/t=50$)



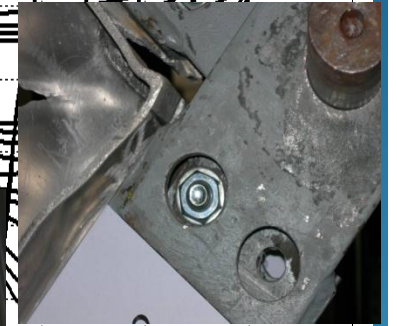
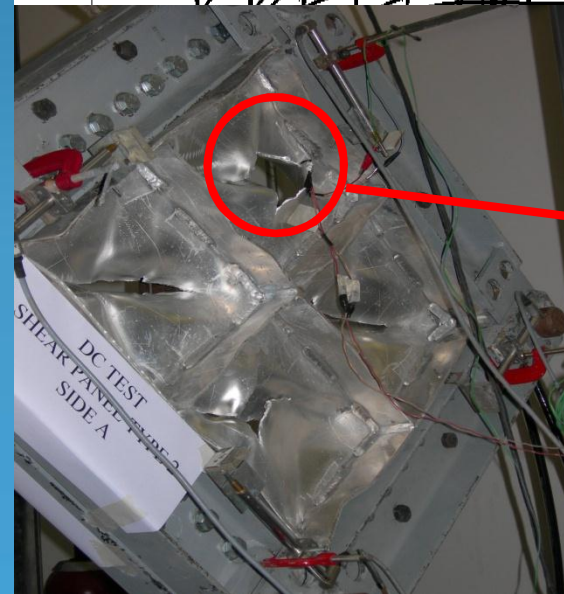
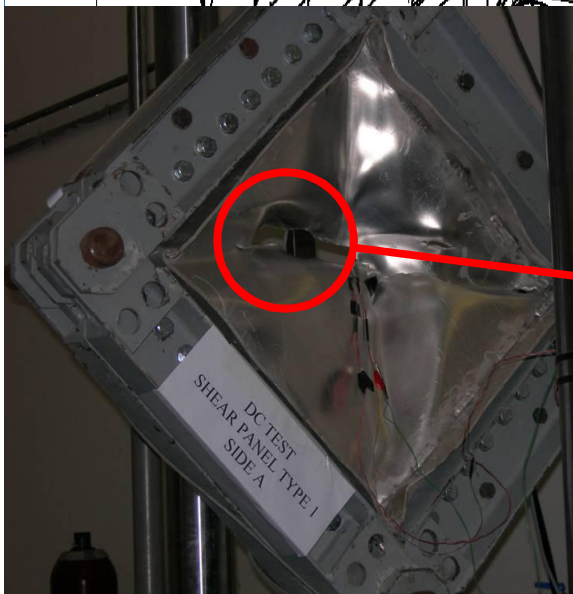
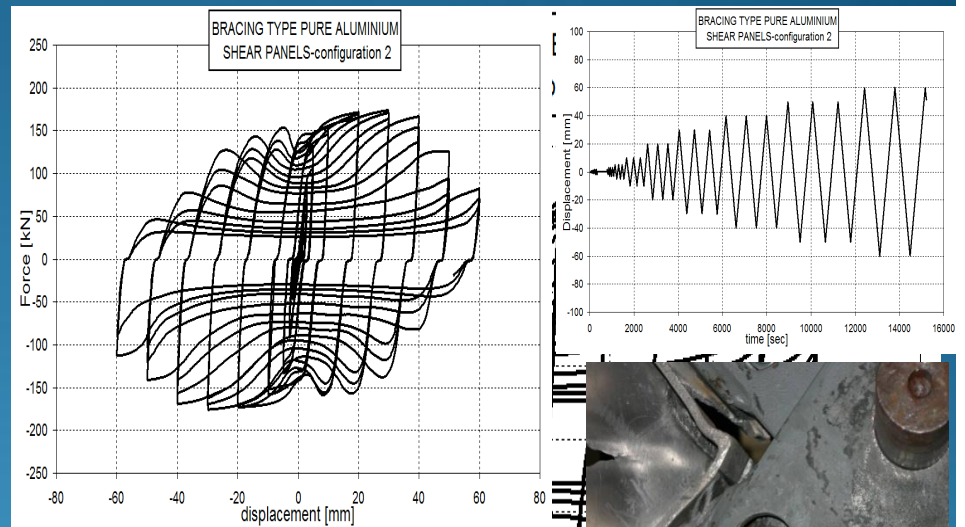
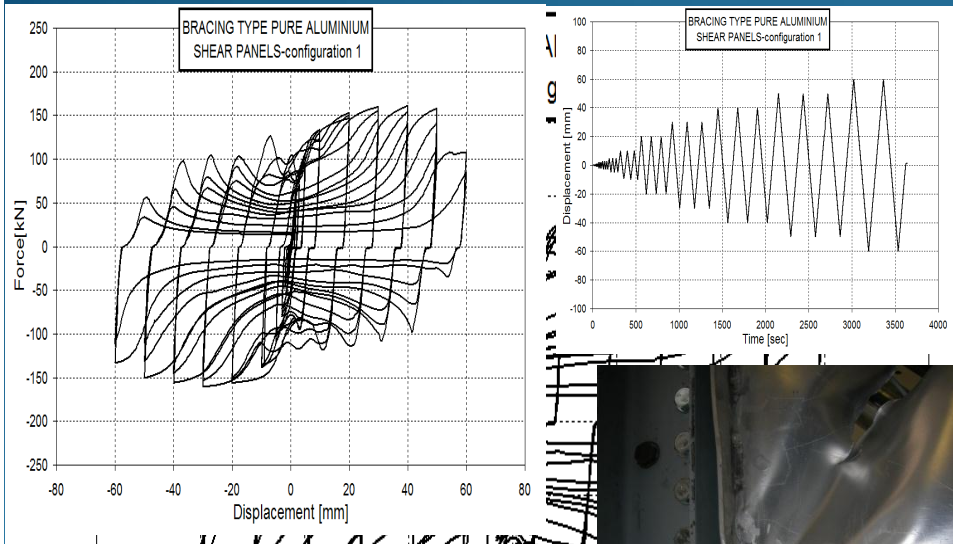
BRACING TYPE PURE ALUMINIUM SHEAR PANELS

Testing apparatus



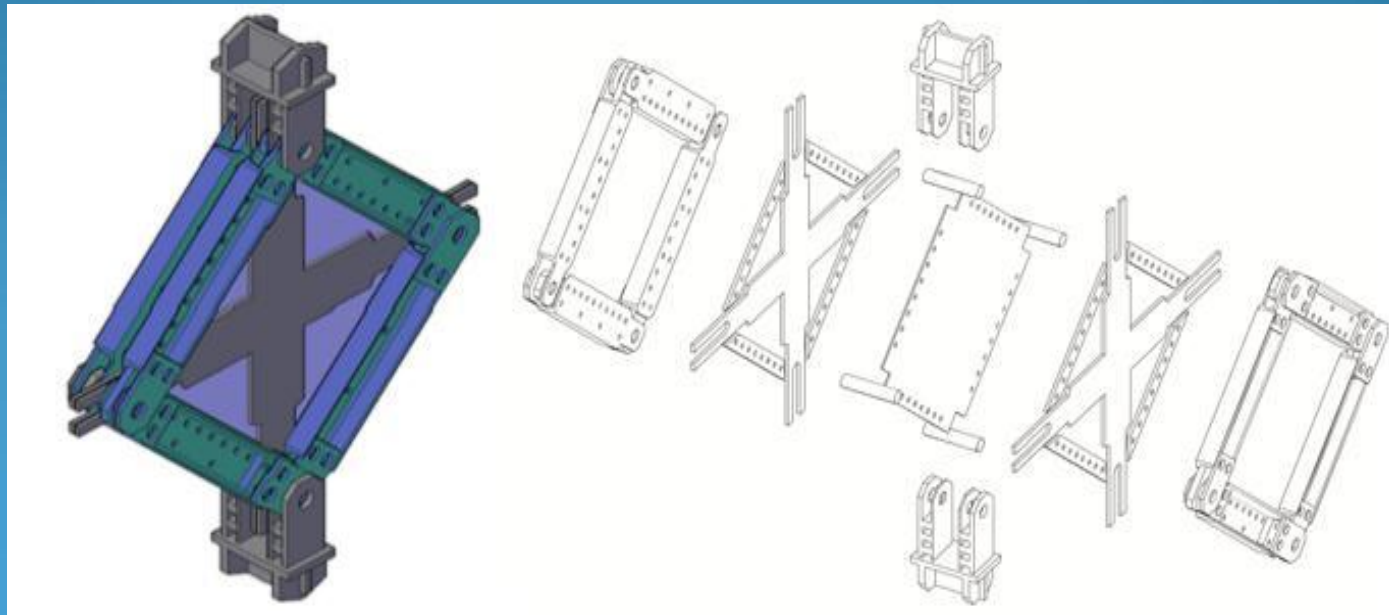
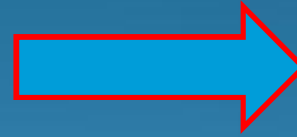
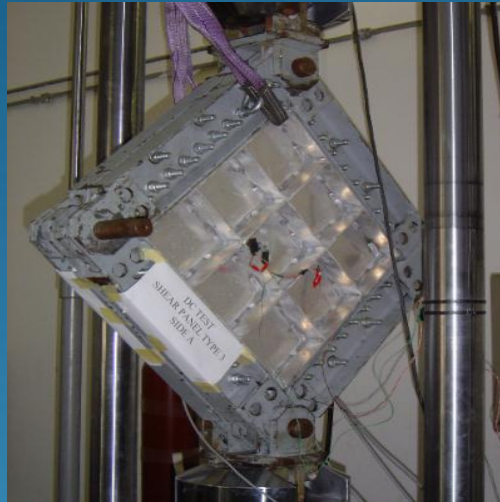
BRACING TYPE PURE ALUMINIUM SHEAR PANELS

Test results

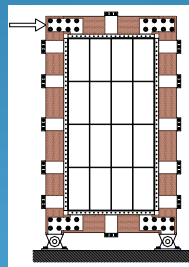


Evolution of the system to avoid residual stresses negative effects

From welded to bolted stiffeners

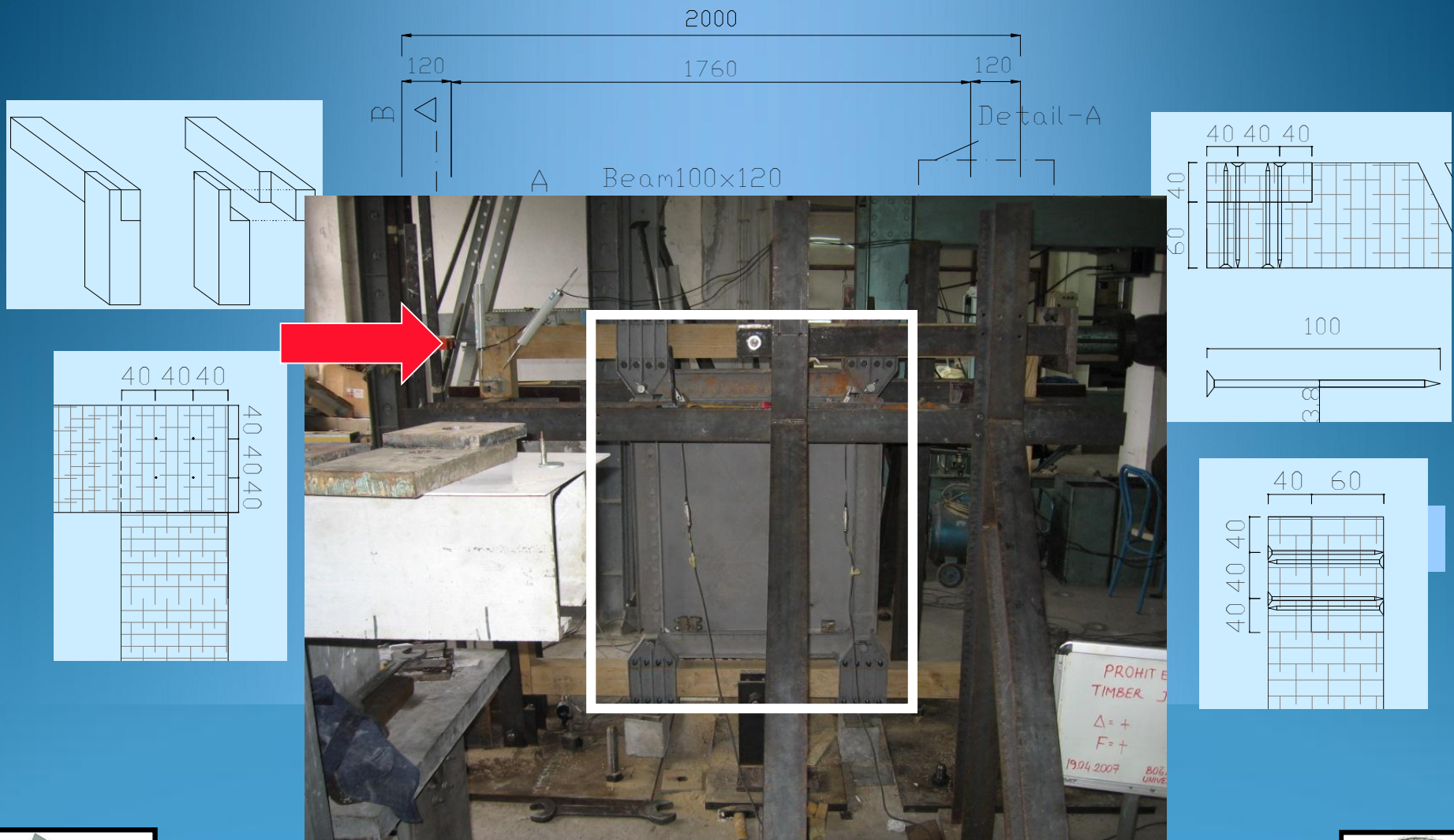


Metal panels for retrofitting timber houses



Special devices using metal panels

Test on timber portal retrofitted with metal panel



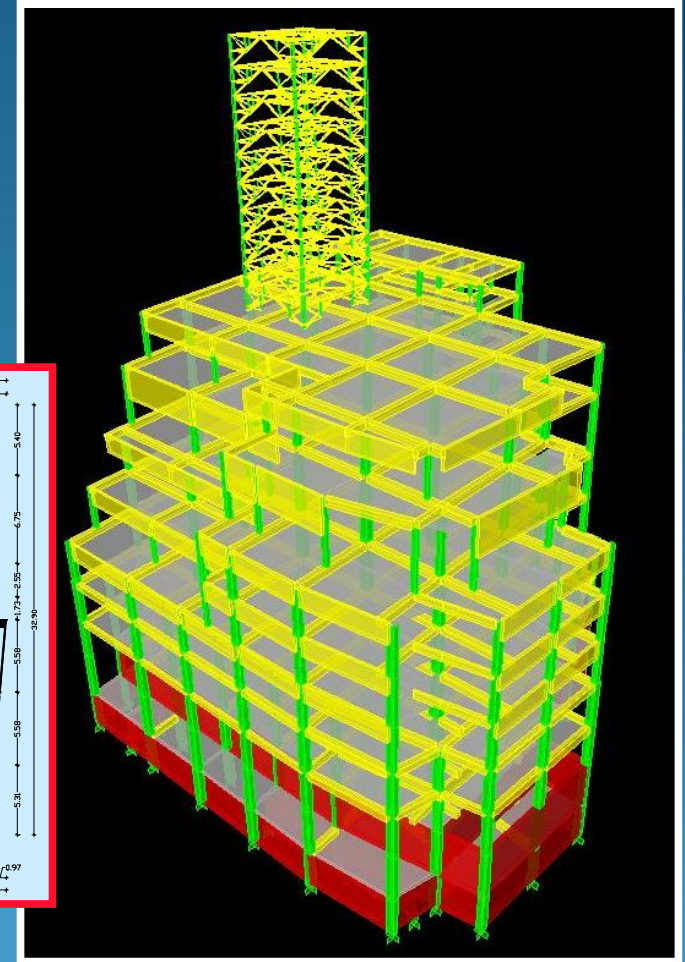
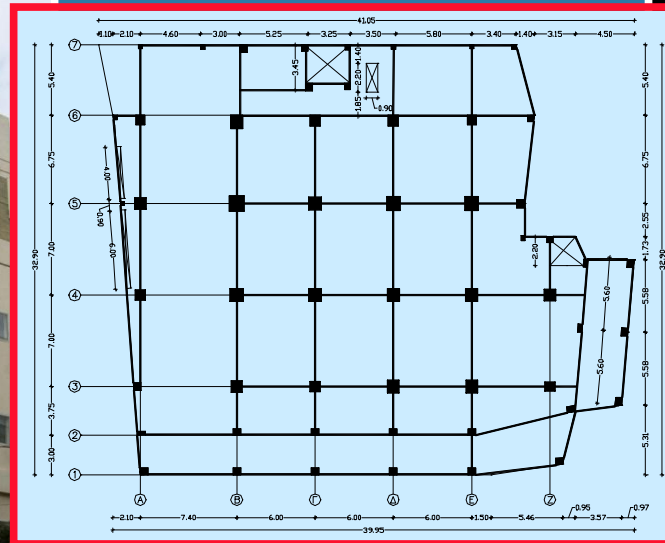
KOLETTI BUILDING (Athens)

Six storey building with two basement levels

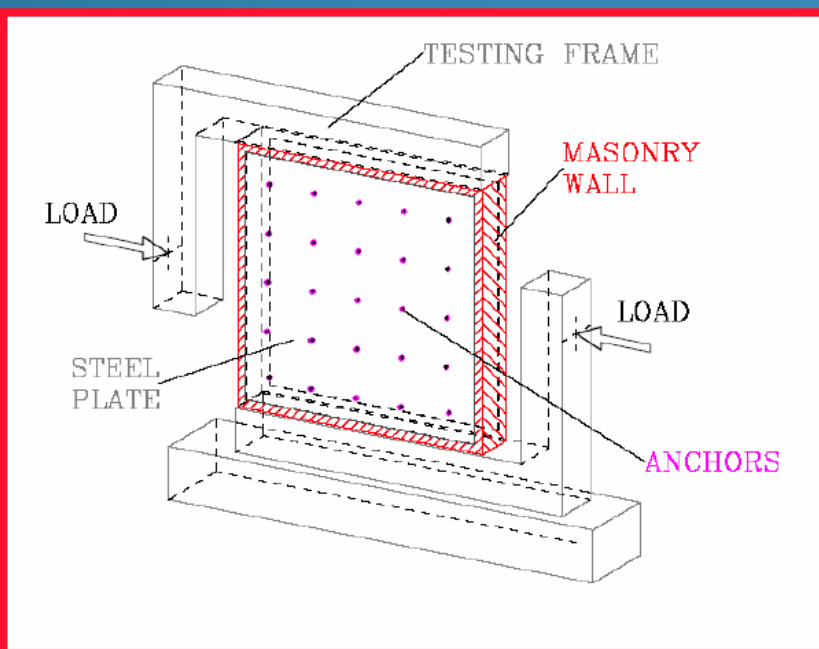
Plan dimensions 41,00 m x 33,00 m

Building height 26,50 m, tower height 20,00 m

Construction year 1979



METAL PANELS FOR MASONRY WALLS

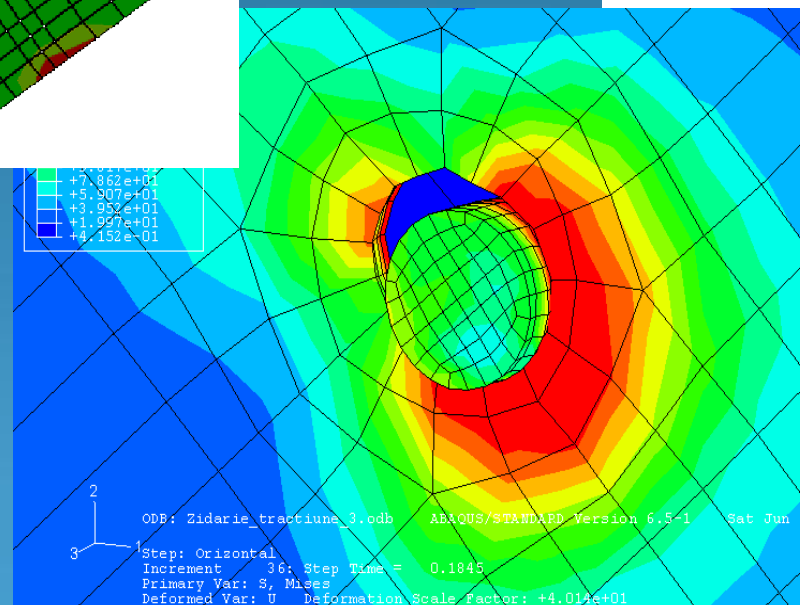
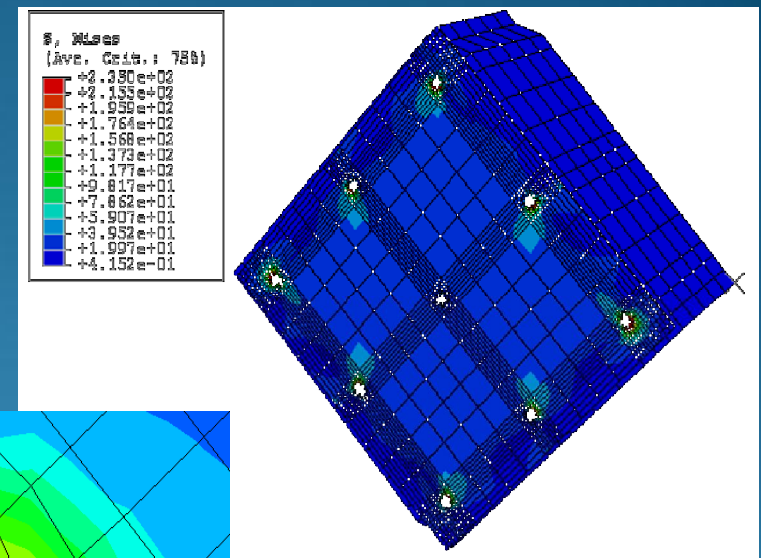
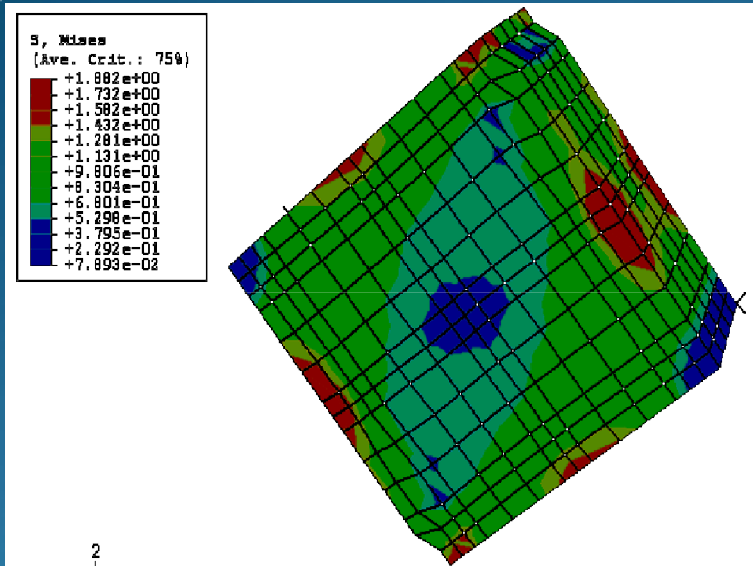


Steel shear plates (SSP)

Steel Wire Mesh (SWM)



METAL PANELS FOR MASONRY WALLS



Simulation of connecting systems in masonry walls reinforced by metal panels

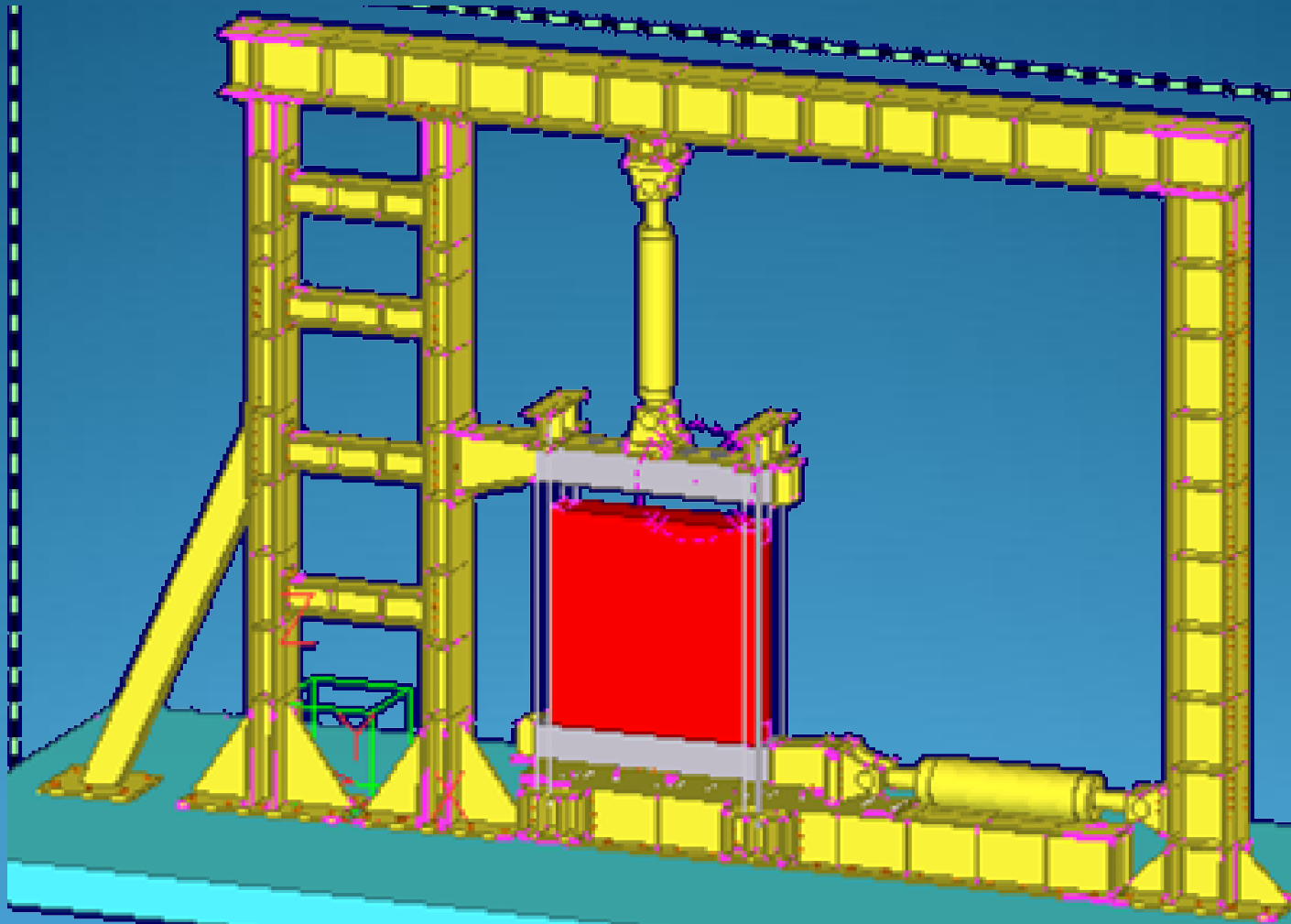
METAL PANELS FOR MASONRY WALLS

- Chemical anchor
- Prestress ties



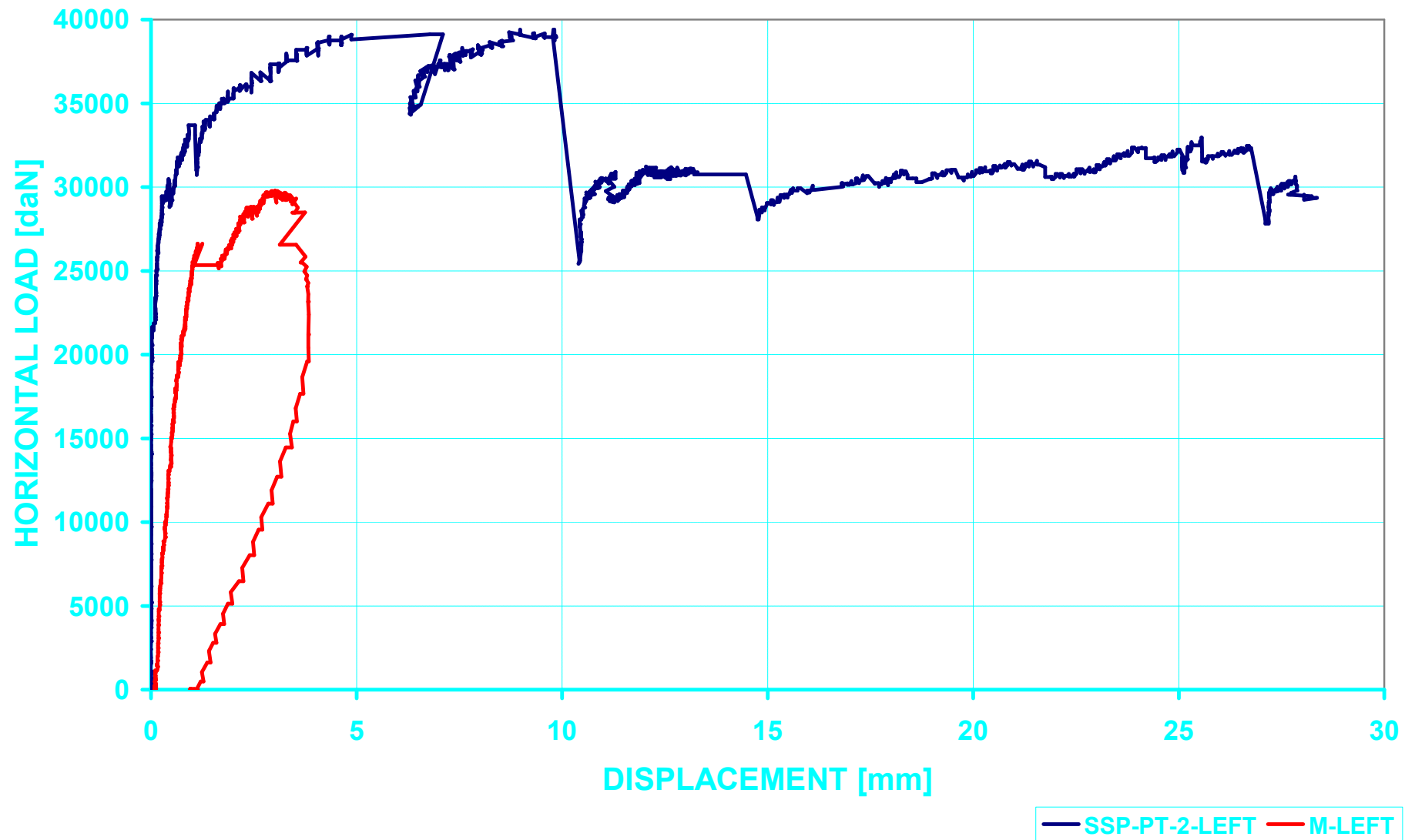
DIAGONAL TESTS ON SMALL SPECIMENS

METAL PANELS FOR MASONRY WALLS



CYCLIC TEST APPARATUS

METAL PANELS FOR MASONRY WALLS



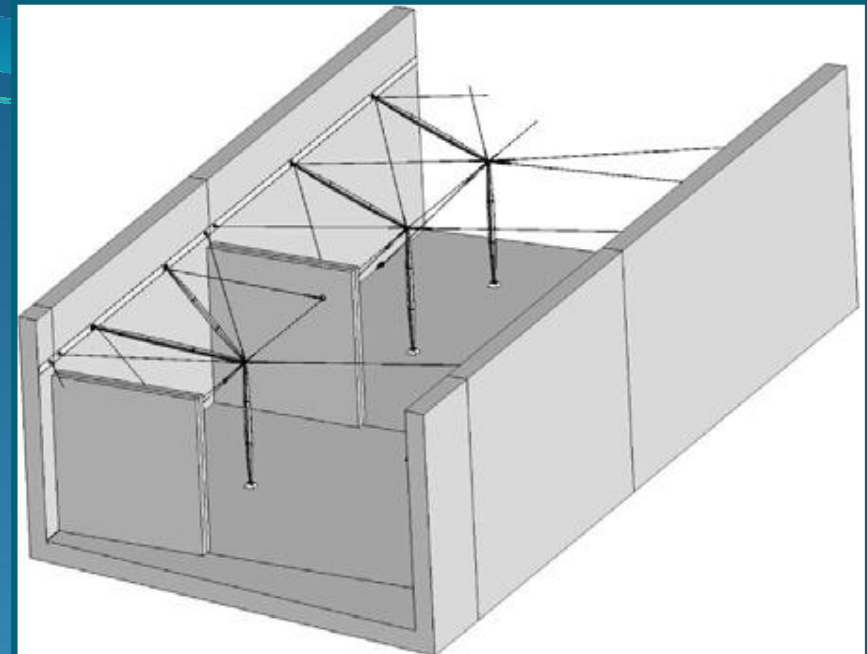
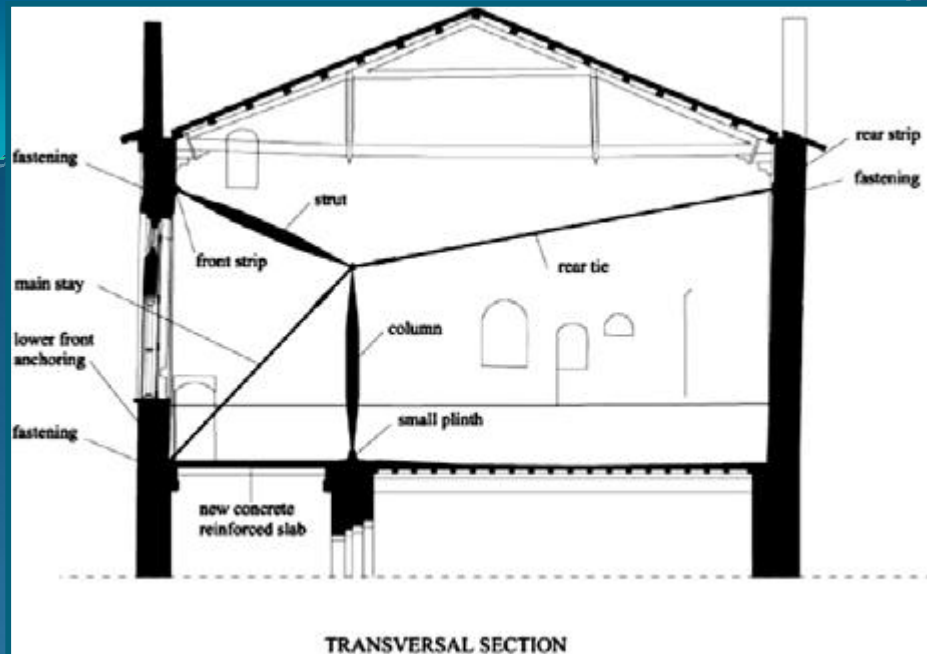
TEST RESULTS

The background is a solid blue color with several thin, wavy, light blue lines near the top edge, creating a sense of movement or a horizon line.

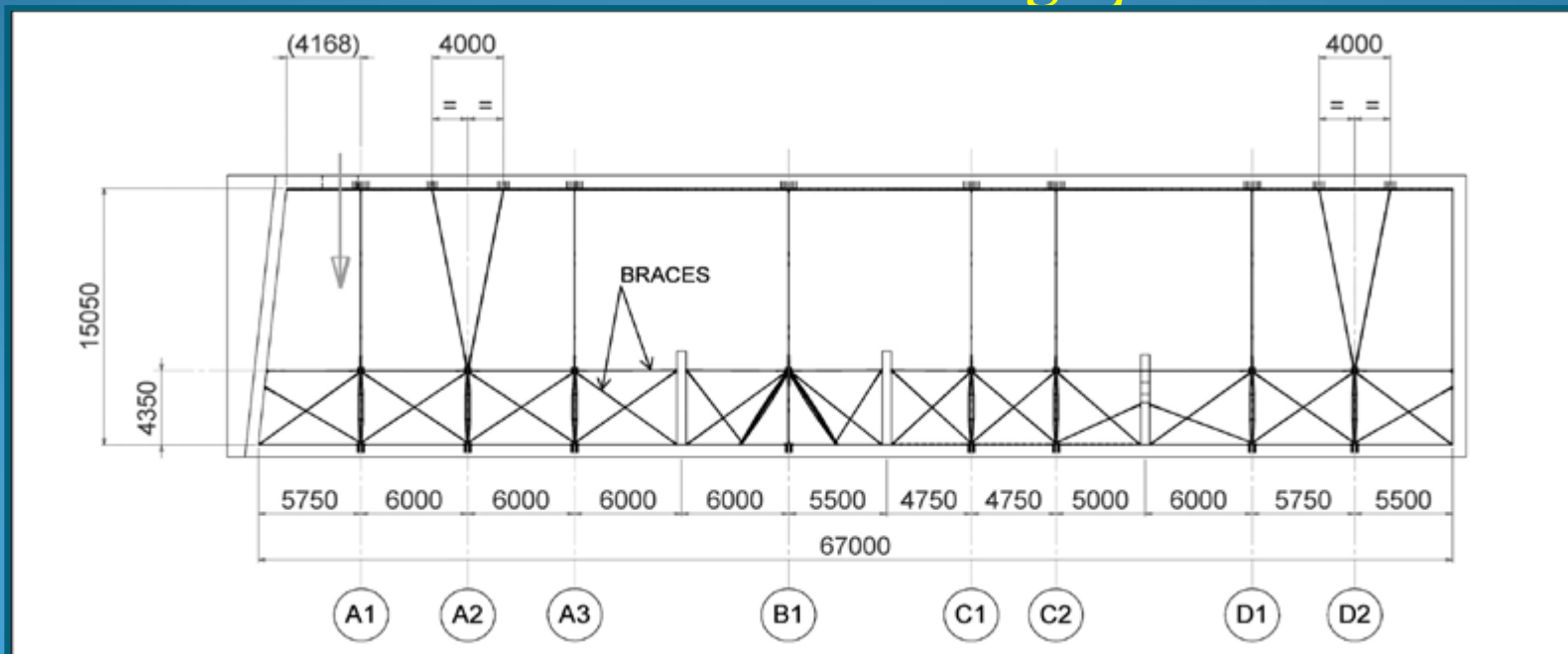
APPLICATIONS TO HISTORICAL BUILDINGS

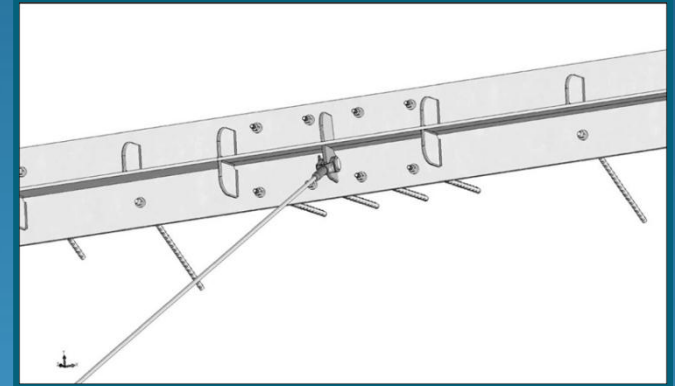
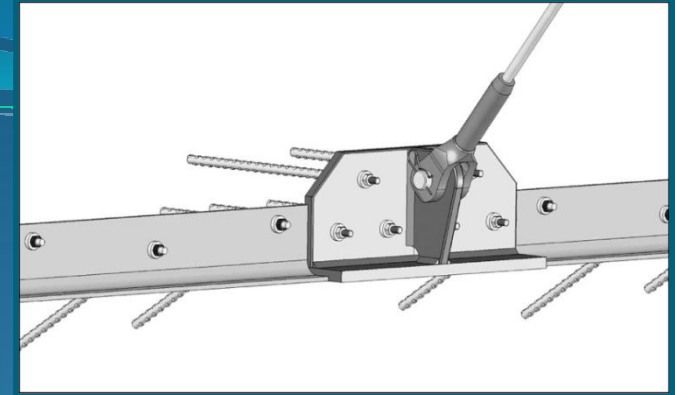
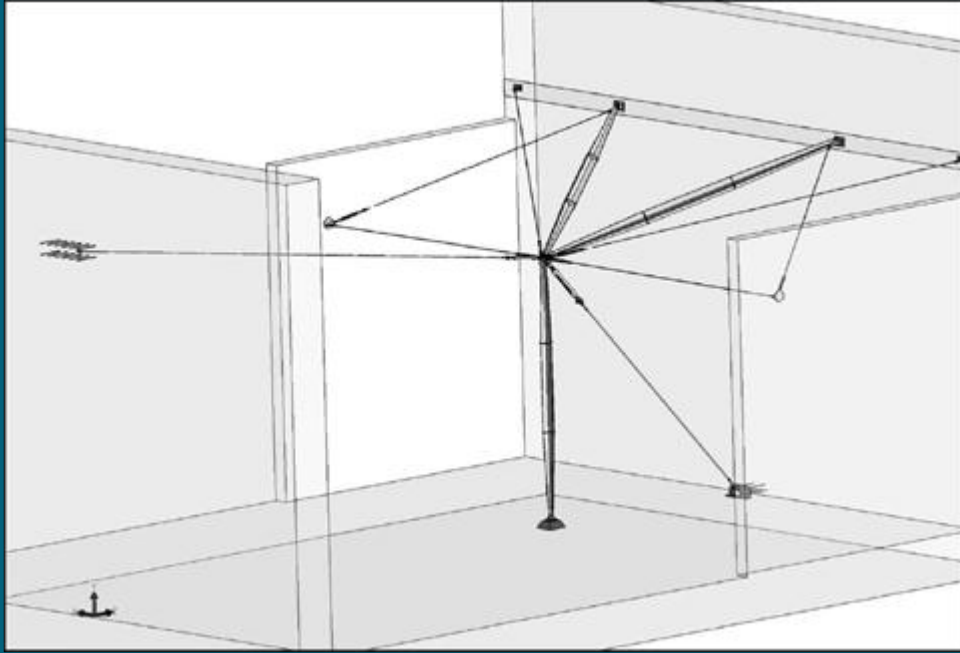
Seismic retro-fitting of the Captain Palace in Mantova



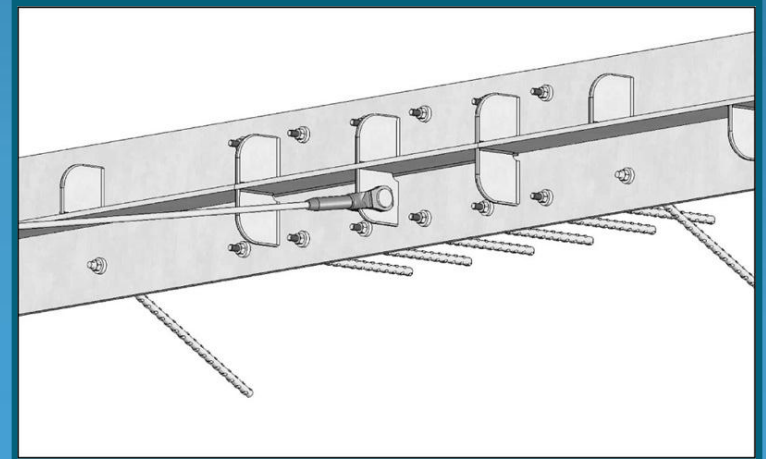
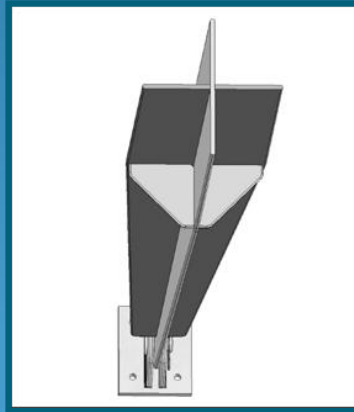
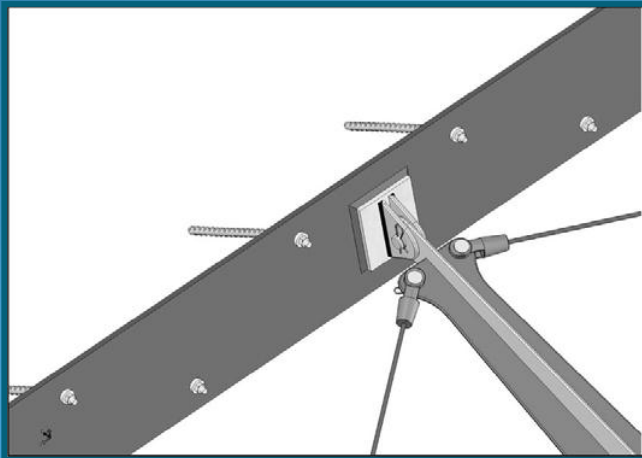


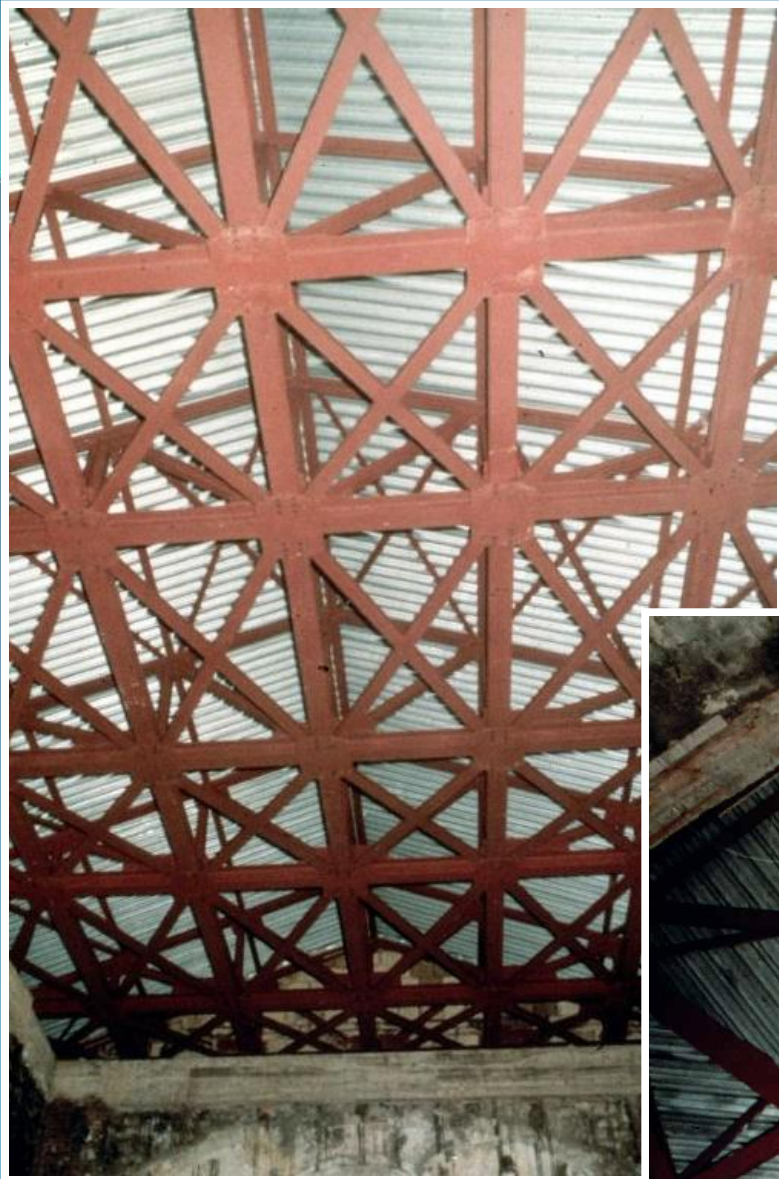
The seismic retro-fitting system





Connection details of the system





New steel roof with a bottom grid
(diafragm effect)



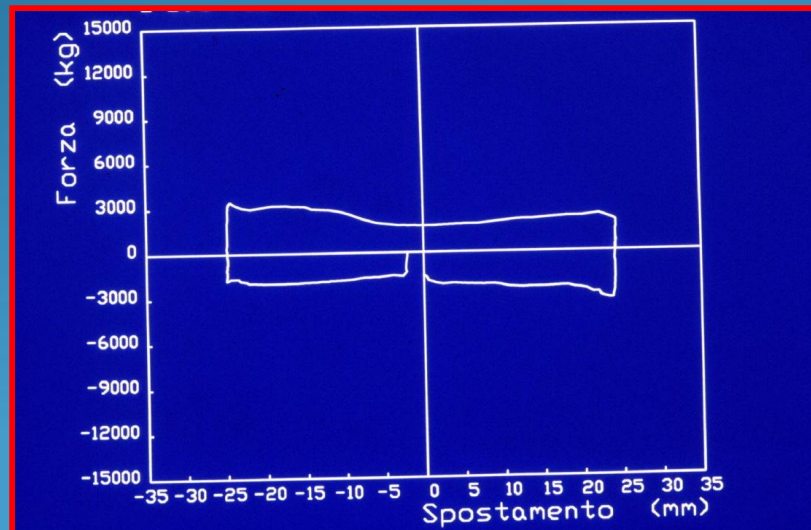
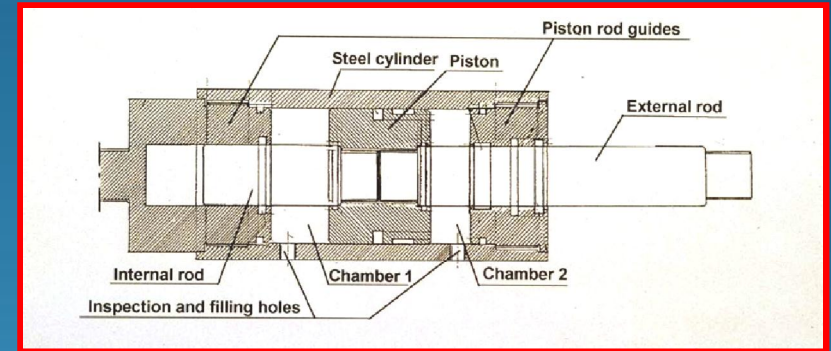
SOLOFRA
(AVELLINO)

The background is a solid blue color with a gradient. At the top, there are several thin, wavy lines in shades of blue and teal, creating a sense of movement or a stylized horizon. The text is centered in the upper half of the image.

