9TH
INTERNATIONAL WORKSHOP ON RELIABLE ENGINEERING COMPUTING
Risk and Uncertainty in Engineering Computations
Virtual Conference: May 17-20, 2021

REC2021

UNIVERSITY OF MESSINA

UNIVERSITY "MEDITERRANEA" OF REGGIO CALABRIA

Presentation of the laboratory University of Messina - C.E.R.I.S.I.

Centre of Excellence Research and Innovation for large dimensions Structures and Infrastructures

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Università degli Studi di Messina
DIPARTIMENTO DI INGEGNERIA

UNIONE EUROPEA
Fondo europeo di sviluppo regionale

PON Ricerca e Competitività 2007-2013

Ministero dell'Istruzione, dell'Università e della Ricerca

Ministero dello Sviluppo Economico

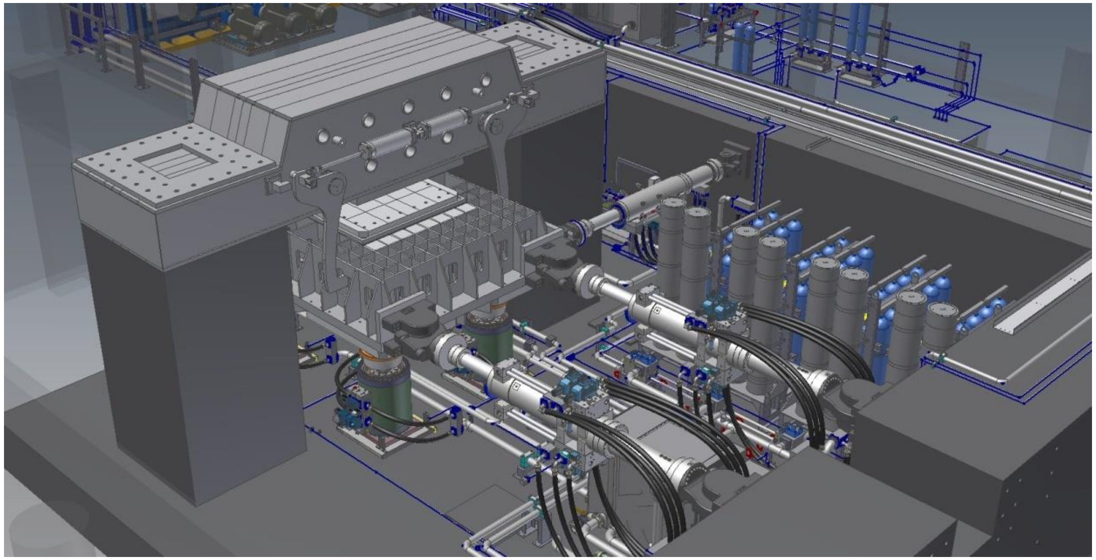
CERISI

Centre of Excellence Research and Innovation for large dimensions Structures and Infrastructures

Research Project funded by the PON (National Operative Programme) 2007-13
Total budget: € 22.100.000,00
Project period: 2012-2015

http://cerisi.unime.it/en.html

Anti-seismic device test facility of CERISI



Qualification and acceptance tests of seismic isolators and energy dissipation devices (hysteretic dampers, viscous dampers, etc.) according to UNI EN 15129:2009

BS EN 15129:2009

EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN 15129

November 2009

ICS 91.120.25

English Version

Anti-seismic devices

Dispositifs anti-sismiques

Erdbebenvorrichtungen

This European Standard was approved by CEN on 19 September 2009.