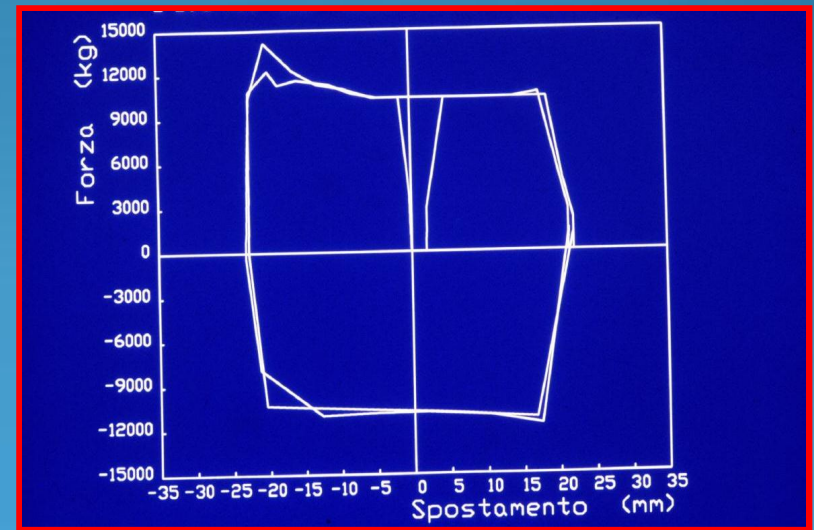
Historical buildings retrofitted with passive control metal systems

year	building	location	Type of evices	N°
★ 1990	St.Giovanni Battista	Carife (Avellino)	Shock block transmitters	18
★ 1996	University "Federico II" New library	Napoli	-shock block transmitters - Neoprene bearings	24 34
1999	"Basilica Superiore" of St.Francisco	Assisi (Perugia)	-shape memory alloys (SMA) -shock block transmitters	47 34
2000	St.Feliciano cathedral	Foligno (Perugia)	Shape memory alloy devices	
2000	Basylic of Santa Maria di Collemaggio	L'Aquila	Elastoplastic dissipators	
★ 2003	RCM industrial building	Sarno (Salerno)	-shock block transmitters -steel dampers	12 12
2008	Cathedral of Siena	Siena	Fluid spring dampers	2

SHOCK BLOCK TRANSMITTER: oleodynamic device

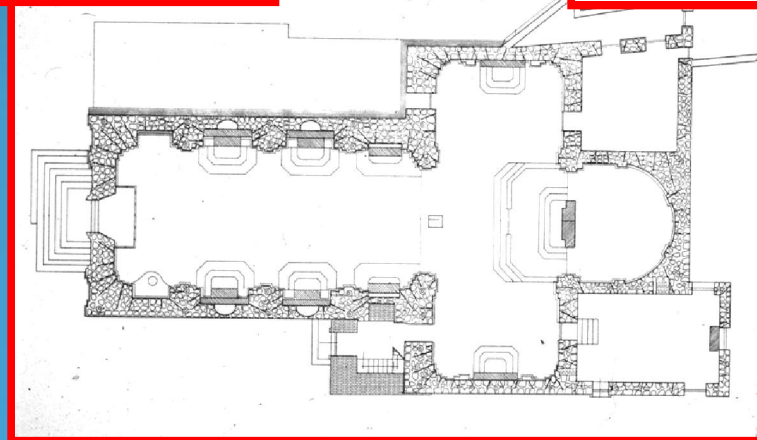
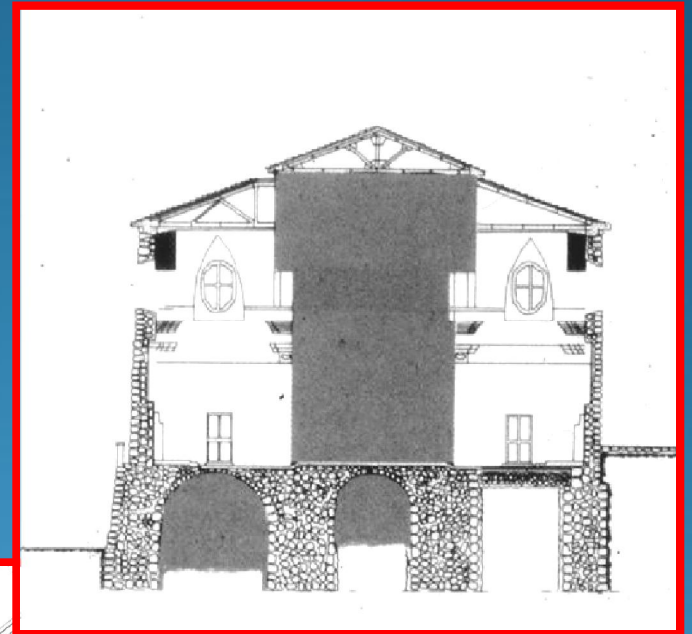
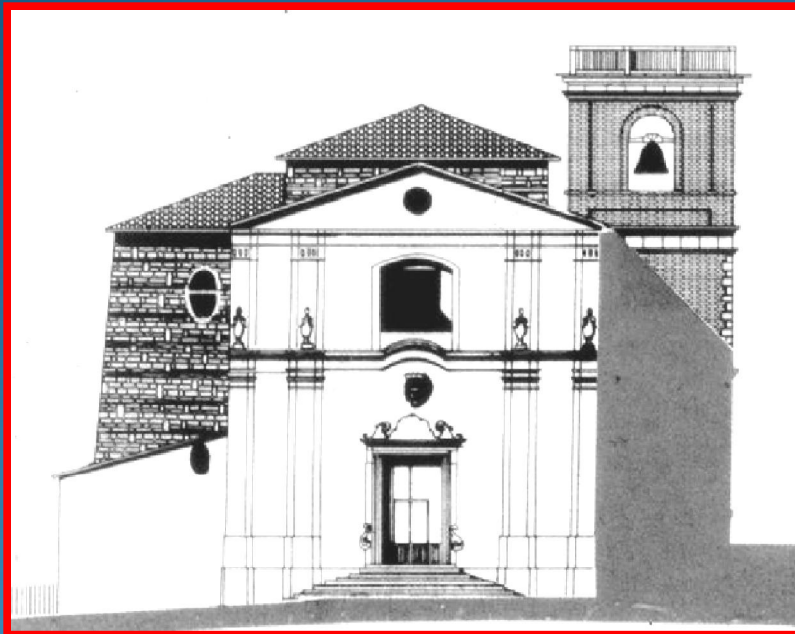


low velocity test

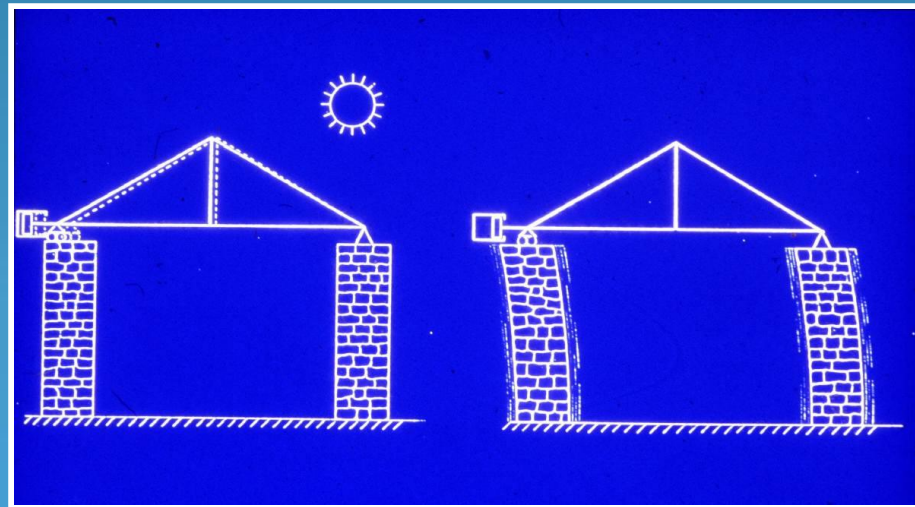
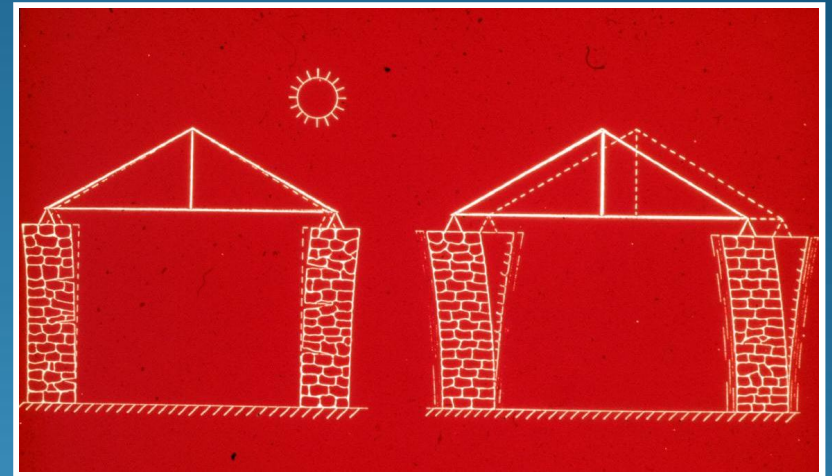
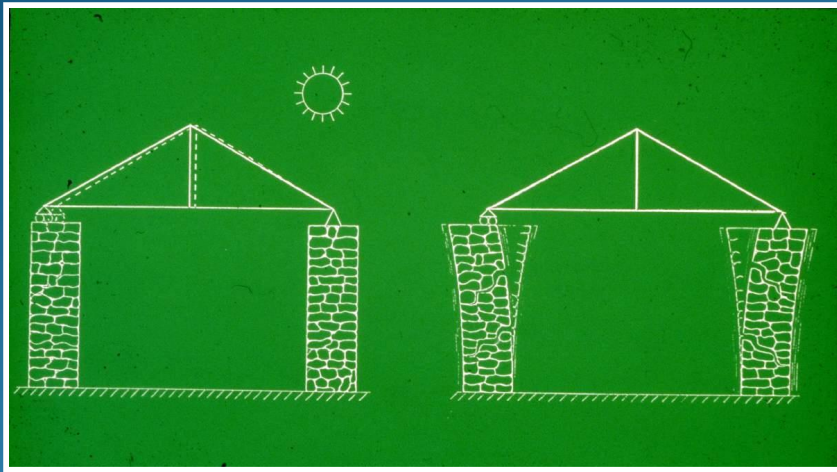


high velocity test

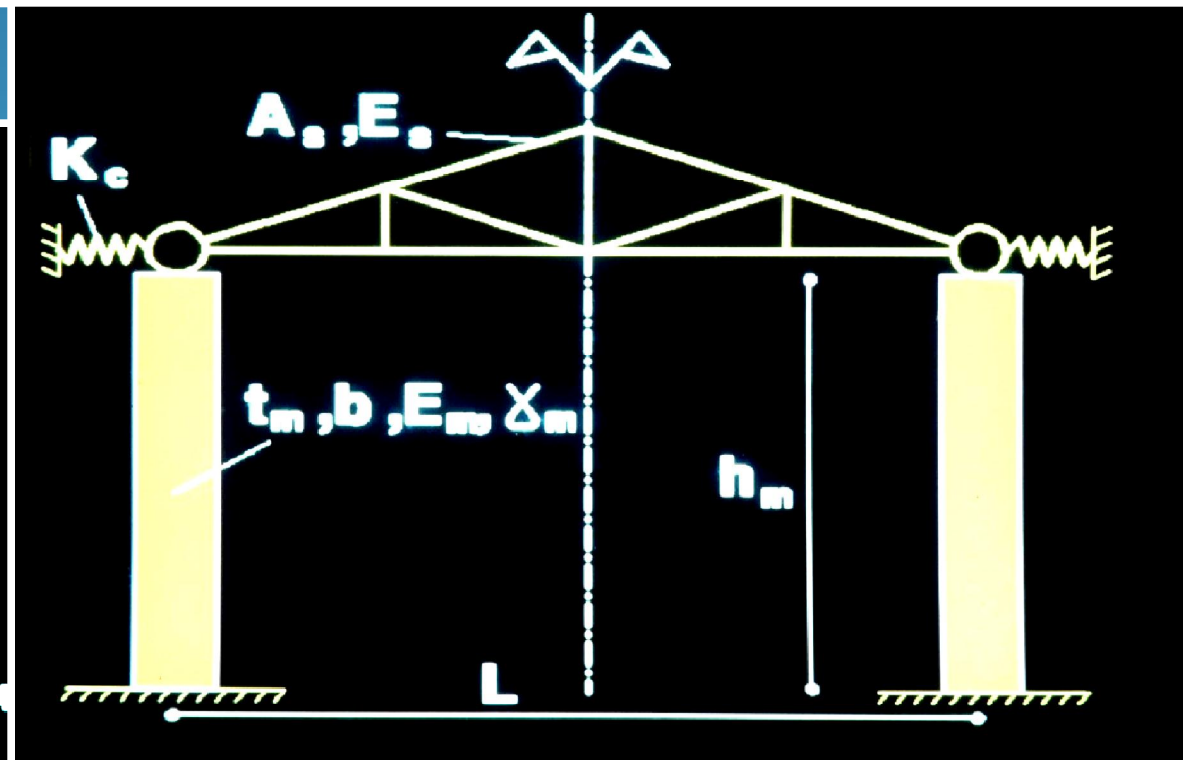
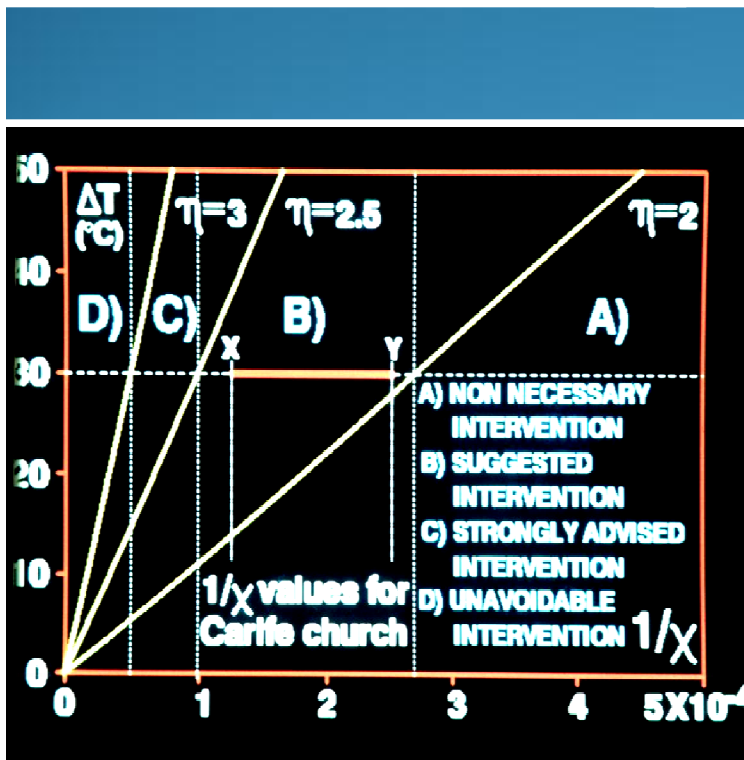
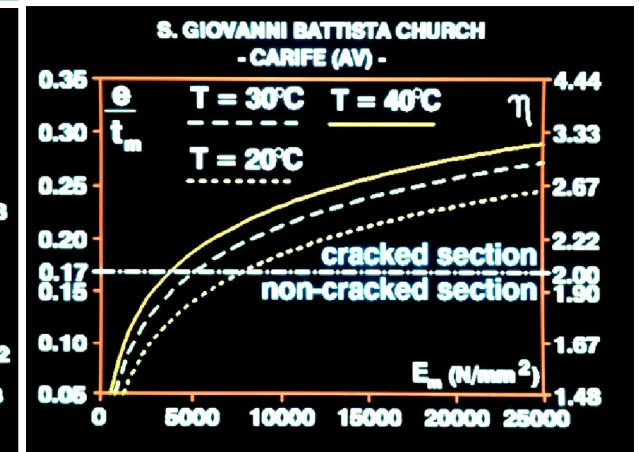
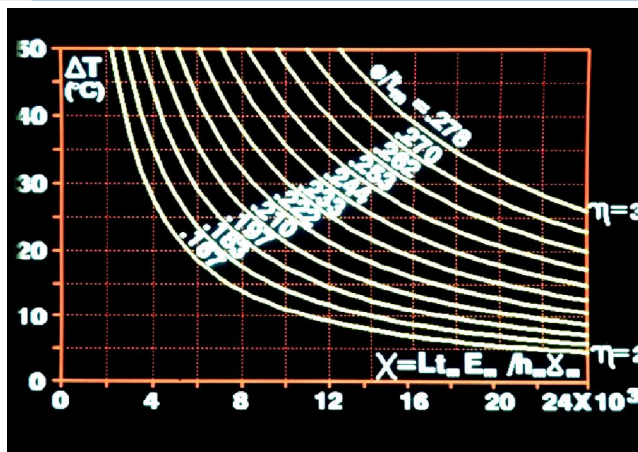
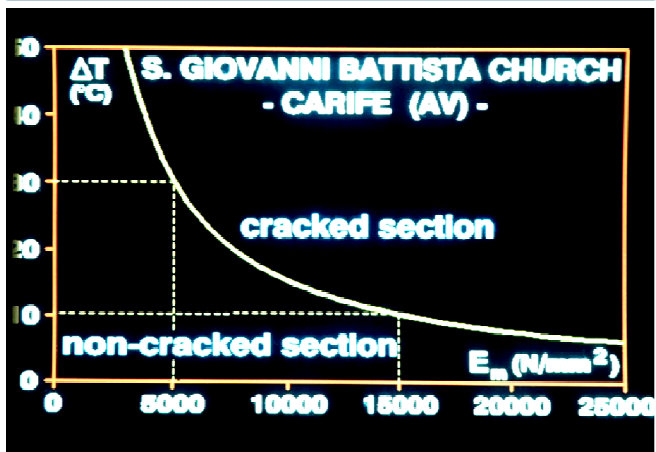
The first application in Italy : The Church of St. Giovanni Battista in Carife



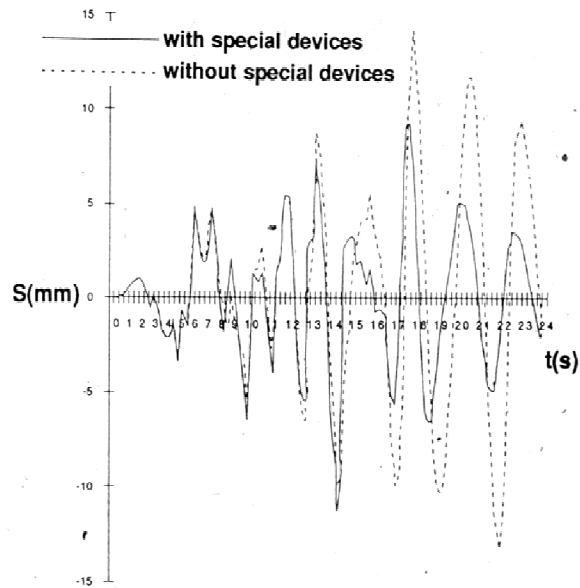
The Church of St. Giovanni Battista in Carife



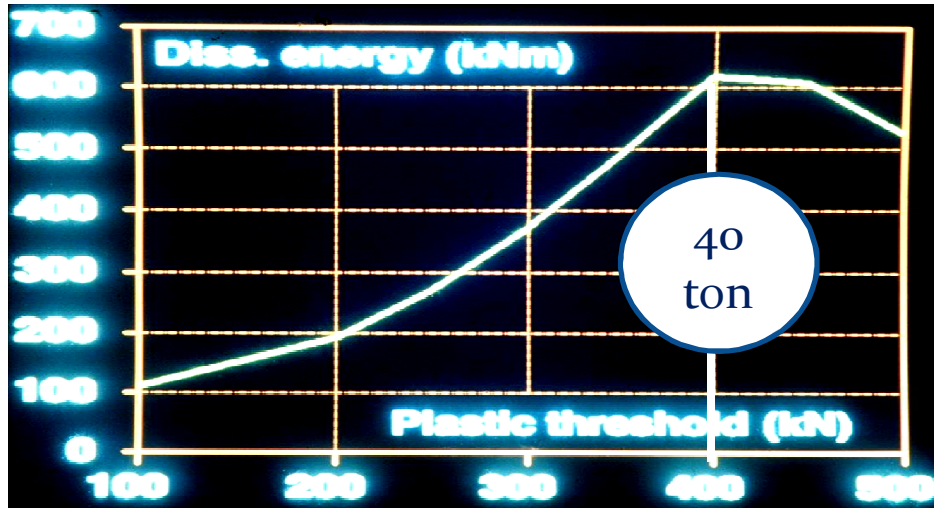
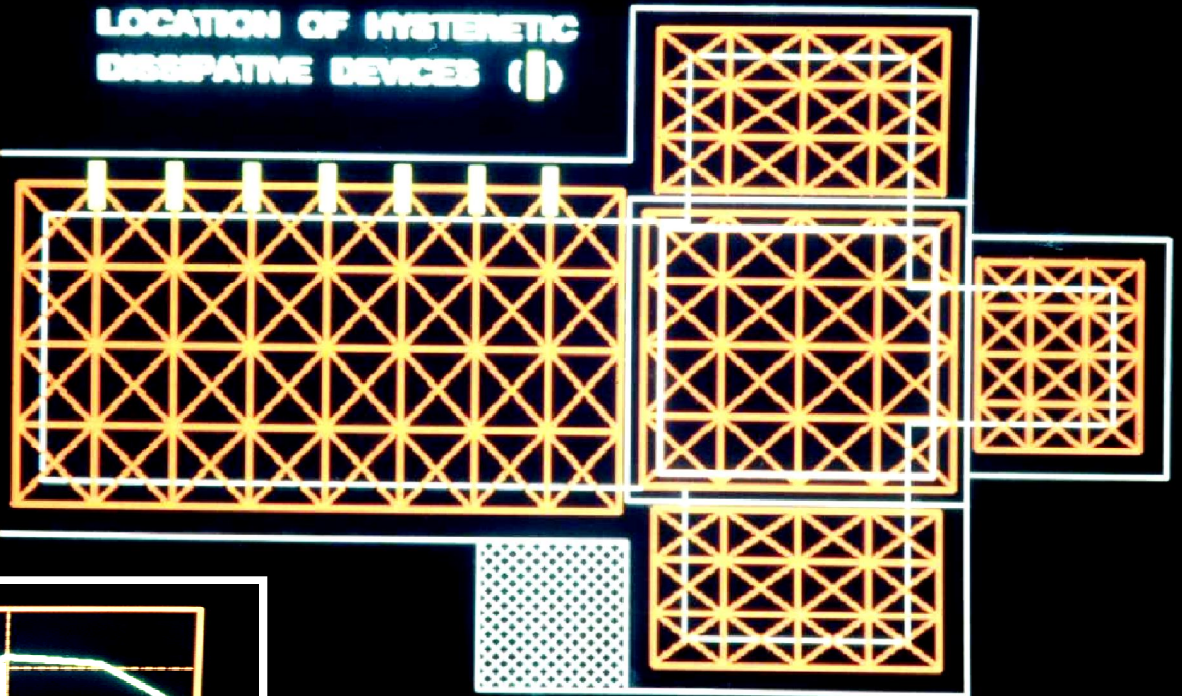
The Church of St. Giovanni Battista in Carife



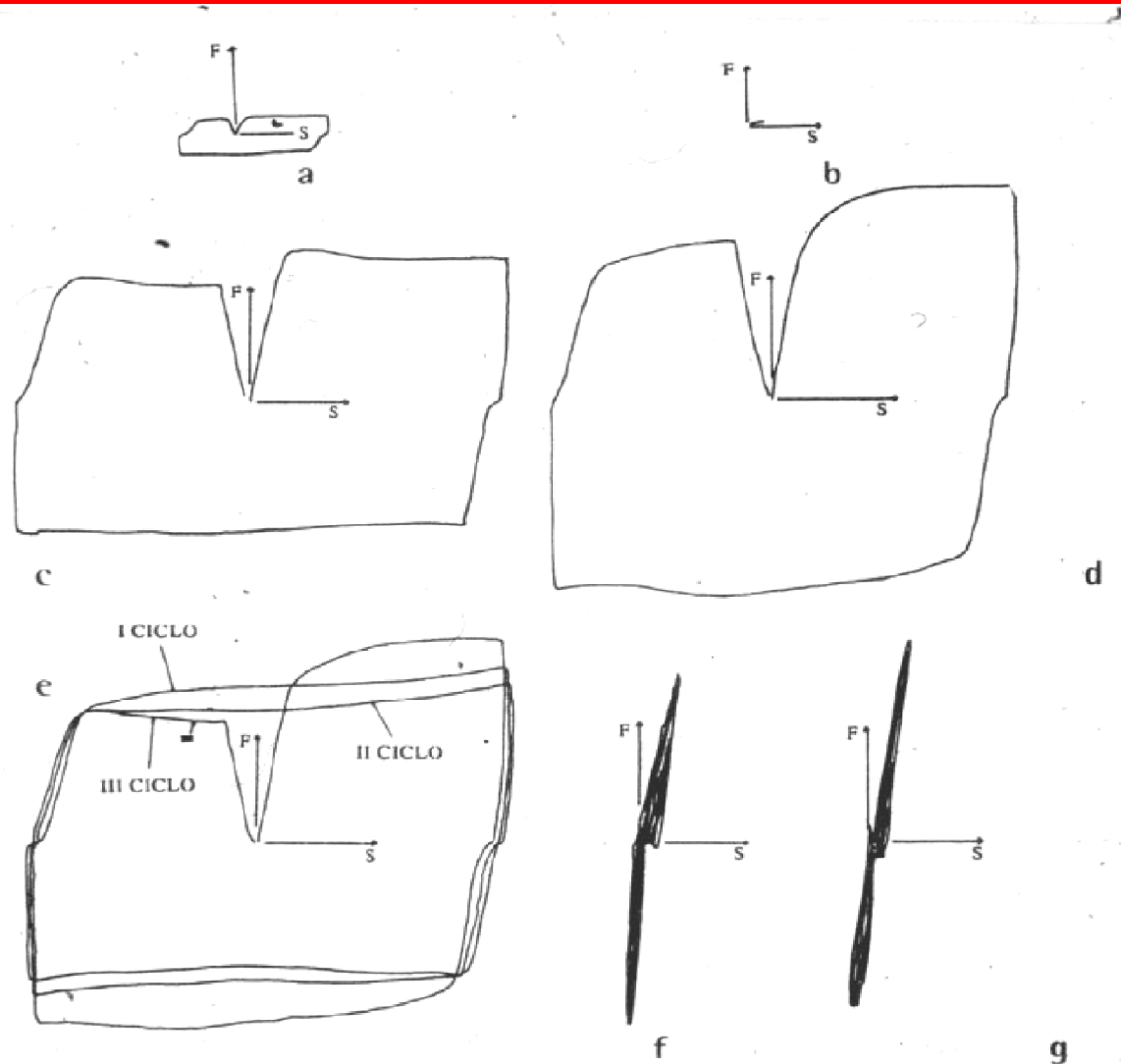
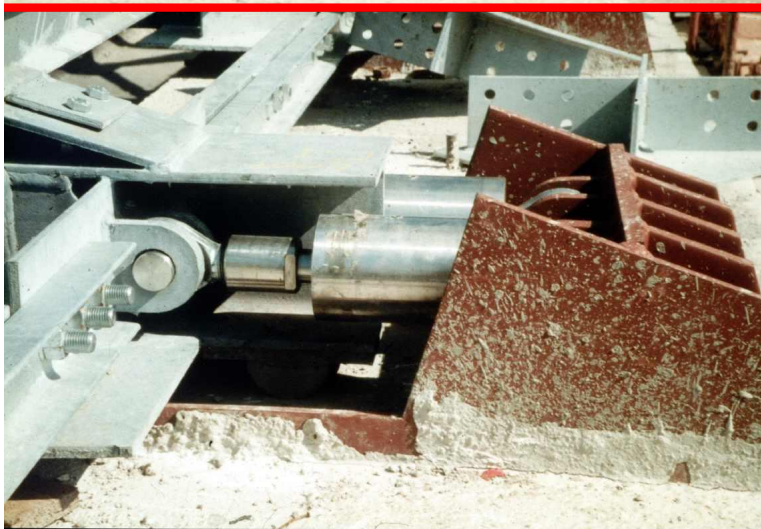
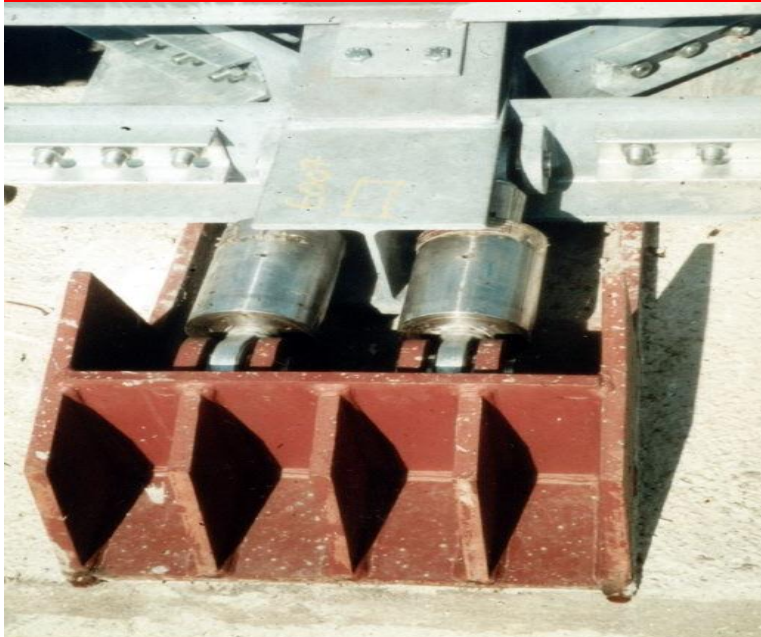
The Church of St. Giovanni Battista in Carife



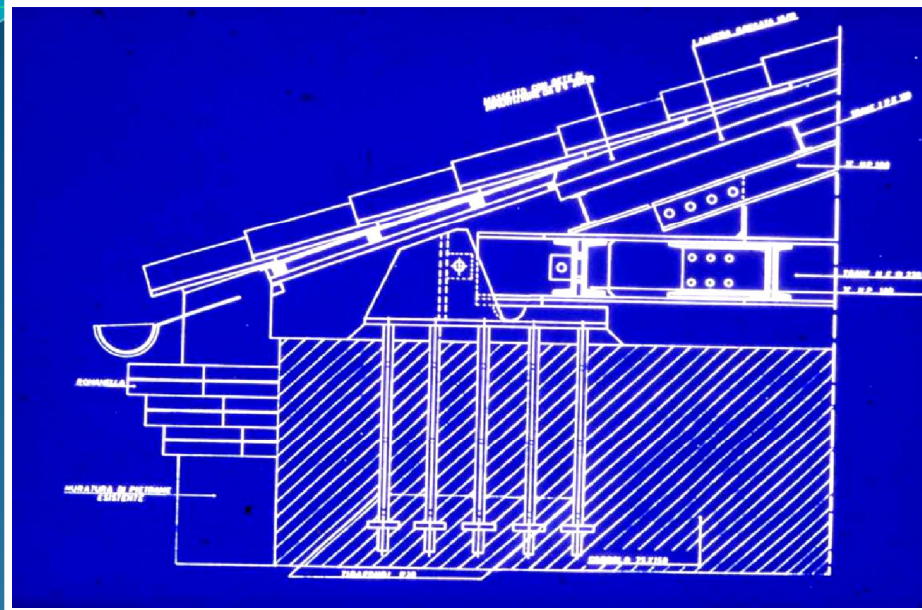
LOCATION OF HYSTERETIC DISSIPATIVE DEVICES (||)



The Church of St. Giovanni Battista in Carife



The Church of St. Giovanni Battista in Carife

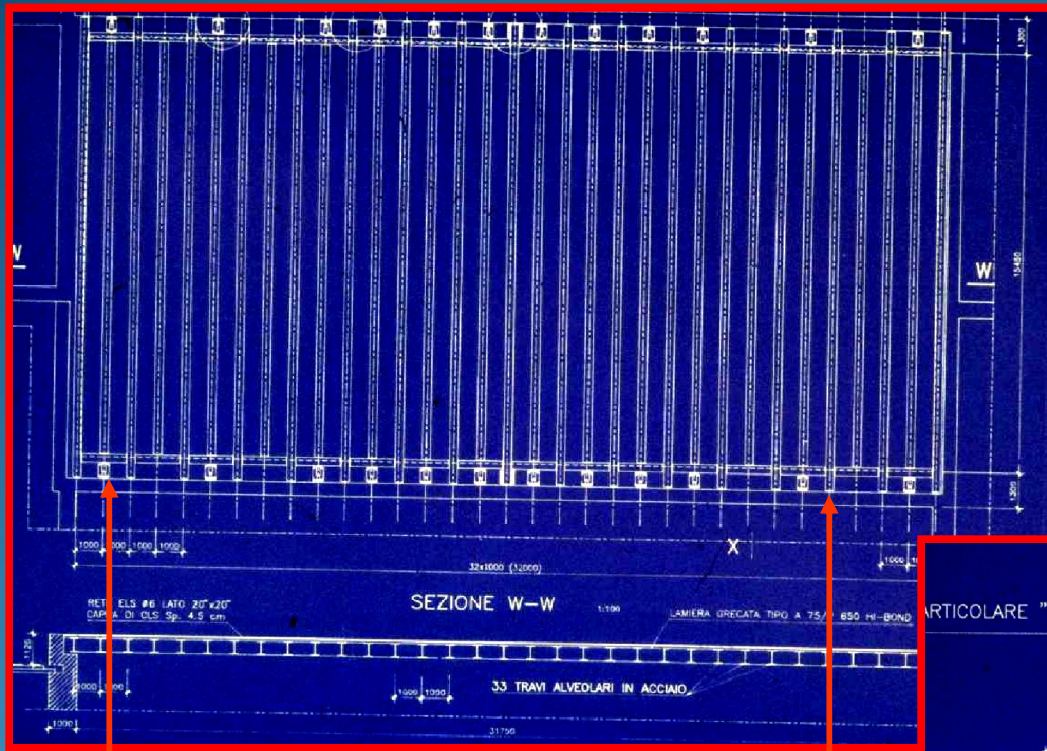


The New Library of the University of Naples



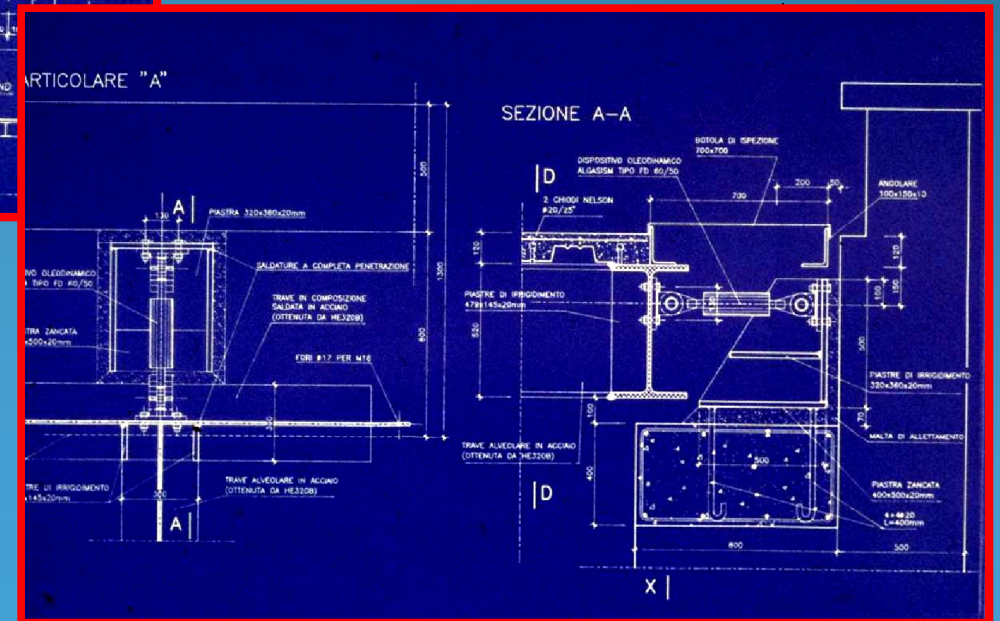
The original r.c. structure

The New Library of the University of Naples

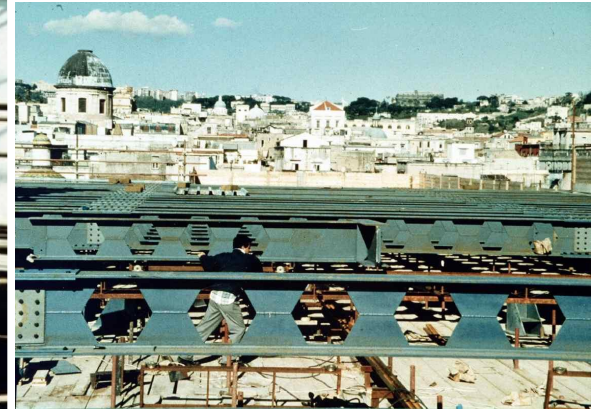


Design drawings

24 shock transmitters
34 neoprene bearings

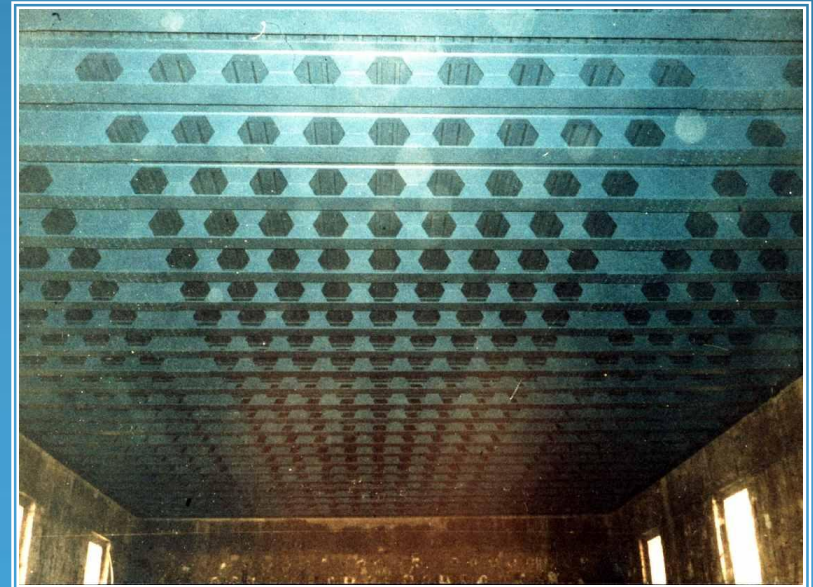
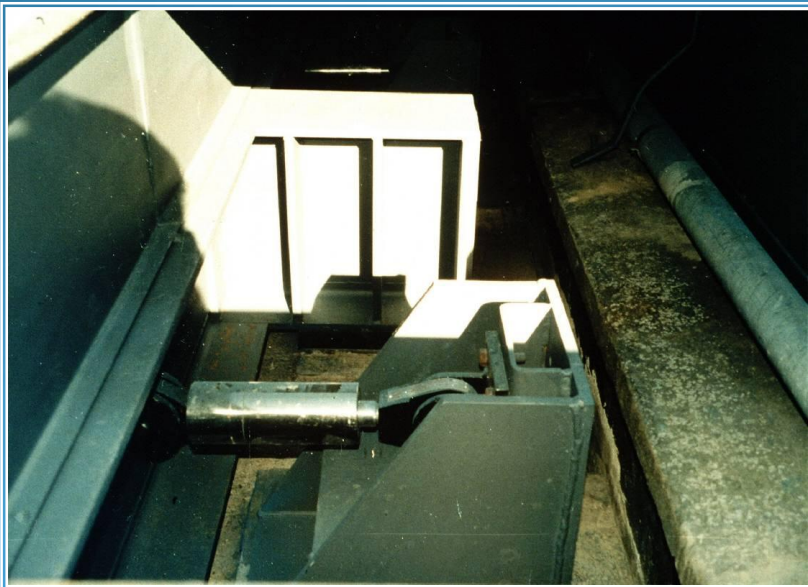
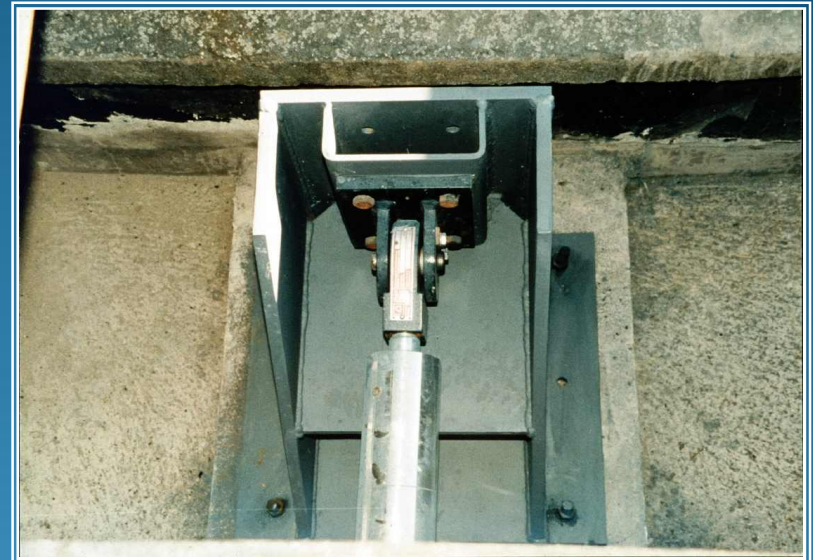


The New Library of the University of Naples



Erection phases

The New Library of the University of Naples



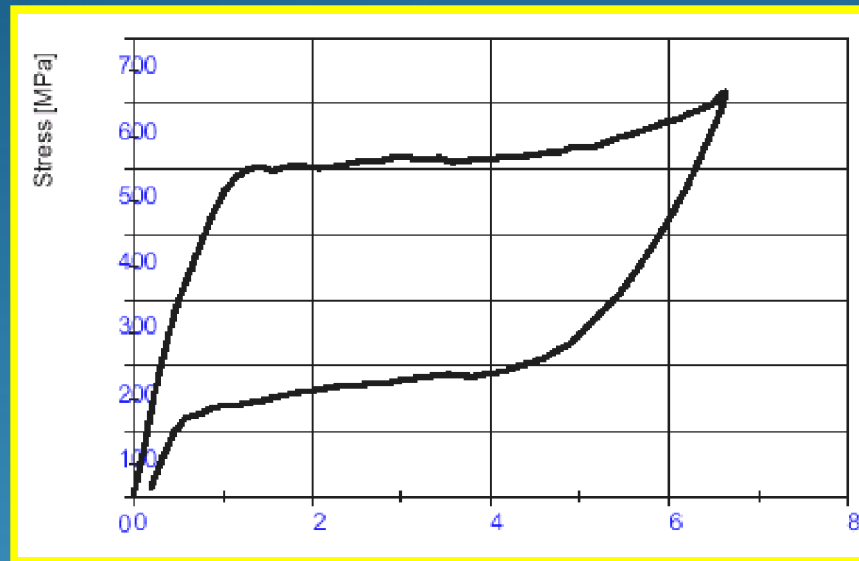
The restoration of the Church of St. Francesco in Assisi

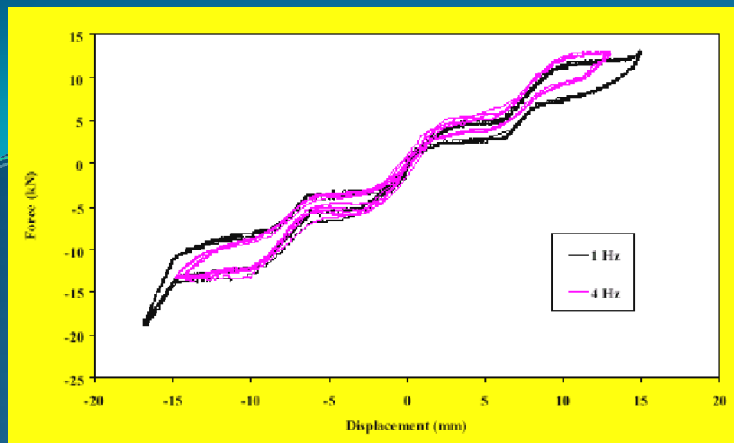


The restoration of the Church of St. Francesco in Assisi



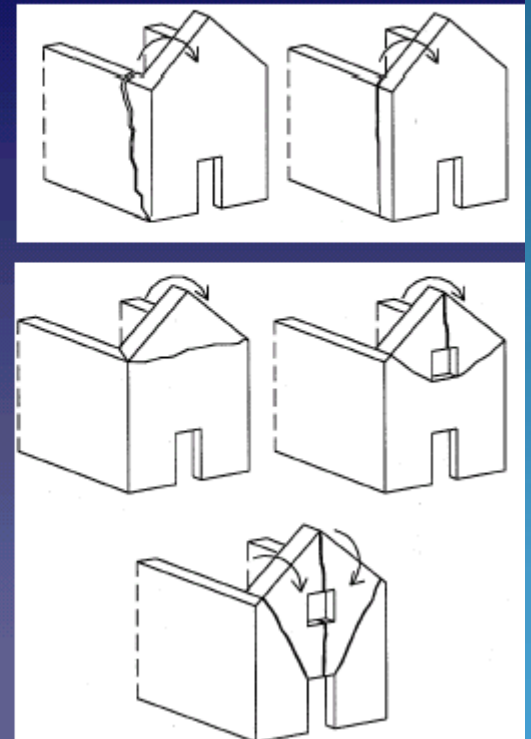
Shape Memory Alloy Devices (SMADs): the superelastic behaviour of the material



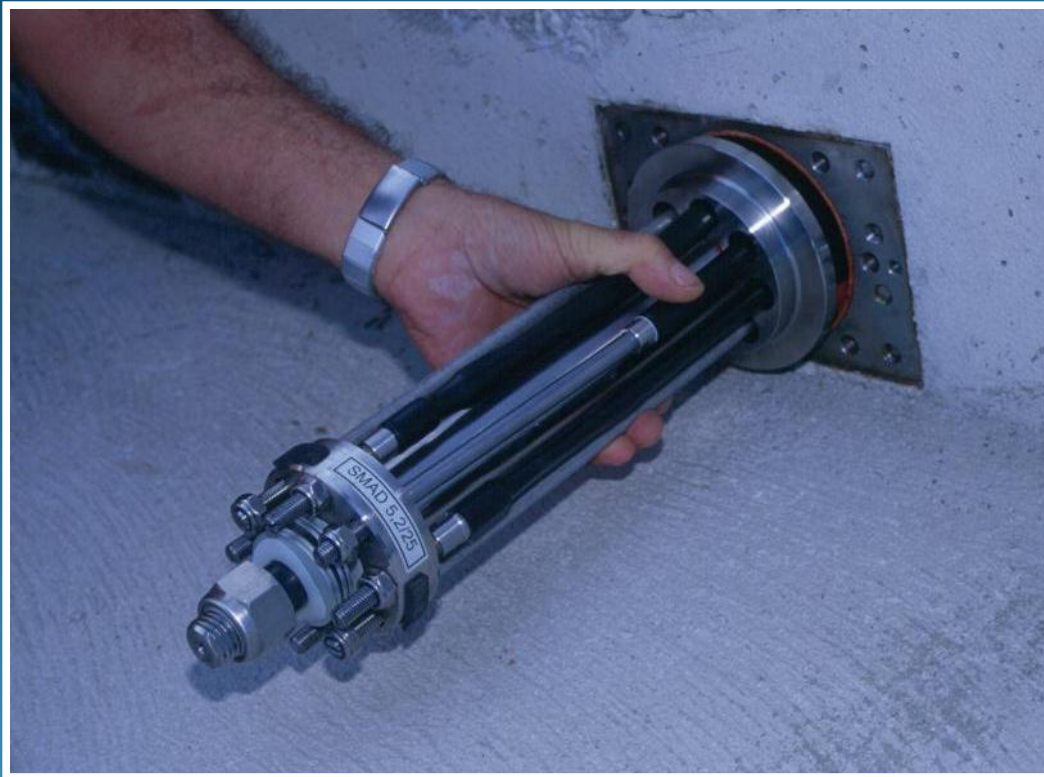


SMADs used as horizontal ties

Shape Memory Alloy Devices can be used in series with horizontal conventional steel ties to improve the out-of-plane behaviour of masonry elements, in particular to prevent rocking and pounding of gable-end walls



The restoration of the Church of St. Francesco in Assisi



**SMA
devices**

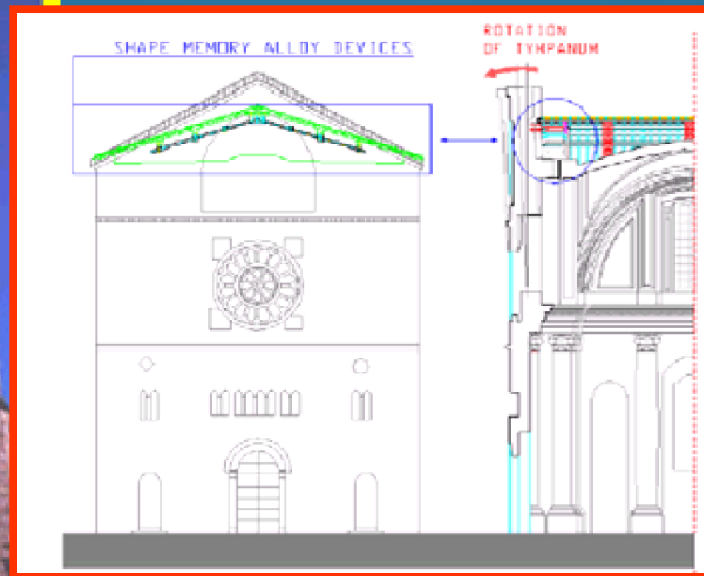
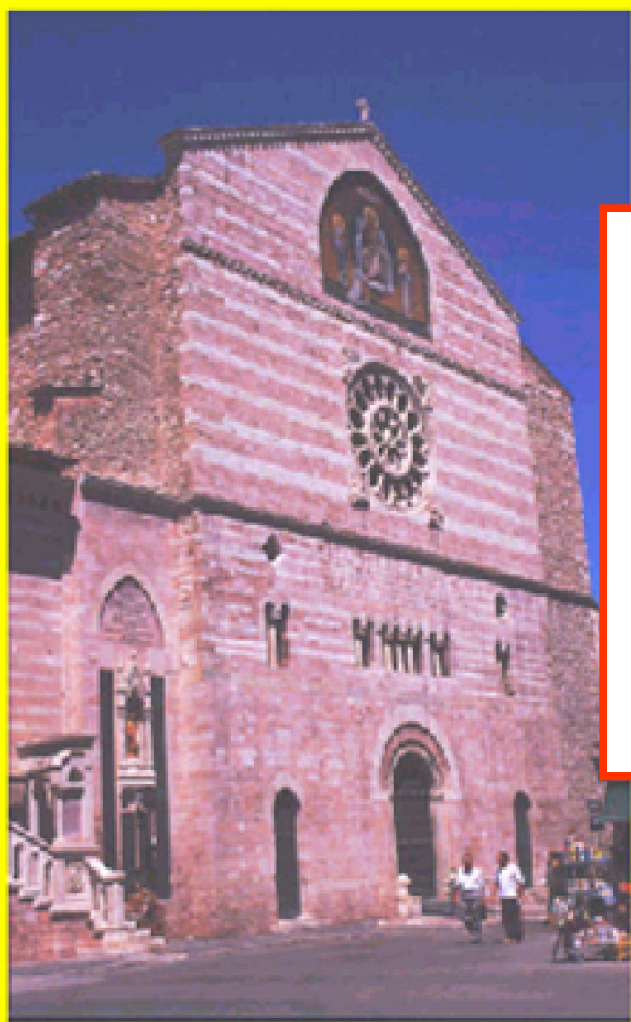


**Shock transmitters installed
between nave and transept**

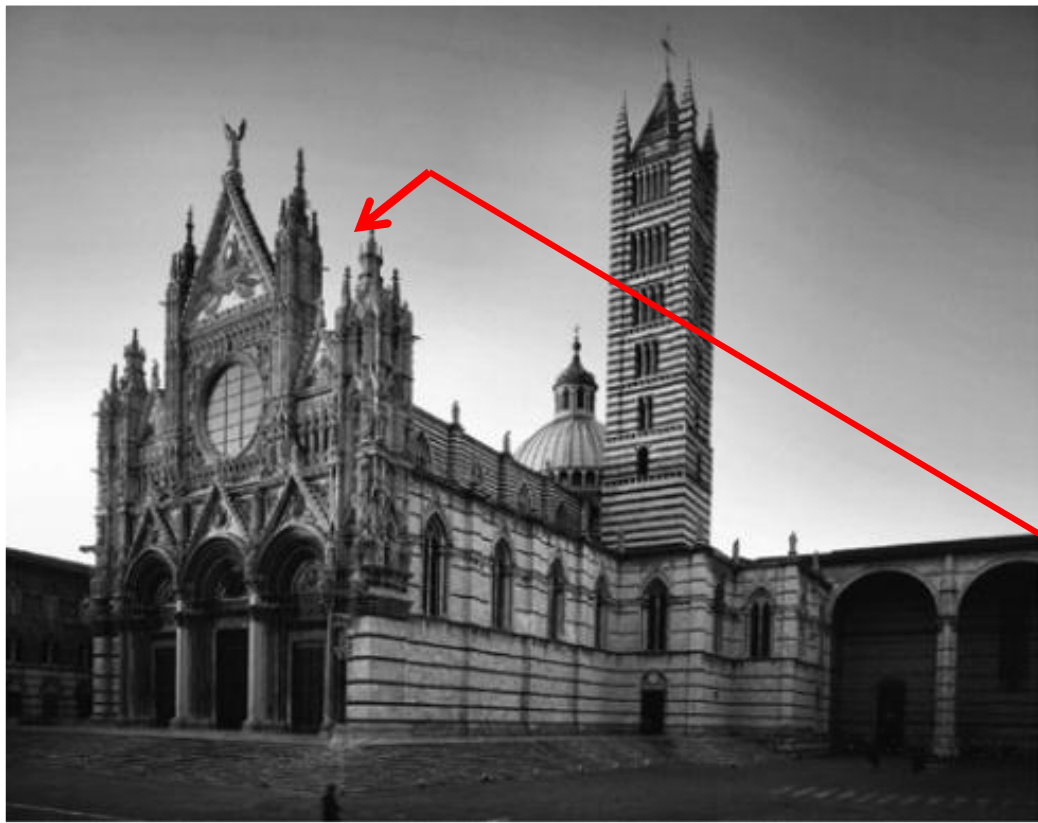
The restoration of the Church of St. Francesco in Assisi



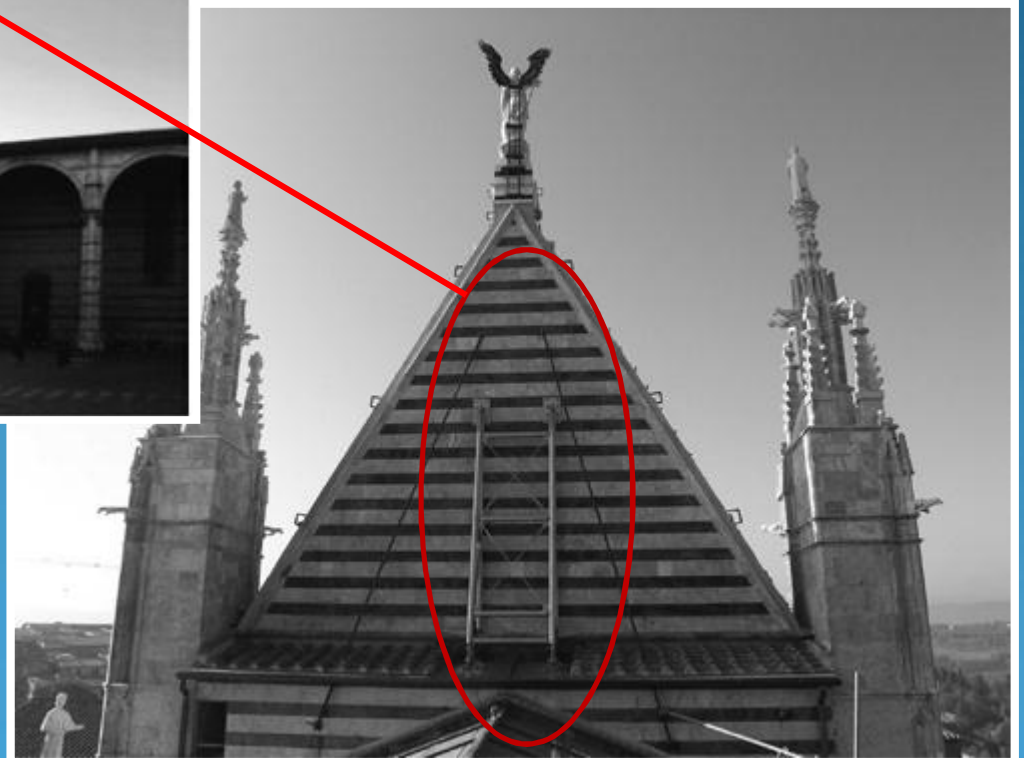
Cathedral of San Feliciano (Foligno - Italy)

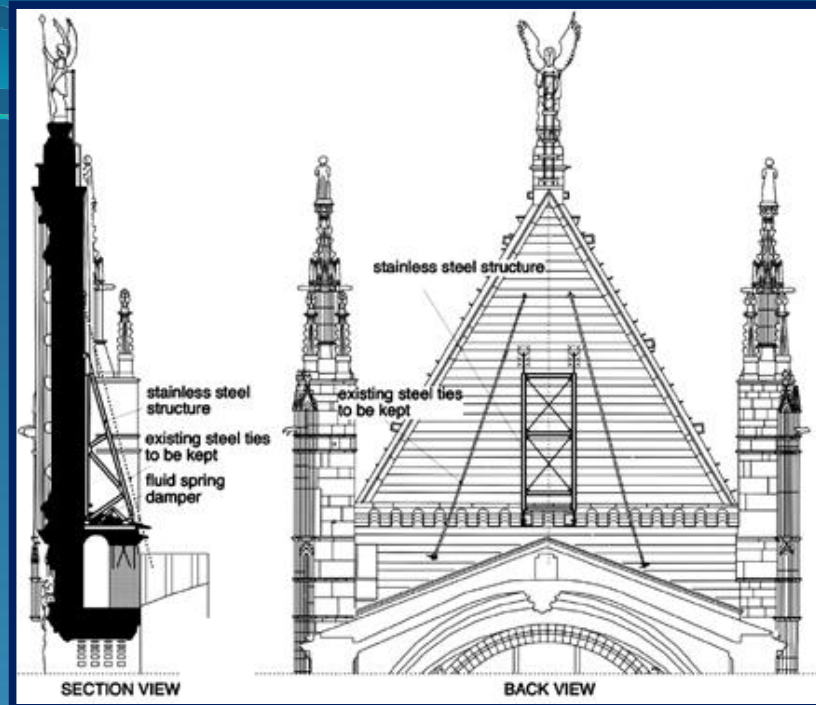
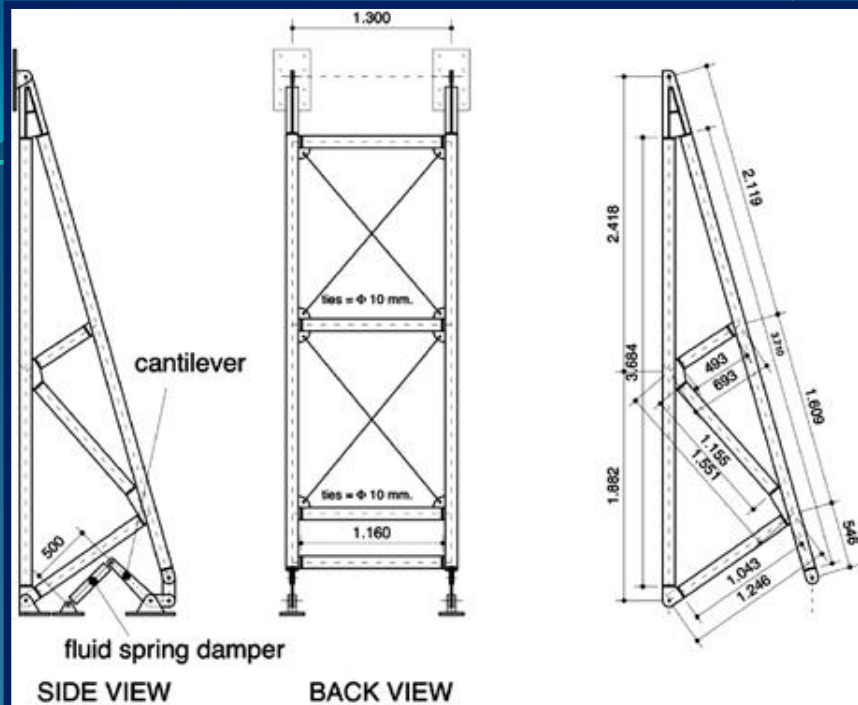


Fluid spring dampers for the seismic protection of the Cathedral of Siena



consolidation intervention
on the tympanum of the
main facade





consolidation intervention on the tympanum of the main facade



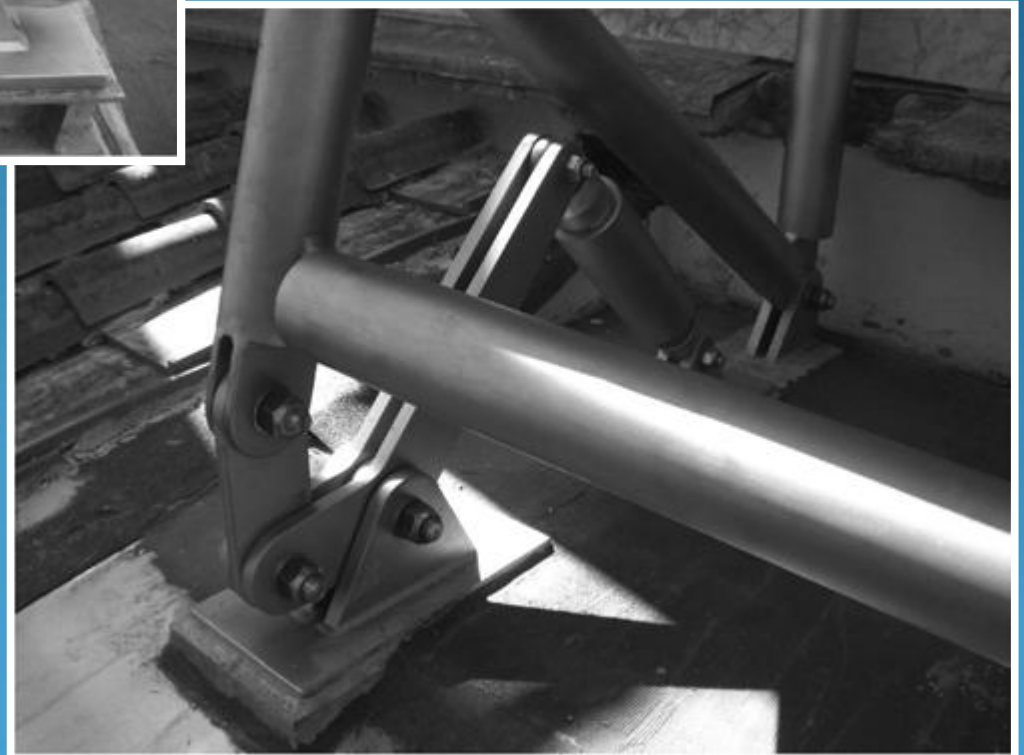
Cathedral of Siena

Cathedral of Siena



consolidation intervention
on the tympanum of the
main facade

One of the two fluid
spring dampers





RCM
Industrial building
in Sarno (Salerno)

Industrial archeology



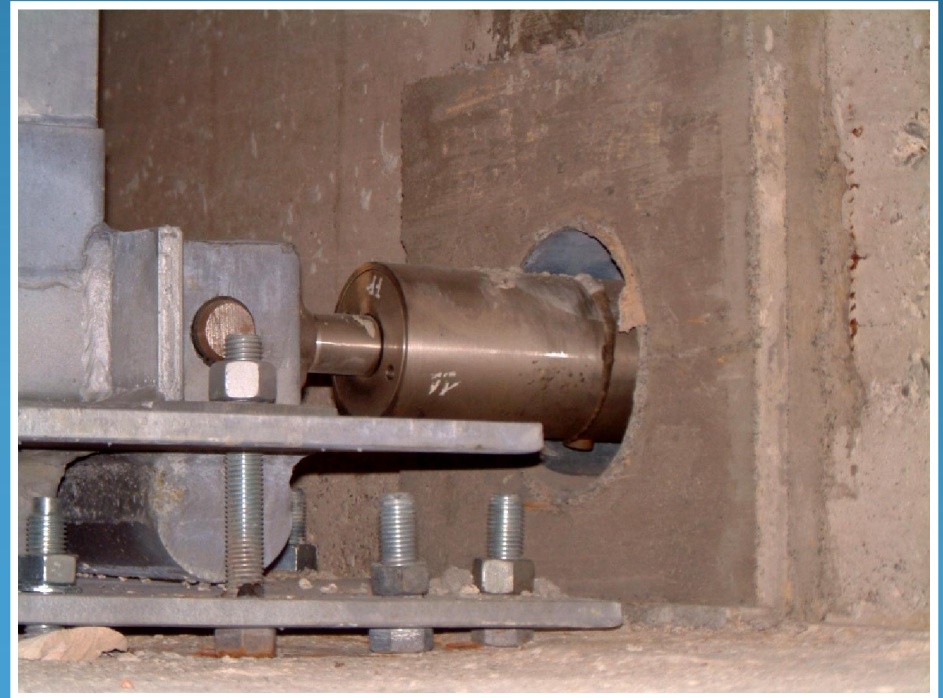


**RCM Industrial building
in Sarno (Salerno)**

RCM Industrial building in Sarno (Salerno)



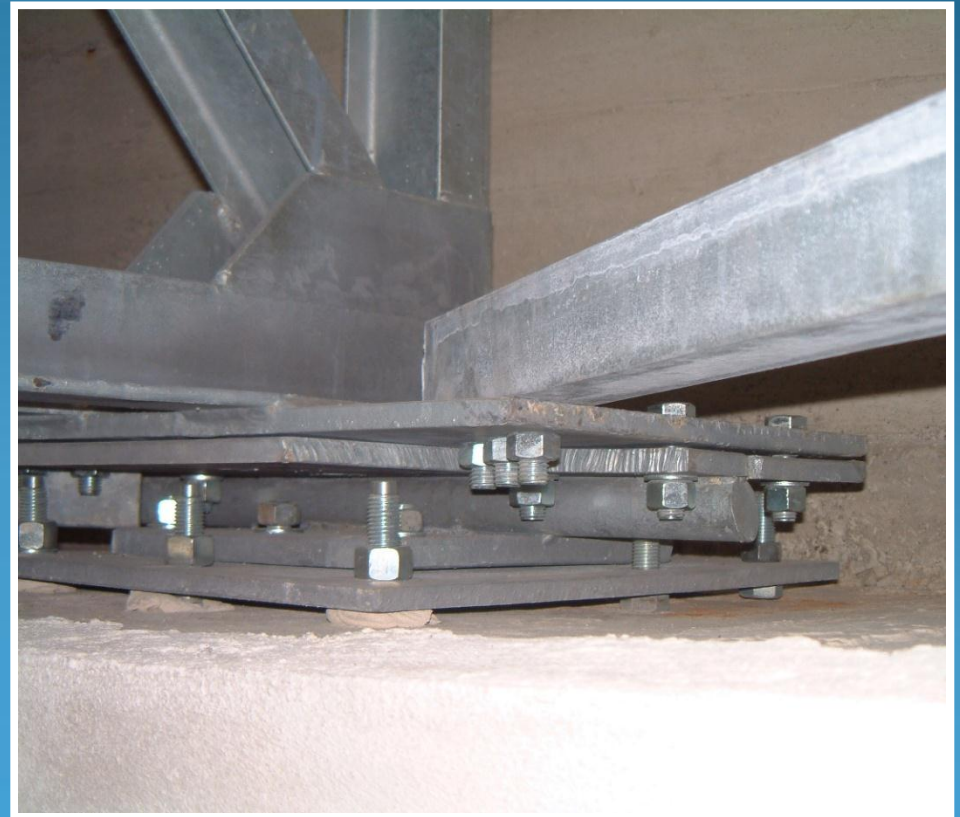
North side device : 12 shock transmitters



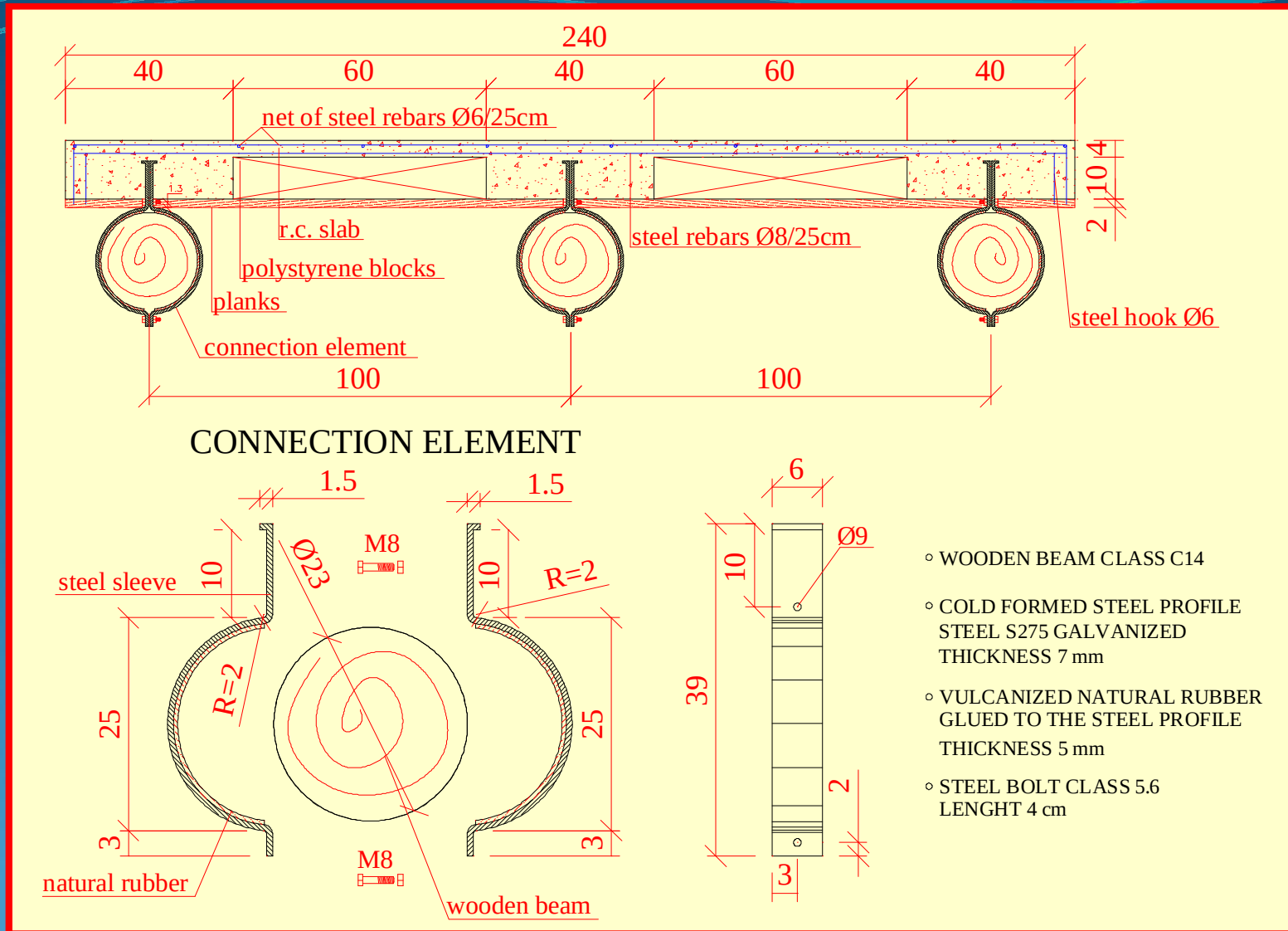
RCM Industrial building in Sarno (Salerno)



South side device : 12 steel dampers



Consolidation of wooden floors



Consolidation of wooden floors: steel connectors

Wooden stock



$d_m = 150 \text{ mm}$
 $L = 400 \text{ mm}$

Steel sleeve



$w = 60 \text{ mm}$
 $t = 6 \text{ mm}$

2 bolts M8

Steel sleeve and glued rubber



$w = 60\text{--}80 \text{ mm}$
 $t = 5 \text{ mm}$

Rough sleeve surface



Wood-rubber separation



Push-out test on circular sections

MATERIALS

Wood: Chestnut

Rubber: SISMI 60

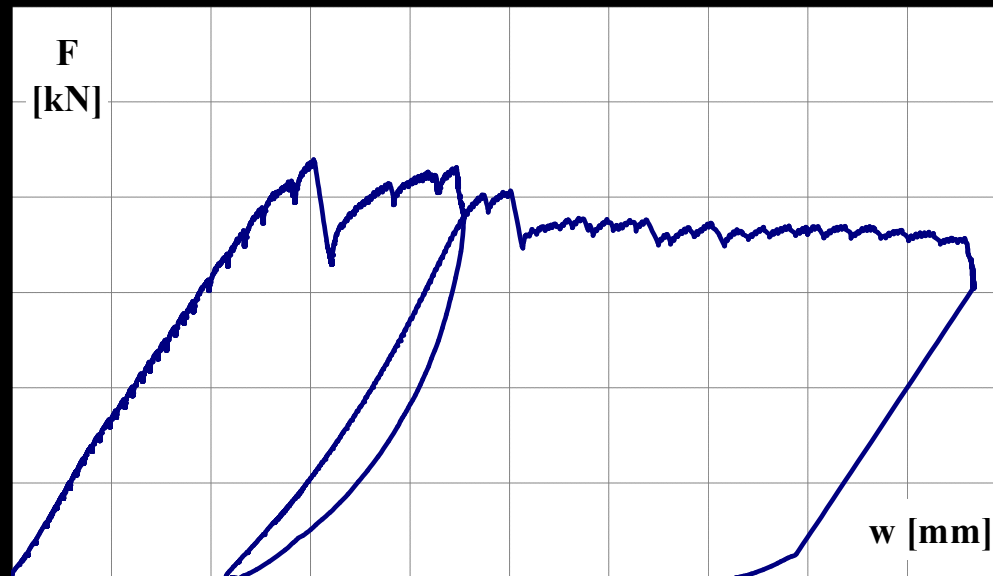
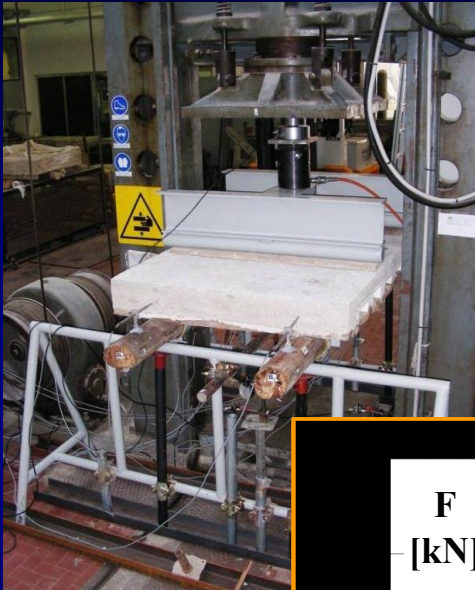
Steel sleeves: S275

Bolts: Class 5.6

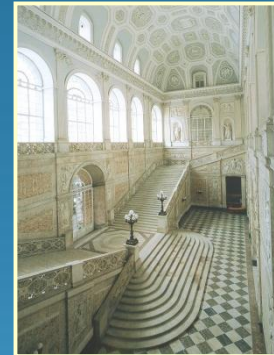
Glue: Adesilex G19

Test on consolidated timber floor

Mohr Federhaff machine



CASE STUDY: THE ROYAL PALACE OF NAPLES



FEDERICO M. MAZZOLANI | University of Naples | Federico II



THE ROOF STRUCTURES OF THE ROYAL PALACE OF NAPLES –



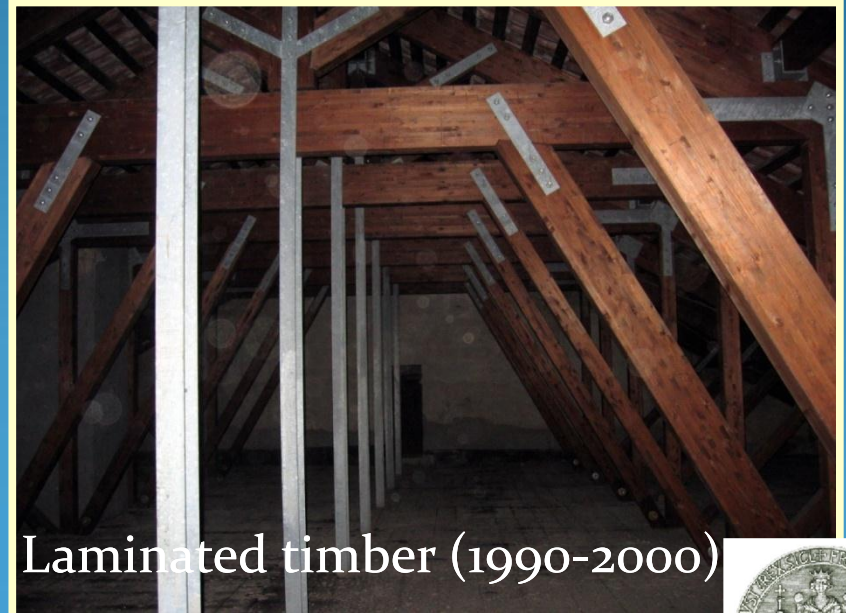
Old wood (1600-1700)



Reinforced concrete (1960-70)

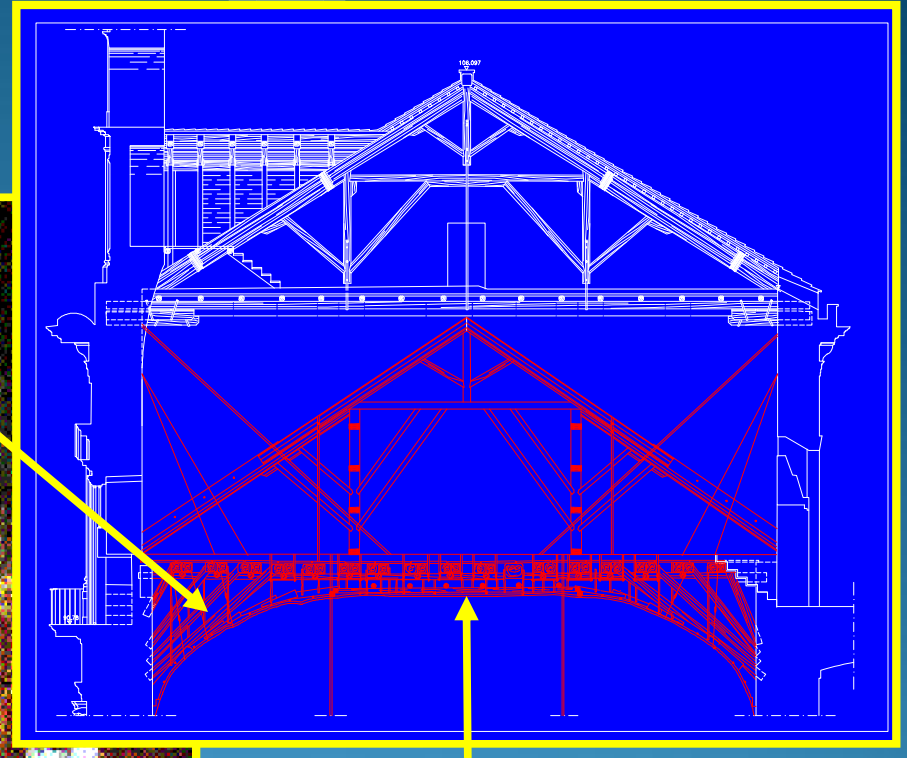
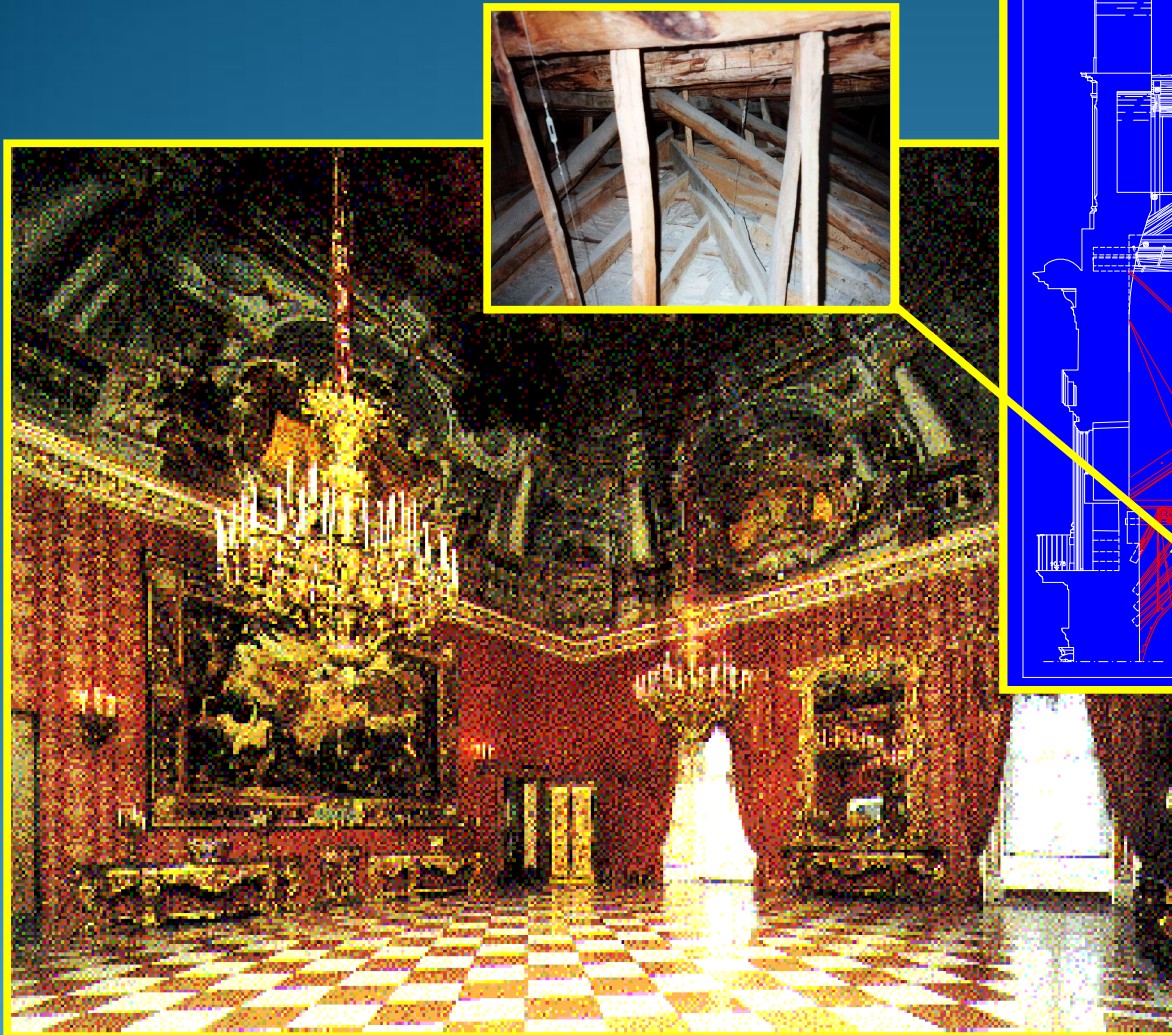


Steelworks (1970-80)



Laminated timber (1990-2000)

The wooden structures of the Royal Apartment of Naples: the Diplomatic Hall



THE TIMBER ROOFING STRUCTURES OF THE ROYAL APARTMENT :

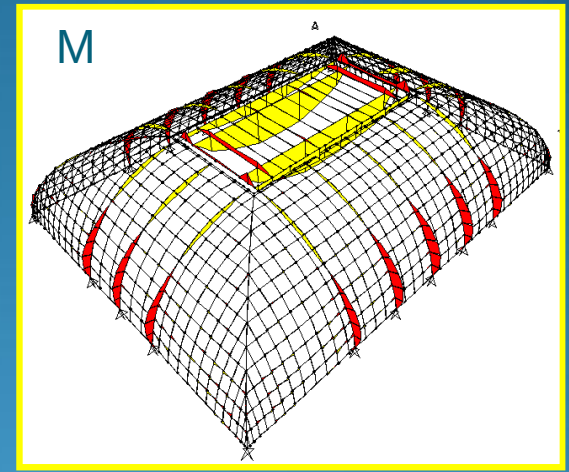
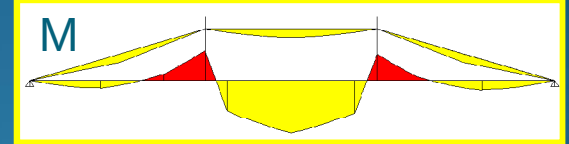
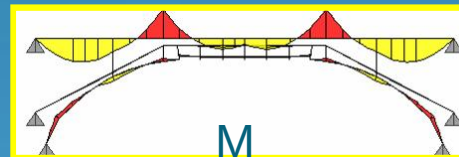
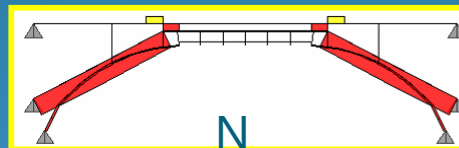
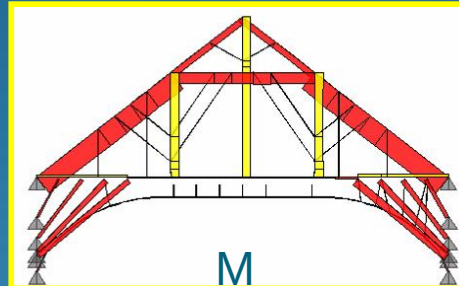
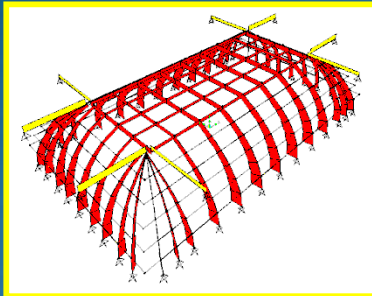
Structural identification

1: self-bearing vault

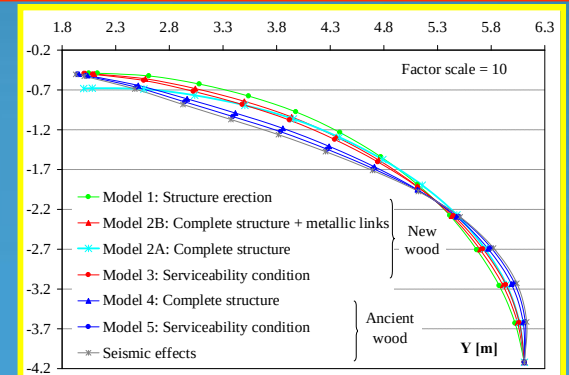
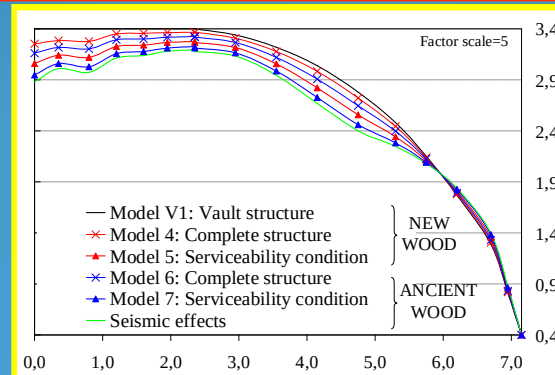
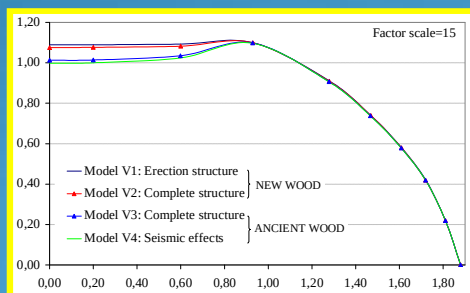
2: vault linked to the floor beams

3: vault linked to rad hoc structure

Stress state



Deformation state

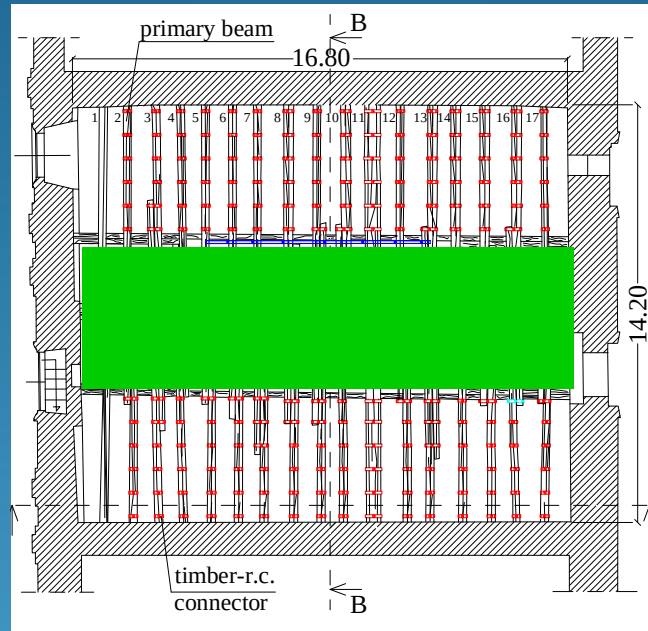
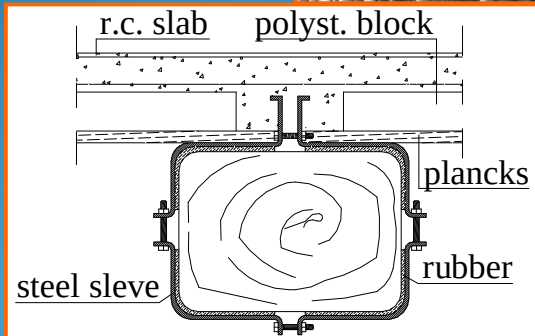
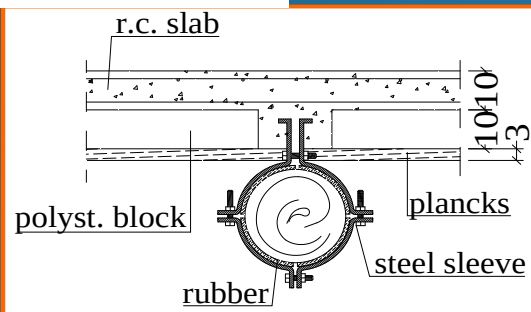


DIPLOMATIC HALL: retrofitting interventions

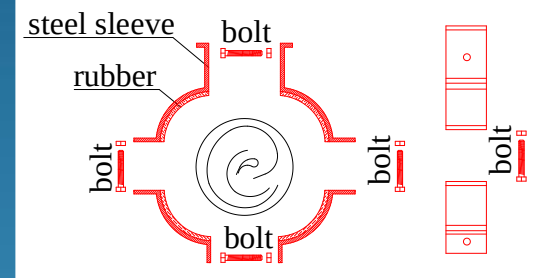
improvement of the complex vault-floor system: stiffness and strength (*Mazzolani et al., 2005-2009*)

□ beam floor steel-timber-concrete composite structure

single beam



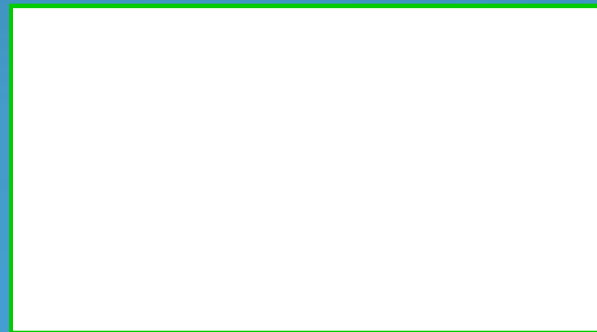
collar connector parts



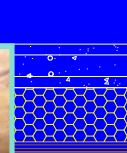
MATERIALS

- concrete: C25/30
- steel bars: Feb 44k
- galvanized steel: S275
- natural rubber: SISMI 60

multiple beam



DESIGN OF THE CONSOLIDATION SYSTEM



Ø14
Ø20

ab
material
ber table
eel

The Royal
“old wood
composit
An exam



FEDERICO M. MAZZOLANI ï University of Naples ã Federico II

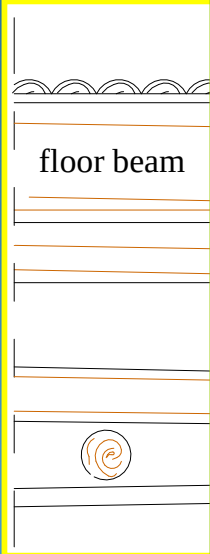


THE TIMBER ROOFING STRUCTURES OF THE ROYAL APARTMENT : *Interventions*

GLOBAL II



Realiza



4k
S275
ISMI 60



FULL SCALE TESTS

The two BUILDINGS



A

The buildings belong to the former ILVA steel mill in Bagnoli (Naples), which has been recently dismantled.

Reinforced concrete framed structures infilled by masonry walls, which were designed for gravity loads during the 70s, when the area was not yet included in seismic zone.



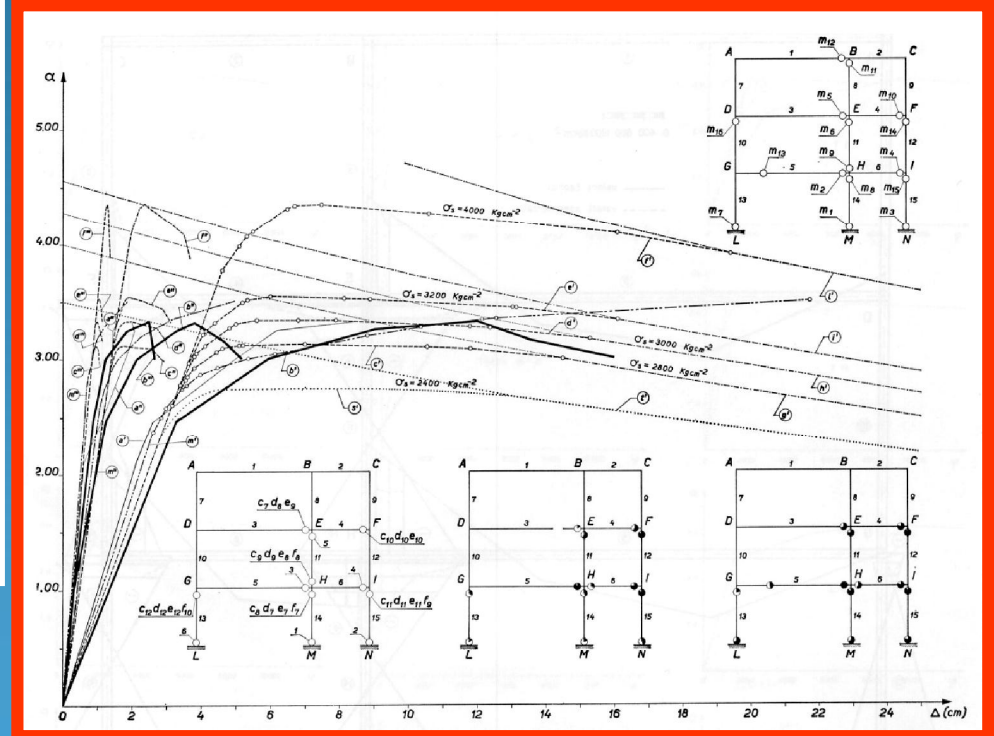
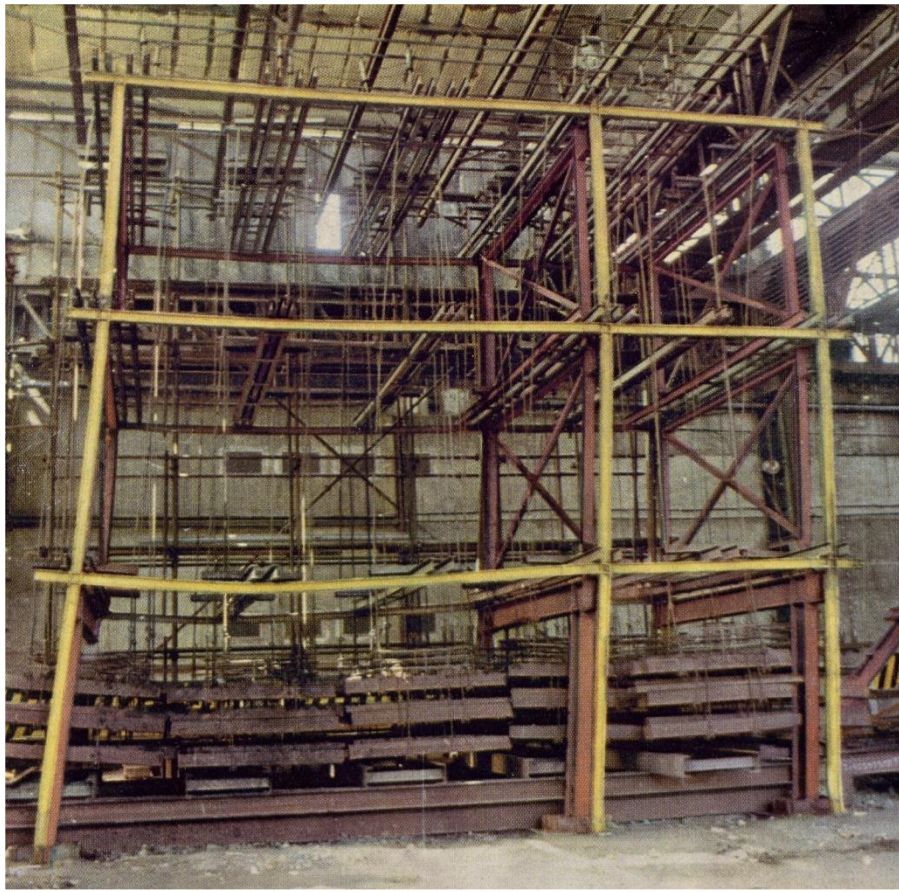
B

FULL SCALE TEST ON MR STEEL FRAME (1963-1966)



UNIVERSITY of NAPLES "FEDERICO II" Prof. F.M. Mazzolani

FULL SCALE TEST ON MR STEEL FRAME (1963-1966)



Earthquake Protection of Historical Buildings by Reversible Mixed Technologies



ITALY (Napoli, Chieti)



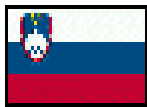
BELGIUM (Liège)



PORTUGAL (Lisbon)



MACEDONIA (Skopje)



SLOVENIA (Ljubljana)



ROMANIA (Bucarest, Timisoara)



GREECE (Athens)



MOROCCO (Rabat)



EGYPT (Cairo)



ISRAEL (Haifa)



ALGERIA (Algiers)

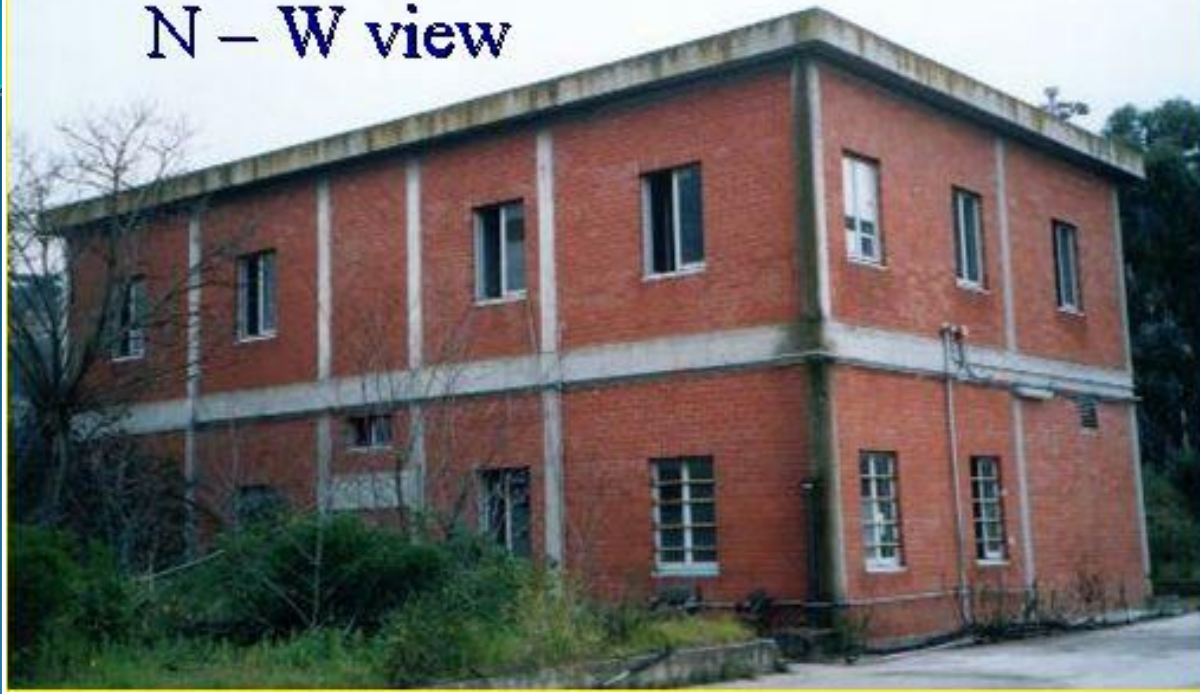


TURKEY (Istanbul)

ROHITECH
Coordinator Federico M. Mazzolani

Building B

N – W view

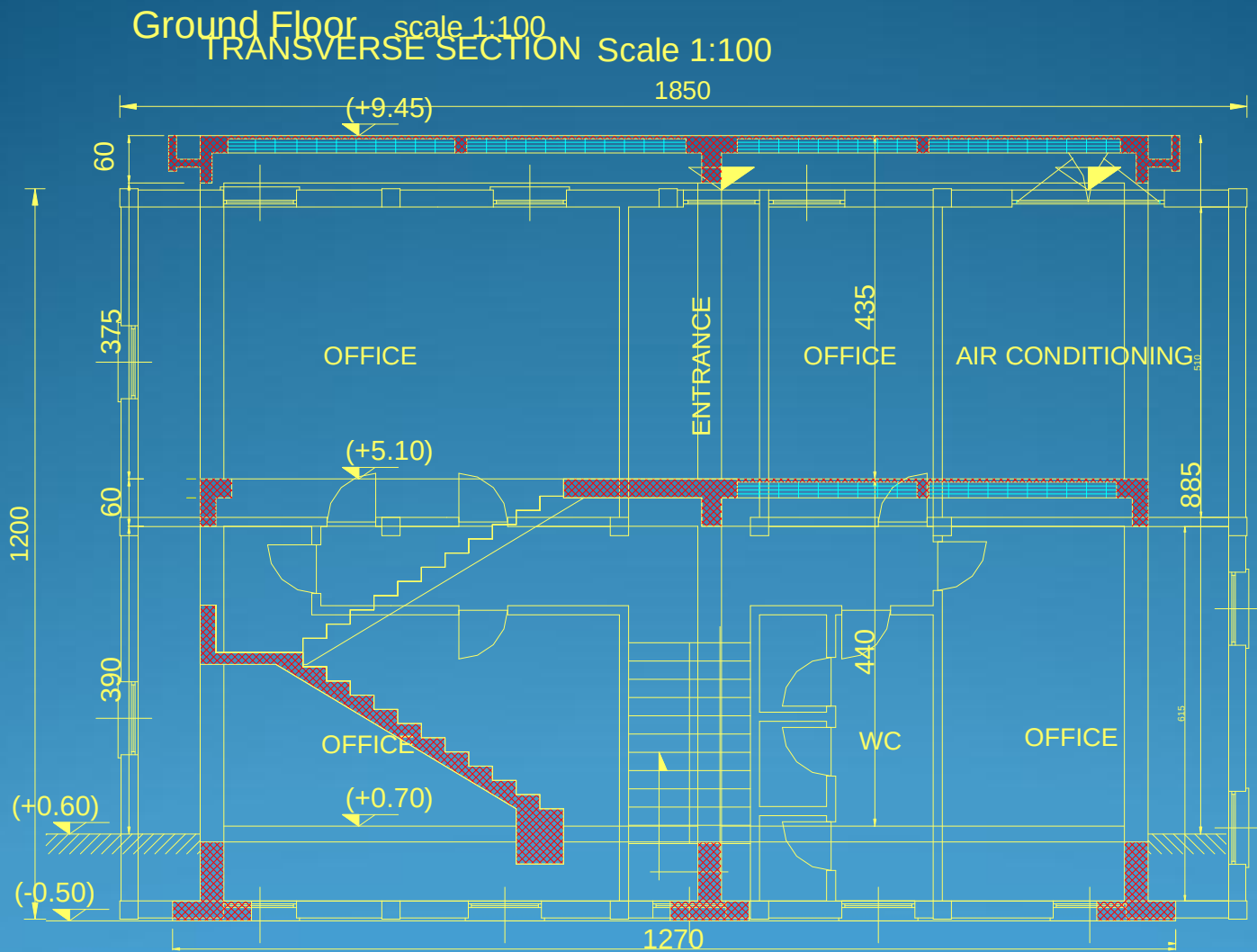


BASIC DATA

- Construction period: end of '70s
- Plan dimensions: 18.50m x 12.00m
- Floor area: 222 mq
- N° of floors: 2
- Total height on ground: 8.85 m
- Total volume: 1965 mc

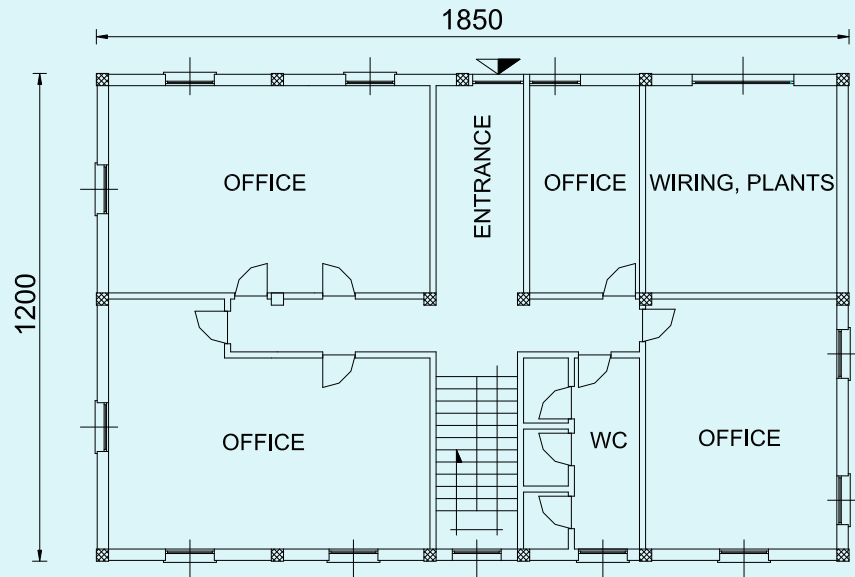


Building B

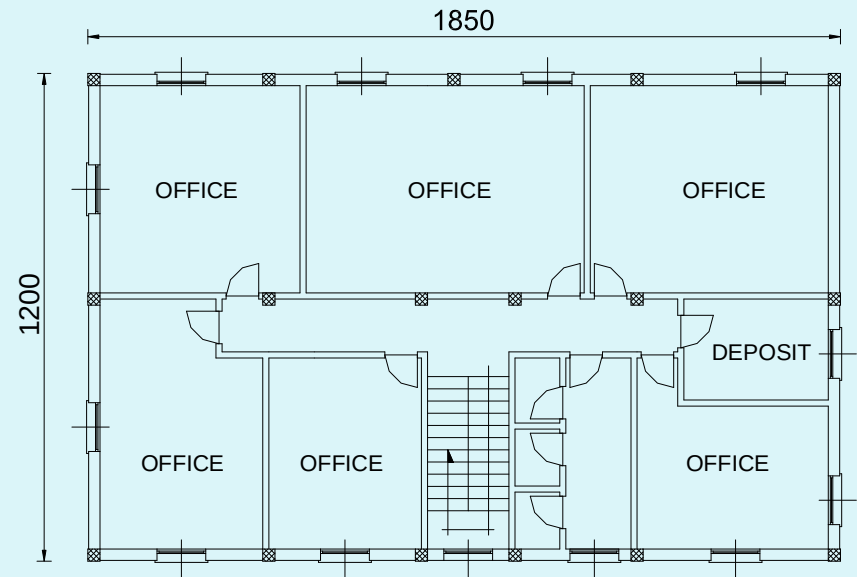


Building B

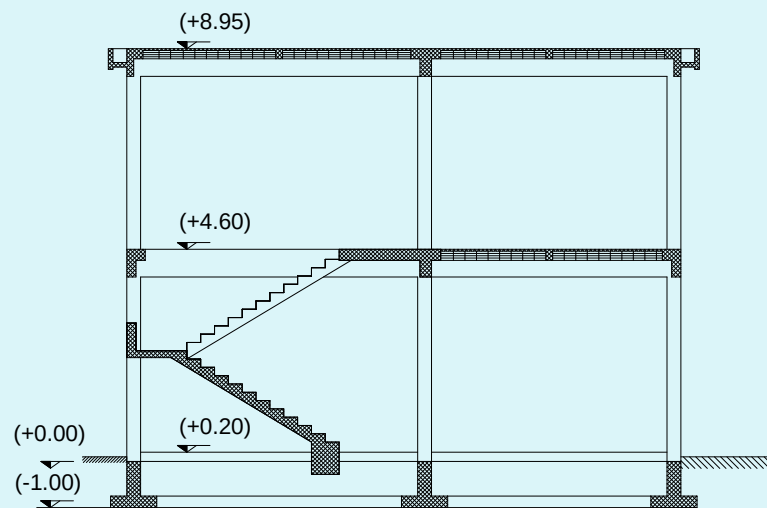
Ground Floor



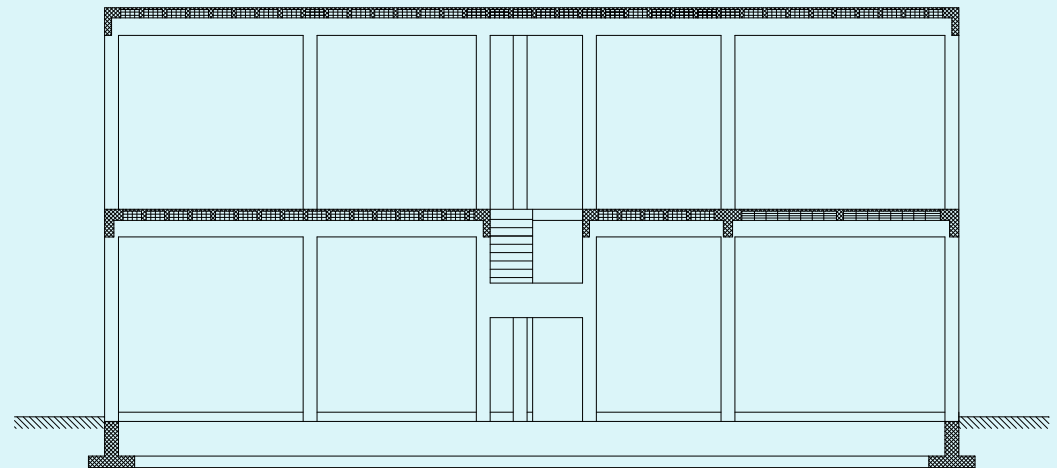
Second (Top) Floor



TRANSVERSE SECTION



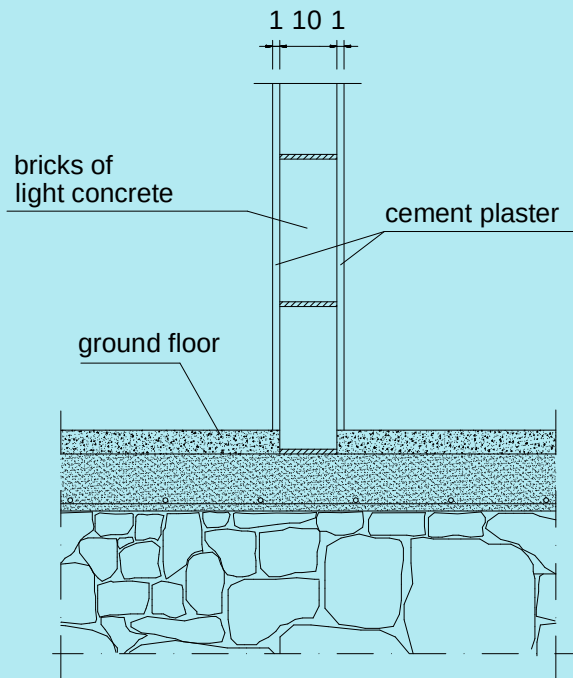
LONGITUDINAL SECTION



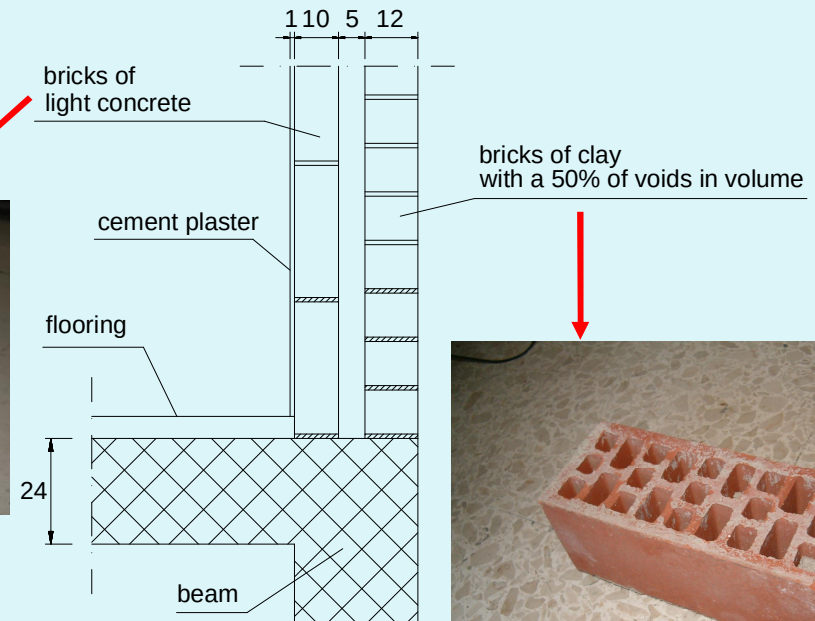
Building B

- External claddings: two parts
internal part: hollow light-concrete tiles ($t = 10\text{ cm}$)
external part: hollow clay tiles ($t = 12\text{ cm}$)
- Internal partitions: hollow light concrete tiles ($t = 10\text{ cm}$)