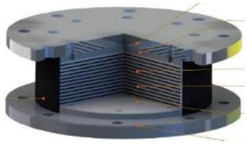
CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN Management Centre or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the CEN Management Centre has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

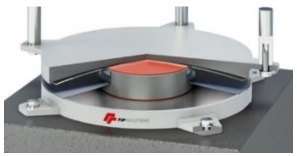
3D Render image of the anti-seismic device test facility

Rubber bearings (HDRB and LDRB)



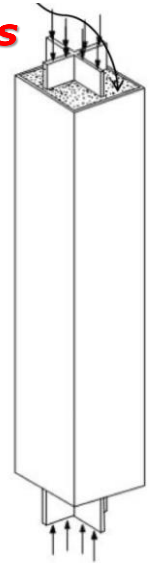
LRB isolator

FPS isolator



Viscous damper

Buckling restrained braces



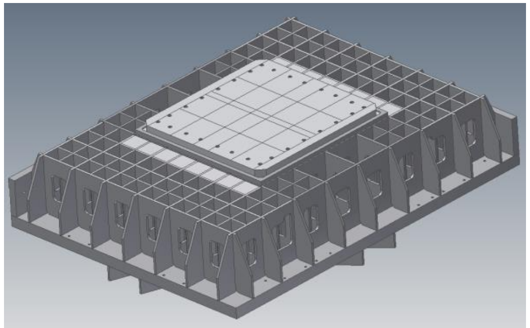
Hysteretic (metallic) dampers …

Table 1 — Most common types of Anti-seismic devices

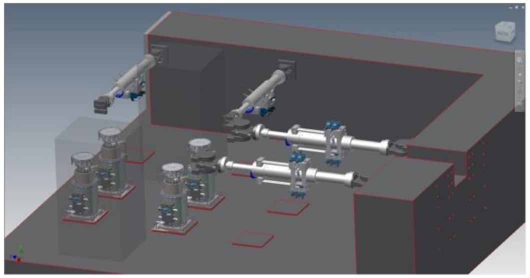
Description of the Device			Relevant Clause	Graphic Representation: Plan view	Graphic Representation: Elevation view, Direction x	Graphic Representation: Elevation view, Direction y	Notes
Rigid Connection Devices (RGDs)	Permanent Connection Devices (PCDs)	Fixed	5.1				This type of device corresponds to type 8.1 (Restraint bearing) in Table 1 of EN 1337-1:2000 (*)
Rigid Connection Devices (RGDs)	Permanent Connection Devices (PCDs)	Moveable	5.1				This type of device corresponds to type 8.2 (Guide bearing) in Table 1 of EN 1337-1:2000 (*)
Rigid Connection Devices (RGDs)	Fuse Restraints	Mechanical Fuse Restraints (MFRs)	5.2			-	
Rigid Connection Devices (RGDs)	Fuse Restraints	Hydraulic Fuse Restraints (HFRs)	5.2			-	
Rigid Connection Devices (RGDs)	Temporary Connection Devices (TCDs)		5.3			-	This type of device is usually referred to as Shock Transmission Unit (STU)
Displacement Dependent Devices (DDDs)	Linear Devices (LDs)		6.1			-	
Displacement Dependent Devices (DDDs)	Non linear Devices (NLDs)		6.2			-	
Velocity Dependent Devices	Fluid Viscous Dampers (FVDs)		7.1			-	This graphic representation applies also to two-shaft dampers
Velocity Dependent Devices	Fluid Spring Dampers (FSDs)		7.1			-	
Seismic Isolators	Elastomeric		8.2				The isolators are shown in the deformed position to underscore their lateral flexibility
Seismic Isolators	Lead Rubber Bearings		8.2				
Seismic Isolators	Curved Surface Sliders		8.3				The symbols apply to both Single and Double Curved Surface Sliders
Seismic Isolators	Flat Surface Sliders		8.4				The symbols apply to both types 2.3 (free sliding pot bearing) and 3.5 (free sliding spherical bearing) in Table 1 of EN 1337-1:2000 (■)

Anti-seismic device test facility of CERISI

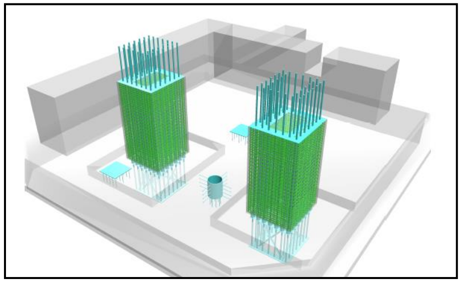
The facility consists of nine main parts:



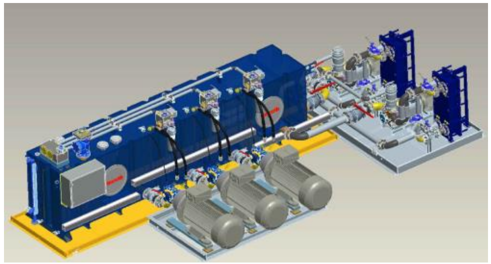
- a shaking table, which has a test area for isolators of $2000 \times 2000mm$



- 4 vertical actuators (Z axis)
- 4 horizontal actuators (X and Y axes)



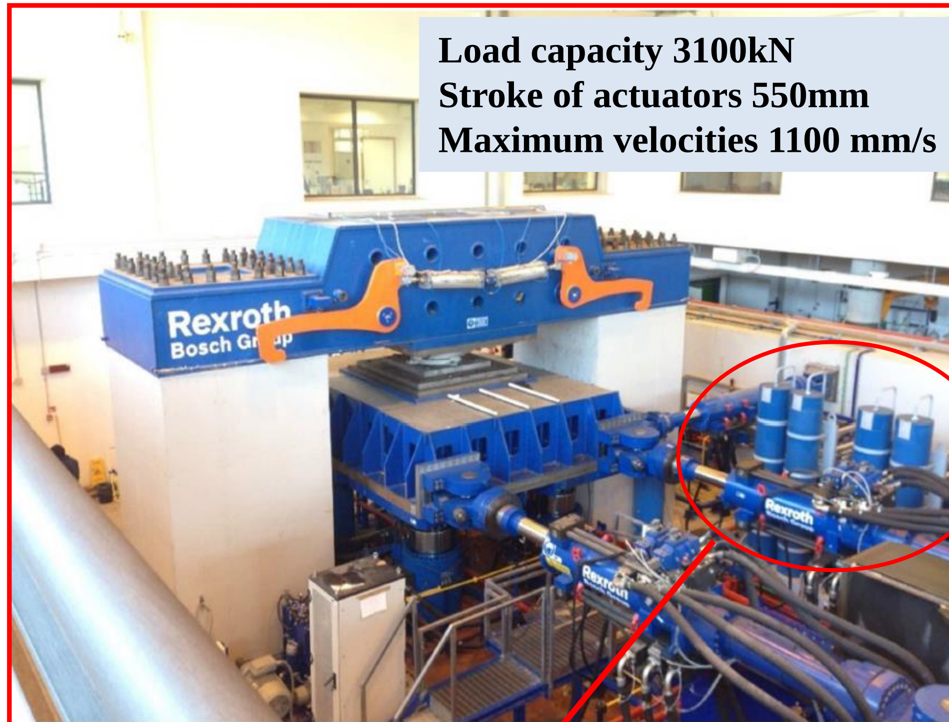
- an upper box girder steel beam
- 2 reinforced concrete columns
- "L-shaped" strong wall (in concrete)
- a foundation (in concrete)



- an energy storage system
- a hydraulic power unit

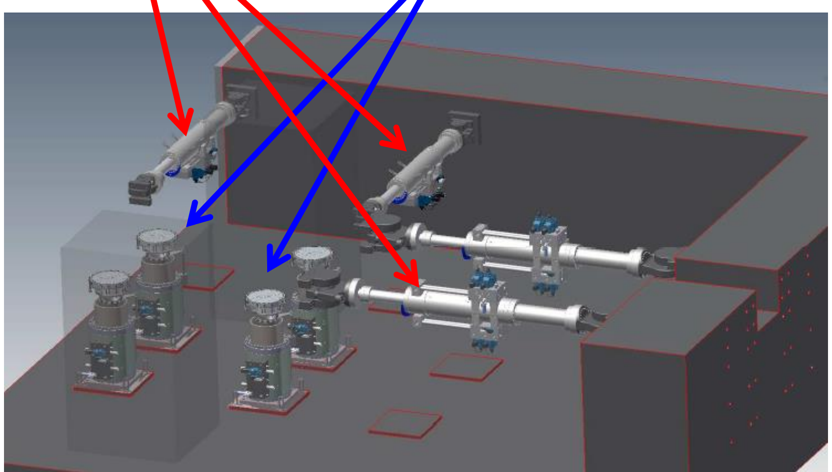
Anti-seismic device test facility of CERISI