INTERNAL PARTITION WALLS

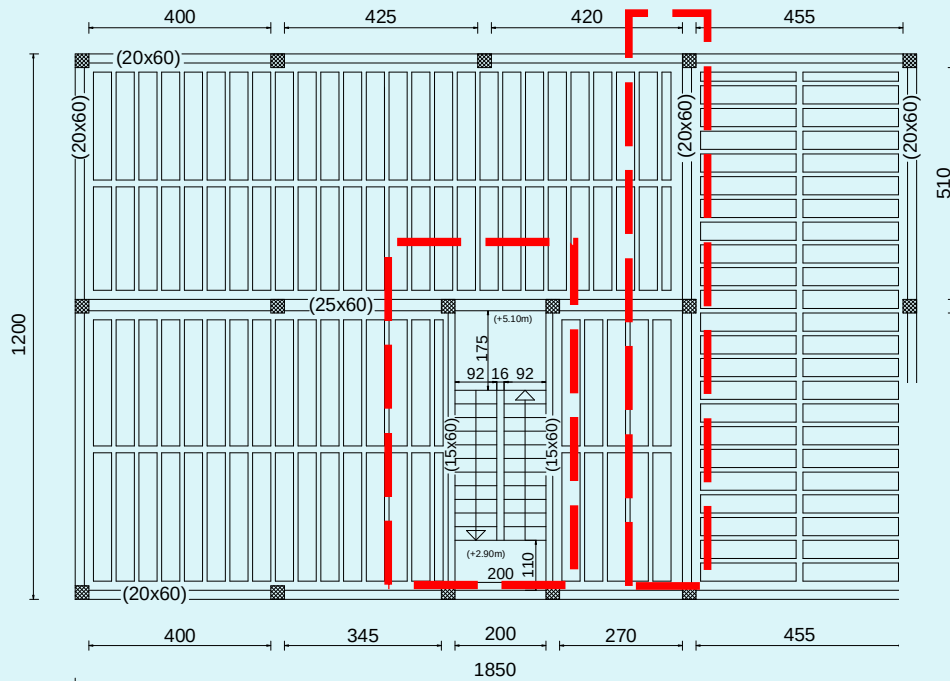


EXTERNAL CLADDING DETAIL



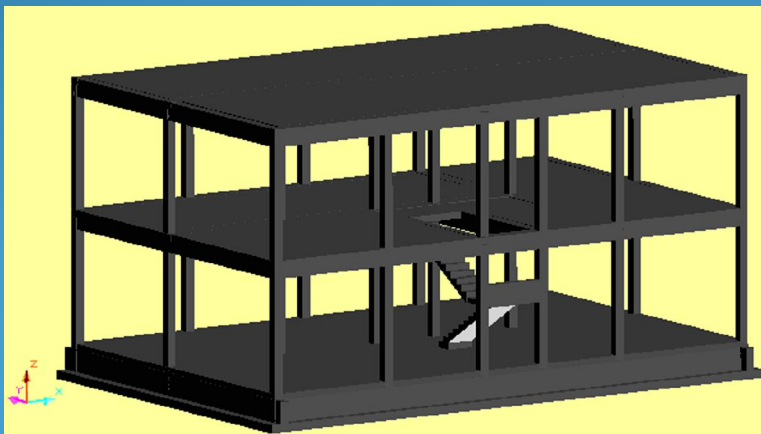
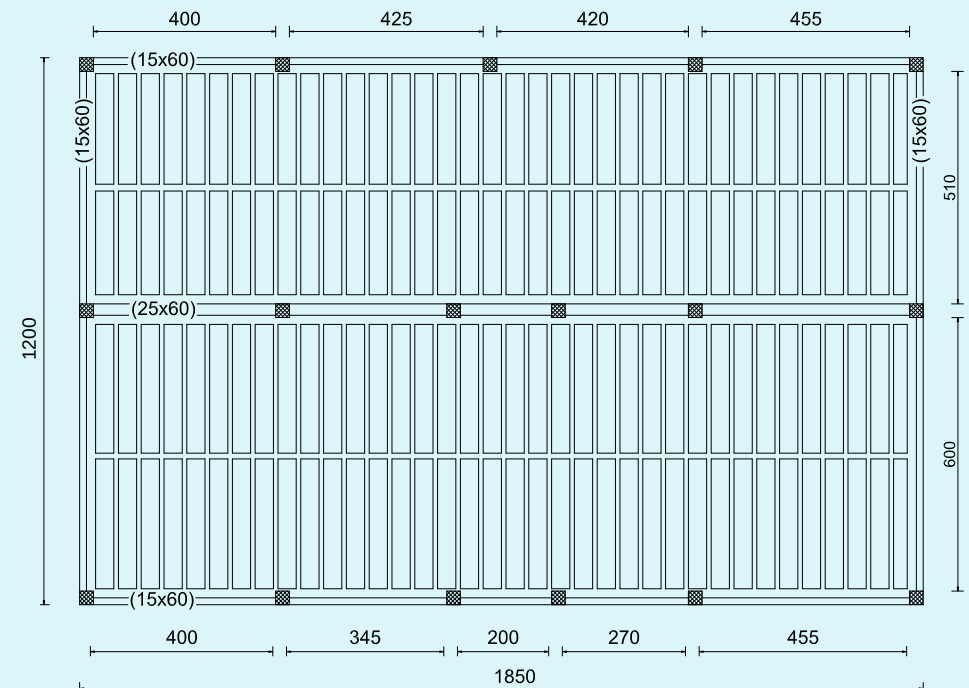
Building B

FIRST FLOOR TECHNICAL SECTION



- 17 Columns: 30x30cm; 12 rebars with diameter of 14mm; stirrups 8mm spaced at 20mm
- Beams: 15x60cm; 20x60cm; 25x60cm
- First floor slab: mixed RC-hollow tiles $d = 20+4 = 24$ cm
- Second floor slab: mixed RC-hollow tiles $d = 18+4 = 22$ cm

SECOND FLOOR TECHNICAL SECTION



BUILDING B: Dynamic identification

Excitation system



- Dimensions 200cmx100cmx100cm (length, height, depth)
- Structural weight of frame: 500Kg
- Maximum number of masses placed in each counterrotating flat basket:
4x33Kg and 3x27Kg
- Flat basket diameter: 90cm
- Power input: 2kw

BUILDING 2: Dynamic identification

Acceleration



accelerometer
width: DC
le range
ity: 10V
y: < 100
sis: < 0.1
axis sensi



(alignment)

reference sensors: Accelerometers 14 and 15

In order to have a
the
vibrodyne and also
"reference" sensor



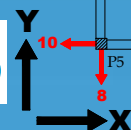
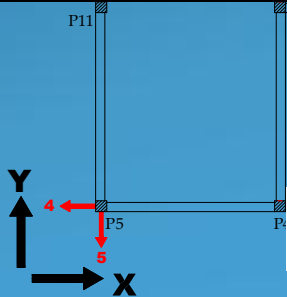
Accelerometers 7 and 9

ation sig
aken at
placed ne



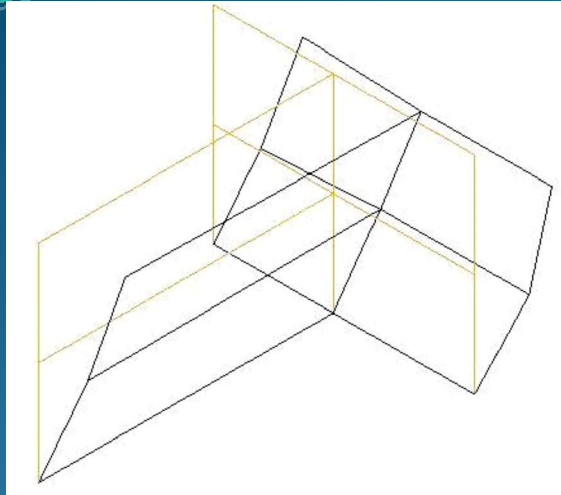
Accelerometers 8 and 10

al force of
nels, two

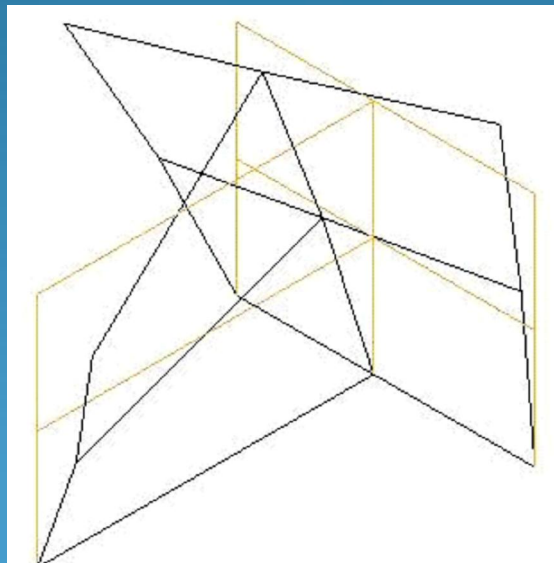


Arrows define the positive direction of each measure

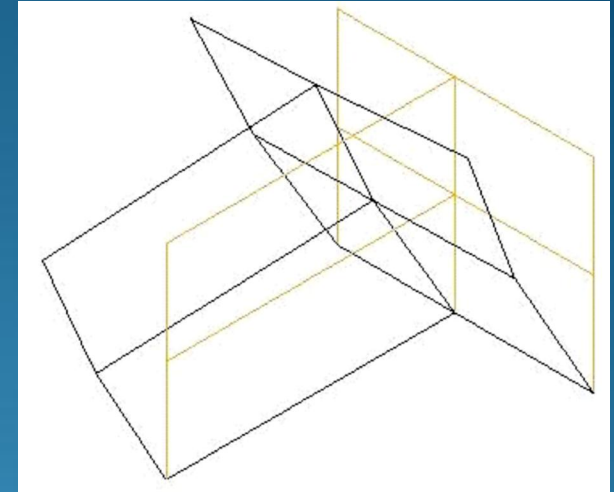
BUILDING B: Dynamic identification



1st mode in X direction,
frequency = 1.84 Hz, ξ = 1.84%



3rd mode torsional,
frequency = 2.52 Hz, ξ = 1.71%

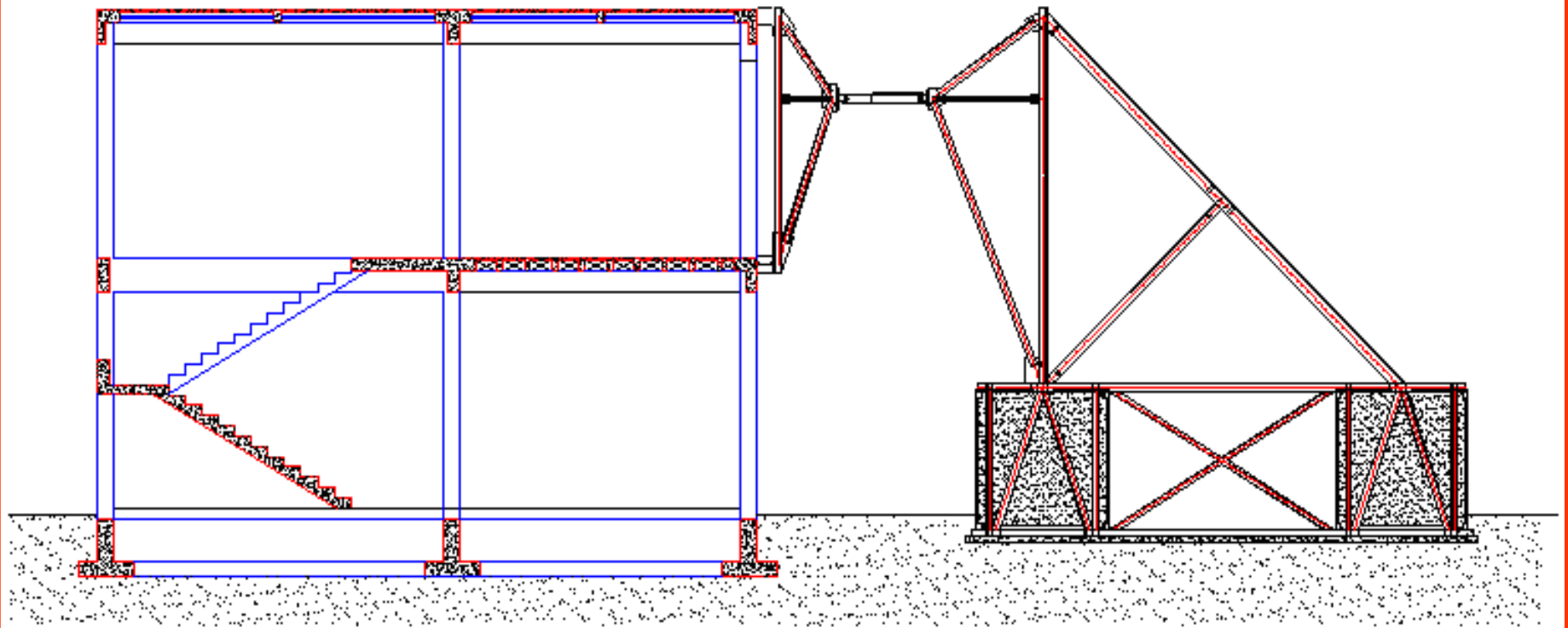


2nd mode in Y direction,
frequency = 2.00 Hz, ξ = 1.37%

Stability diagram

Building B

APPLICATION OF HORIZONTAL FORCES

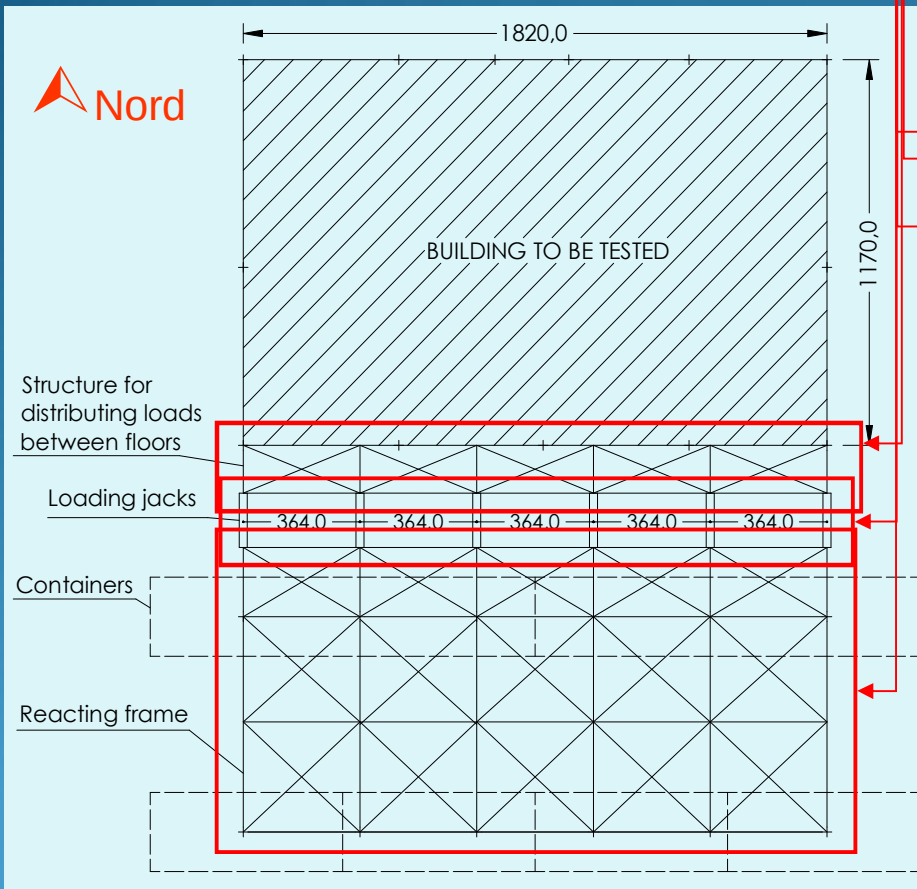


Test equipment

EXTERNAL ACTIONS

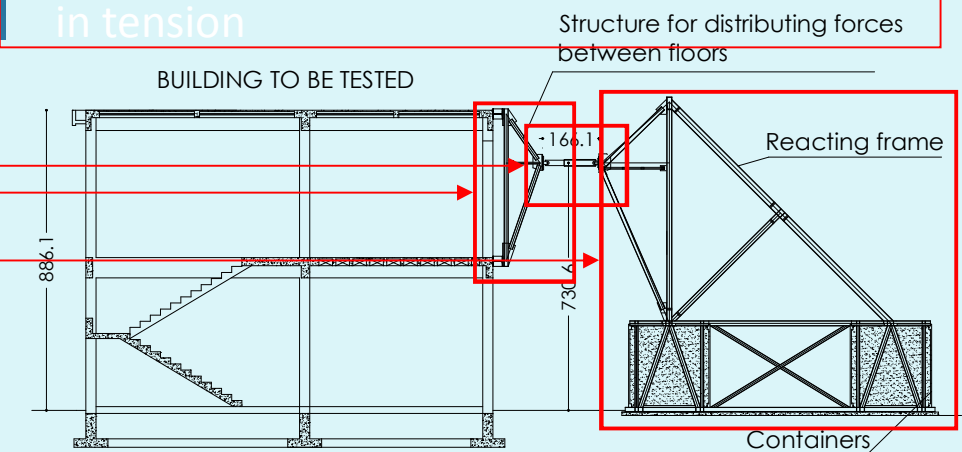
Å Vertical loads: weight of the building

Å Horizontal loads: applied by means of 6 hydraulic jacks with an inverted triangular pattern



EXPERIMENTAL APPARATUS

- Reacting steel frame stabilised by soil placed in containers
- Triangulated steel structure for distributing loads between the two floors
- Hydraulic jacks: displacement capacity 60 cm; load capacity 496 kN in compression, 264 kN in tension



Building B

Test equipment



Prof. F.M. Mazzolani - UNIVERSITY of NAPLES "FEDERICO II"

Building B

Test equipment

LOAD AND DISPLACEMENT MEASUREMENT

Å Load measuring: monitoring total load by a digital manometer (precision: 1 bar (4-2 kN))

Å Displacement measuring: monitoring of 8 points

floor 1: points 1, 2, 3, 4

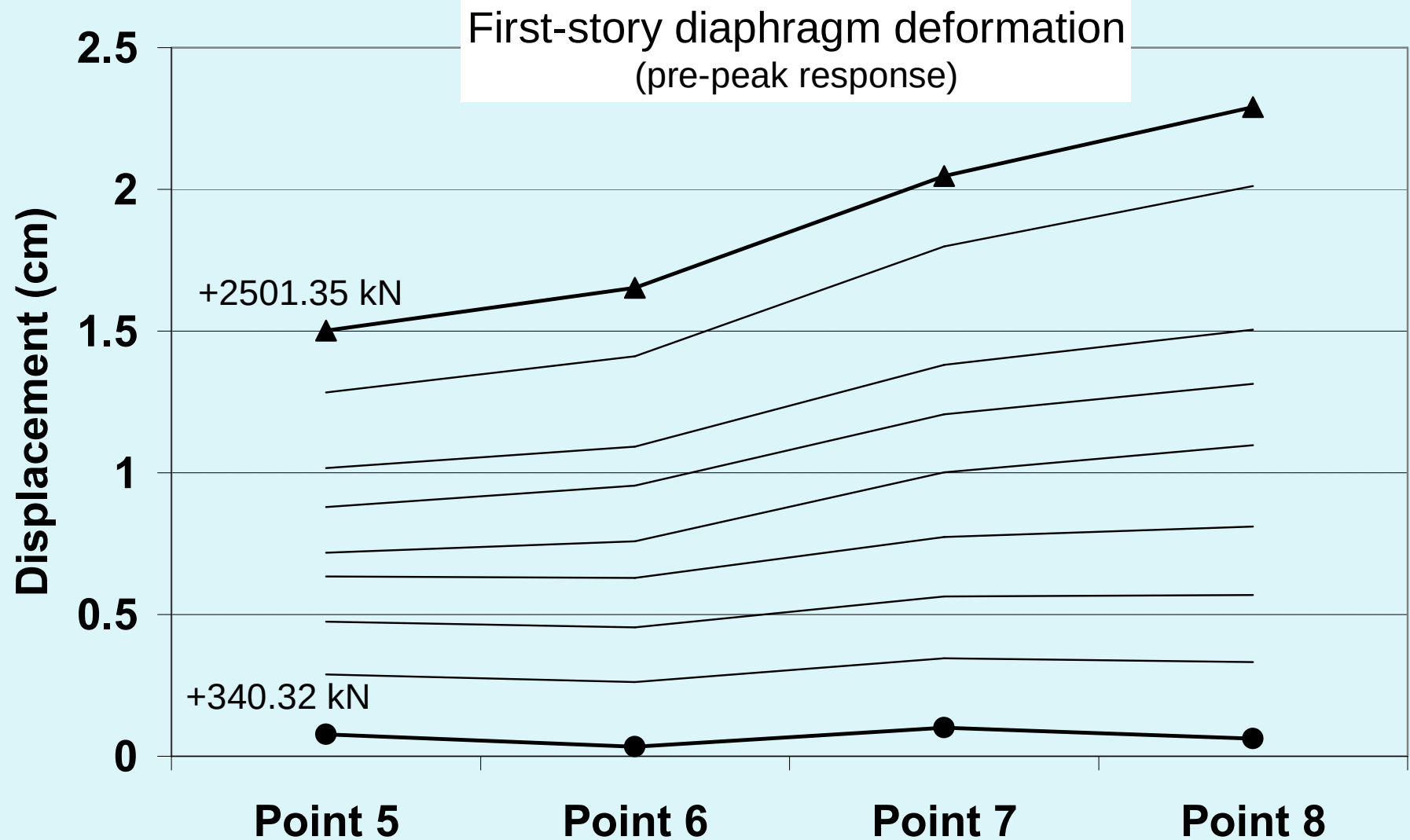
floor 2: points 5, 6, 7, 8

Zeiss-Trimble S10 total station



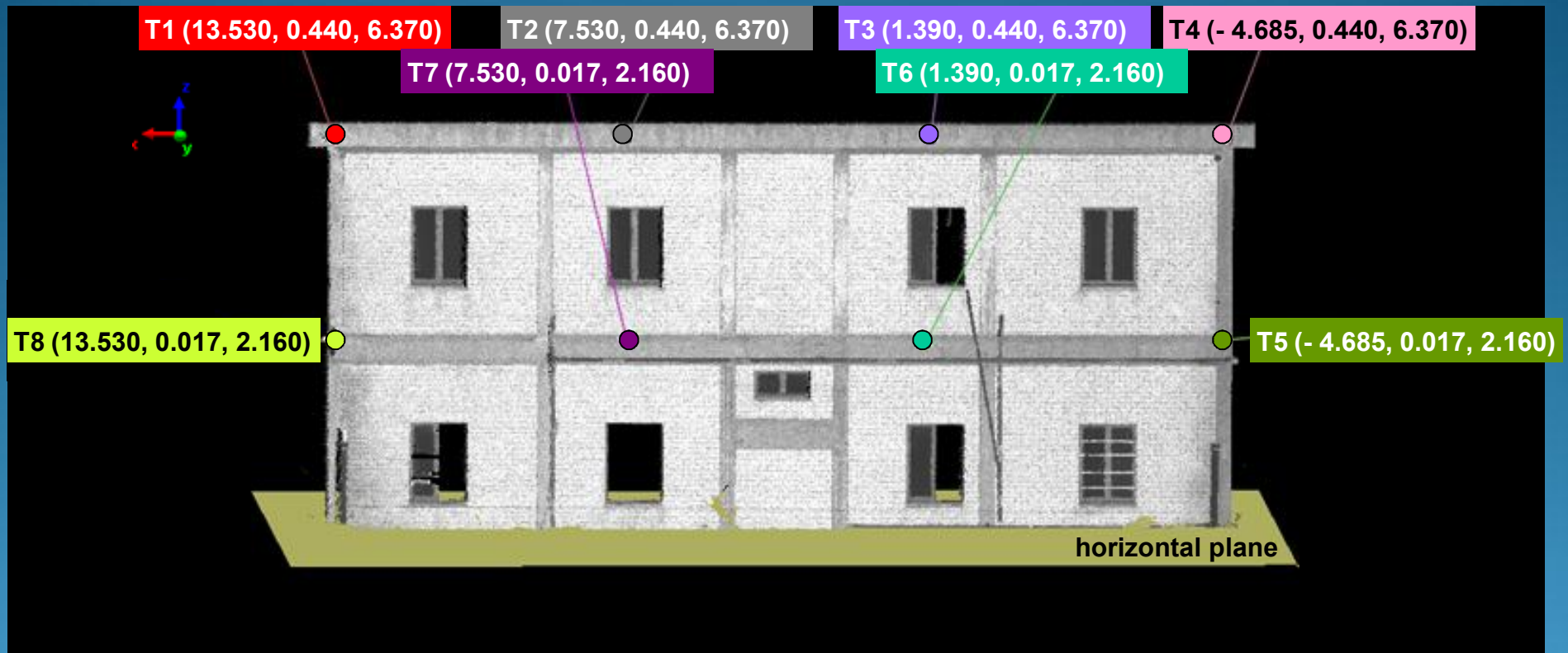
Building B

Experimental results



Building B

DISPLACEMENT MEASUREMENT BY LASER SCANNER SYSTEM

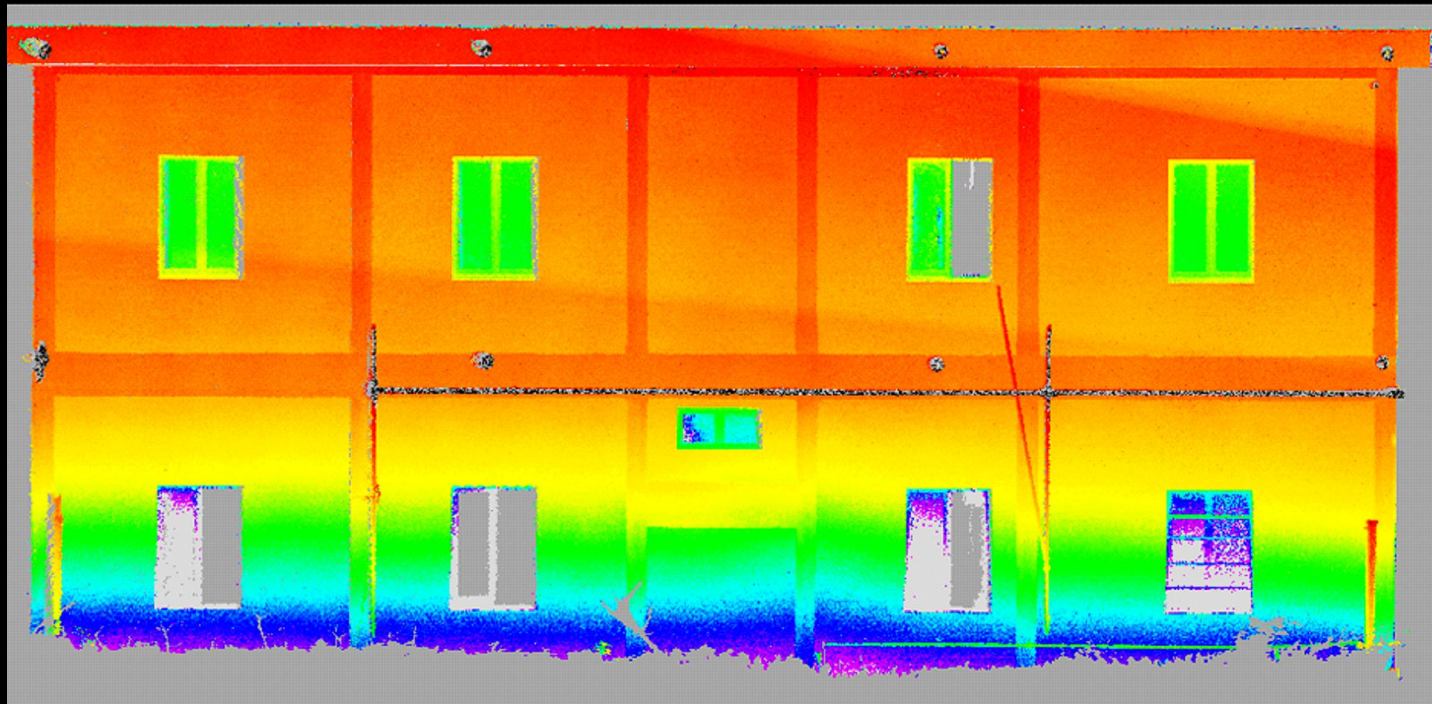


Target points's coordinates



Building B

DISPLACEMENT MEASUREMENT BY LASER SCANNER SYSTEM



0.228
0.216
0.204
0.192
0.180
0.168
0.156
0.144
0.132
0.120
0.108
0.096
0.084
0.072
0.060
0.048
0.036
0.024
0.012
0.000

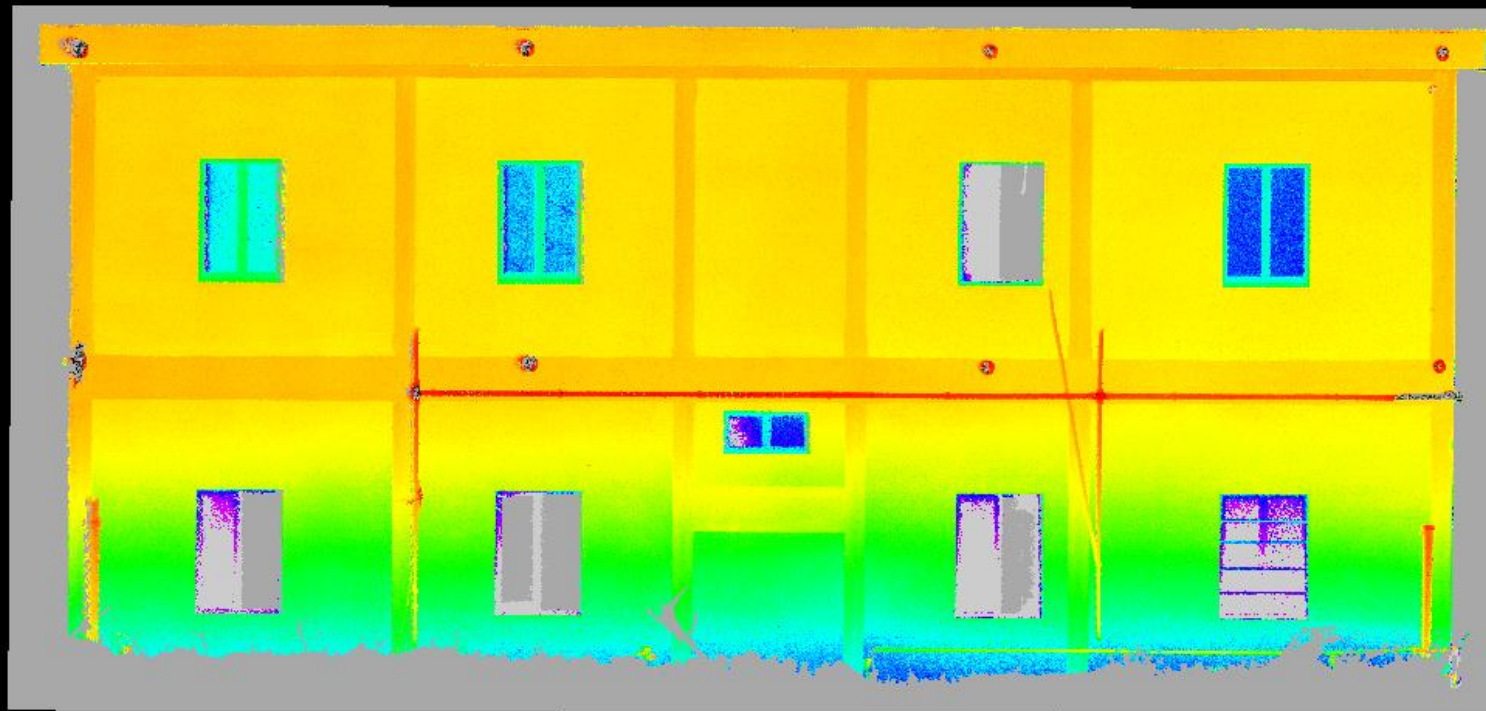
Y-direction displacements at the point of maximum deformation

Prof. F.M. Mazzolani - UNIVERSITY of NAPLES "FEDERICO II"



Building B

DISPLACEMENT MEASUREMENT BY LASER SCANNER SYSTEM

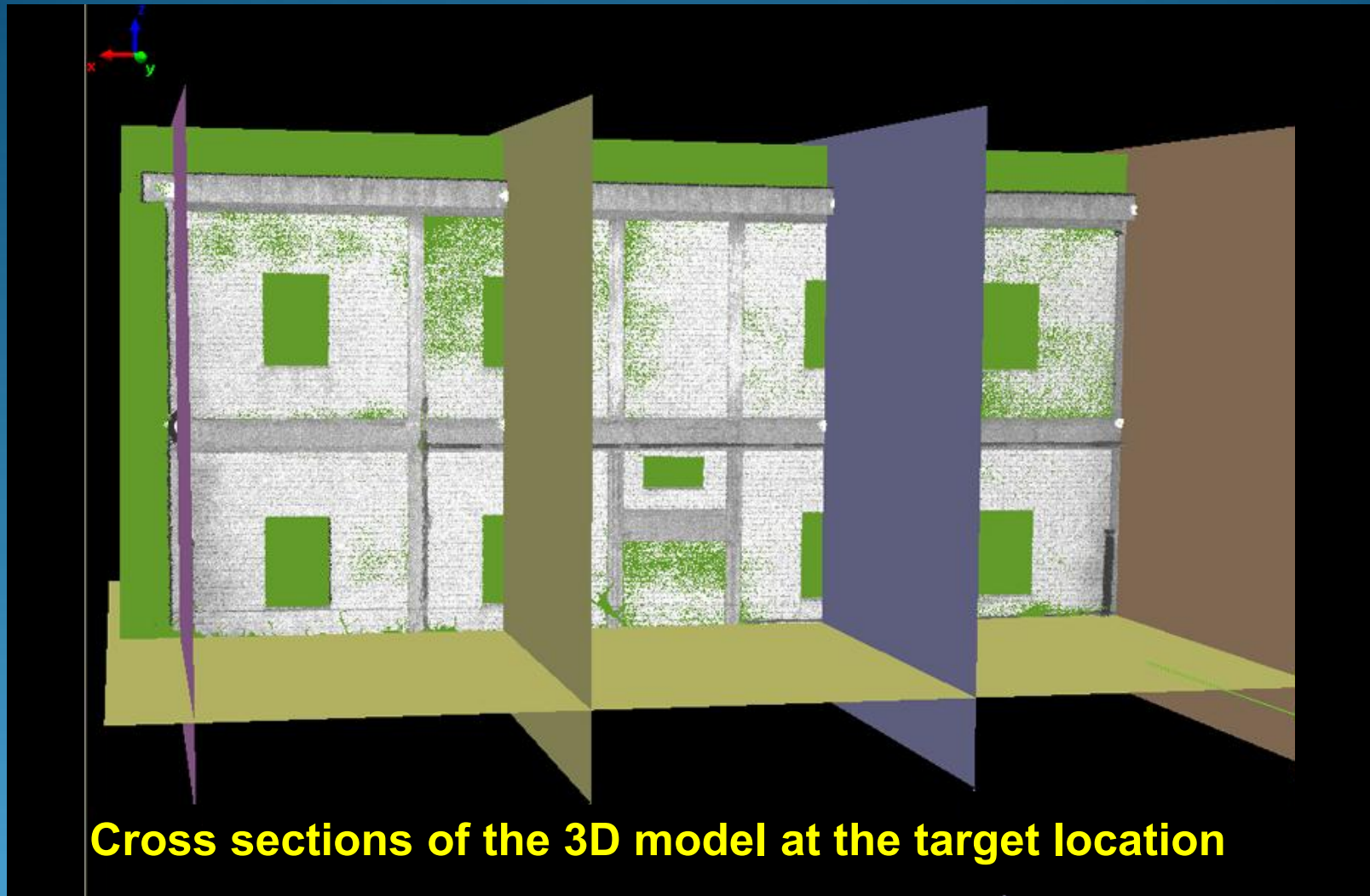


Y-direction displacements at the point of residual deformation

Prof. F.M. Mazzolani - UNIVERSITY of NAPLES "FEDERICO II"

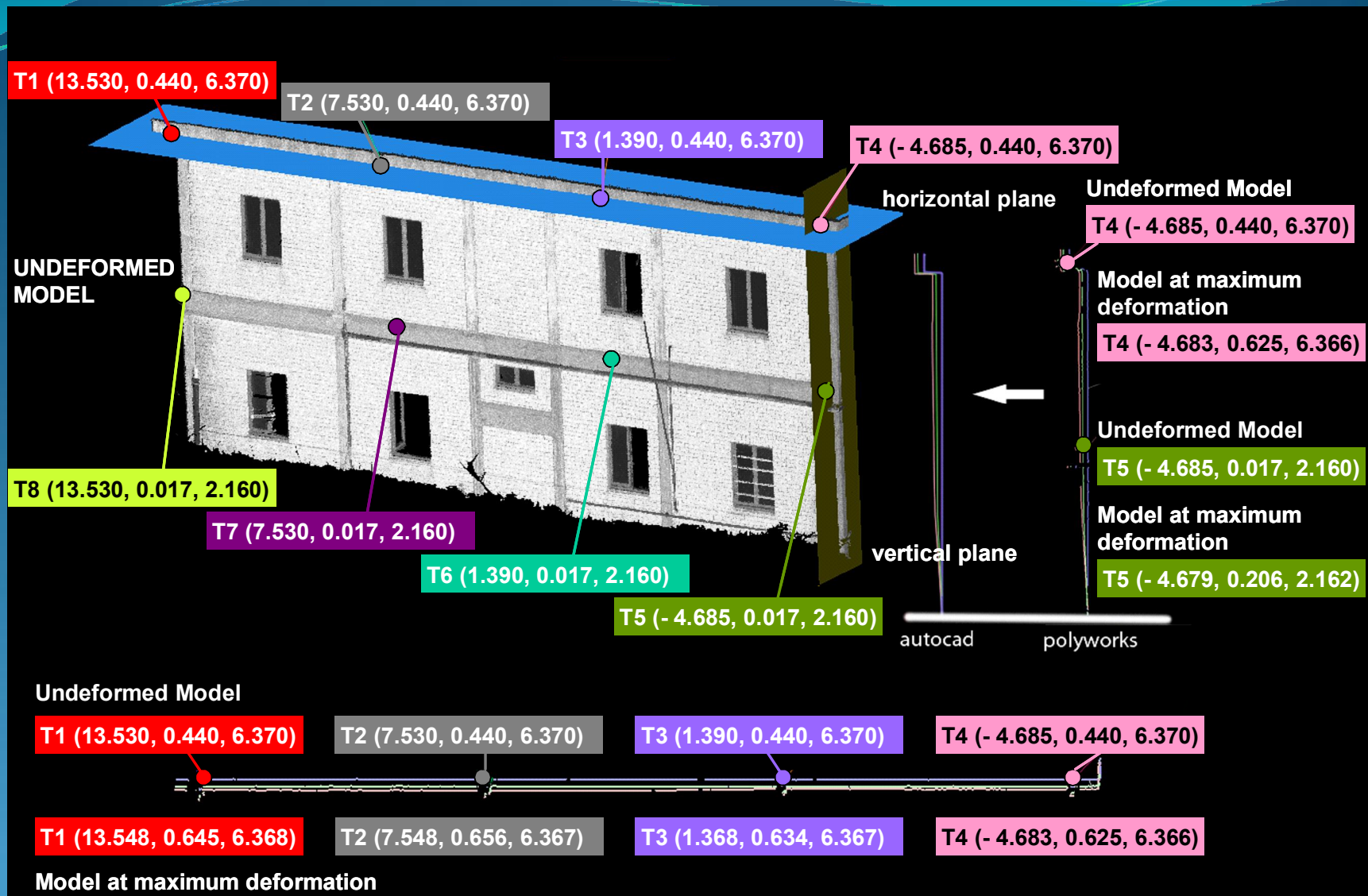


DISPLACEMENT MEASUREMENT BY LASER SCANNER SYSTEM



Building B

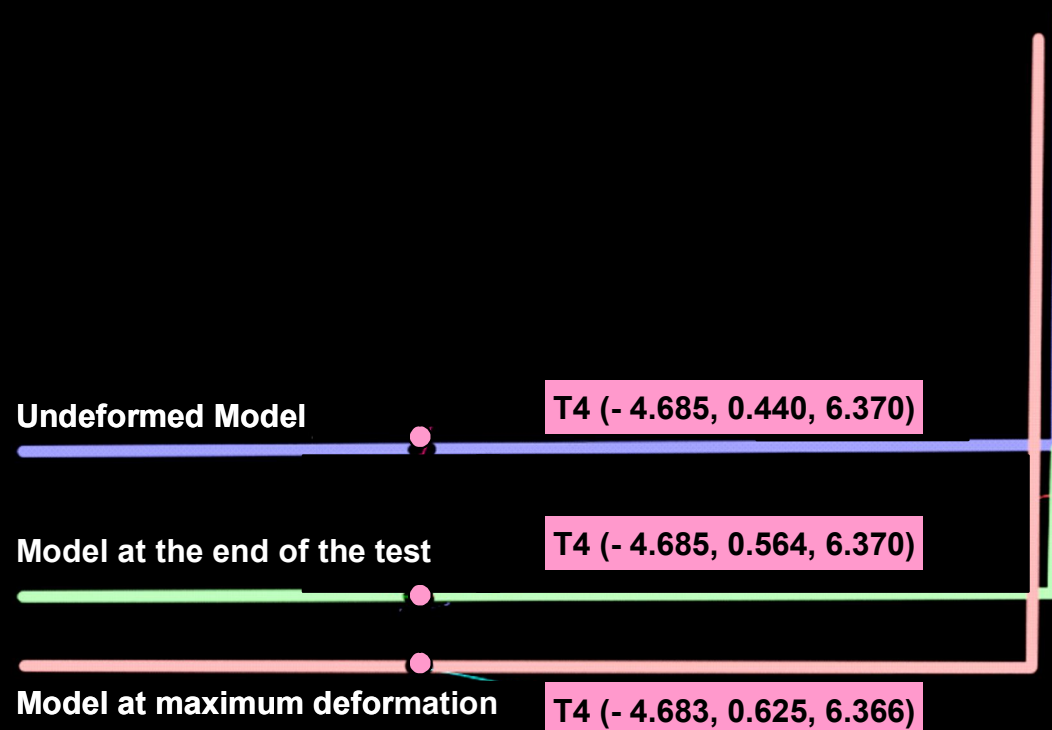
DISPLACEMENT MEASUREMENT BY LASER SCANNER SYSTEM



Cross sections of the 3D model at the target location

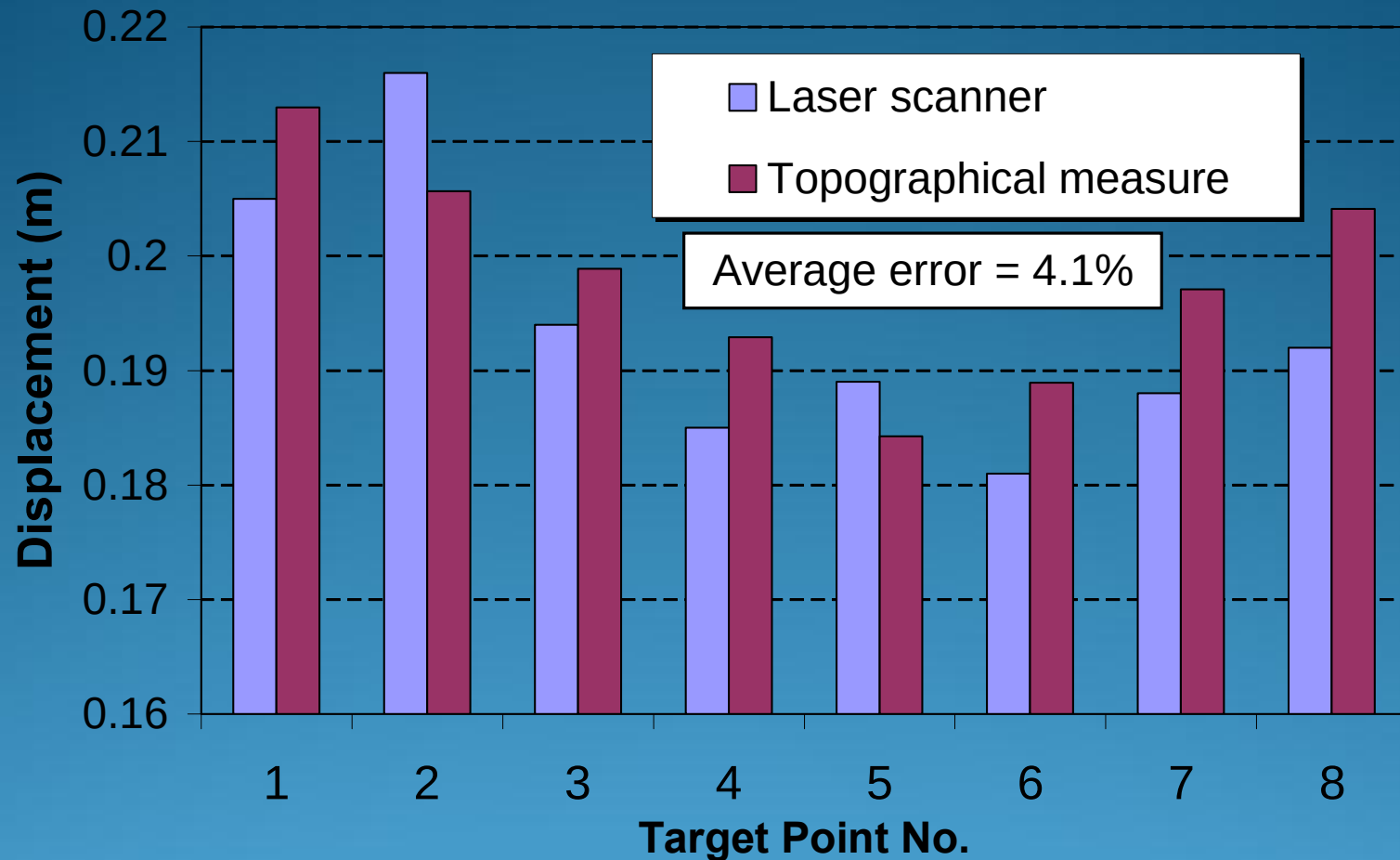
Building B

DISPLACEMENT MEASUREMENT BY LASER SCANNER SYSTEM



Cross section of the 3D model at the target location

DISPLACEMENT MEASUREMENT BY LASER SCANNER SYSTEM



The scatters of measurements between the topographical station and the laser scanner range from 2.5% to 5.9%.

Building B

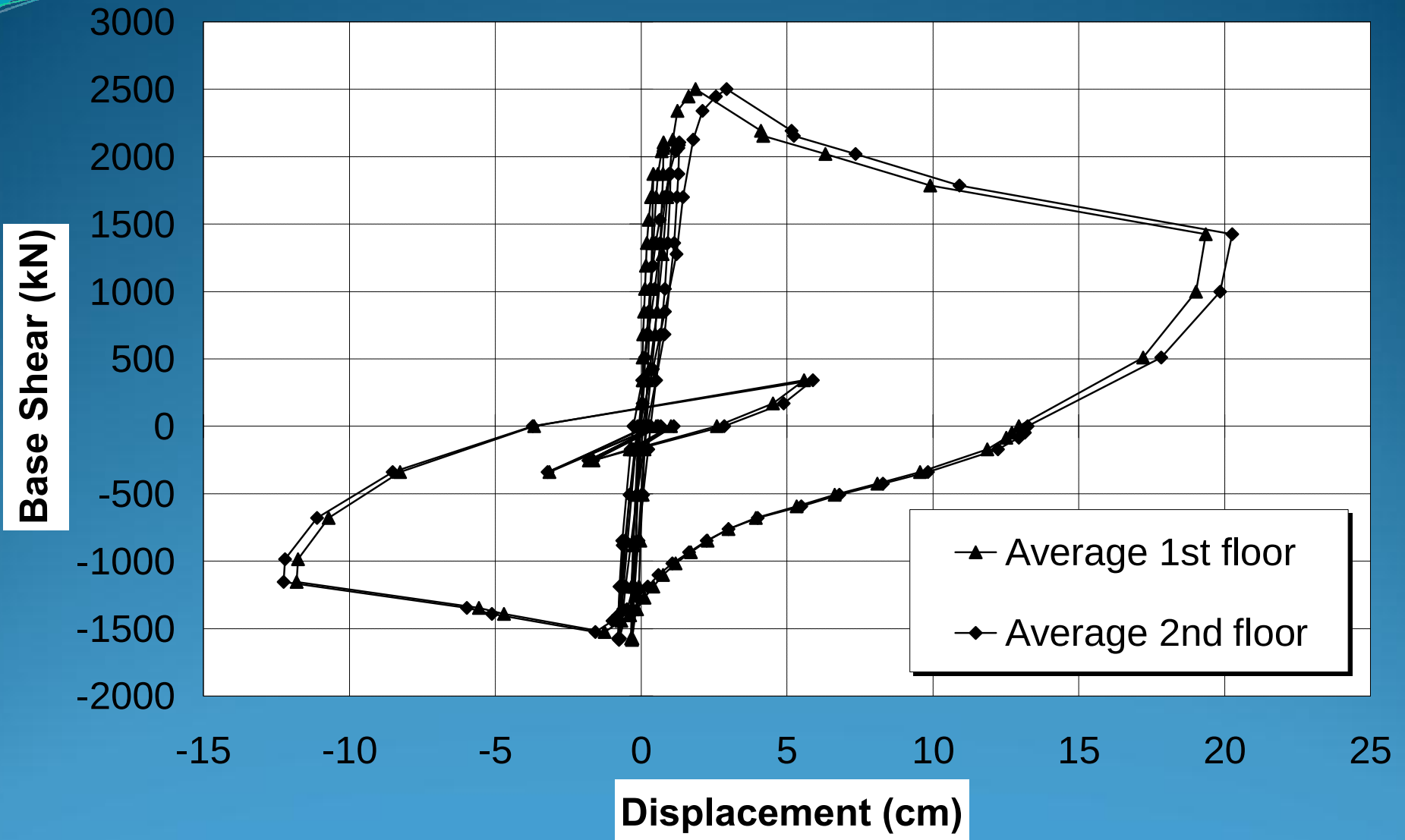
testing apparatus



Prof. F.M. Mazzolani - UNIVERSITY of NAPLES "FEDERICO II"

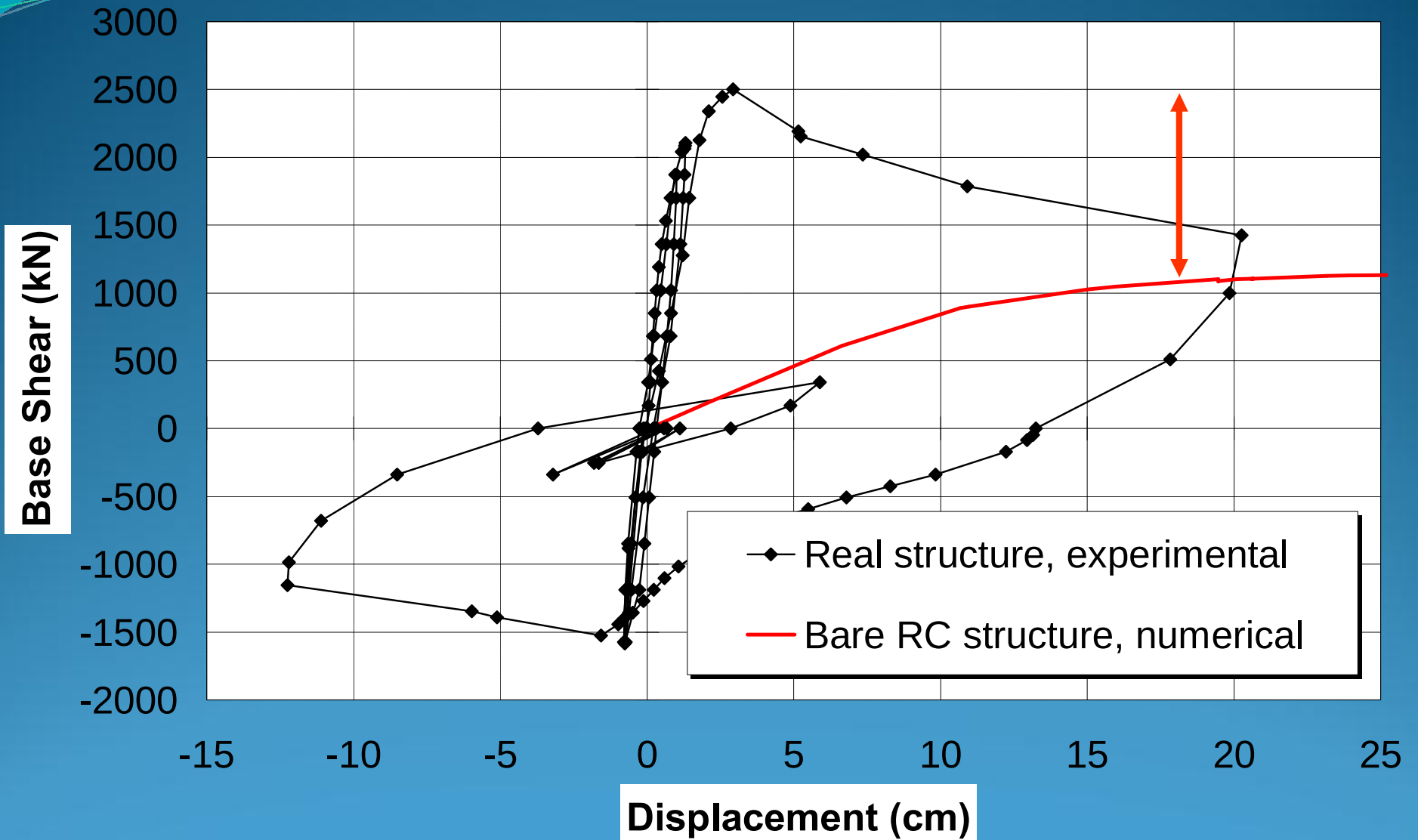
Building B

Experimental results of test #1



Building B

Experimental results of test #1



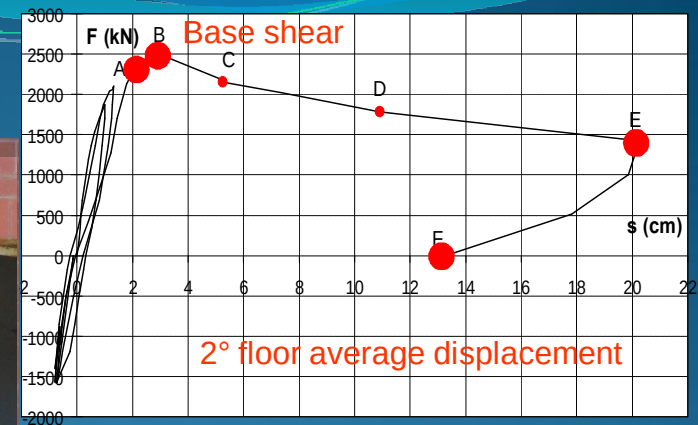
Building B: Experimental results of test 1

Failure mechanisms

Masonry

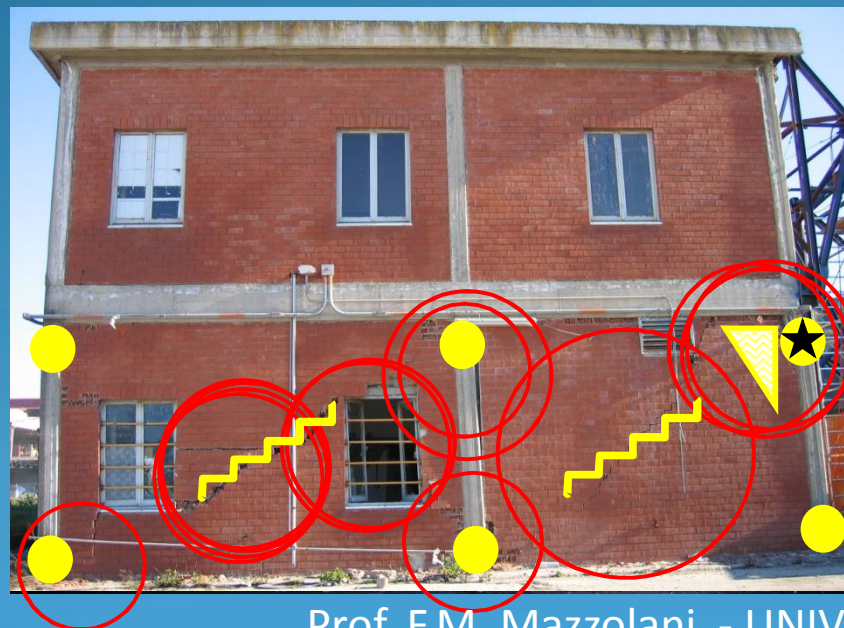
Reinforced concrete

	Diagonal tension failure		Flexural plastic hinge
	Local crushing of masonry		Shear plastic hinge



Point F
 $(d/h)_1 = 0.030$, $(d/h)_2 = 0.0010$

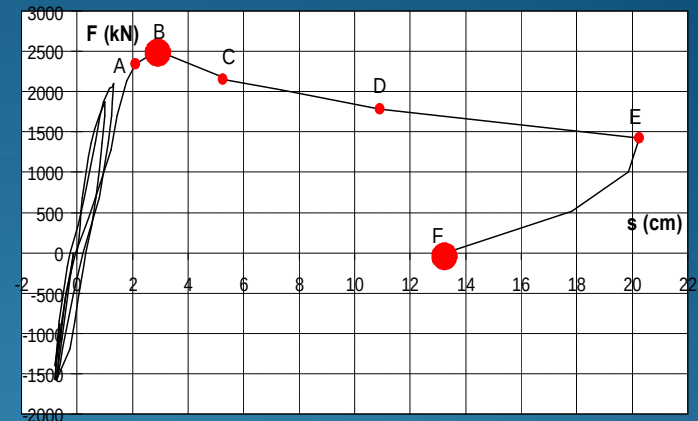
West view



East view



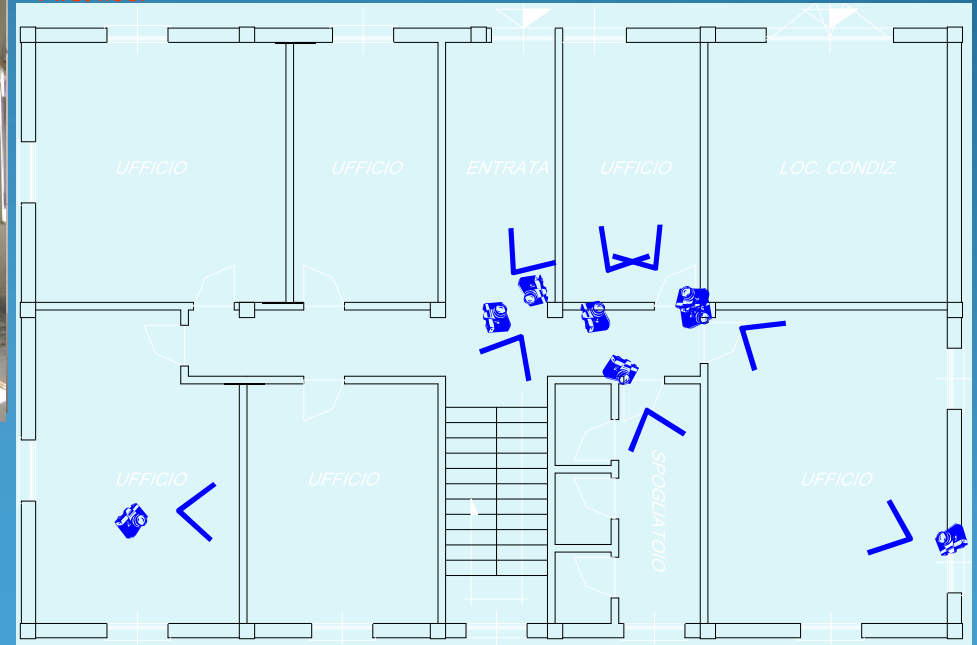
Building B: Experimental results of test #1



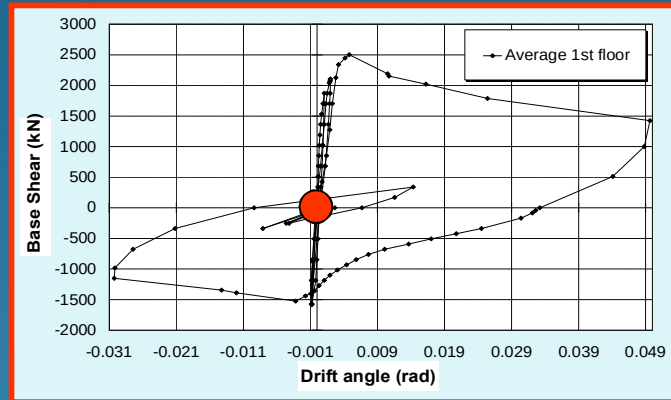
Point B
 $(d/h)_1 = 0.0048$, $(d/h)_2 = 0.0025$

Point F
 $(d/h)_1 = 0.030$, $(d/h)_2 = 0.0010$

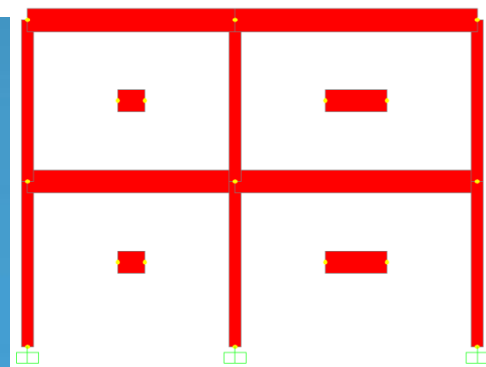
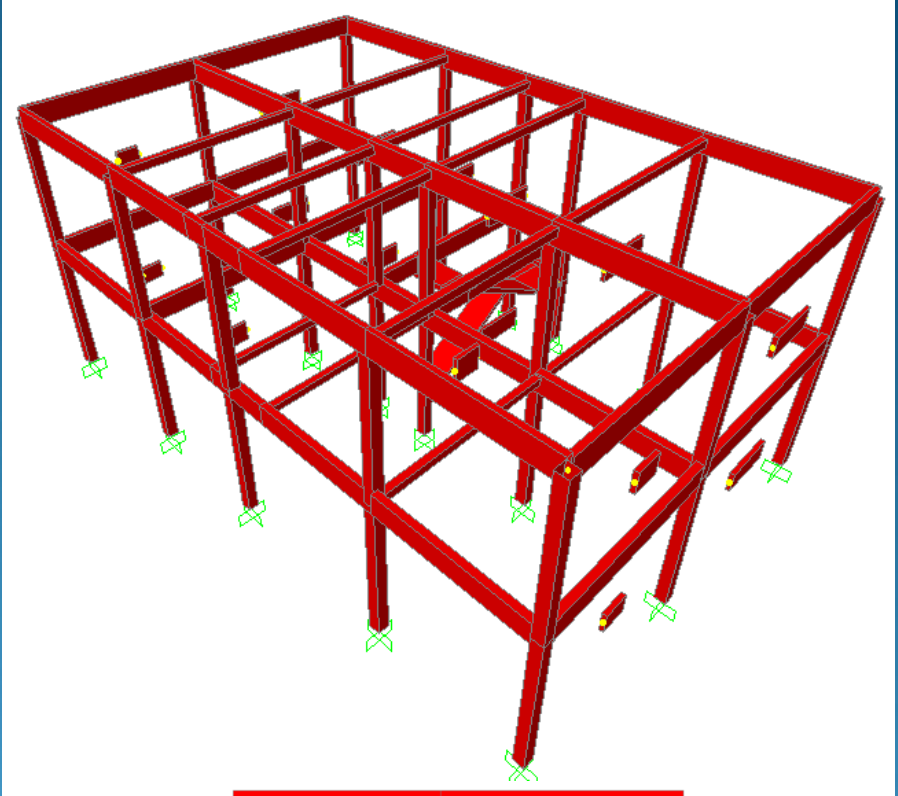
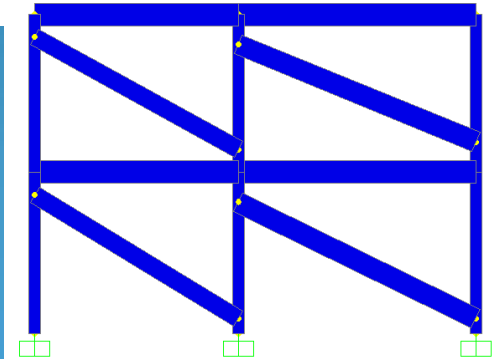
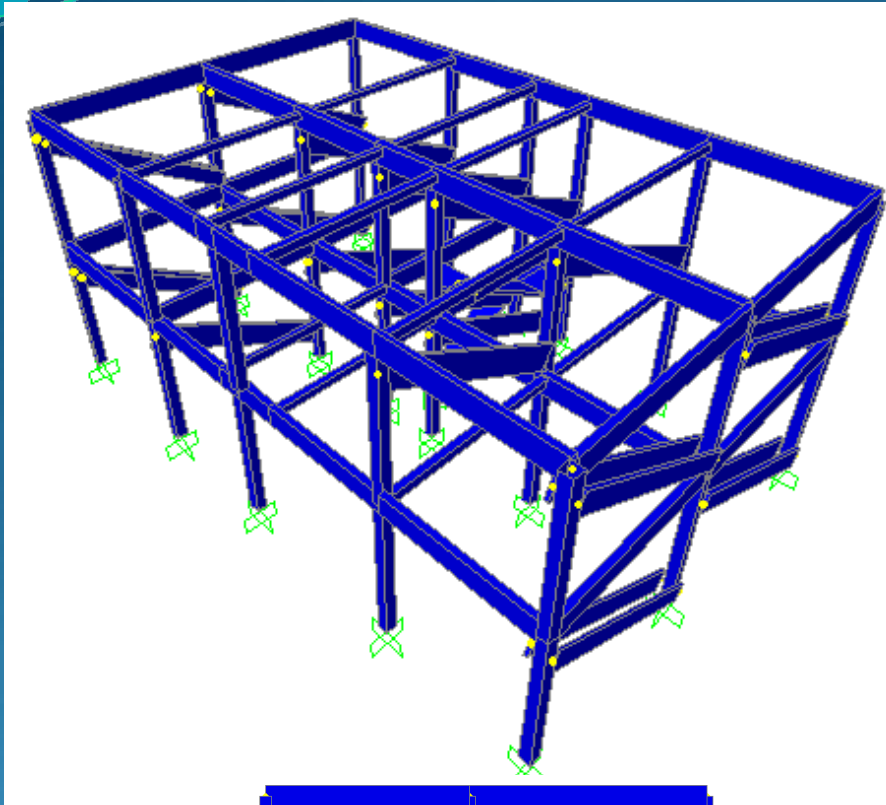
First floor



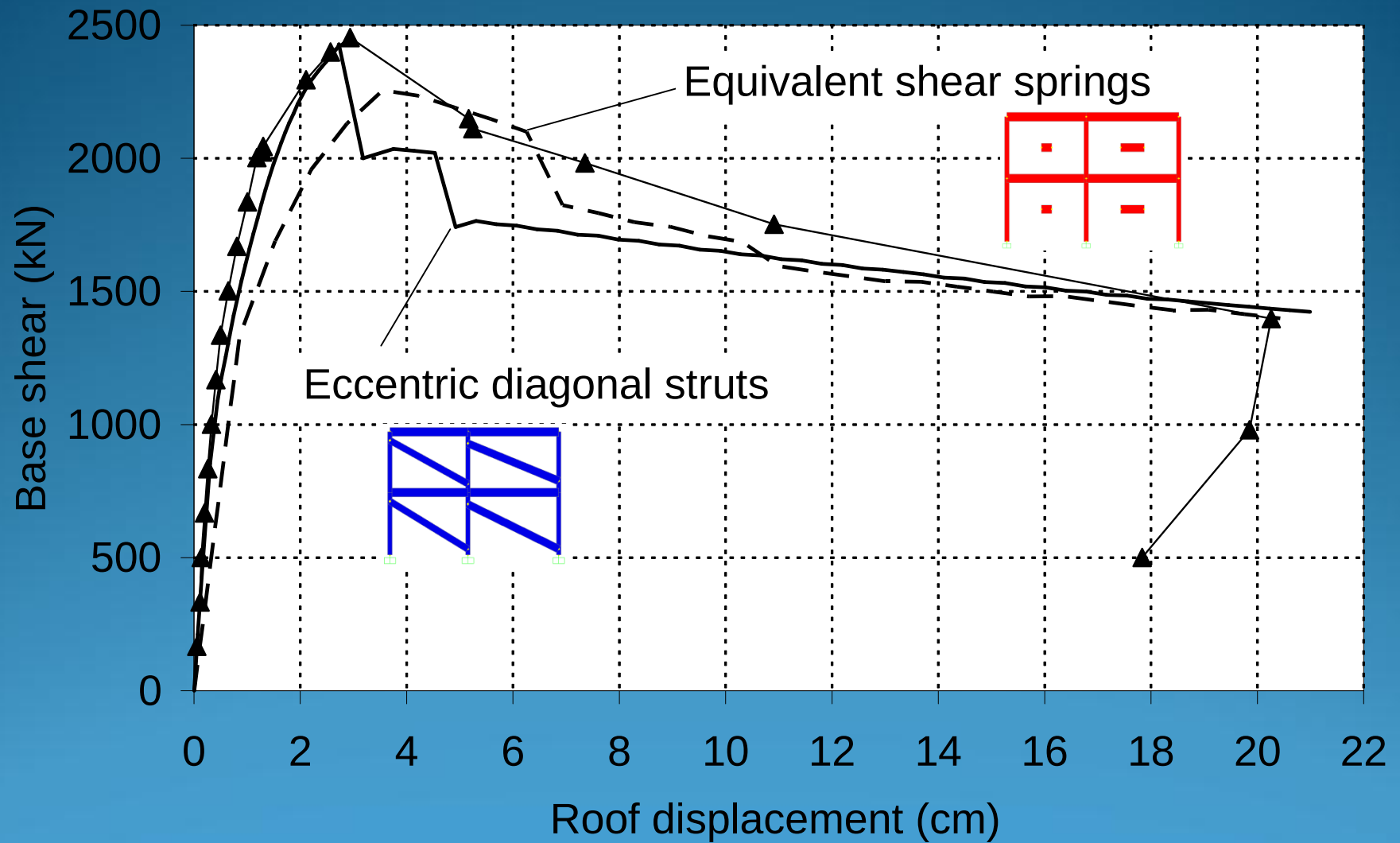
Building B: Experimental results of test #1



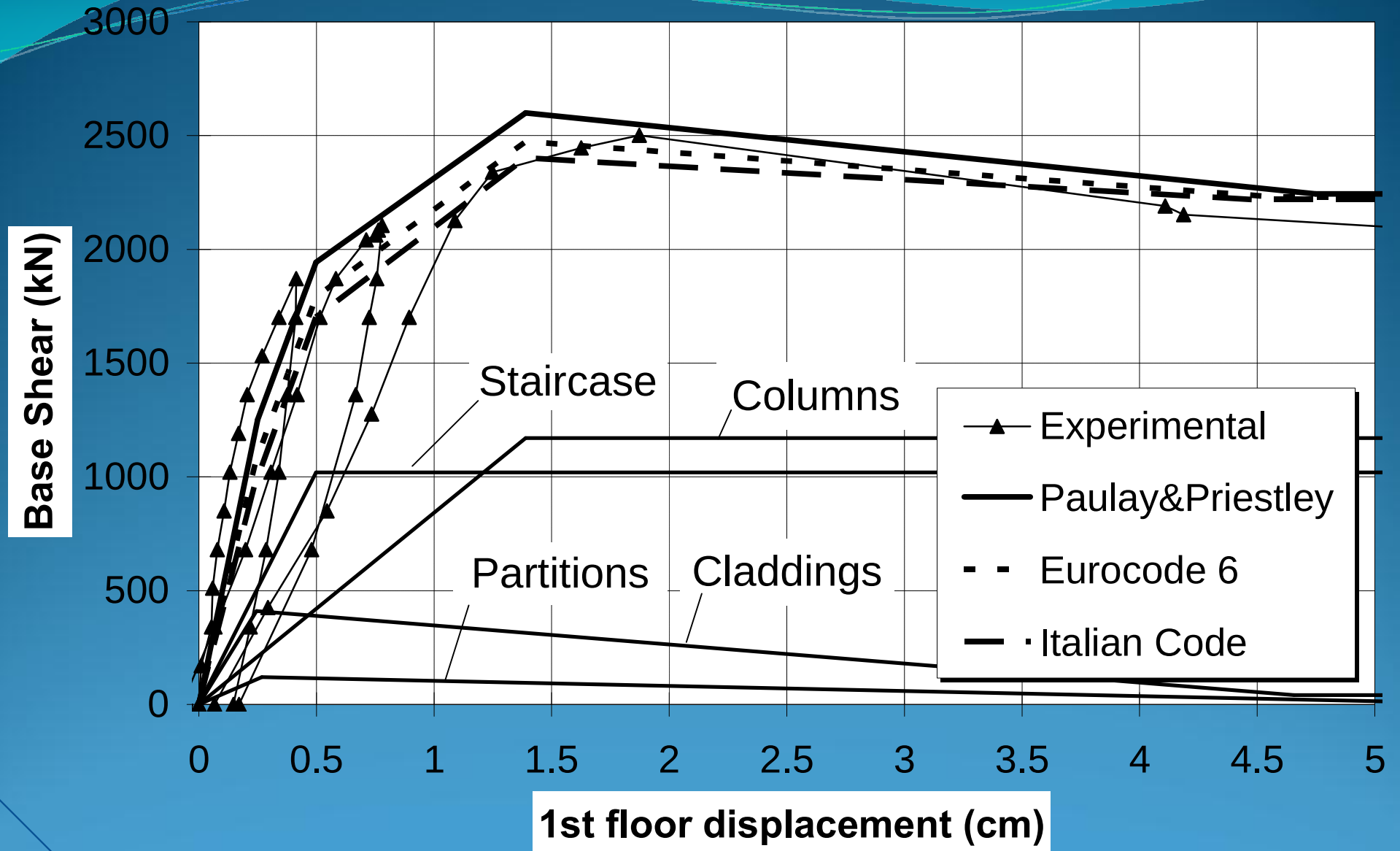
Building B: Numerical modelling



Building B: Numerical modelling

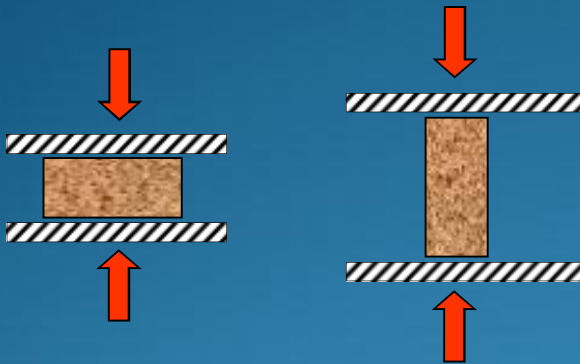


Building B: comparisons

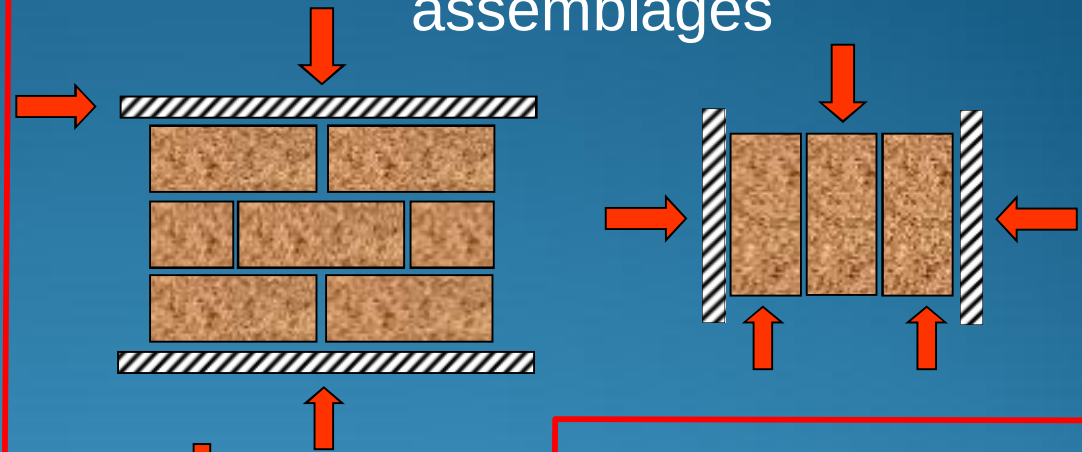


Tests on masonry specimens

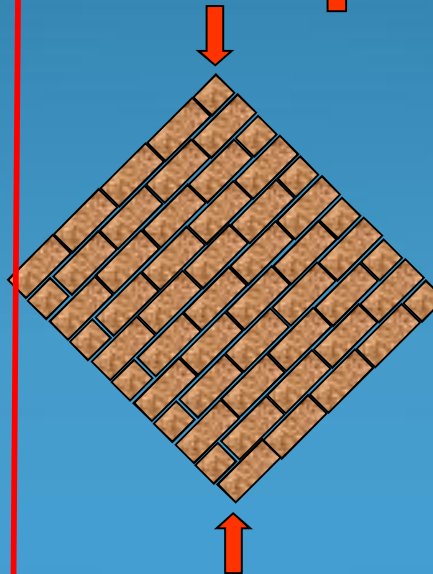
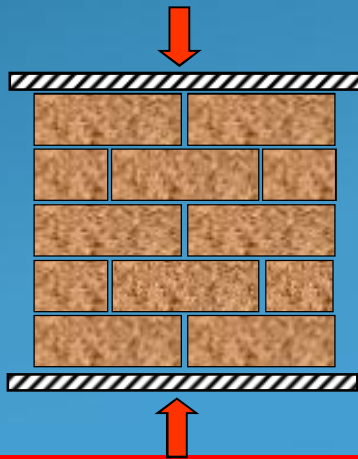
Tests on single blocks



Shear tests on sub-assemblages



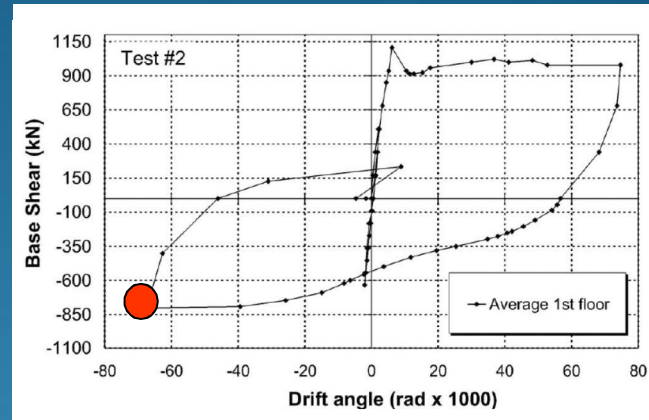
Compression tests on sub-assemblages



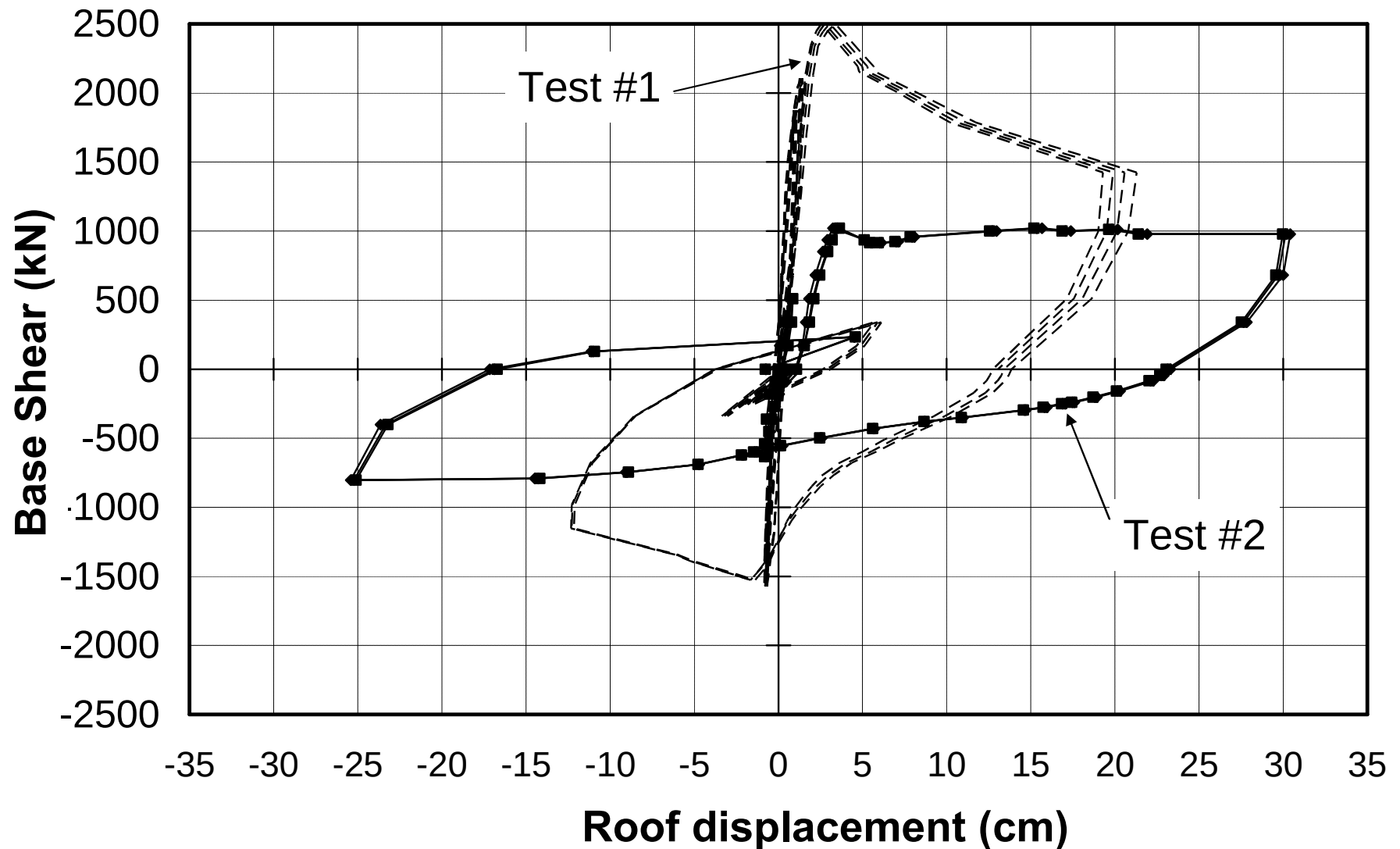
Reconstruction and strengthening of perimeter walls by means of C-FRP wires (test #2)



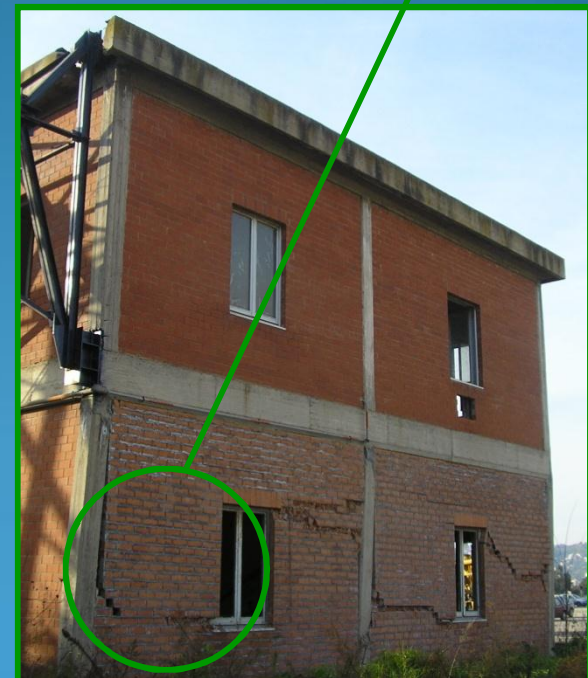
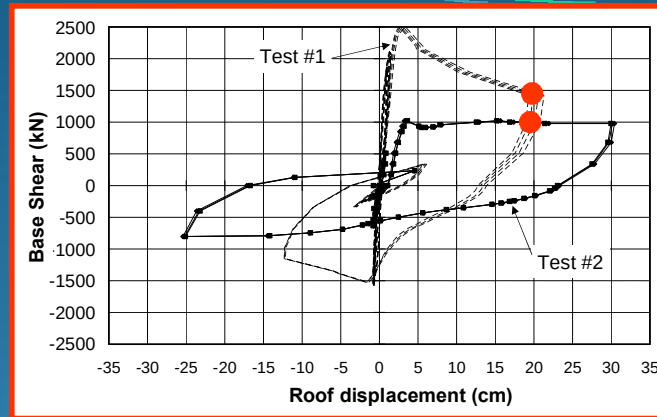
Building B – Test #2



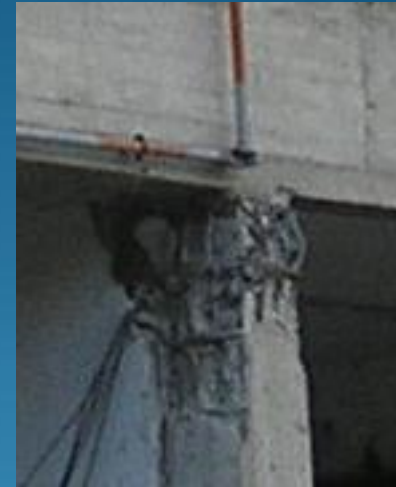
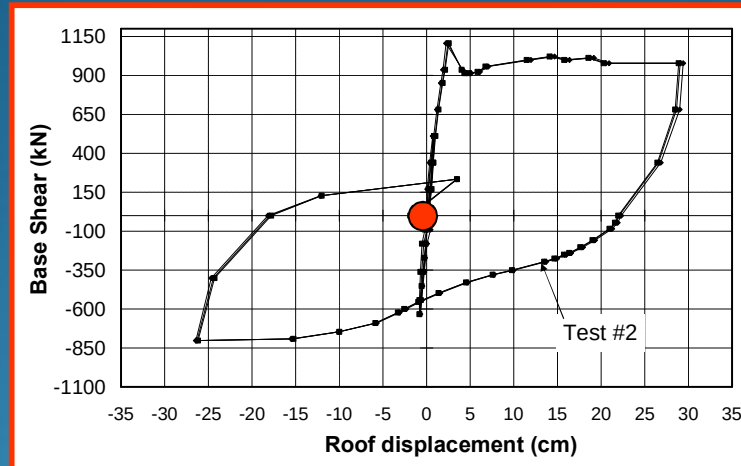
“Push-pull” test #1 + test #2



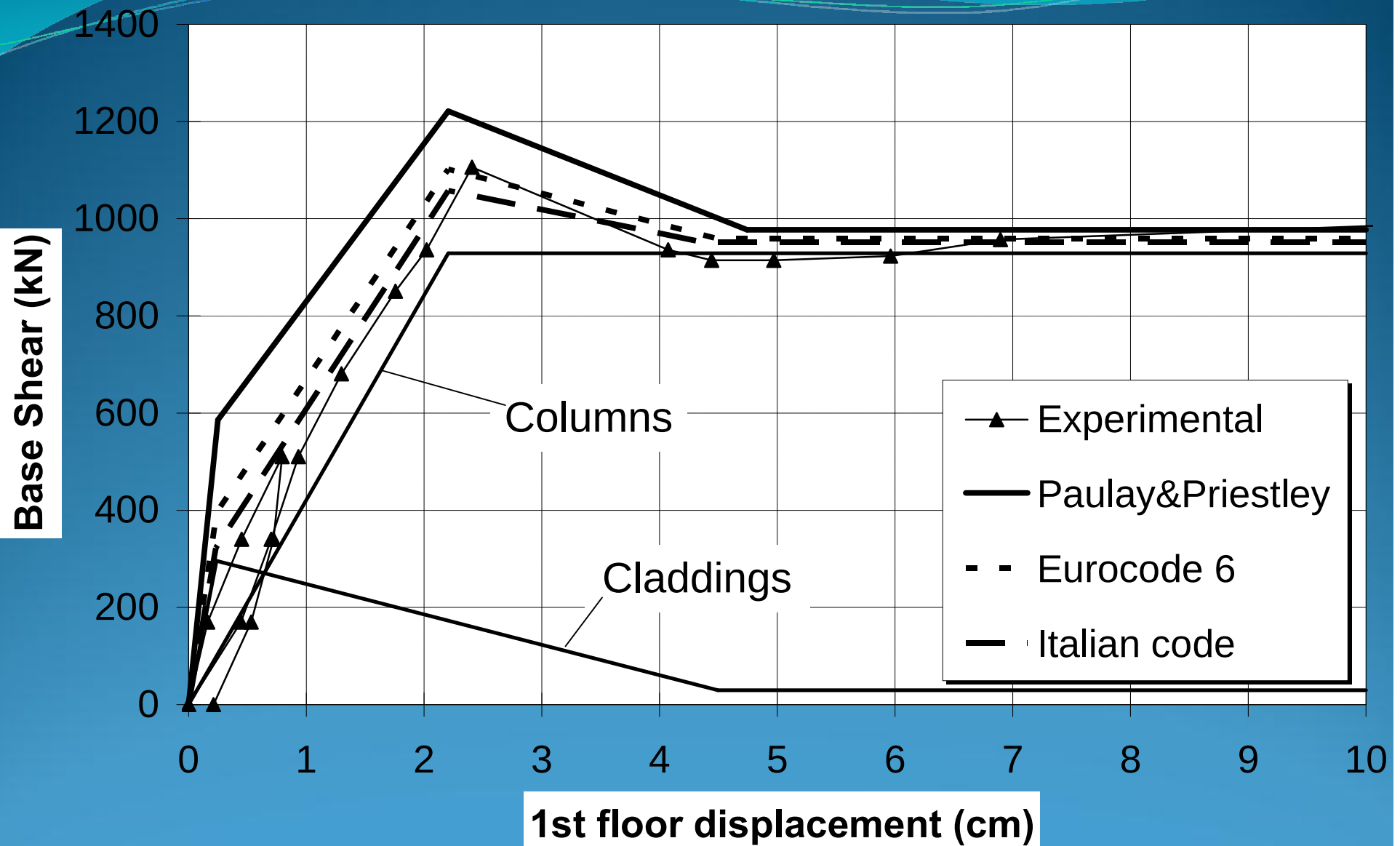
Test #1 vs. Test #2: comparison



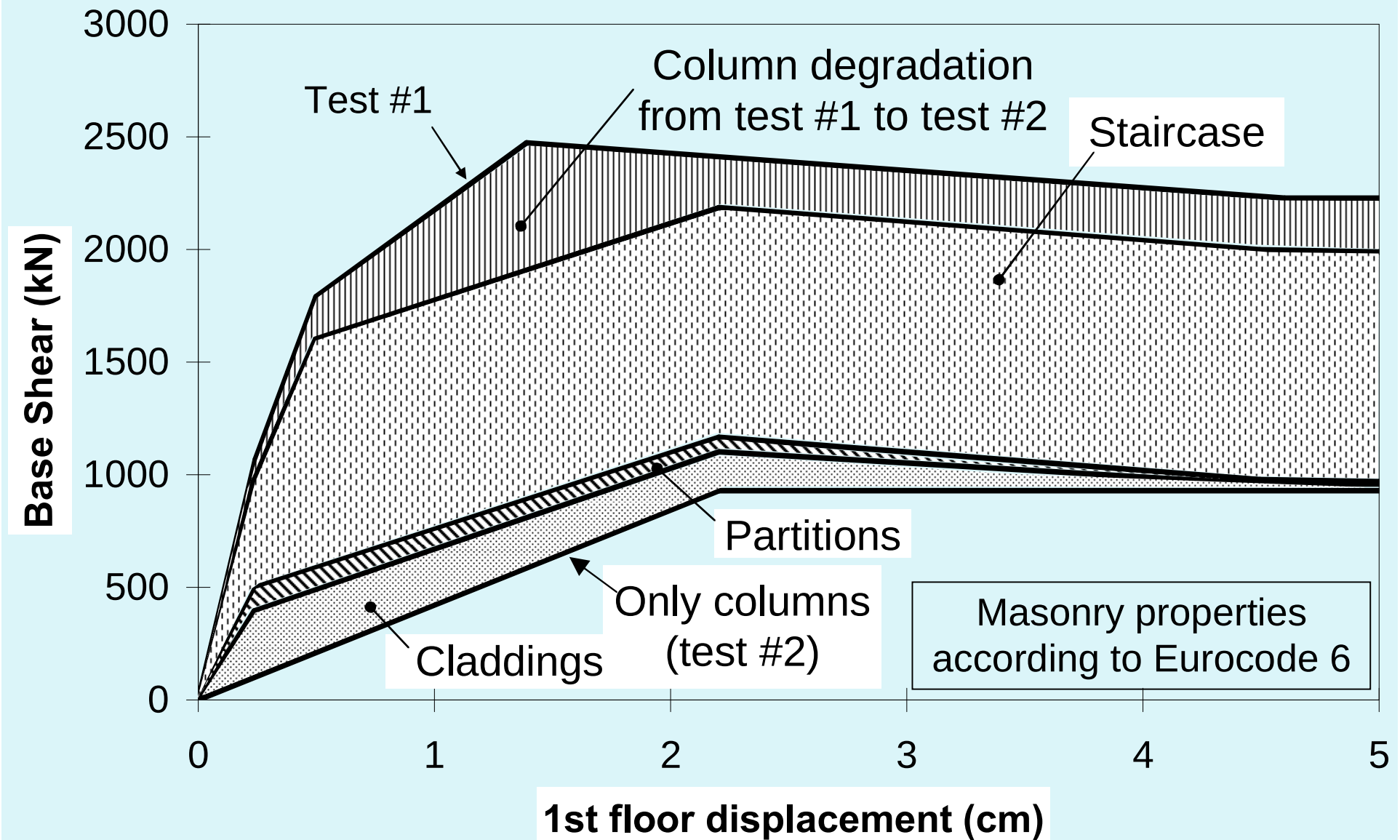
Push-pull test #2



Simulation test # 2



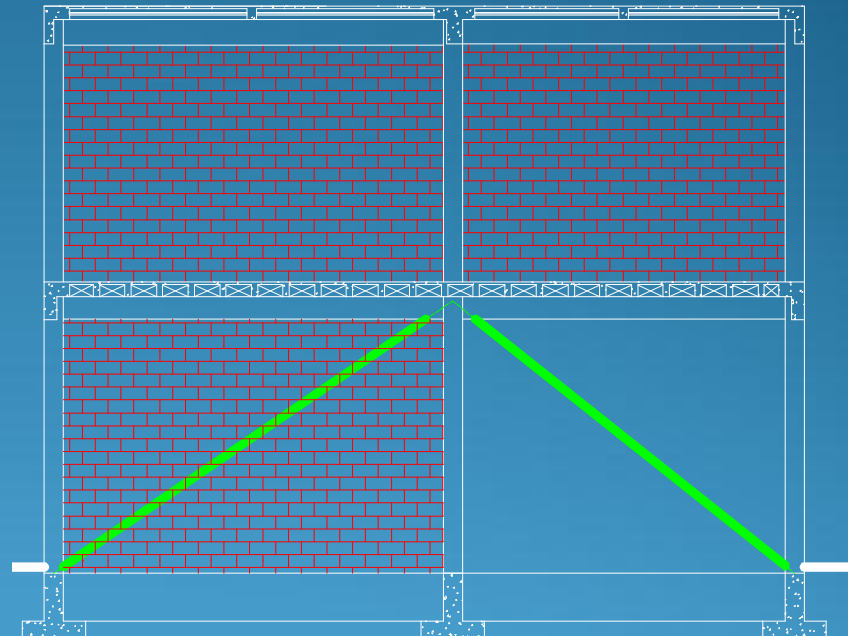
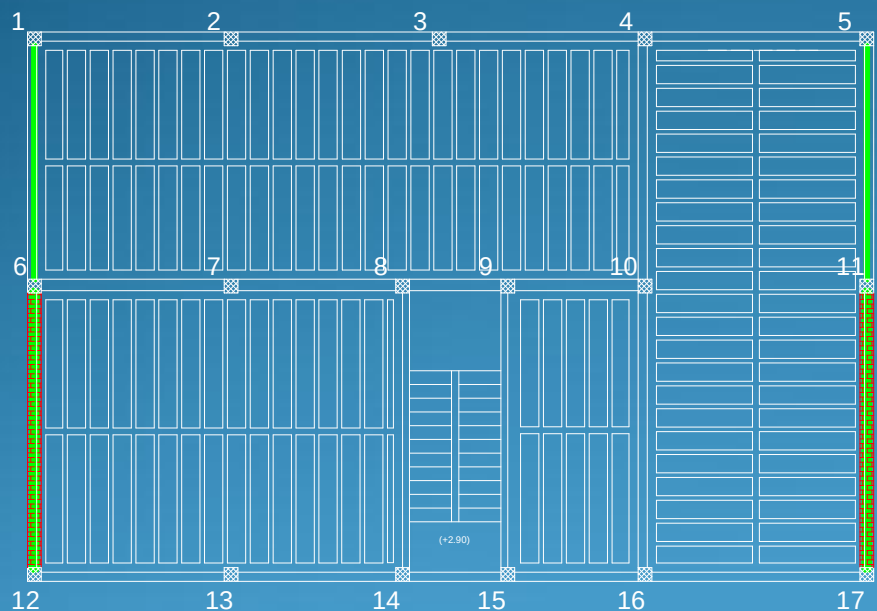
Confronto test #1- test #2



Building B – Tests # 3, 4, 5

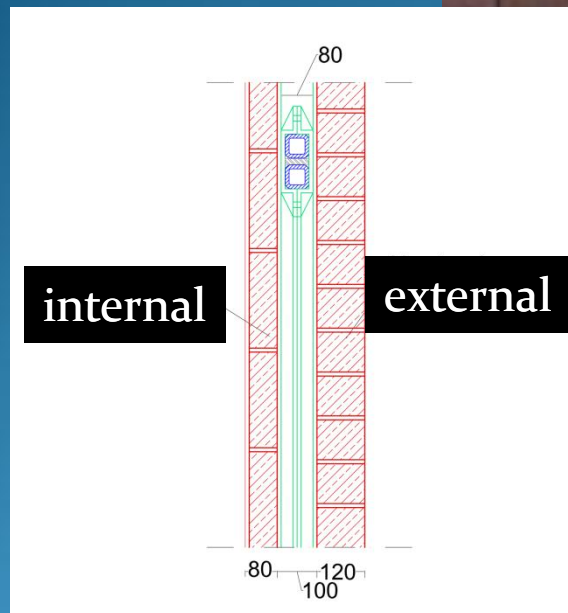
BRB arrangement

BRBs have been mounted only at the first floor and placed at the perimeter in the direction of the building short side.

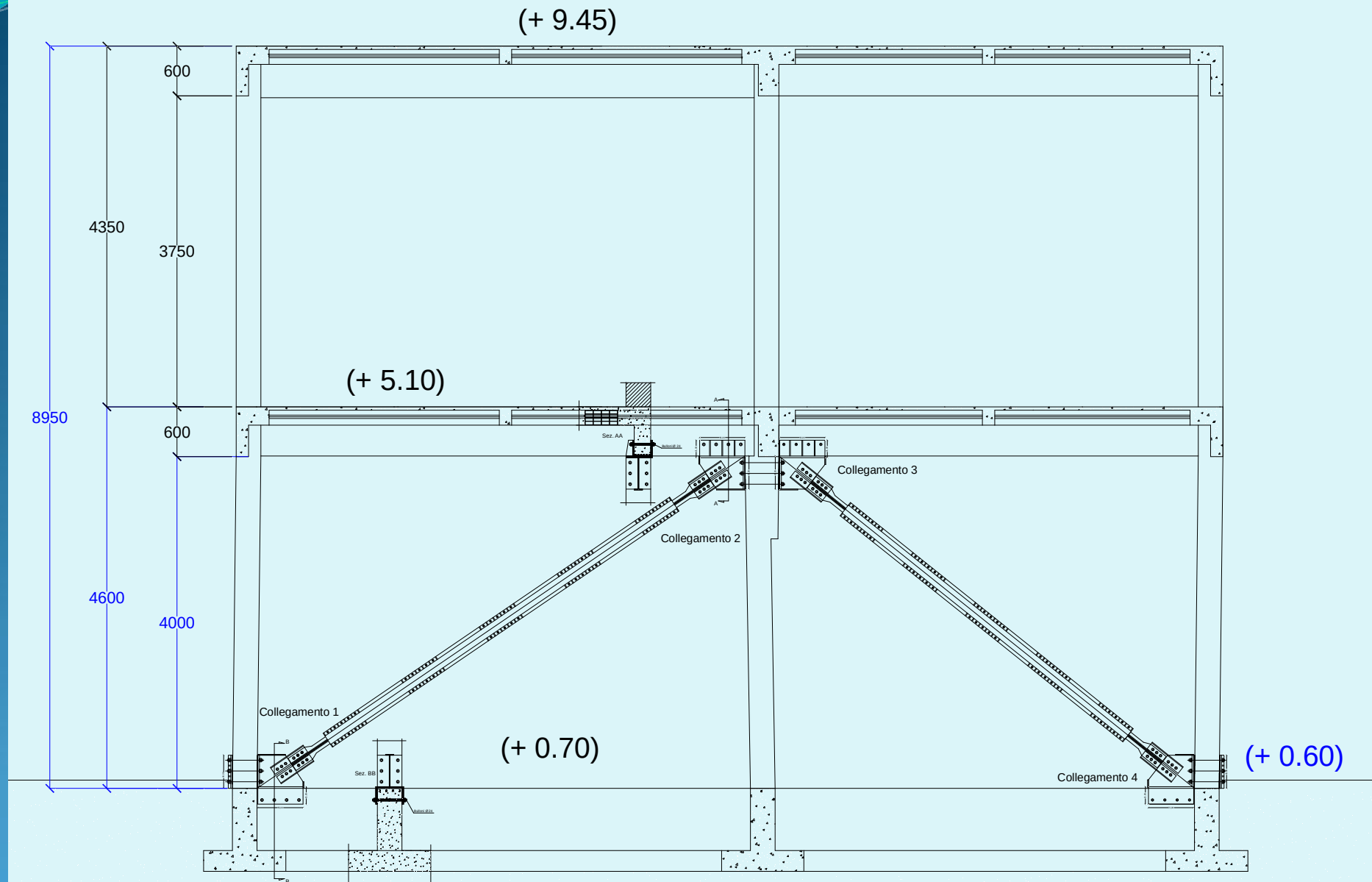


In particular, in one bay the infill wall has been reconstructed, in such a way to directly evaluate the interaction between the brace and the wall

Buckling-restrained brace inside of two masonry panels



Experimental test on building B with BRB

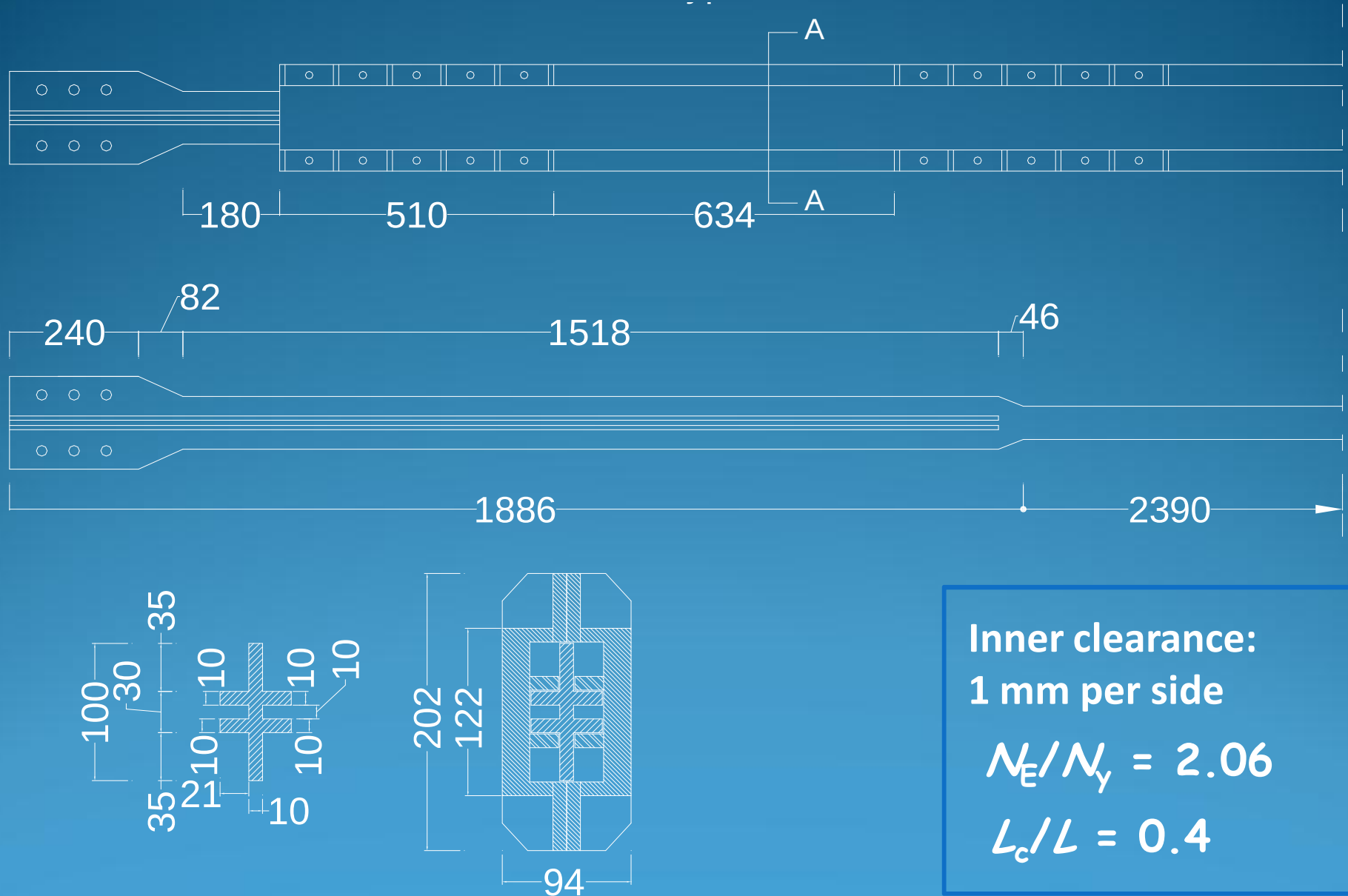


Experimental test on building B with BRB



FABRICATION PHASES

Building B – Test # 3



Inner clearance:
1 mm per side

$$N_E/N_y = 2.06$$

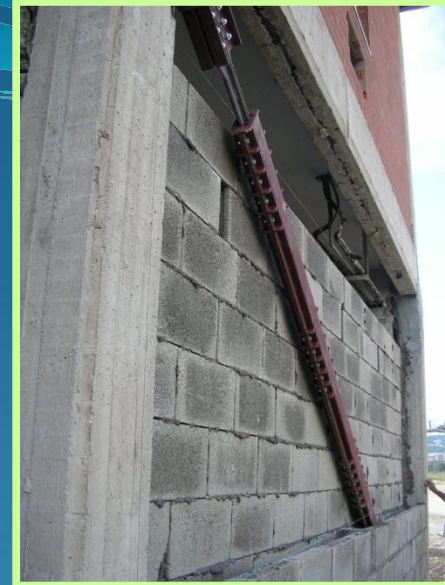
$$L_c/L = 0.4$$

Experimental test on building B with BRB



ERECTION PHASES

ERECTION PHASES



Building B - Test # 3

Braces' erection and reconstruction of infill walls



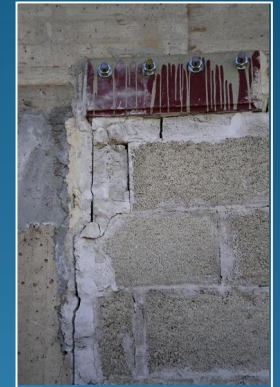
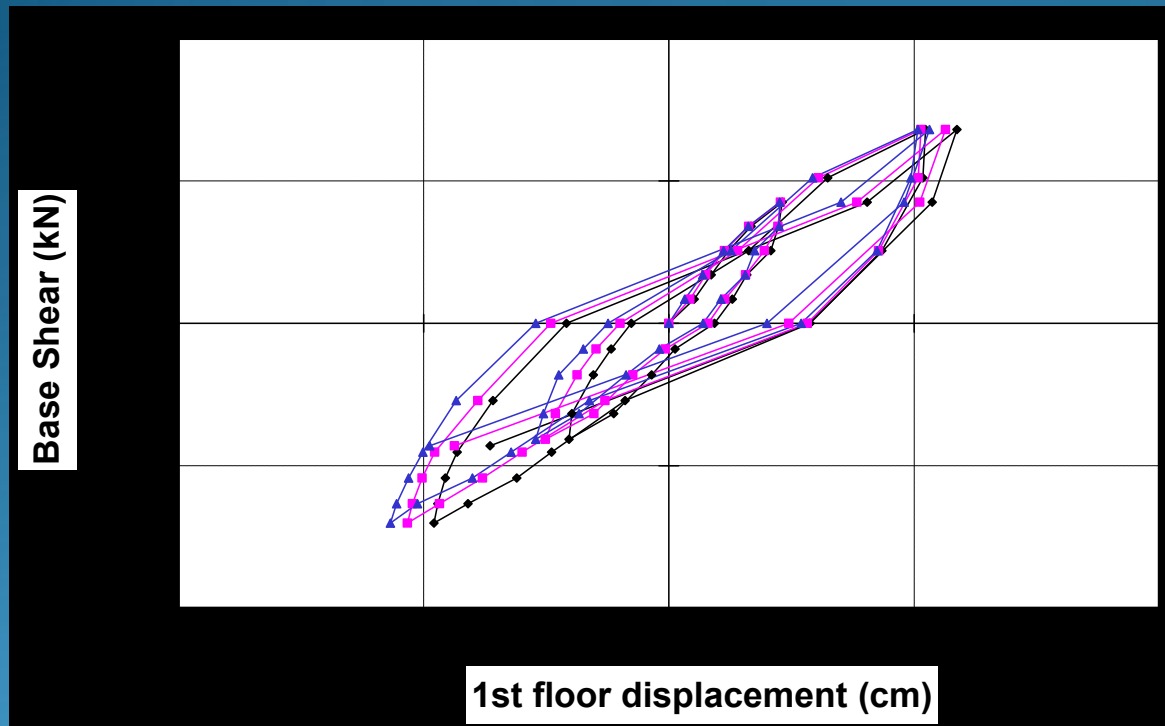


READY FOR TEST

Building B with BRB

EXPERIMENTAL RESULTS: test #3

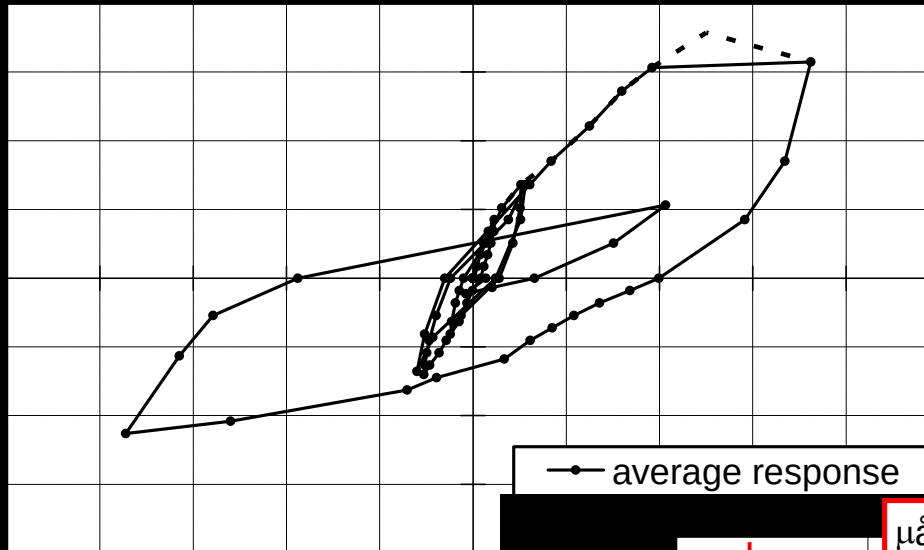
Base shear vs. first story lateral displacement relationships for the first three cycles



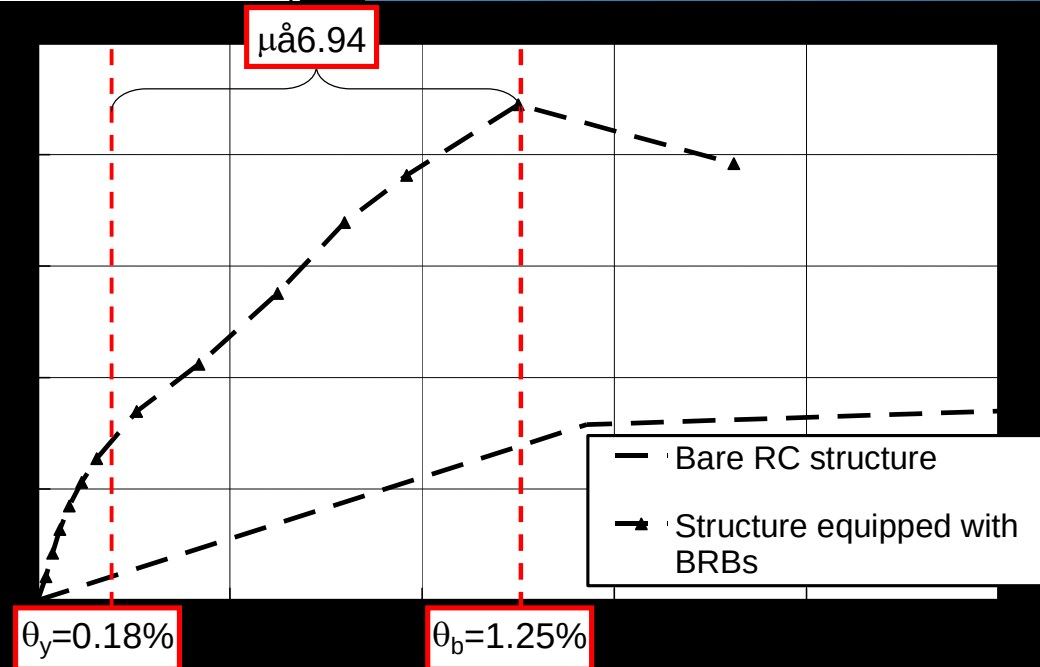
diagonal cracking and detachment between facing walls and RC structure

EXPERIMENTAL RESULTS: test #3

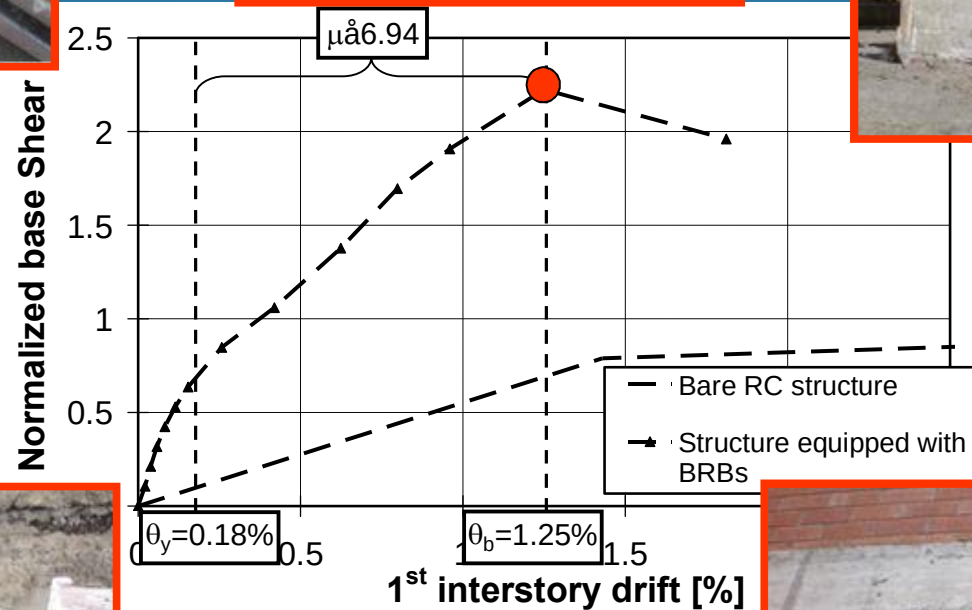
Base Shear (kN)



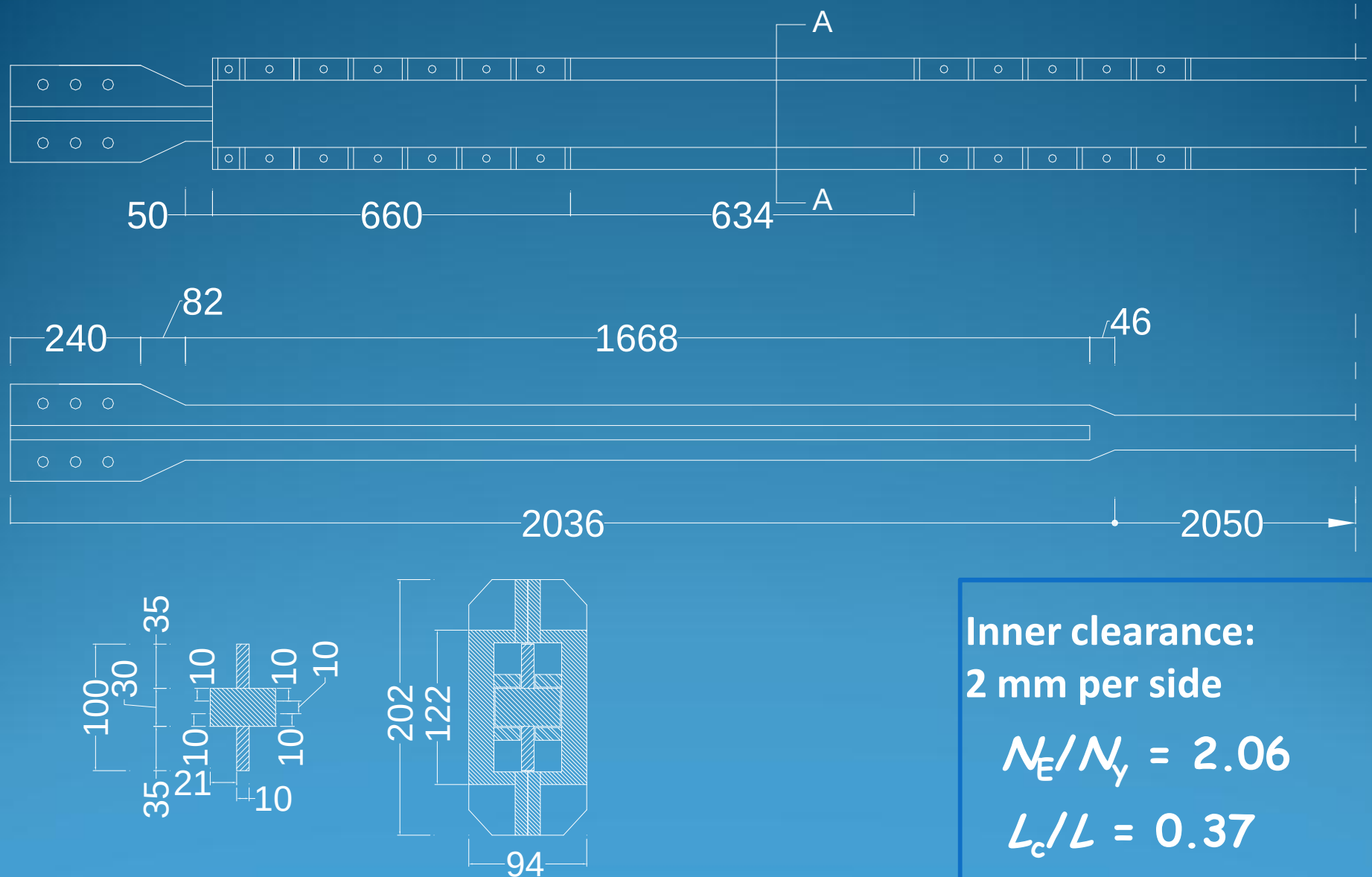
Normalized base Shear



EXPERIMENTAL RESULTS: test #3



Building B – Test # 4

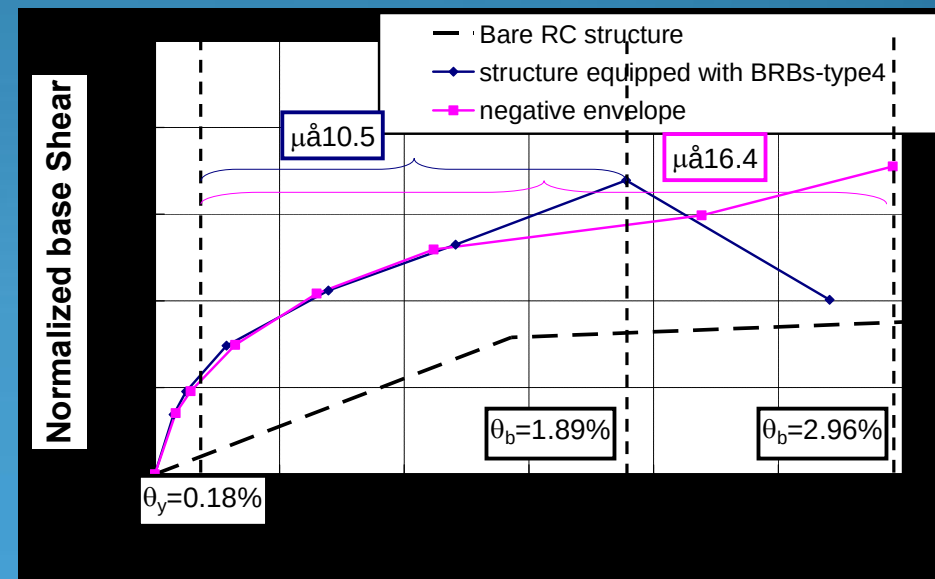
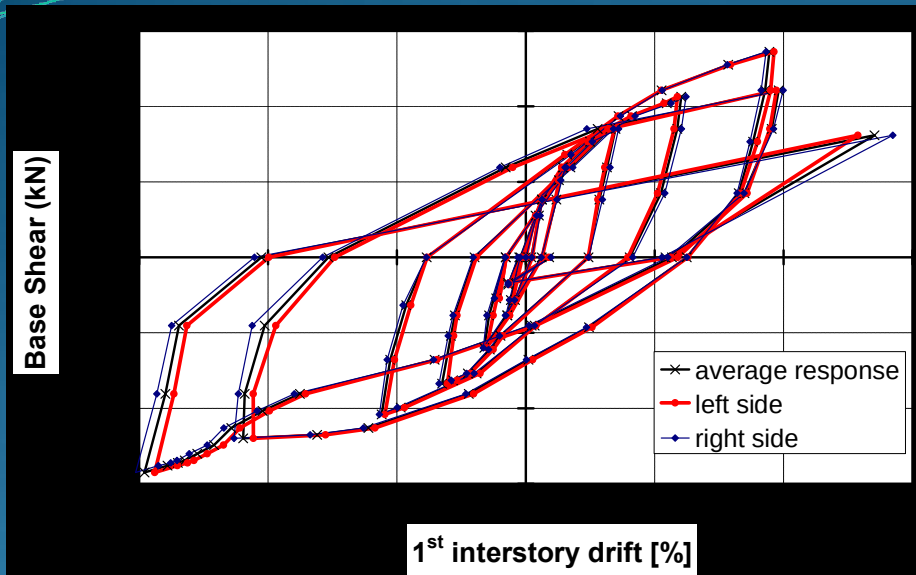


Inner clearance:
2 mm per side

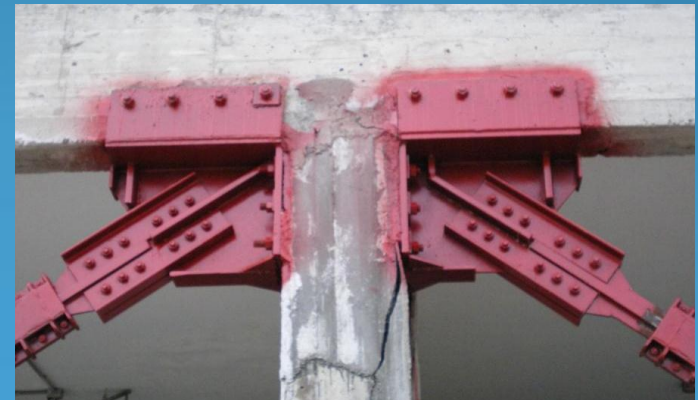
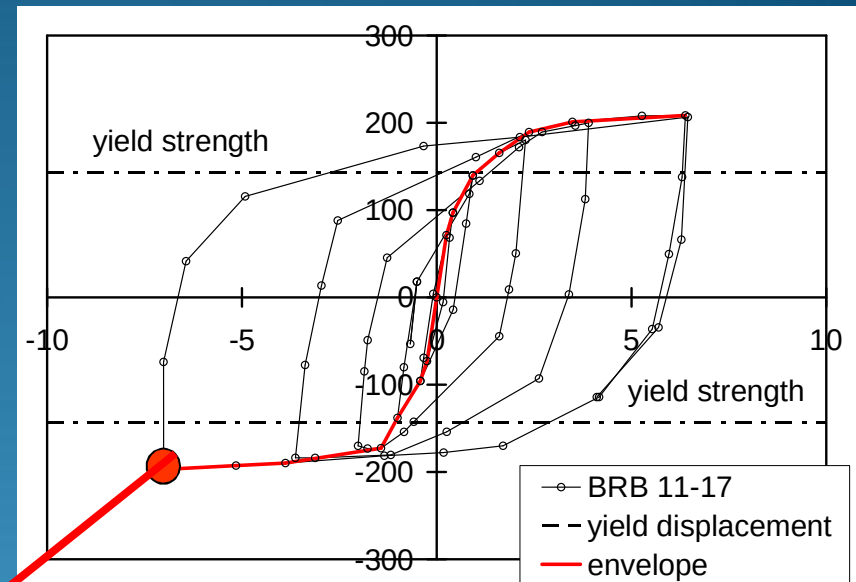
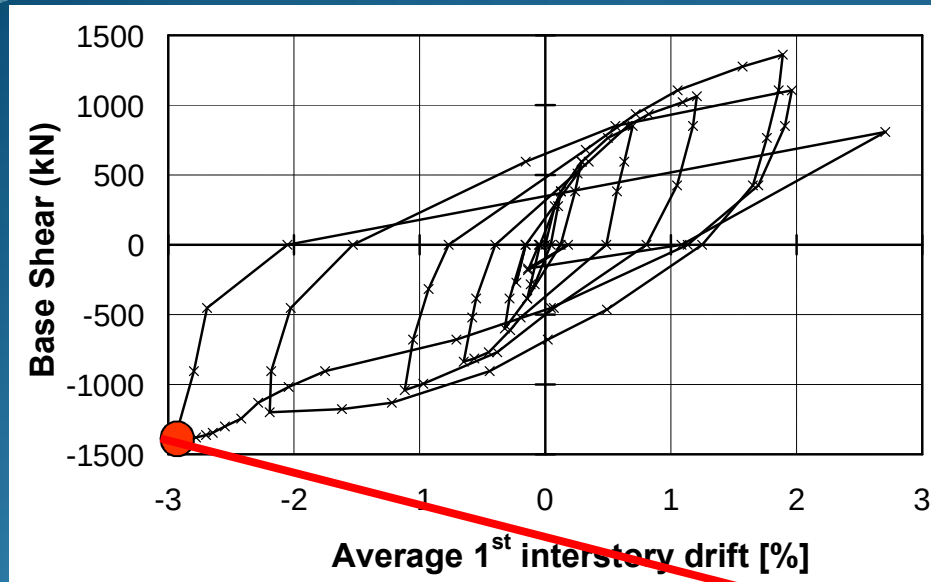
$$N_E/N_y = 2.06$$

$$L_c/L = 0.37$$

EXPERIMENTAL RESULTS: test #4



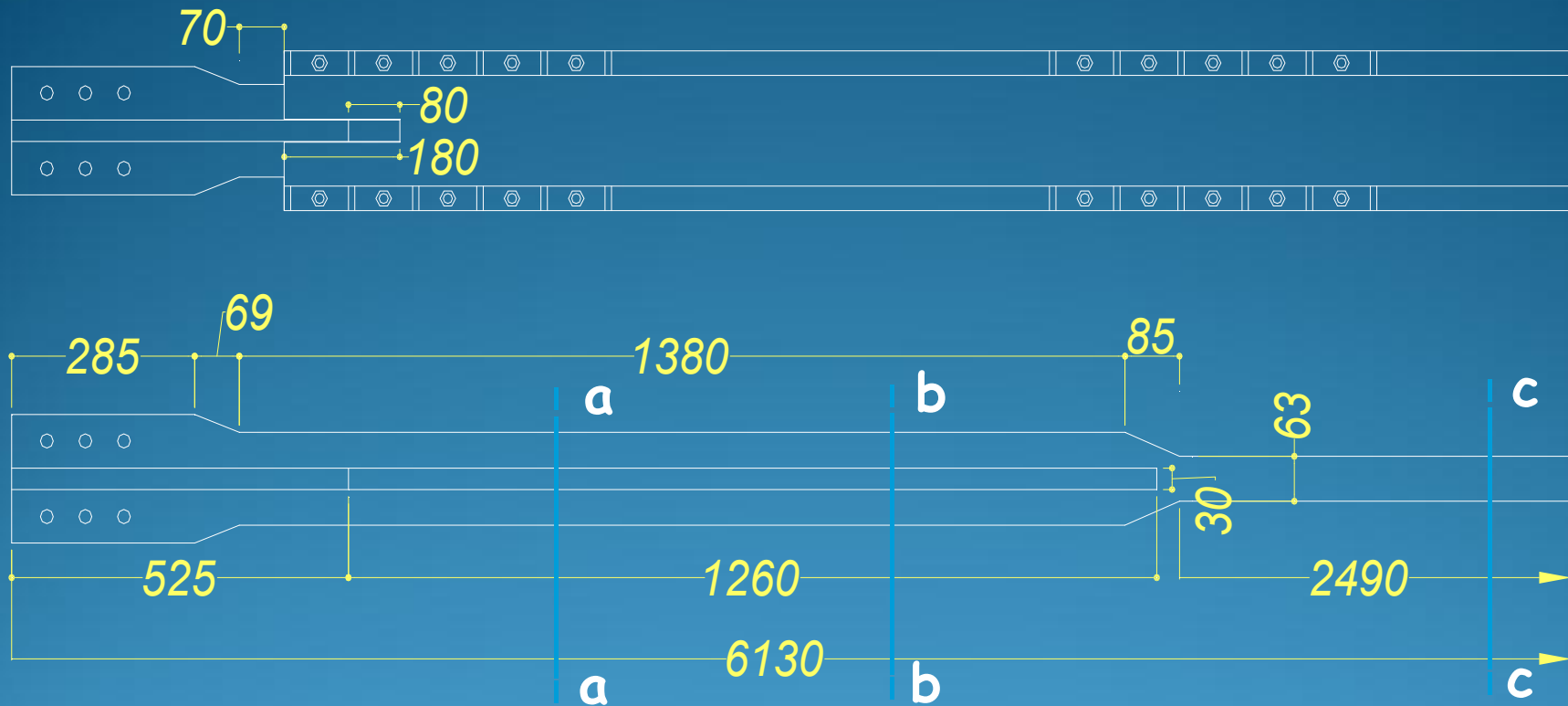
EXPERIMENTAL RESULTS: test #4



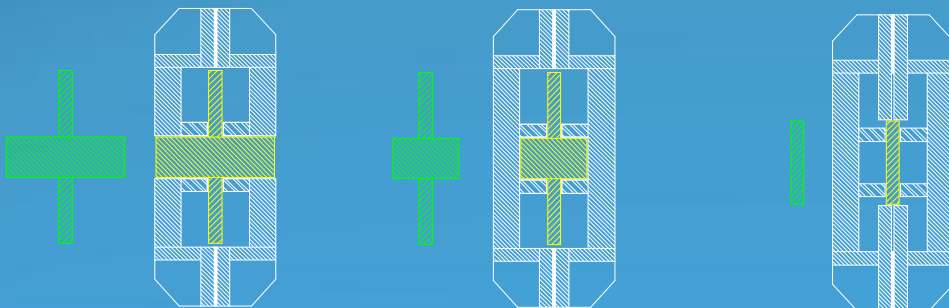
EXPERIMENTAL RESULTS: test #4



Building B – Test # 5



Section a-a Section b-b Section c-c



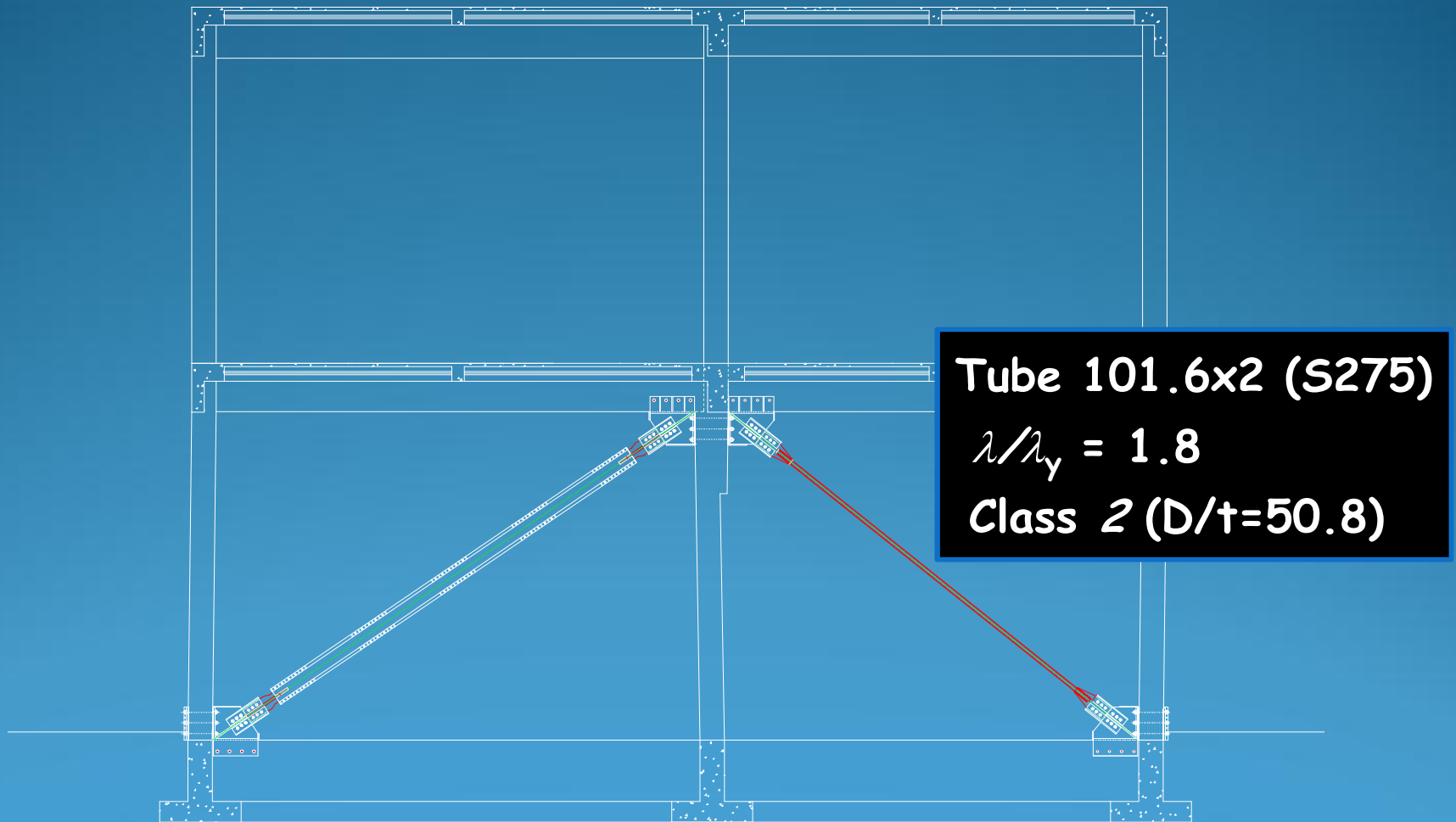
Inner clearance:
2 mm per side

$$N_E/N_y = 2.06$$

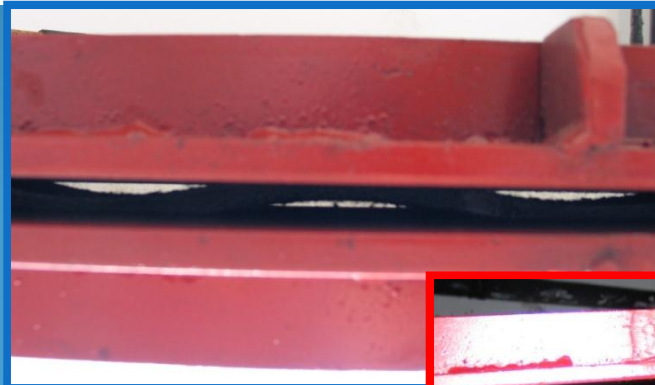
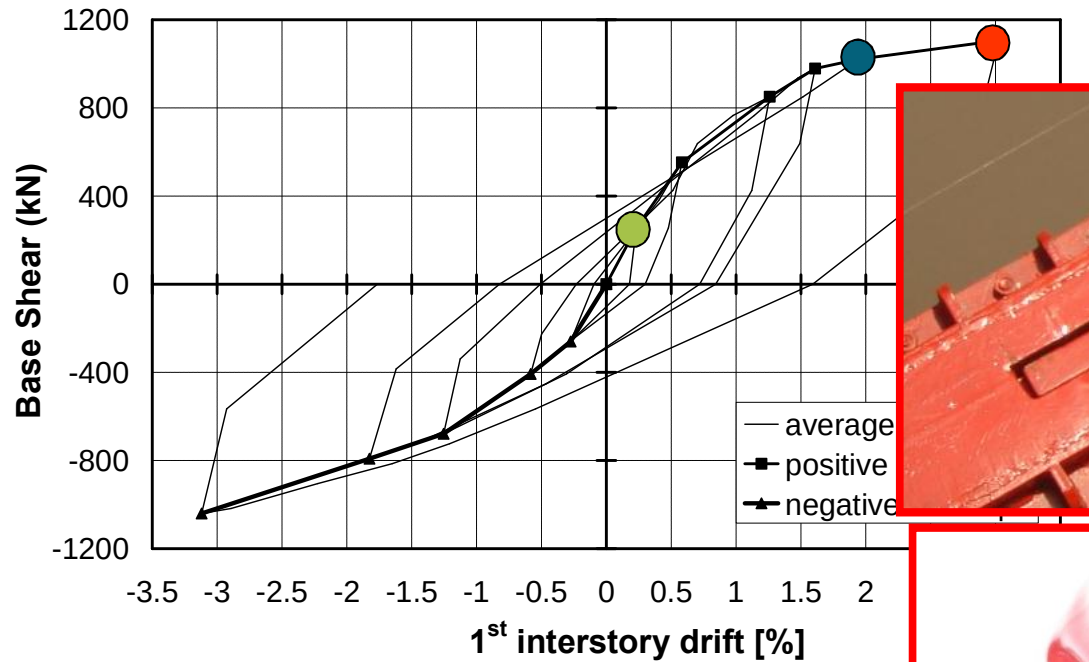
$$L_c/L = 0.4$$

Building B – Test # 5

In this test both classic concentric braces and new BRB prototypes have been tested.



Building B – Test # 5

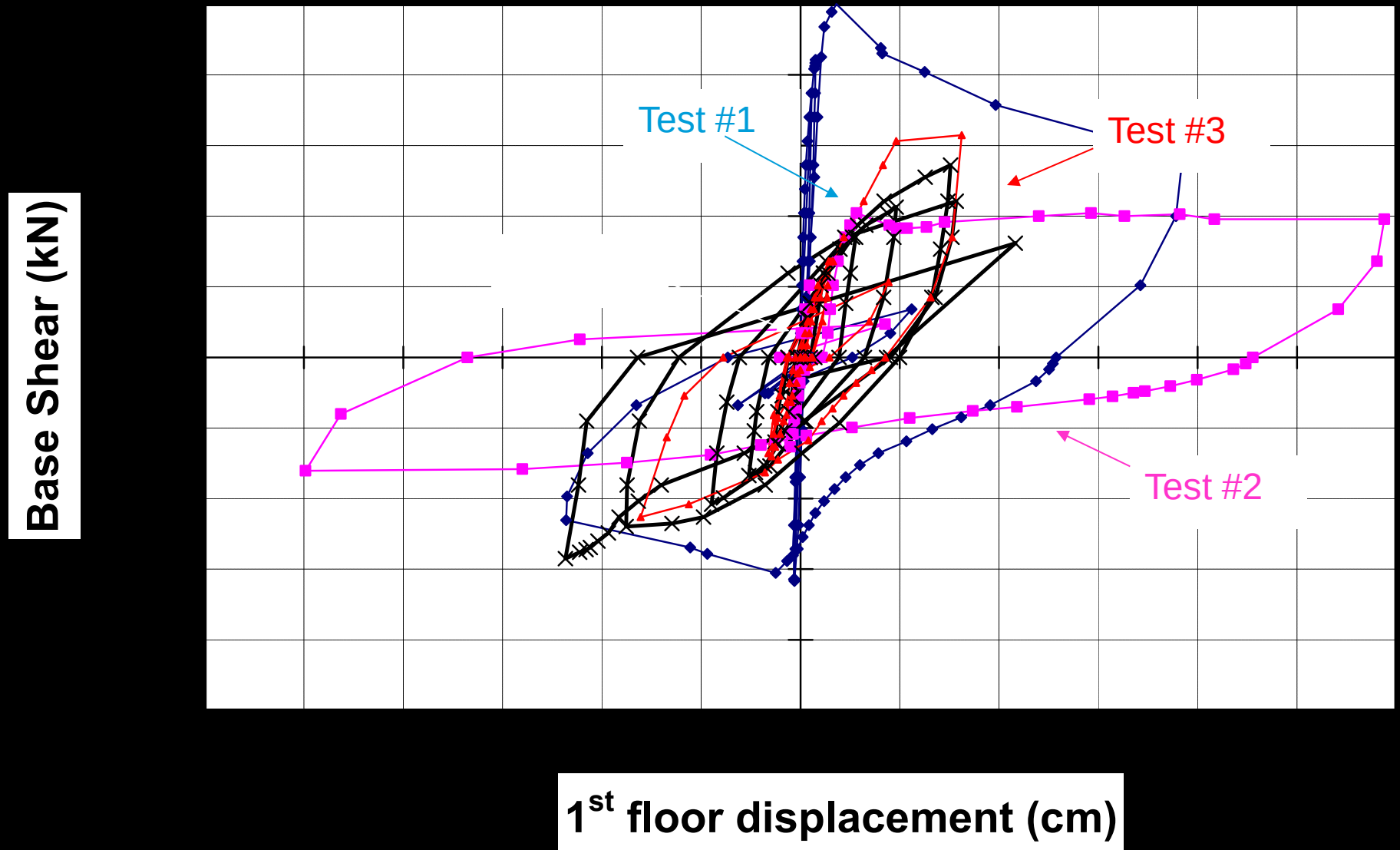


Building B – Test # 5

To improve the performance of the studied devices, in case of Prototype B some local details have been modified in such a way to increase the system “robustness”.



Test comparison



ILVA – IDEM Project

“AN INTELLIGENT DEMOLITION”

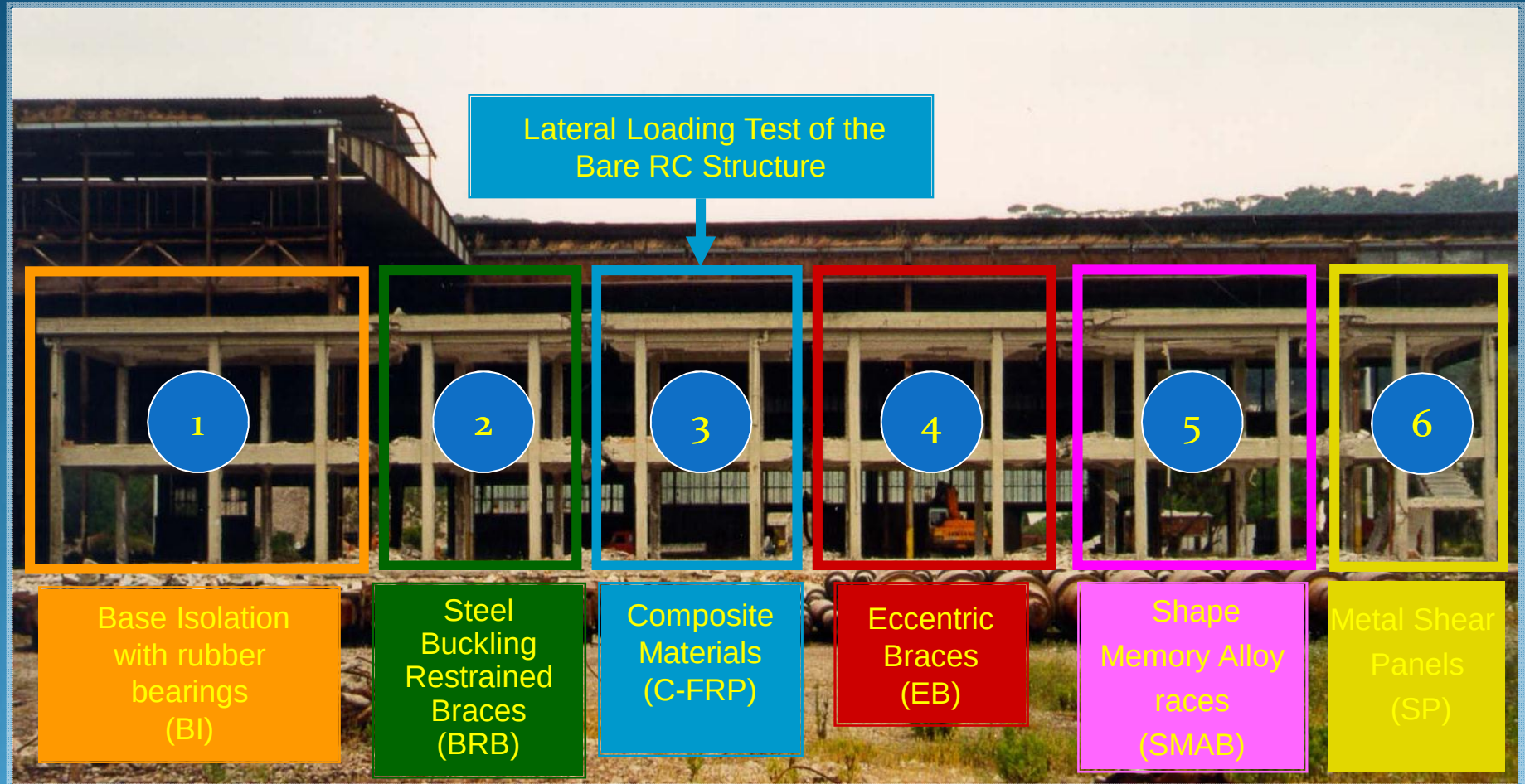
in the ex-industrial area ‘ITALSIDER’

ON-FIELD EXPERIMENTAL INVESTIGATION ON THE SEISMIC
BEHAVIOUR OF RC STRUCTURES AND INNOVATIVE RETROFITTING
TECHNIQUES



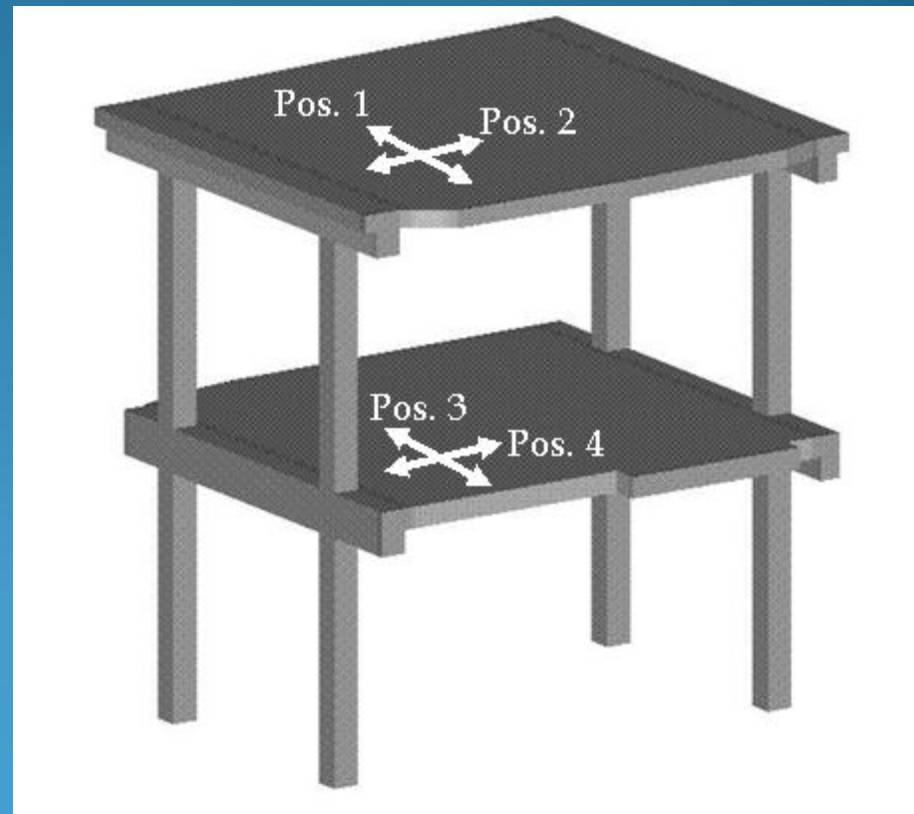
Federico M. Mazzolani
Department of Structural Analysis and Design
Faculty of Engineering
University of Naples “Federico II”

BUILDING A (substructuring)



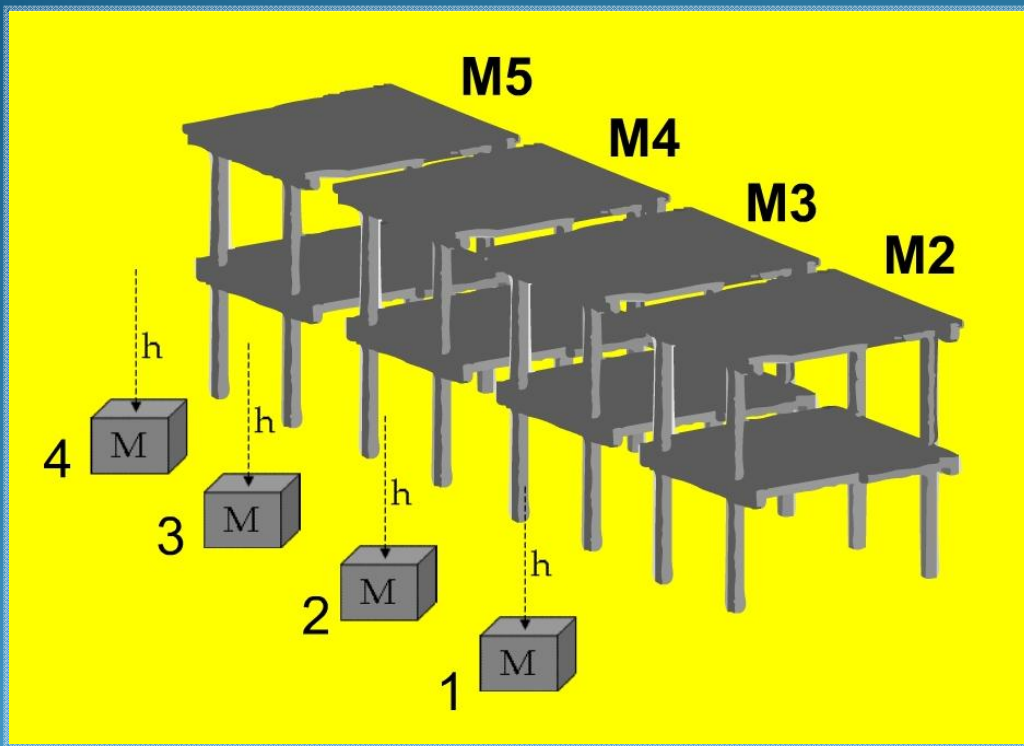
Dynamic Identification Tests on the bare structure

Dynamic shaker (vibrodyne) test



Dynamic Identification Tests on the bare structure

Falling mass Test



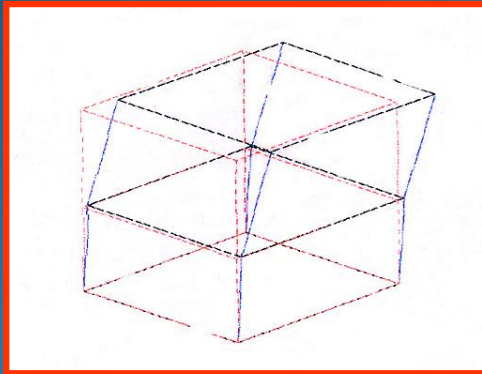
Dynamic Identification Tests on the bare structure

Impacting hammer test

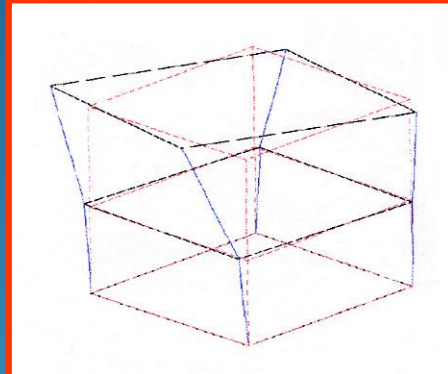


Dynamic Identification Tests results

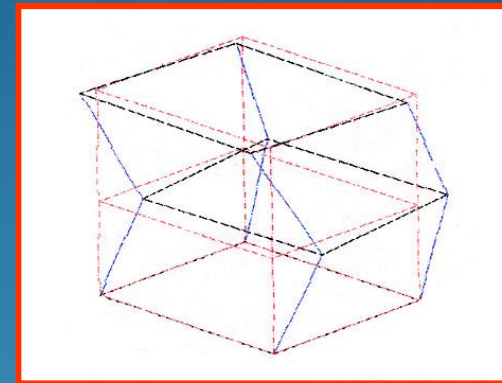
Mode 1



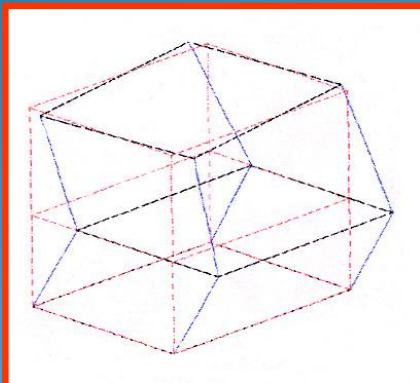
Mode 2



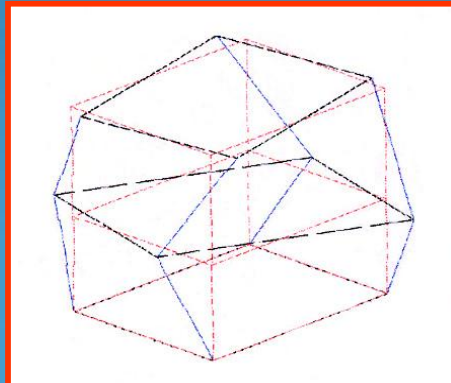
Mode 3



Mode 4



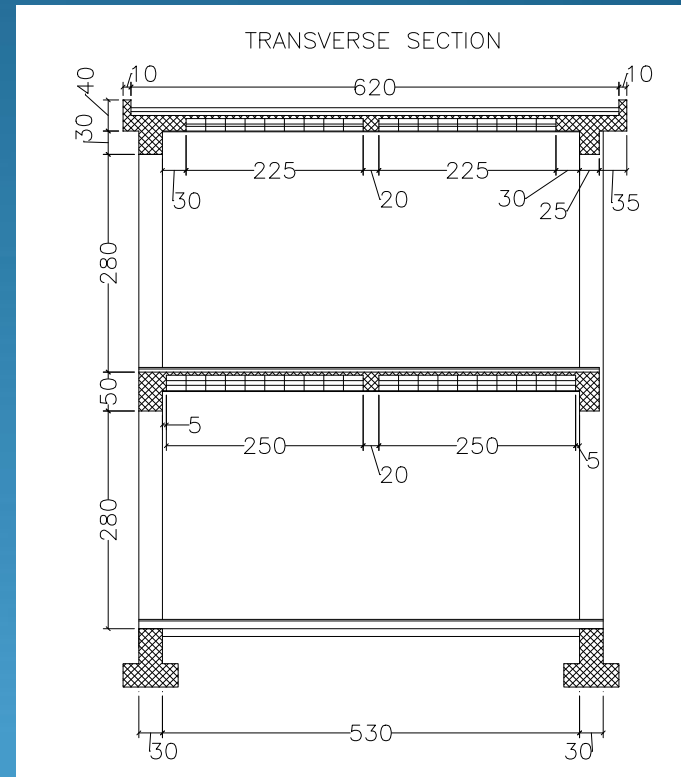
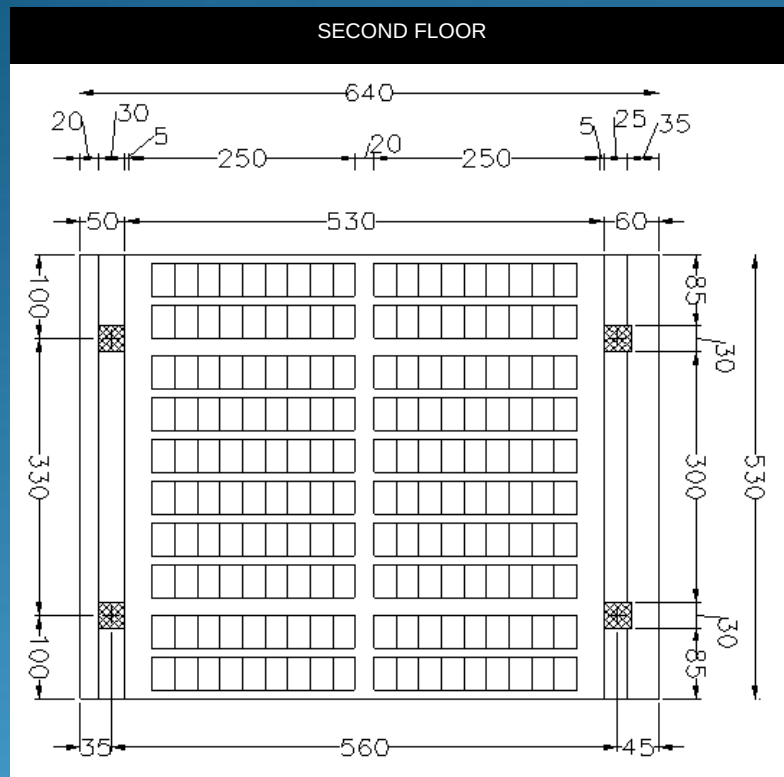
Mode 5



Mode	Frequency (Hz)	Damping (%)
1	1.44	2.7
2	2.20	3.0
3	4.63	2.5
4	5.56	6.3
5	6.85	2.6

Push-over test on the bare RC structure

GEOMETRY OF THE STRUCTURE



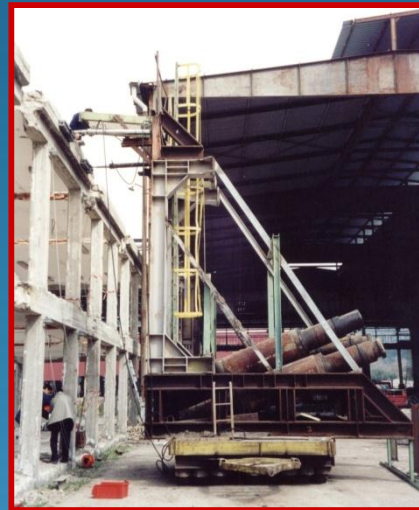
←
Direction
of
Loading

↑
Direction of Loading

Prof. F.M. Mazzolani - UNIVERSITY of NAPLES "FEDERICO II"

Push-over test on the bare RC structure

LOADING AND MEASURING DEVICES



General views of the reacting structure

Displacement measuring devices



Close-up views of the reacting structure with the load jacks

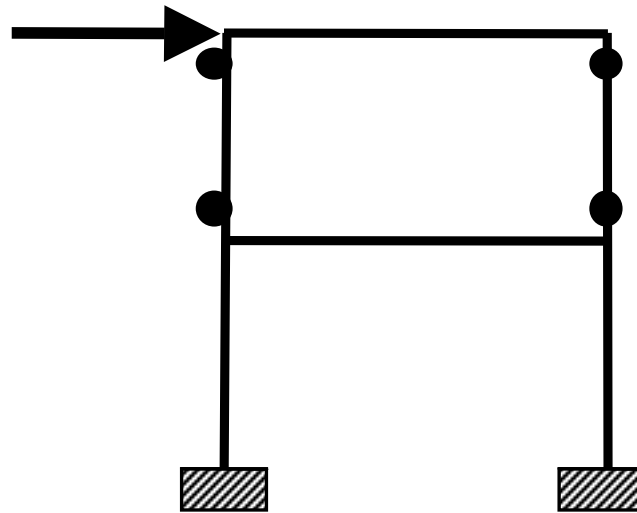


Push-over test on the bare RC structure

PHYSICAL TEST RESULTS



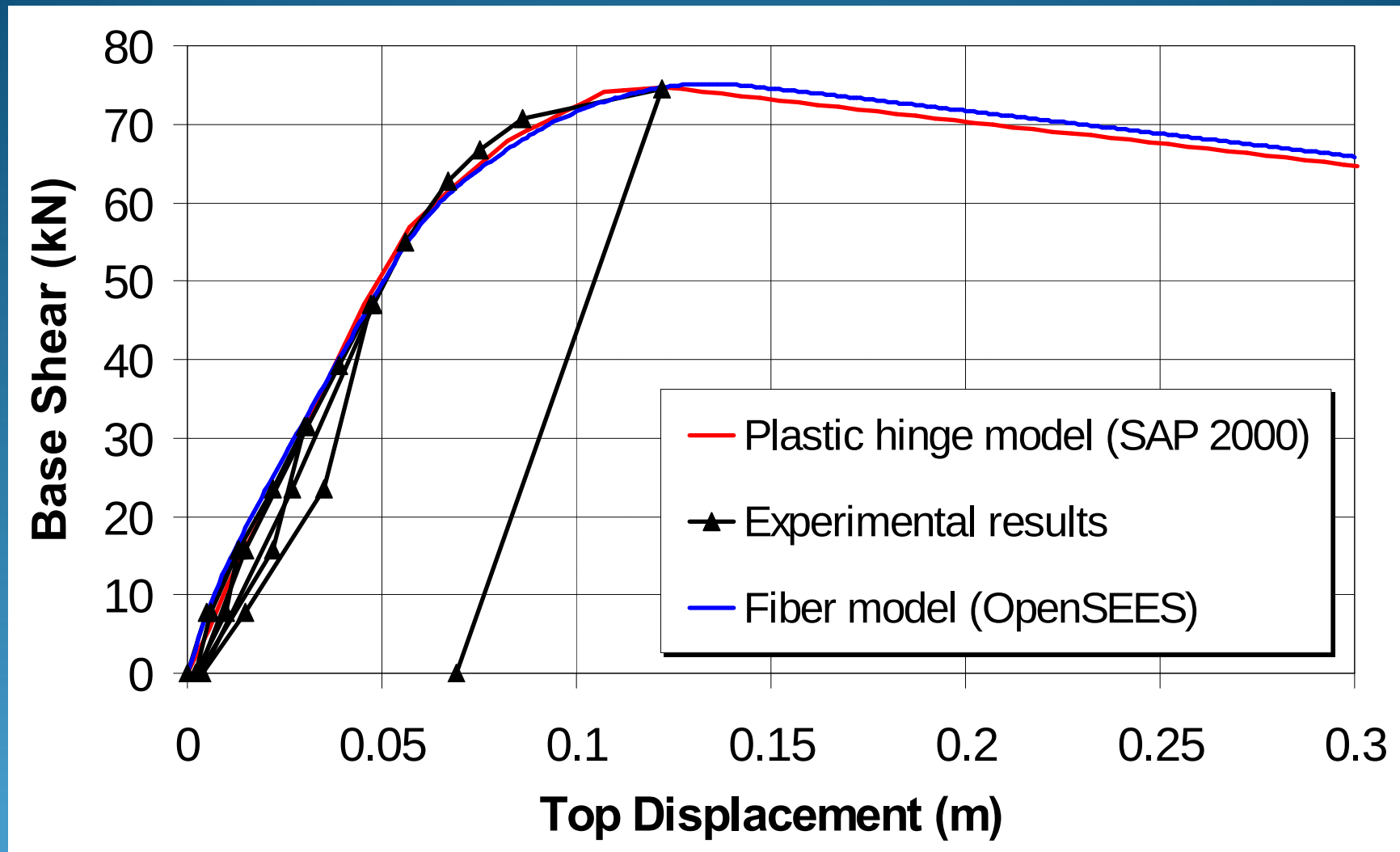
collapse mechanism



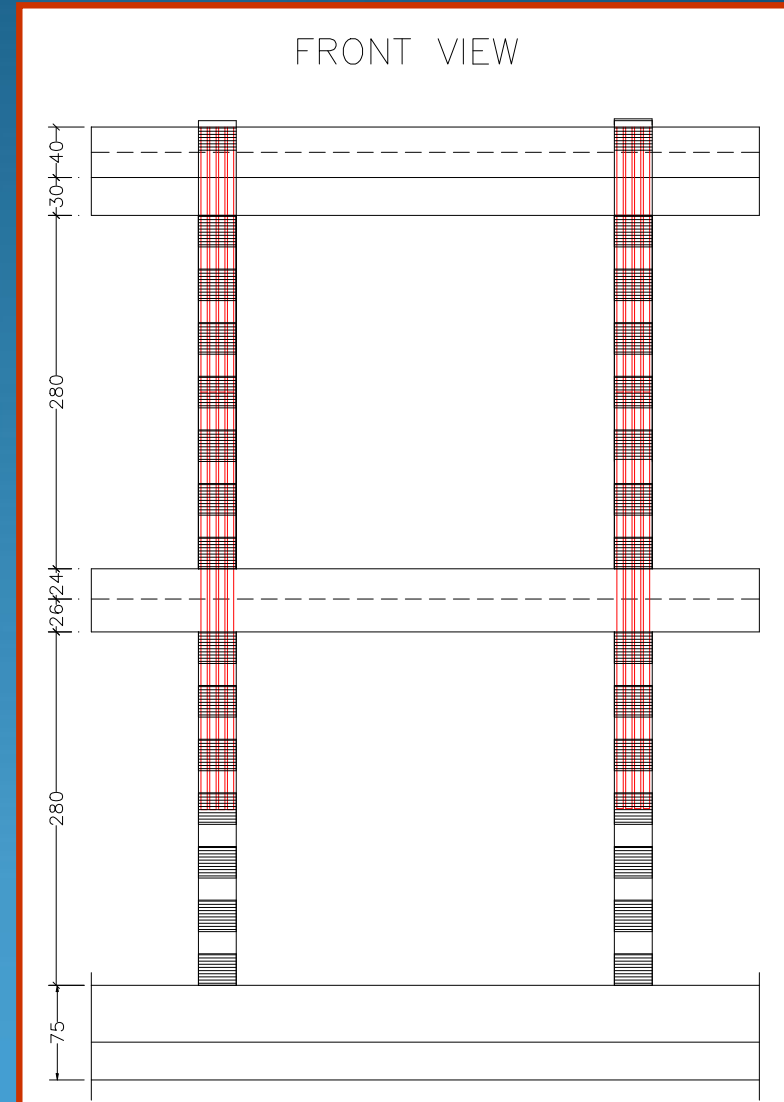
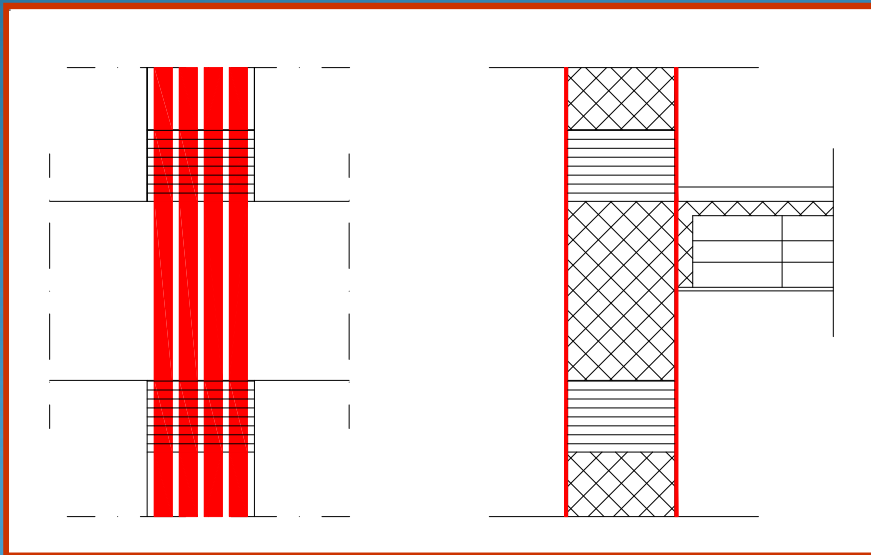
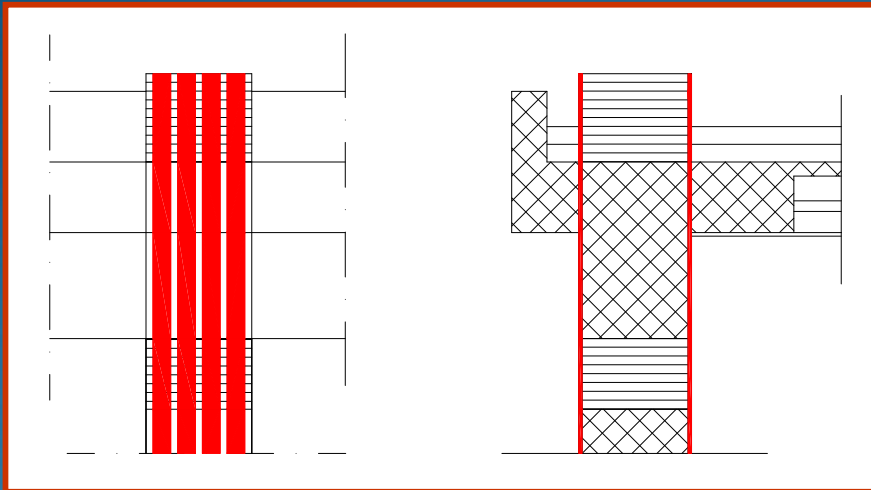
views of plastic



Push-over test on the bare RC structure



Composite fiber reinforced materials



REPAIRING EXECUTION

CFRP system application



Composite fiber reinforced materials

LOADING AND MEASURING DEVICES



General views of the reacting structure



Close-up views of the reacting structure with the load jacks



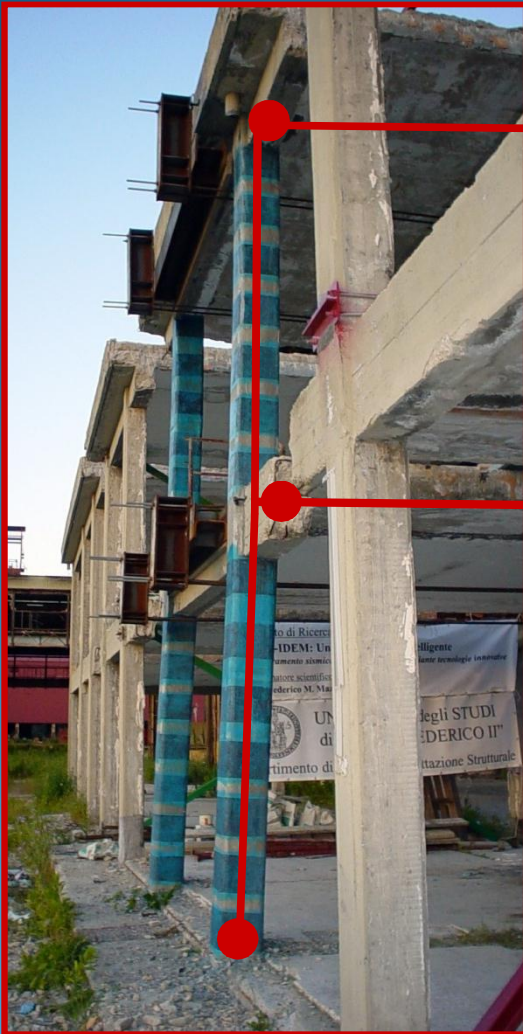
Displacement measuring devices



Composite fiber reinforced materials

PHYSICAL TEST RESULTS: damage pattern

Global collapse mechanism



Close-up views of plastic hinges at the column bases



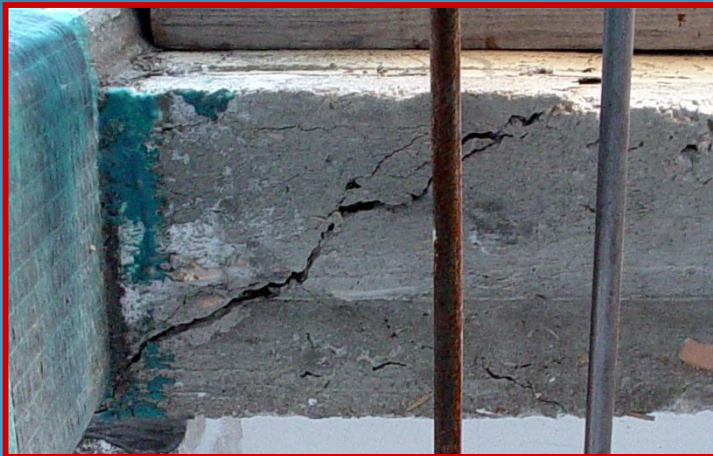
Composite fiber reinforced materials

PHYSICAL TEST RESULTS: damage pattern

Peeling off at a wrong end detail



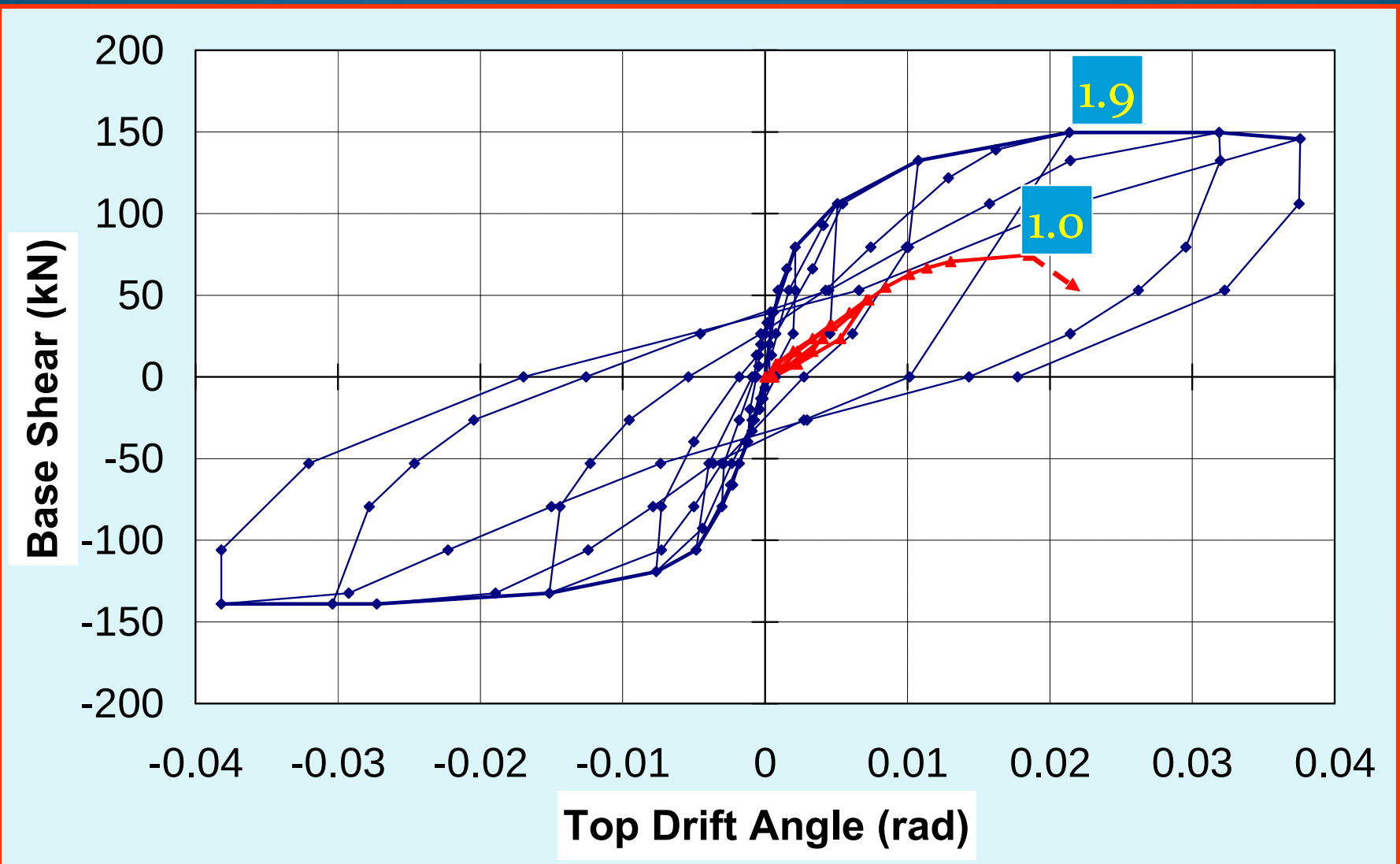
Cracking of beams in torsion



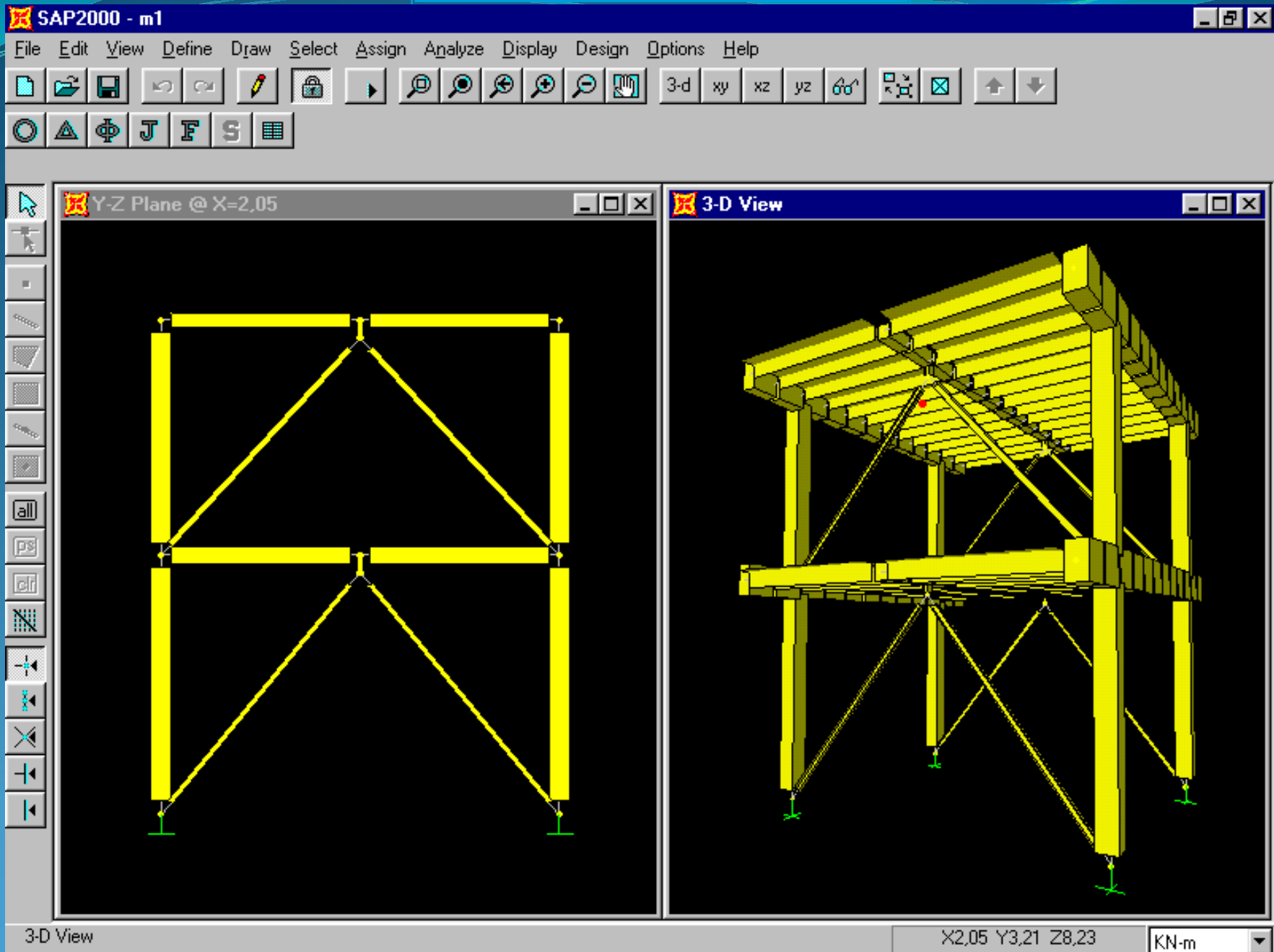
Local buckling of free length portions of strips



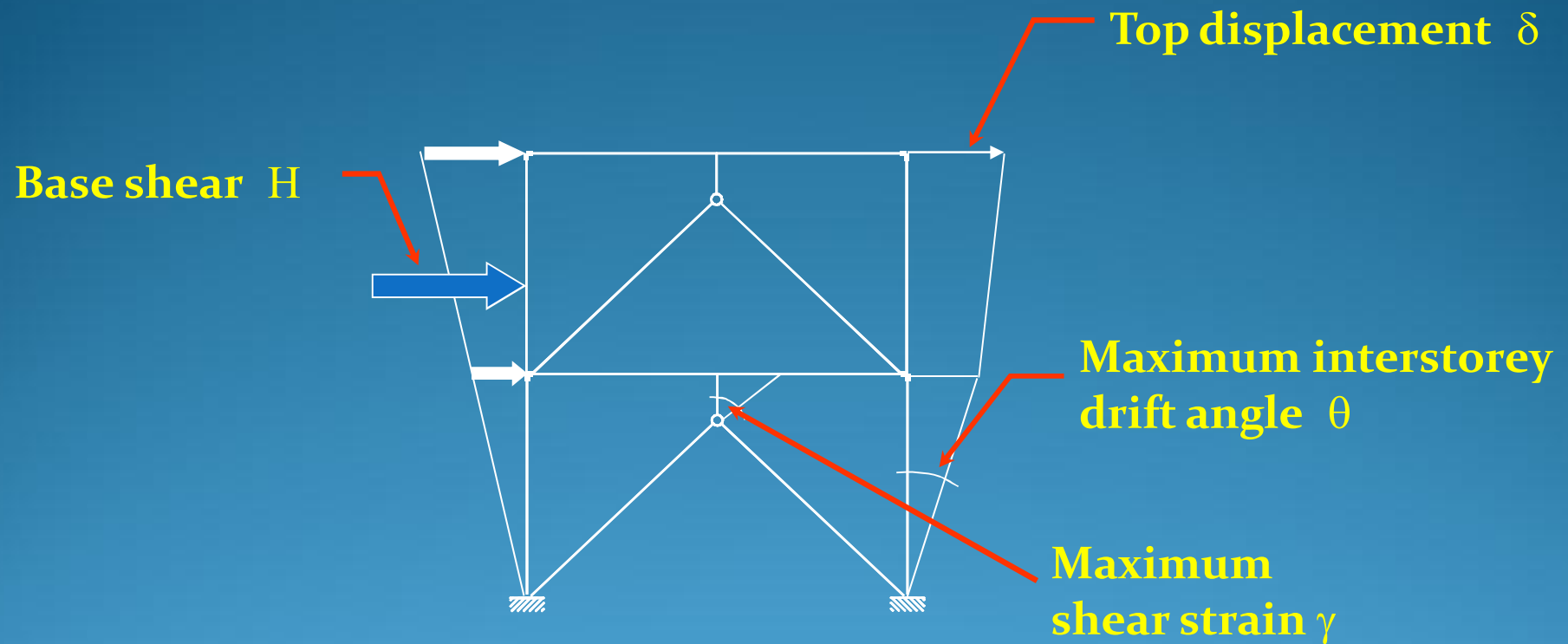
Composite fiber reinforced materials



STRUCTURAL MODEL

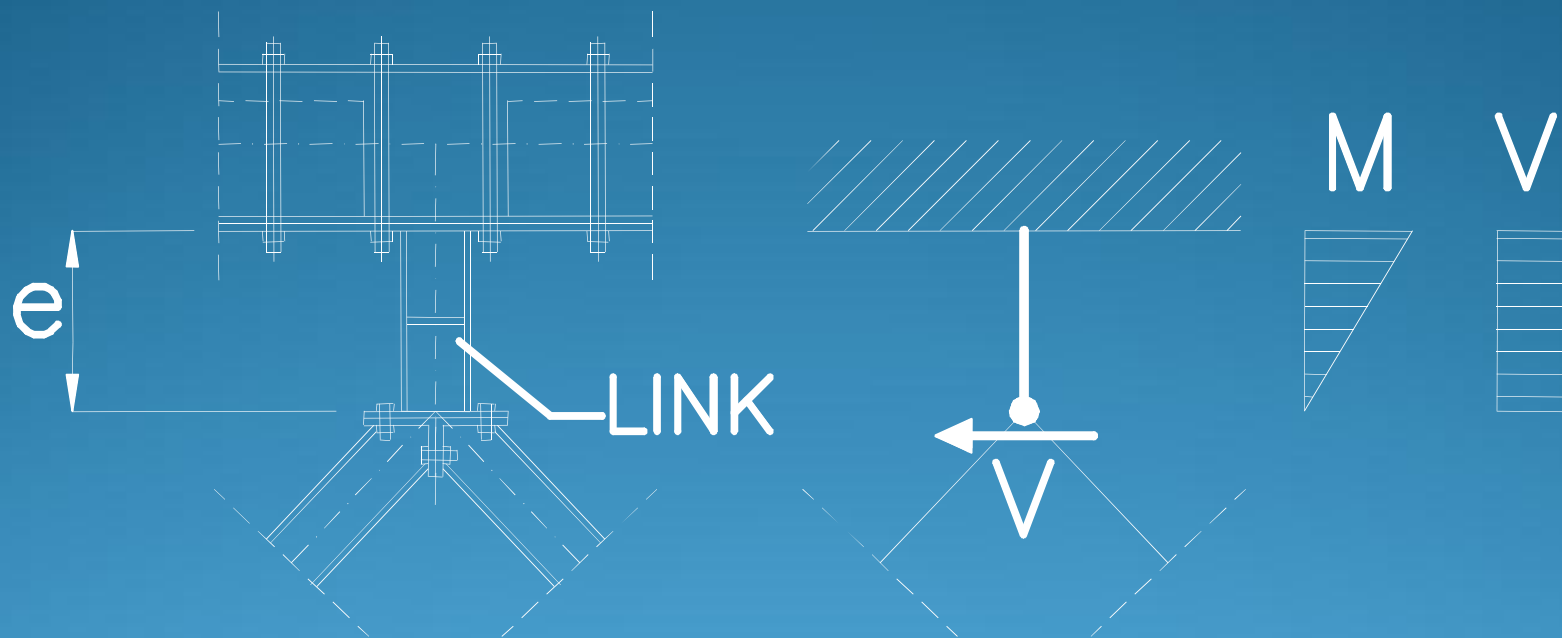


PUSHOVER ANALYSIS



DESIGN CRITERIA OF LINK

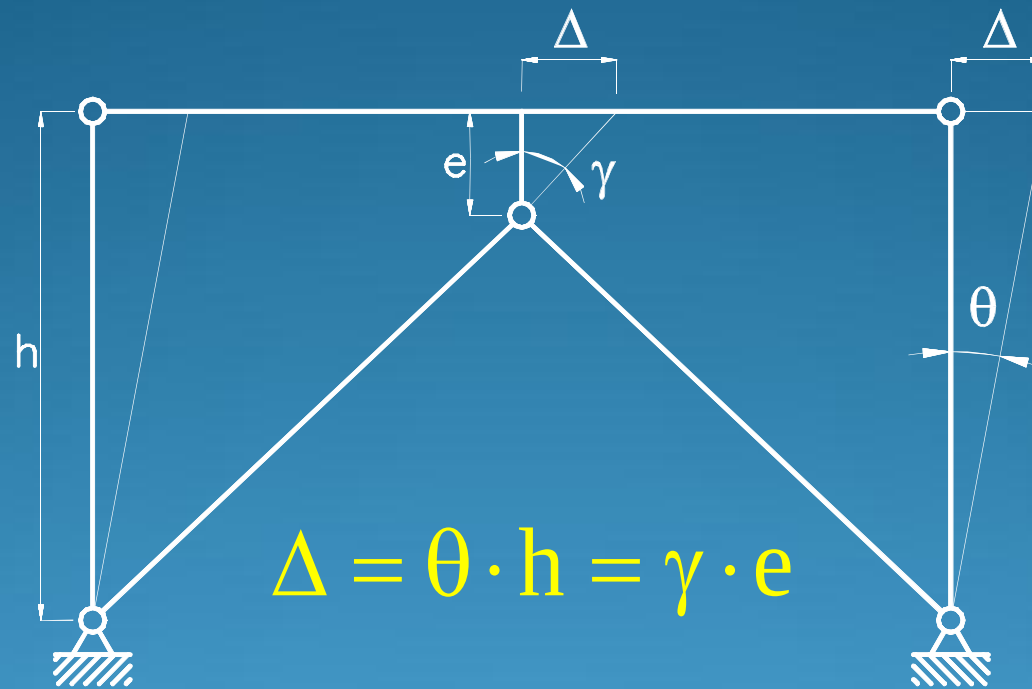
SHORT LINK (Shear dissipative mechanism)



$$1.5 \cdot V_p \cdot e \leq 1.2 \cdot M_p \quad \longrightarrow \quad e \leq 0.8 \frac{M_p}{V_p}$$

DESIGN CRITERIA OF LINK

SERVICEABILITY LIMIT STATE



$$\theta_{SLS} = \frac{\theta_u}{v} = \frac{\gamma_u \cdot e}{v \cdot h} \leq 0.004 \quad \Rightarrow \quad e \leq 0.004 \frac{v \cdot h}{\gamma_u}$$

DESIGN OF LINK

Input data

- Seismic weight : $W_{\text{tot}} = 604.22\text{kN}$
- Peak ground acceleration : $\text{PGA} = 0.35g$
- q – factor : $q = 5.5$ (for EBF)
- Ultimate shear plastic strain of link : $\gamma_u = \pm 0.10\text{rad}$
- Interstorey : $h = 3.00\text{m}$
- ν - factor : $\nu = 2$
- Steel grade Fe430 : $f_y = 275\text{N/mm}^2$

Output data

- Design base shear : $H_d = 96.13\text{kN}$
- Plastic shear resistance of link : $V_d = H_d / 2 = 48.07\text{kN}$
- Length of link : $e \leq 0.004 \frac{\nu \cdot h}{\gamma_u} = 24\text{cm}$

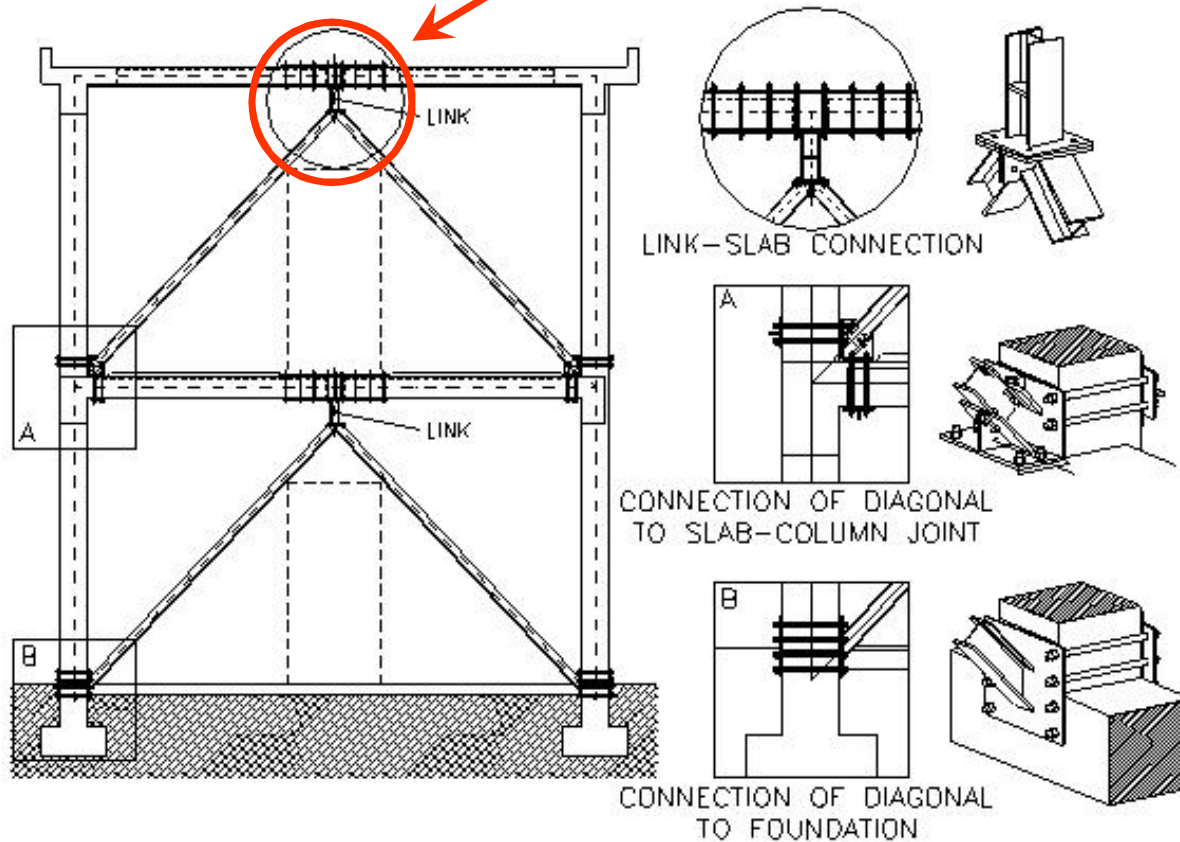


Link:HEA100

- Plastic modulus : $Z = 83000\text{mm}^3$
- Shear area : $A_w = 480\text{mm}^2$
- Length of short link : $e = 0.8 \frac{Z}{A_w / \sqrt{3}} = 24\text{cm}$
- Shear plastic resistance : $V_p = 76.21\text{kN}$
- Plastic base shear : $H_p = 2 \cdot V_p = 152.42\text{kN}$
- Ultimate base shear : $H_u = 1.5 \cdot V_p = 228.63\text{kN}$

ECCENTRIC STEEL BRACING SYSTEM

Y-shaped eccentric bracing system



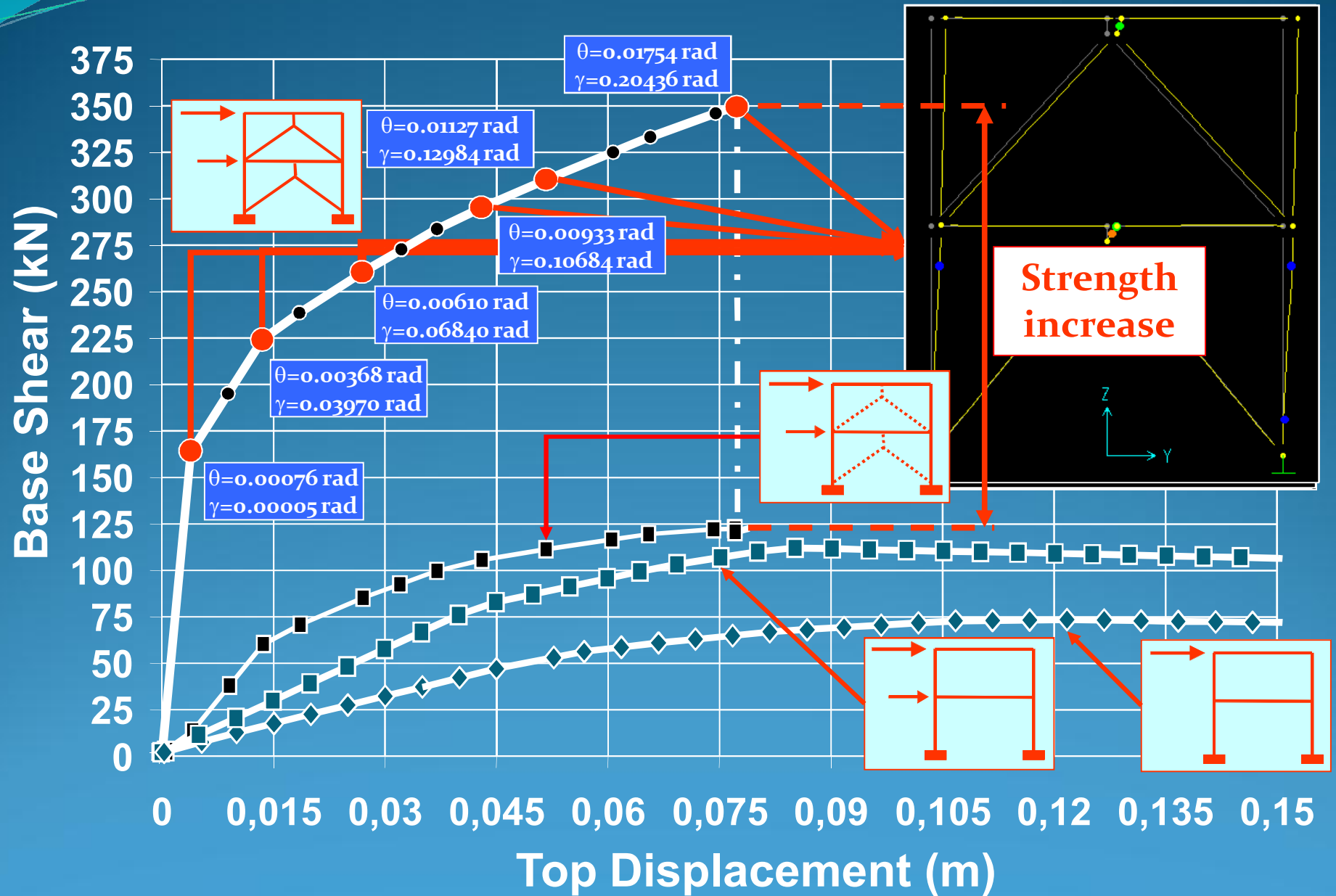
EB MOUNTING



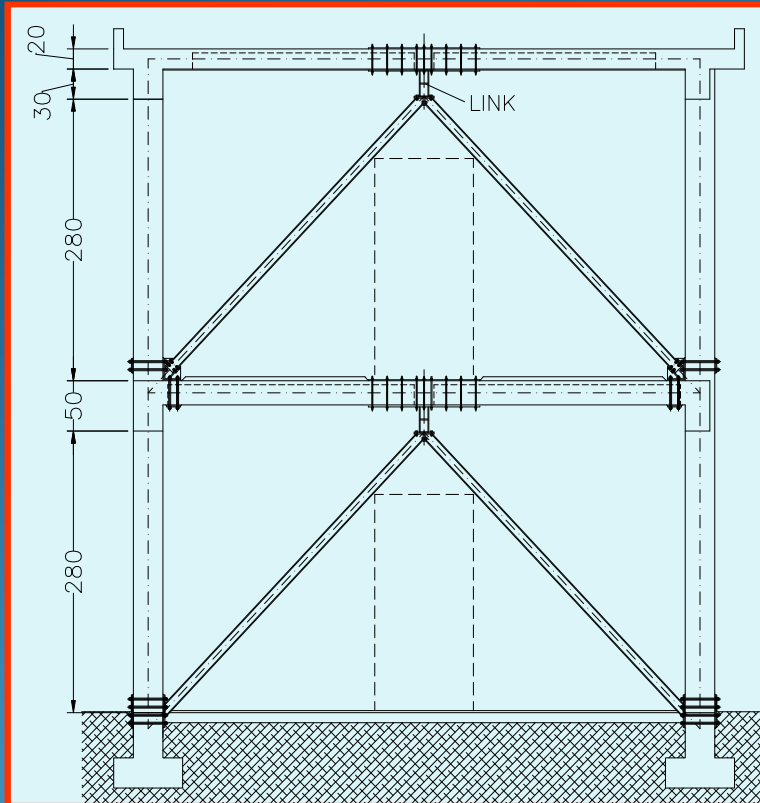
EB MOUNTING



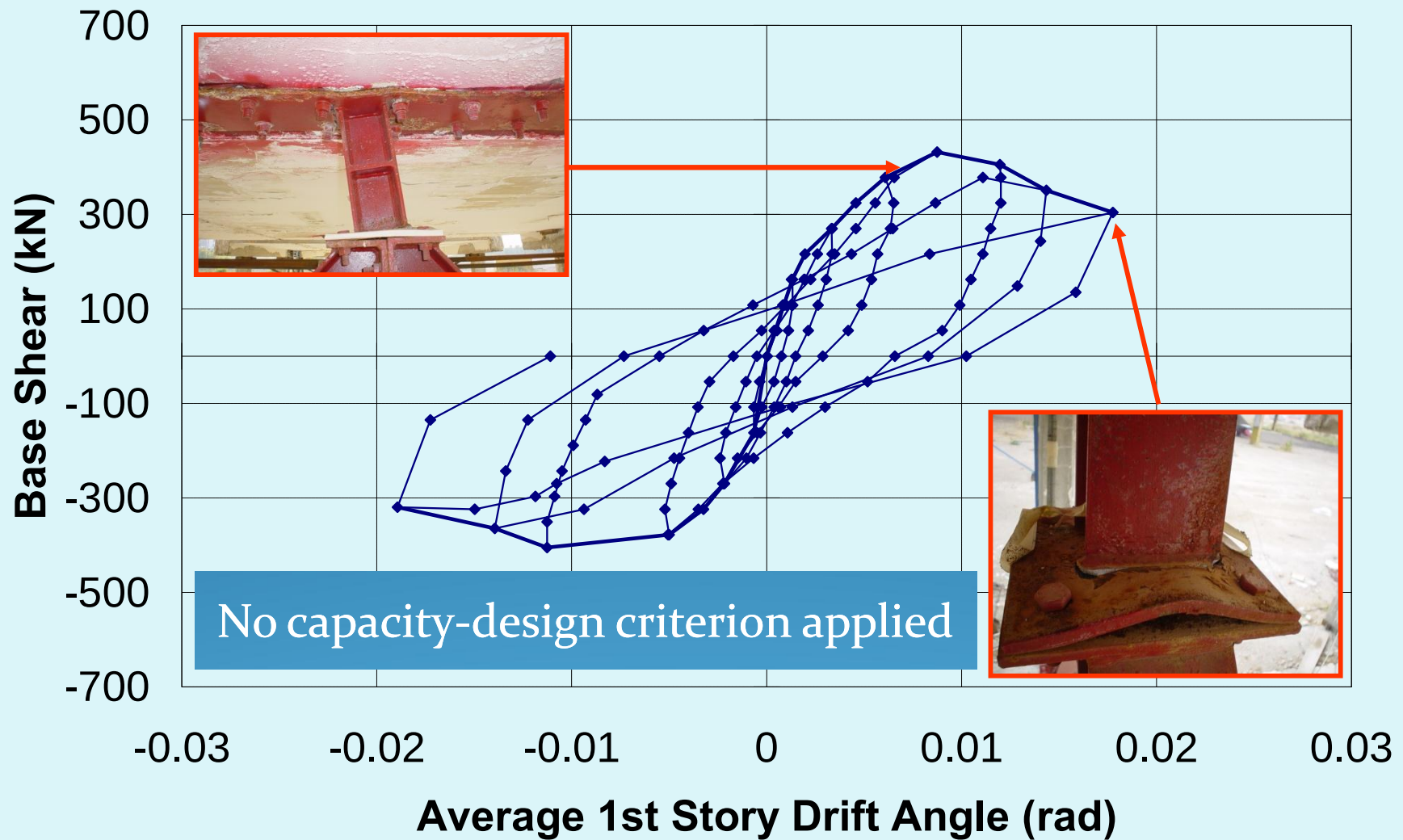
PUSHOVER CURVES



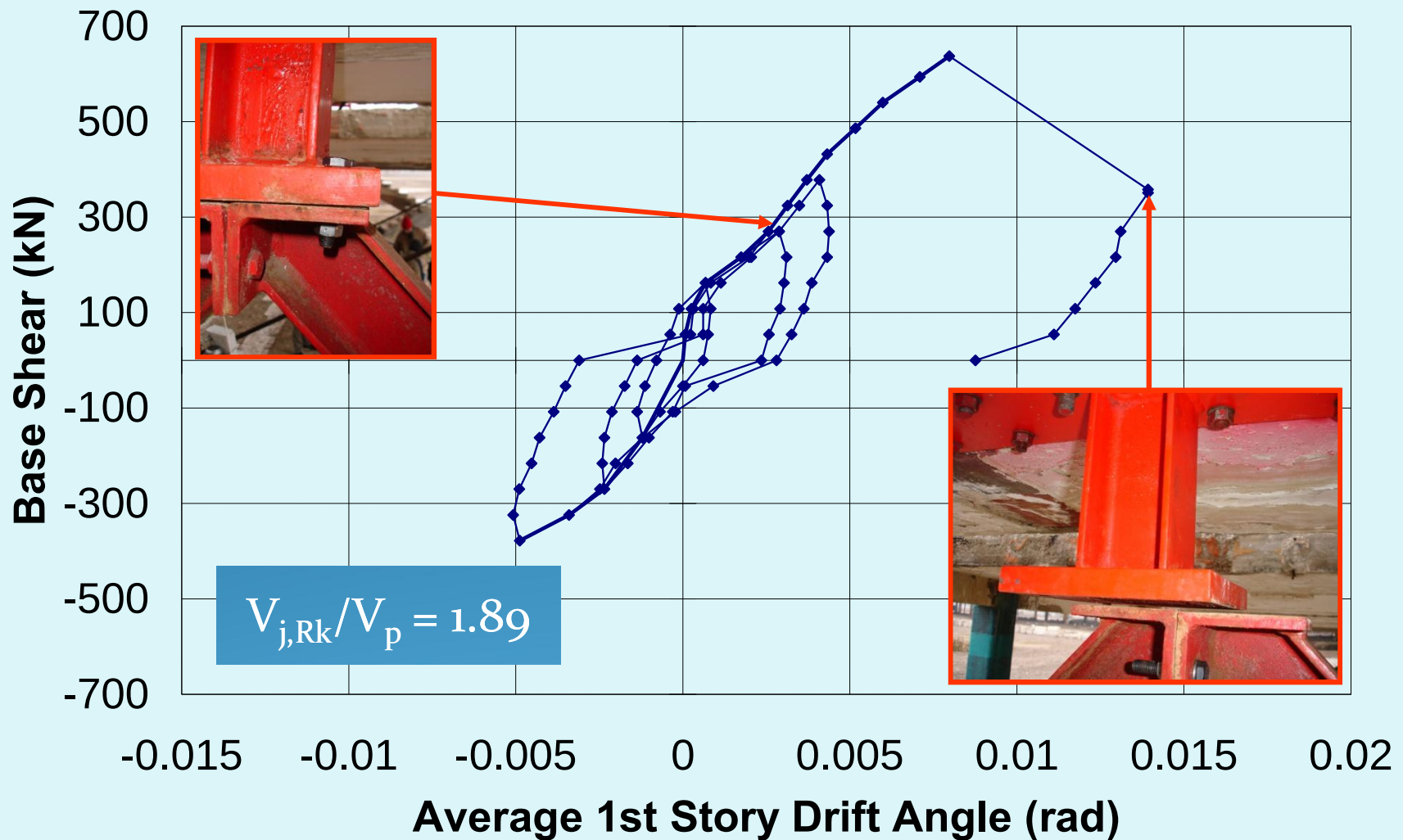
Steel Eccentric Braces (EB)



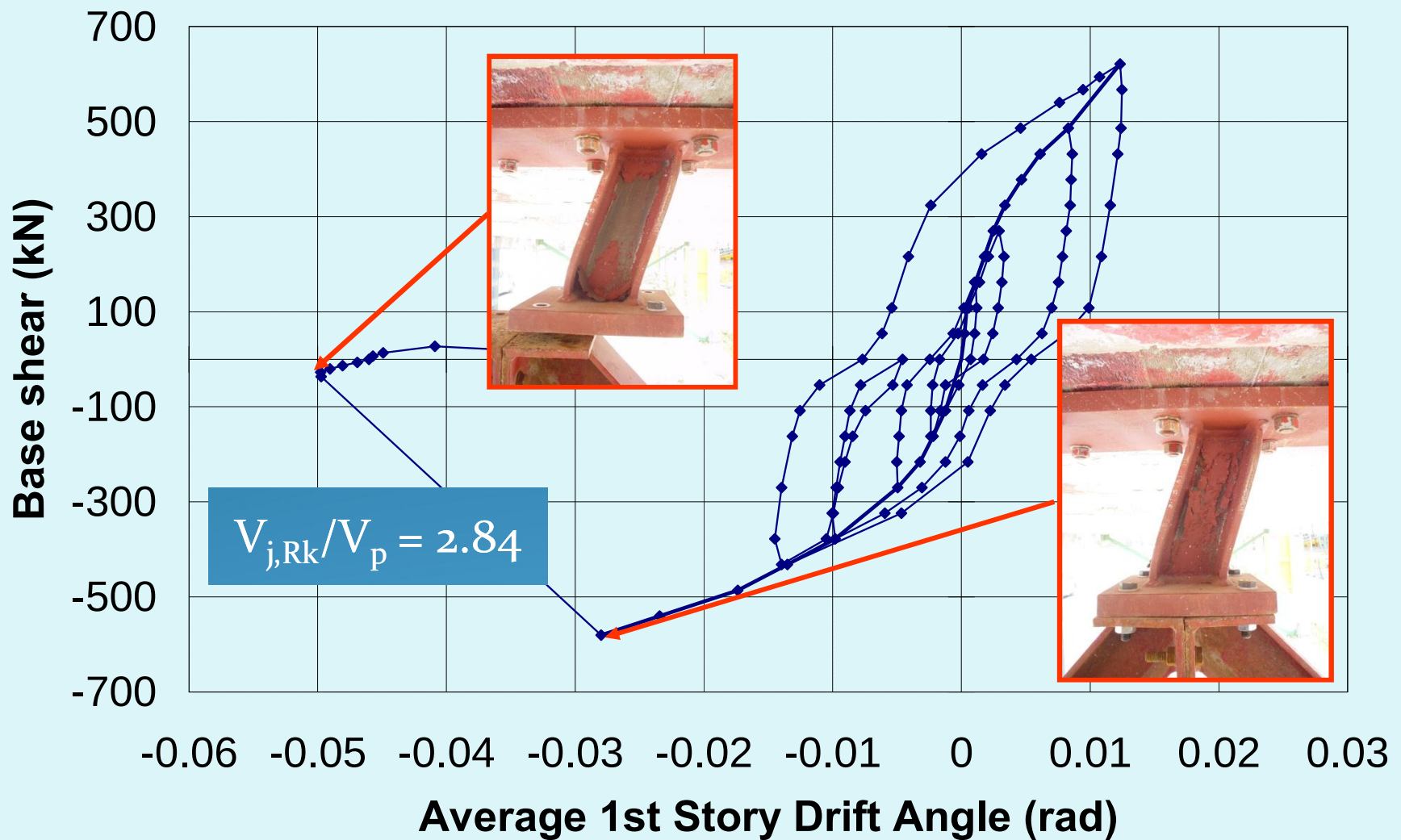
Steel Eccentric Braces (test #1)



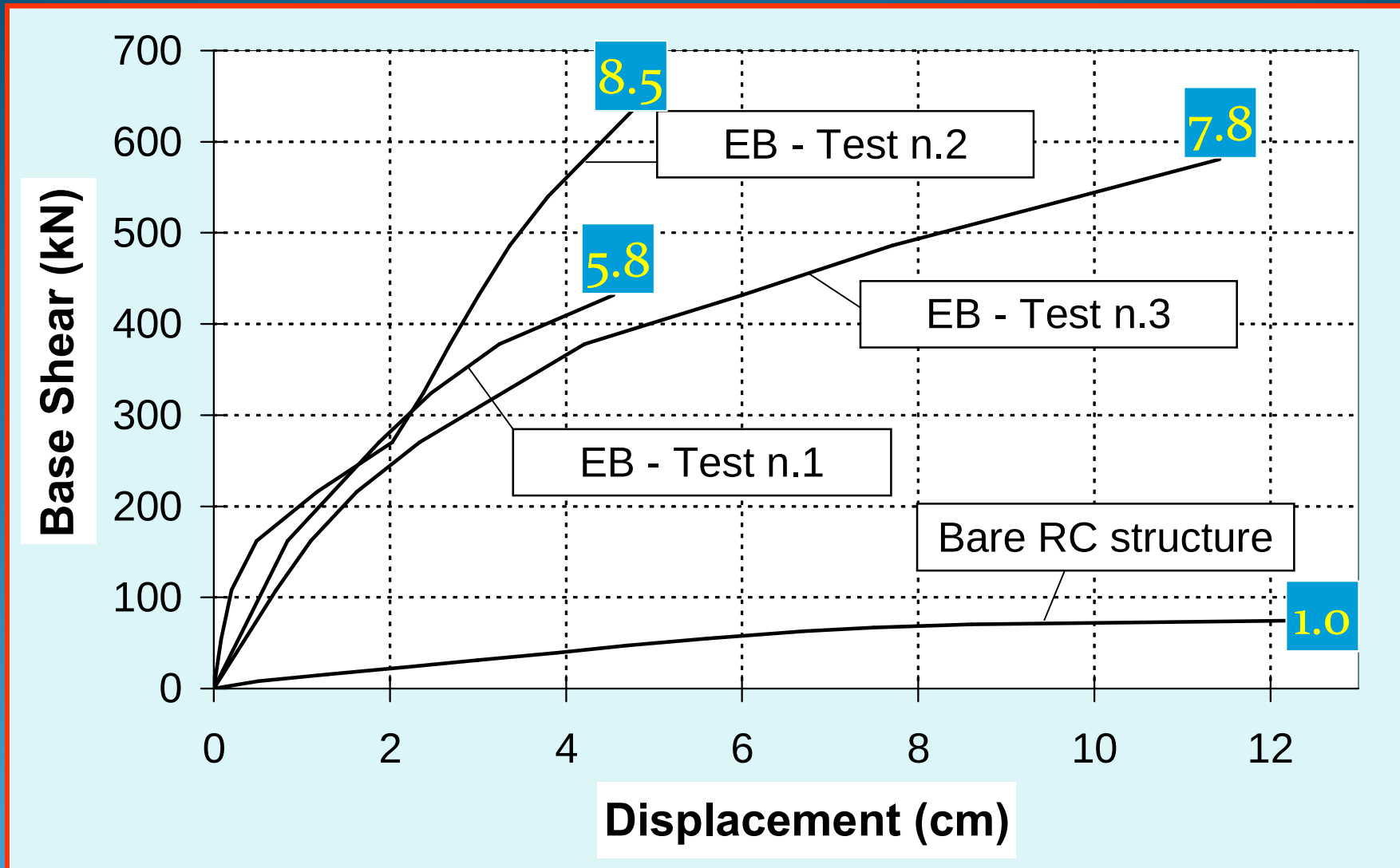
Steel Eccentric Braces (test #2)



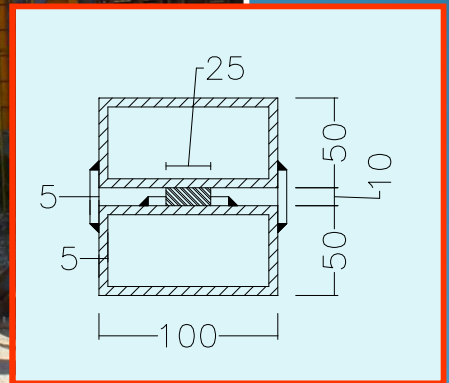
Steel Eccentric Braces (test #3)



Steel Eccentric Braces (comparison)



Steel Buckling Restrained Braces (BRB)

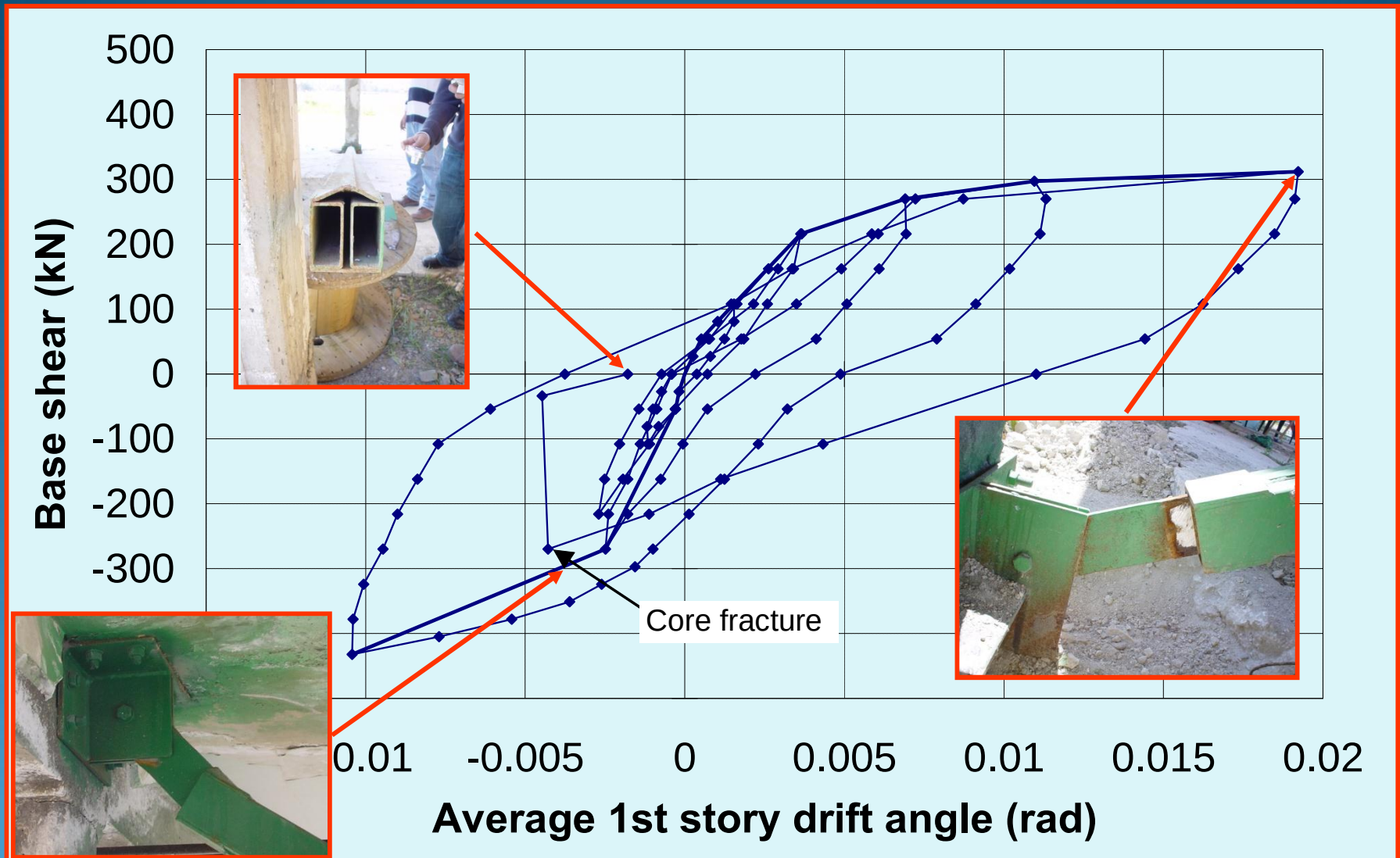


Building No. 1 - BRB test No. 1

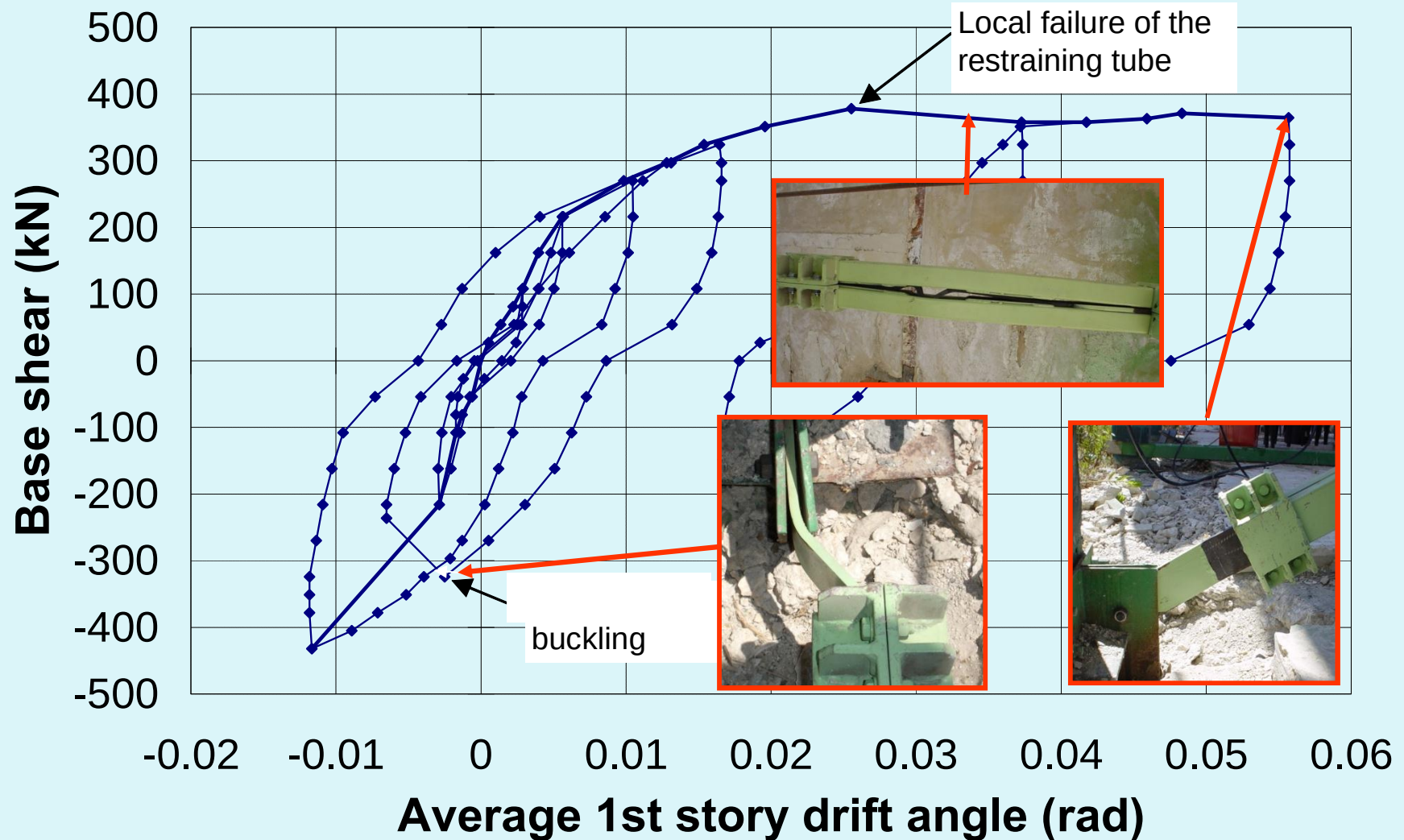


Prof. F.M. Mazzolani - UNIVERSITY of NAPLES "FEDERICO II"

Steel Buckling Restrained Braces (test #1)



Steel Buckling Restrained Braces (test #2)



Building A– BRB test No. 2

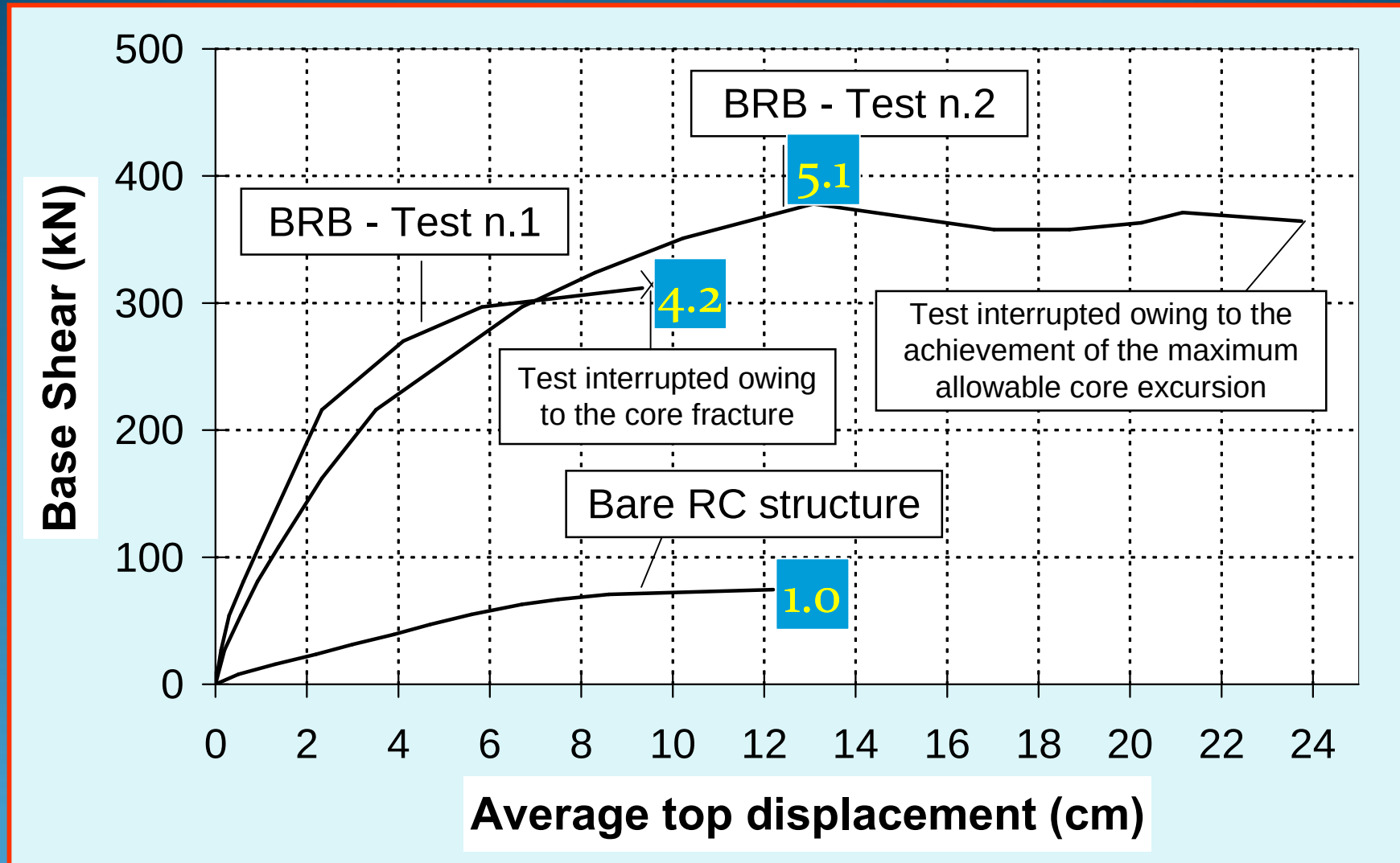
Restrained local buckling of the yielding core



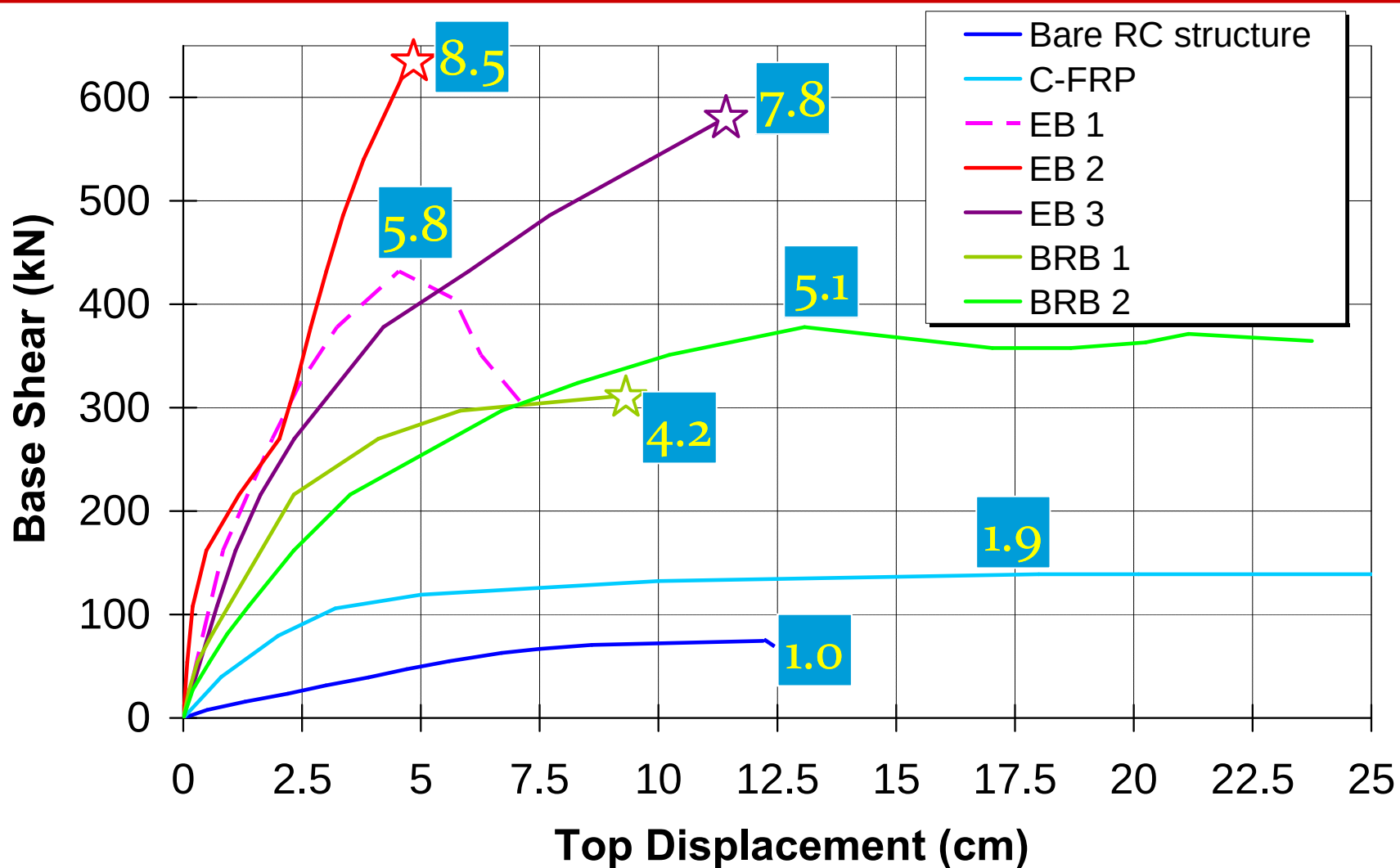
Plastic elongation in tension



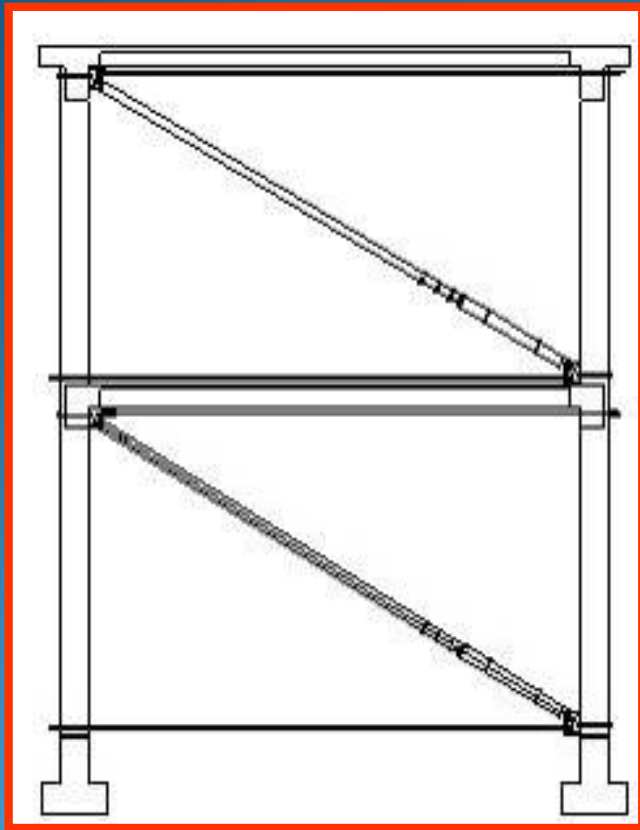
Steel Buckling Restrained Braces (comparison)



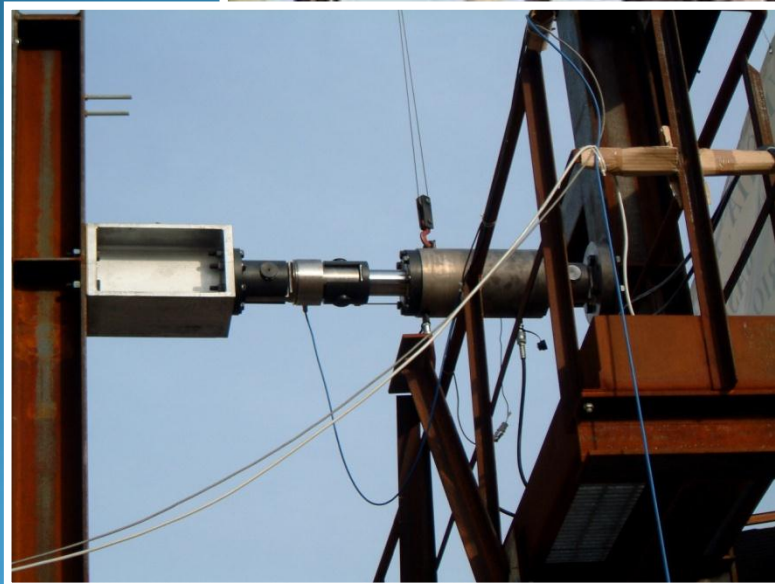
Building A: comparison of results (FRP; BRB; EB)



Shape Memory Alloy Braces



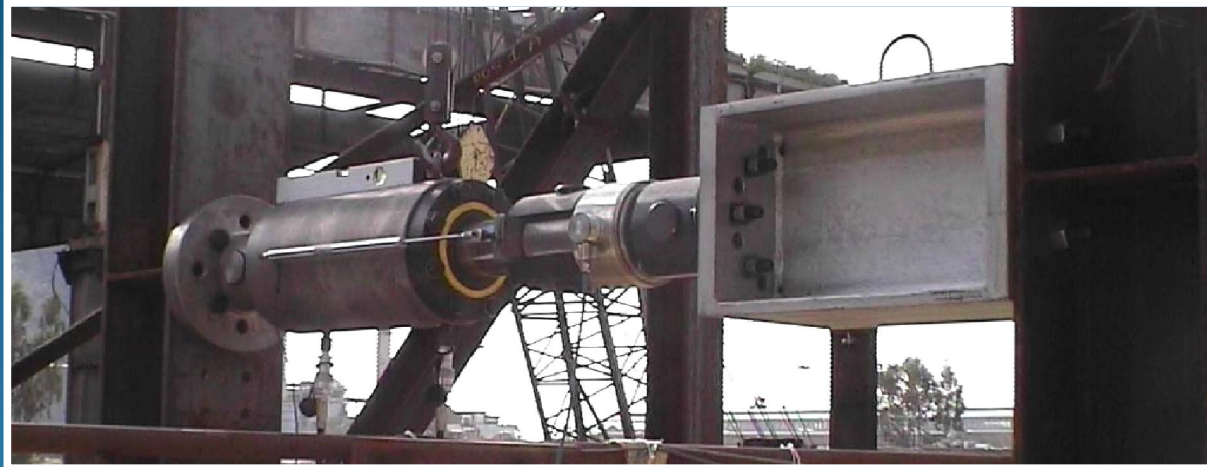
Shape Memory Alloy Braces



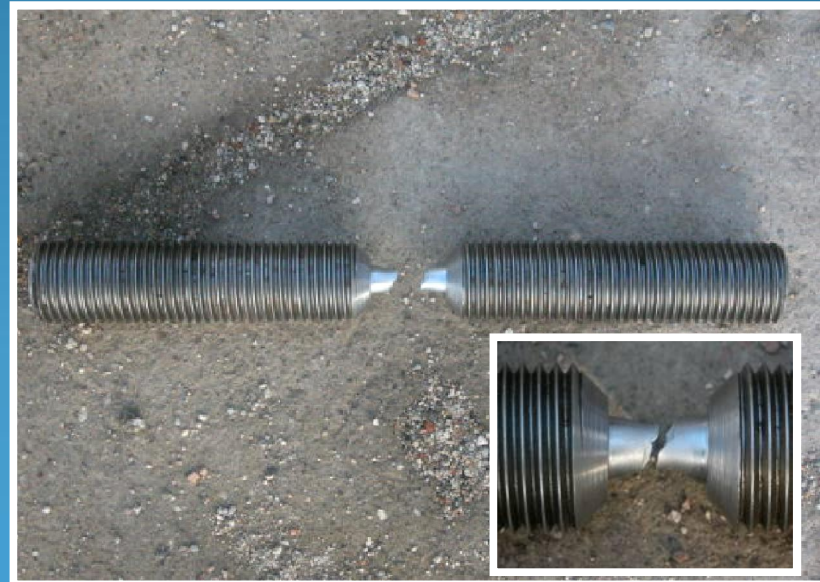
- . Cyclic test
- . Free vibration (release) test

Prof. F.M. Mazzolani - UNIVERSITY of NAPLES “FEDERICO II”
c)

Shape Memory Alloy Braces



Free vibration
(release) test



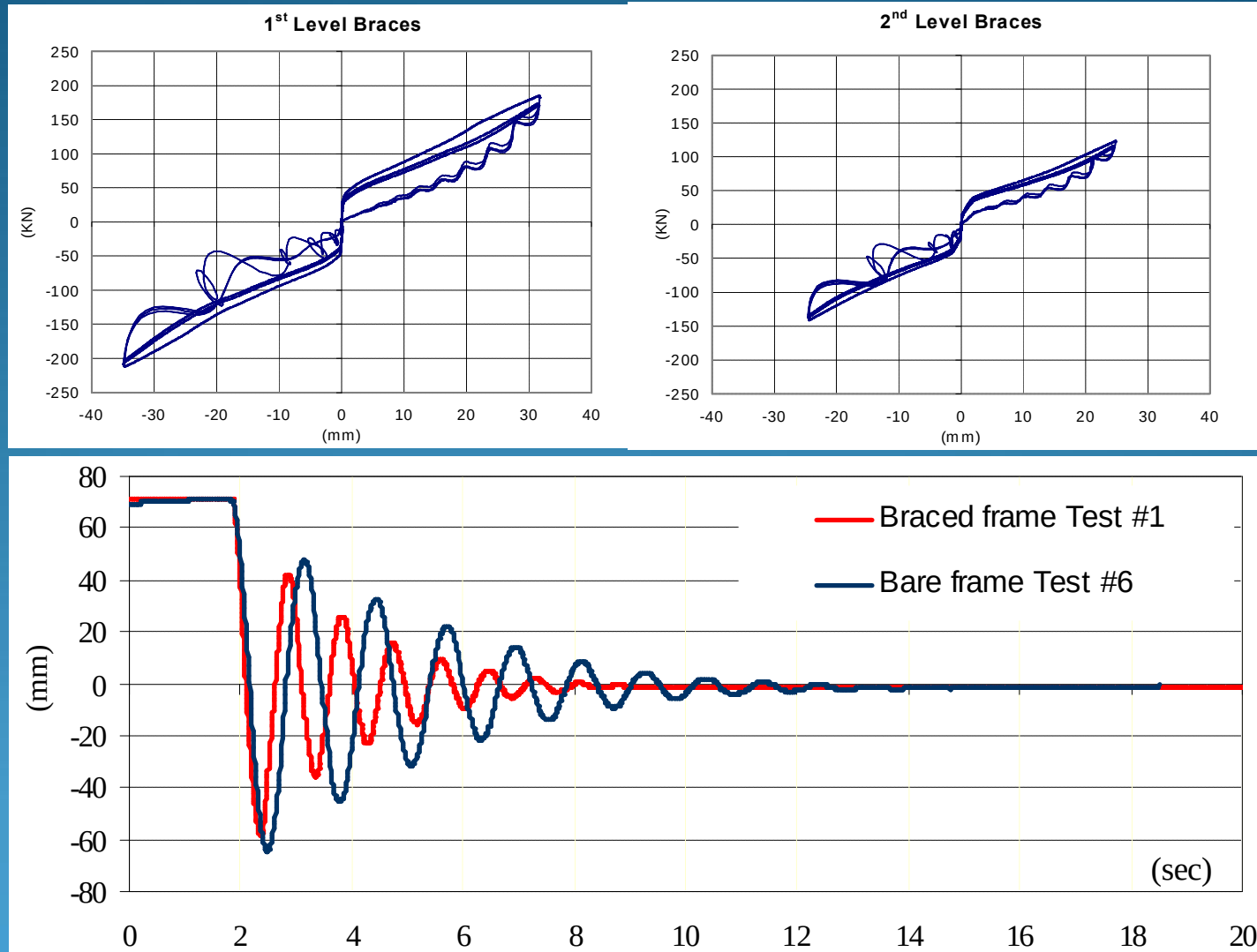
Shape Memory Alloy Braces



Prof. F.M. Mazzolani - UNIVERSITY of NAPLES "FEDERICO II"

Shape Memory Alloy Braces

Static
cyclic
test



Metal Shear Panels



Prof. F.M. Mazzolani - UNIVERSITY of NAPLES "FEDERICO II"

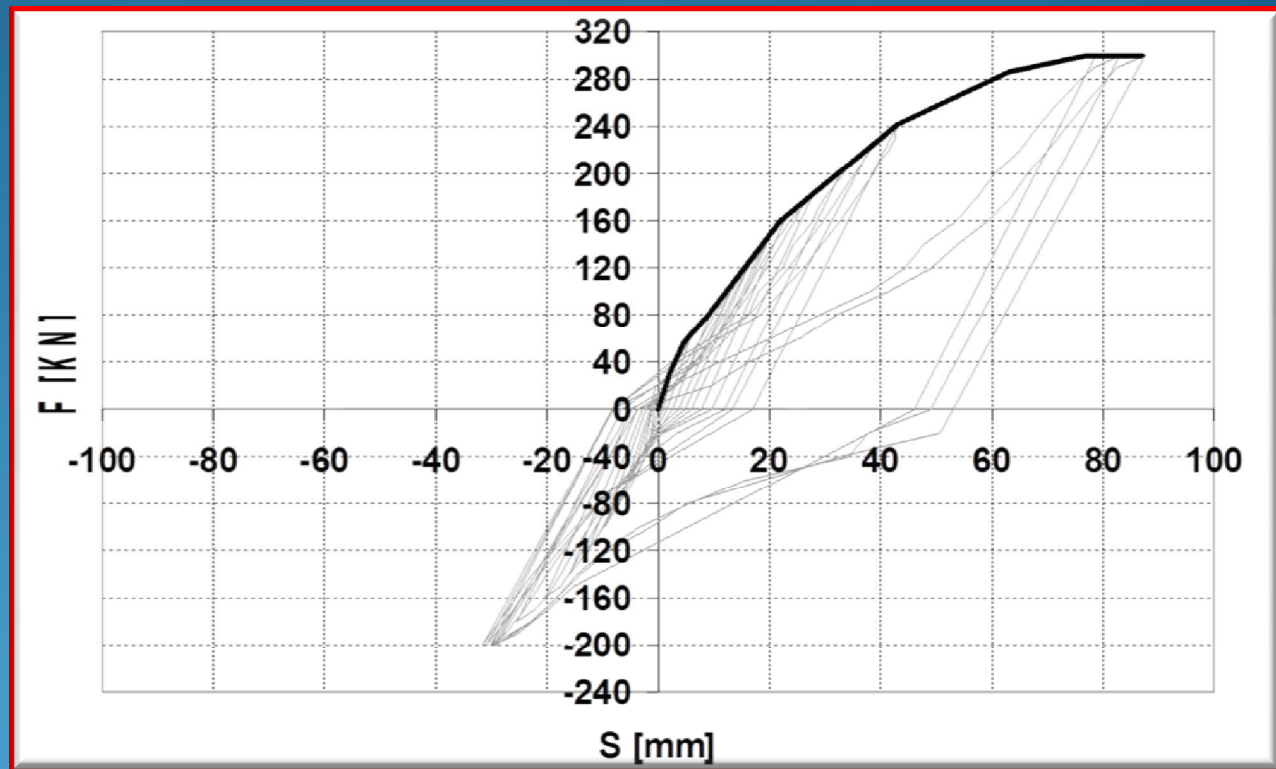
Metal Shear Panels



Prof. F.M. Mazzolani - UNIVERSITY of NAPLES "FEDERICO II"

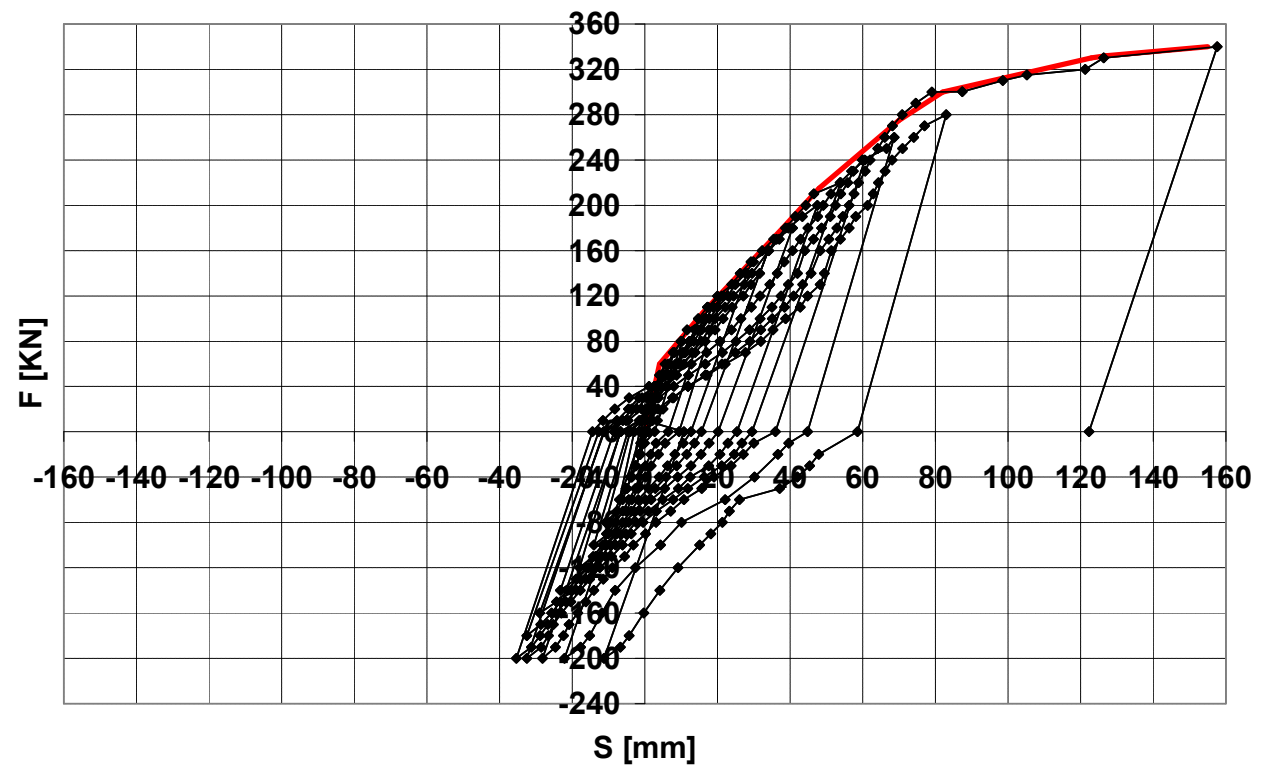
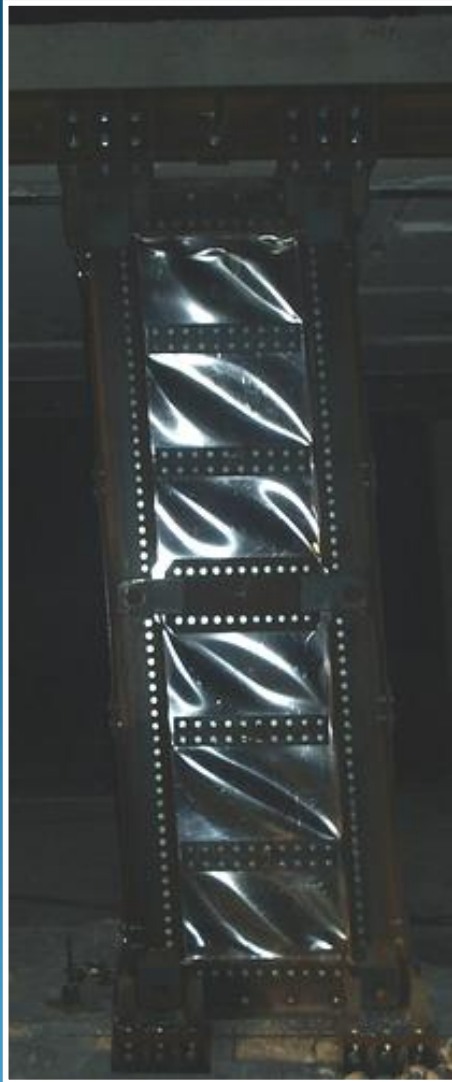
Metal Shear Panels

Steel panels

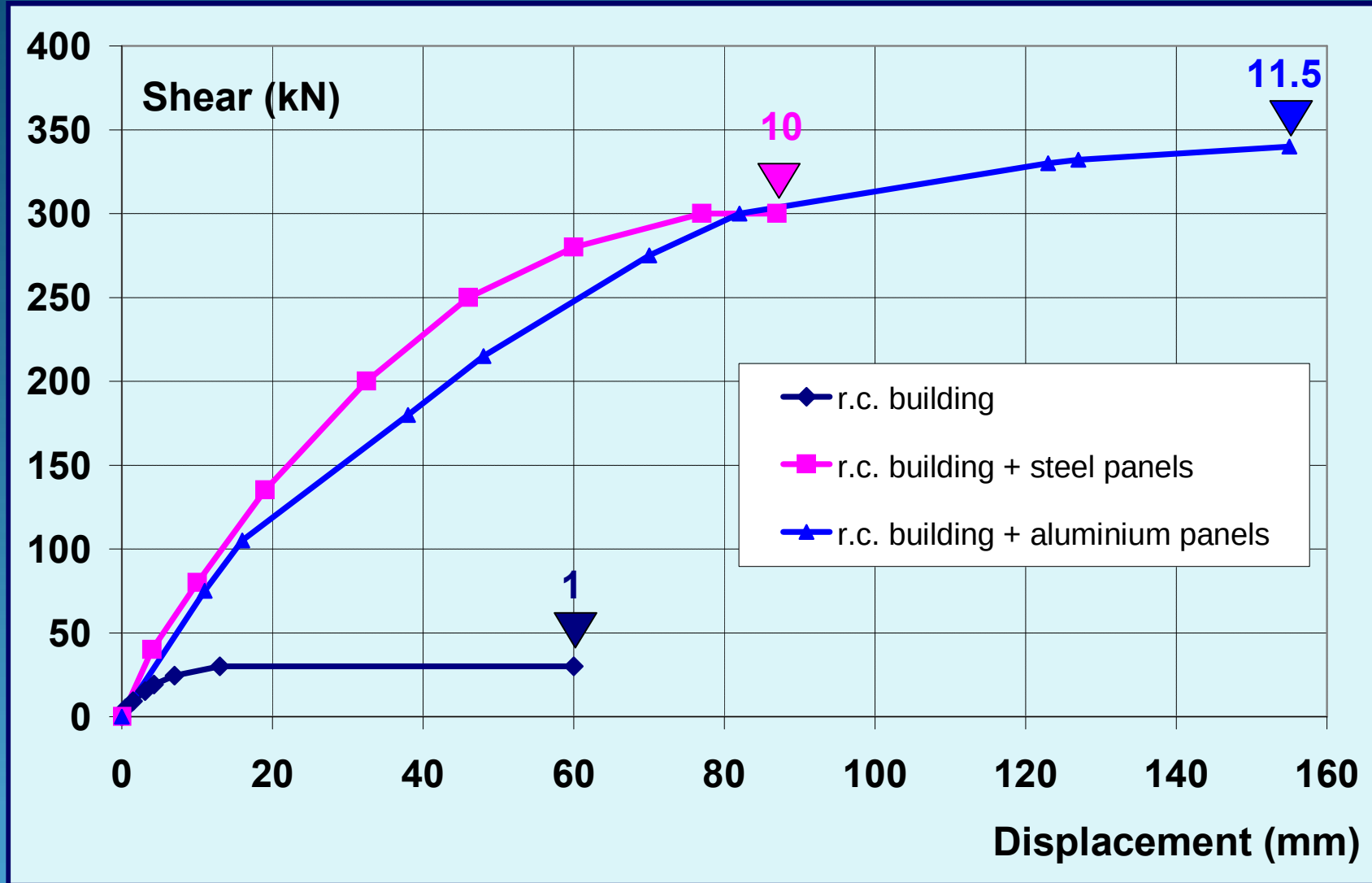


Metal Shear Panels

Aluminium panels



Metal Shear Panels



Base Isolation



Base Isolation



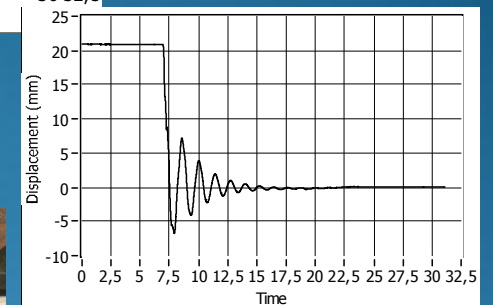
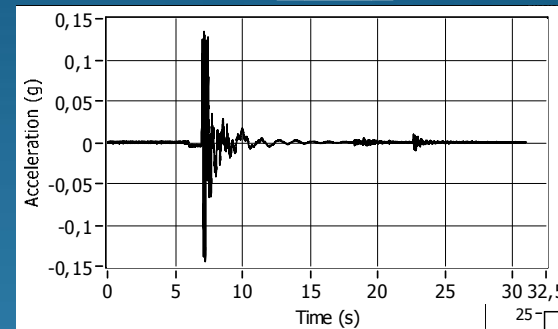
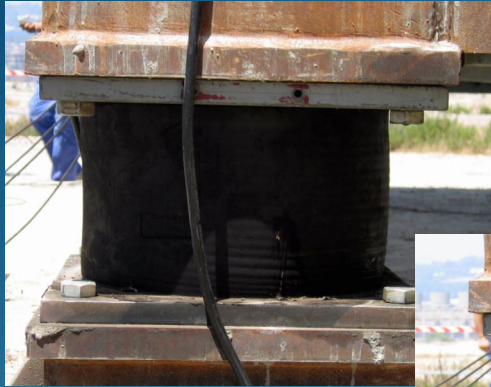
Prof. F.M. Mazzolani - UNIVERSITY of NAPLES "FEDERICO II"

Base Isolation



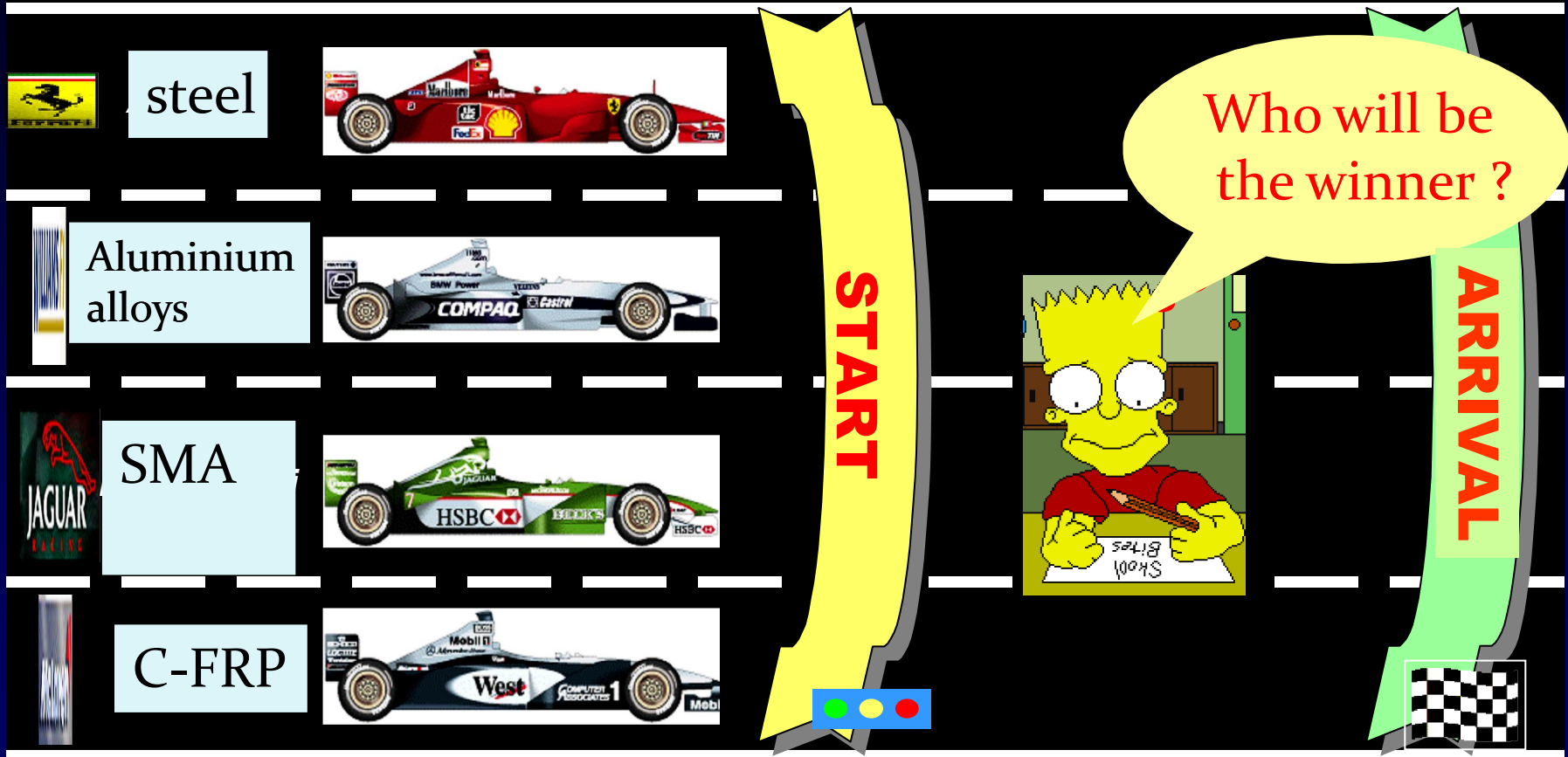
Prof. F.M. Mazzolani - UNIVERSITY of NAPLES "FEDERICO II"

Base Isolation



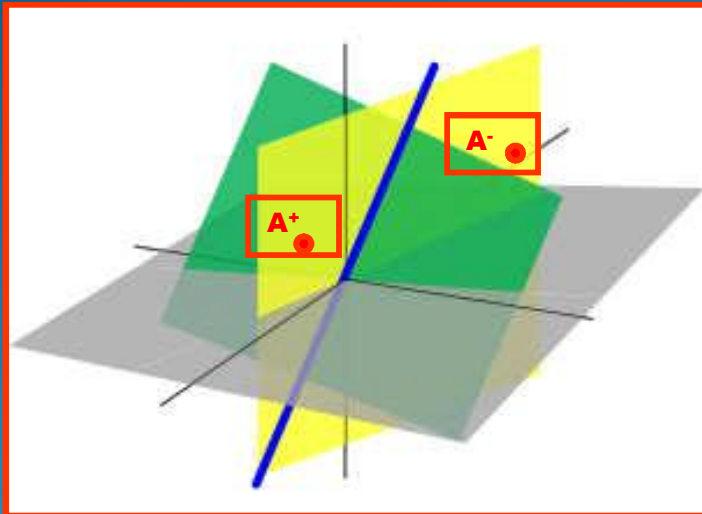
Prof. F.M. Mazzolani - UNIVERSITY of NAPLES "FEDERICO II"

THE FINAL COMPETITION



MULTI-CRITERIA DECISIONAL METHOD

TOPSIS



A^+ = the best virtual alternative

A^- = the worst virtual alternative

which are the points of a space with m dimensions, being m the number of the evaluation criteria

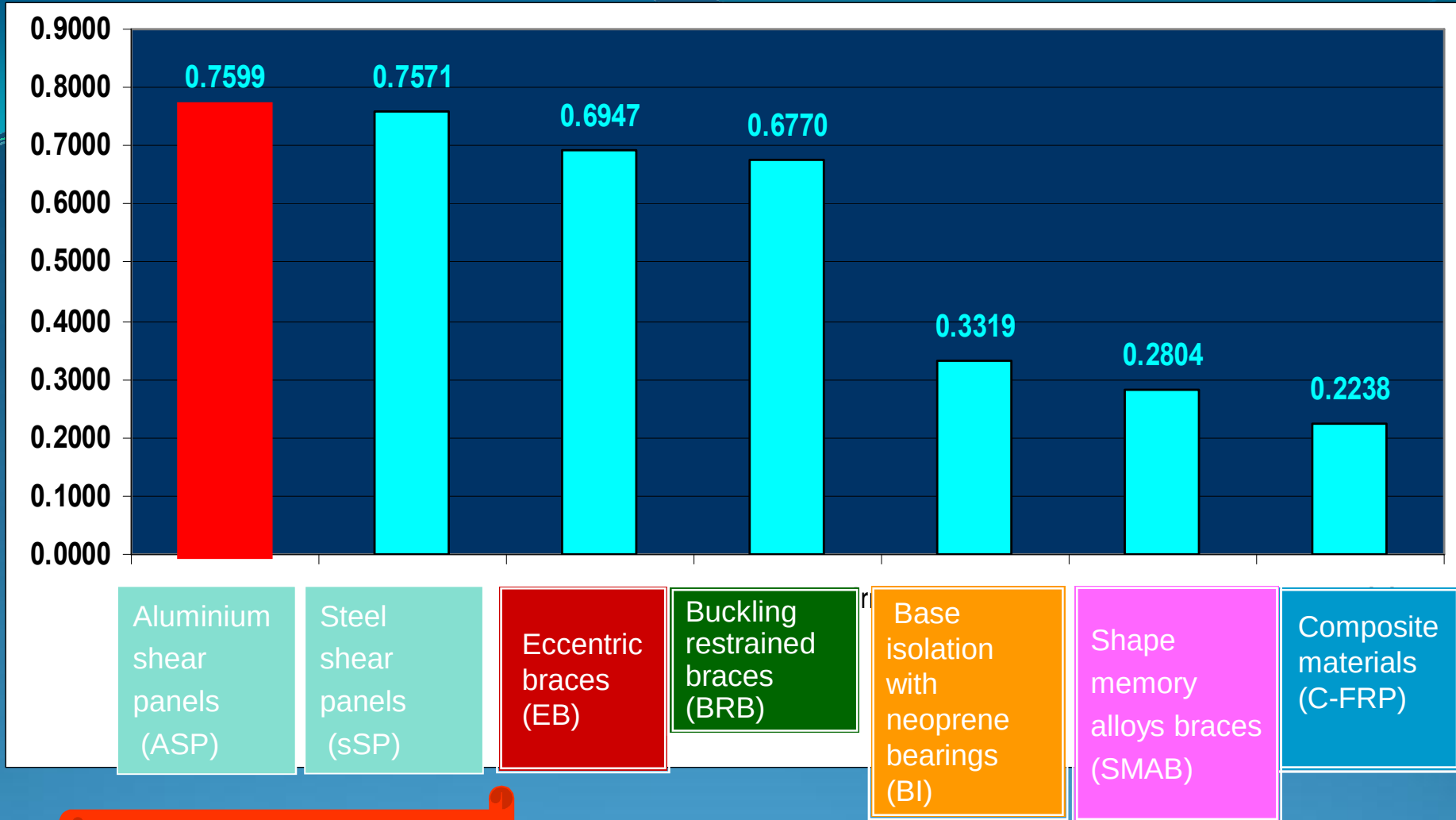
The index C represents the position of each solution respect the two virtual alternatives

$$C_{i^+} = \frac{\overline{A_i A^-}}{\overline{A_i A^-} + \overline{A_i A^+}}$$

The evaluation criteria

★	Cost of the intervention	20.83 %
	Feasibility of the system	13.90 %
	Disturbance to the inoccupants	13.23 %
	Functionality and aesthetic	11.88 %
	Reversibility	12.39 %
★	Reduction of vulnerability	16,31 %
	Damage protection	11.45 %

★ quantitative



THE WINNERS

THE FINAL COMPETITION

The ranking

1



2



3



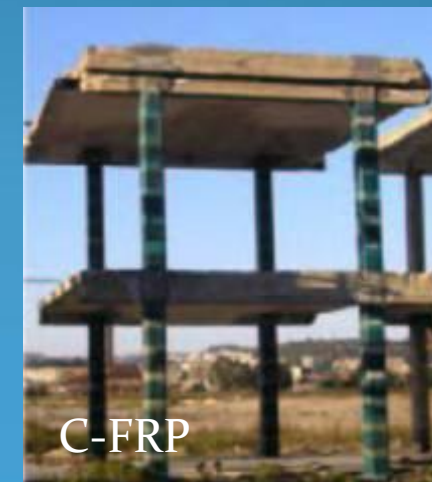
4



5



6



This Volume is a collection of scientific contributions dealing with a wide experimental/theoretical research developed during the years 2000-2005, in the former industrial area of Bagnoli (Naples, Italy). The results of 15 full-scale tests (both static and dynamic) on real RC structures seismically upgraded by means of different, innovative and advanced, techniques are presented and discussed, together with the comparison with relevant theoretical/numerical studies.

The following upgrading techniques have been considered:

1. Base isolation
2. Buckling restrained braces
3. Composite materials
4. Eccentric braces
5. Shape memory alloy braces
6. Steel and aluminium shear panels

The activity has been developed by four Institutions:

- University of Naples "Federico II" (coordination)
- University of Basilicata
- University of Chieti-Pescara
- Italian Department of Civil Protection

Federico Mazzolani is Professor of Structural Engineering at the University of Naples "Federico II", Italy. He is an internationally recognised expert in metal structures, seismic design and rehabilitation of structures. He is the Chairman of the STESSA Conference, which is dedicated to the behaviour of steel structures in seismic areas. In addition, he is the Chairman of the CEN Committee responsible for Eurocode 9 on "Design of Aluminium Structures" and of the ECCS Committee 13 on "Seismic Design of Steel Structures". At national level, he is the Chairman of the UNI-SC3 Committee on "Steel and Composite Structures" (the mirror Committee for Eurocodes 3, 4, 9). Currently, he is coordinator of the international research project PROHITECH on earthquake PROtection of Historical buildings by reversible mixed TECHNOlogies.

The ILVA-IDEM Research Project

Federico M. Mazzolani

Federico M. Mazzolani
co-ordinator & editor

Seismic upgrading of RC buildings by advanced techniques

The ILVA-IDEM Research Project



€ 35,00



Polimetrica
International Scientific Publisher

The ILVA-IDEM Research Project

List of Contents

Foreword

Chapter 1. “As-built” data collection.

Chapter 2. Dynamic testing and modal identification.

Chapter 3. Base isolation.

Chapter 4. Steel buckling-restrained braces.

Chapter 5. Composite fiber reinforced materials.

Chapter 6. Steel eccentric braces.

Chapter 7. Shape-memory alloy braces.

Chapter 8. Metal shear panels.

The background is a solid blue color with a subtle gradient. At the top, there are several thin, wavy lines in shades of blue and teal, creating a sense of movement or a horizon line.

Grazie per l'attenzione

Domande ?