	Vertical	Longitudinal	Transversal
Force	16000 kN	±3100 kN	±1400 kN
Displacement	±35 mm	±550 mm	±375 mm
Speed	±55 mm/s	±1100 mm/s	±1100 mm/s
Rotation angle	±2°	±2°	±2°
Data acquisition rate	4 kS/s	4 kS/s	4 kS/s



2 pairs of actuators

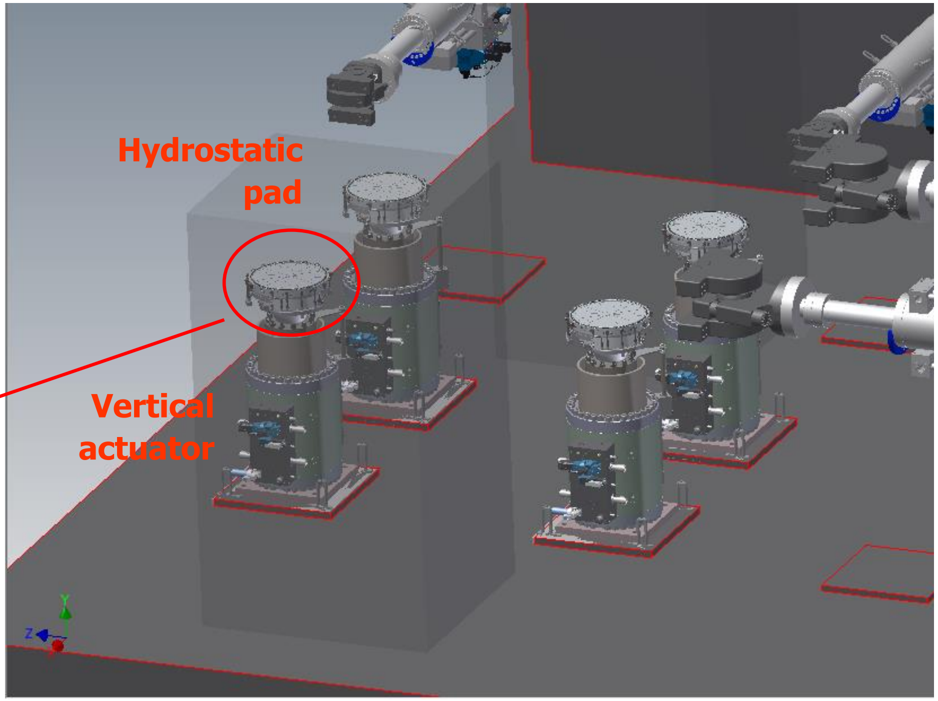
hydrostatic pads with minimal friction coeff



Anti-seismic device test facility of CERISI

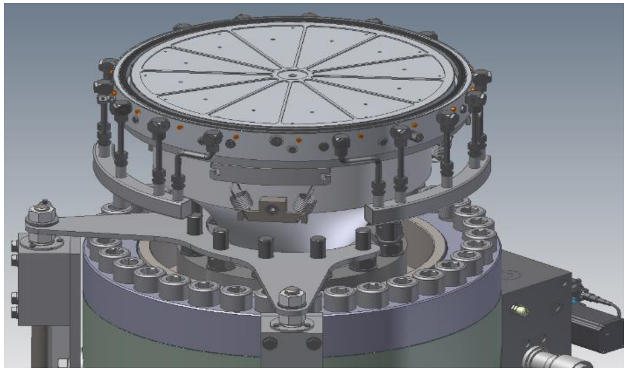
- Vertical actuators are constructed with a low-friction hybrid technology, which allows to drastically reduce the stick-slip phenomenon and friction.

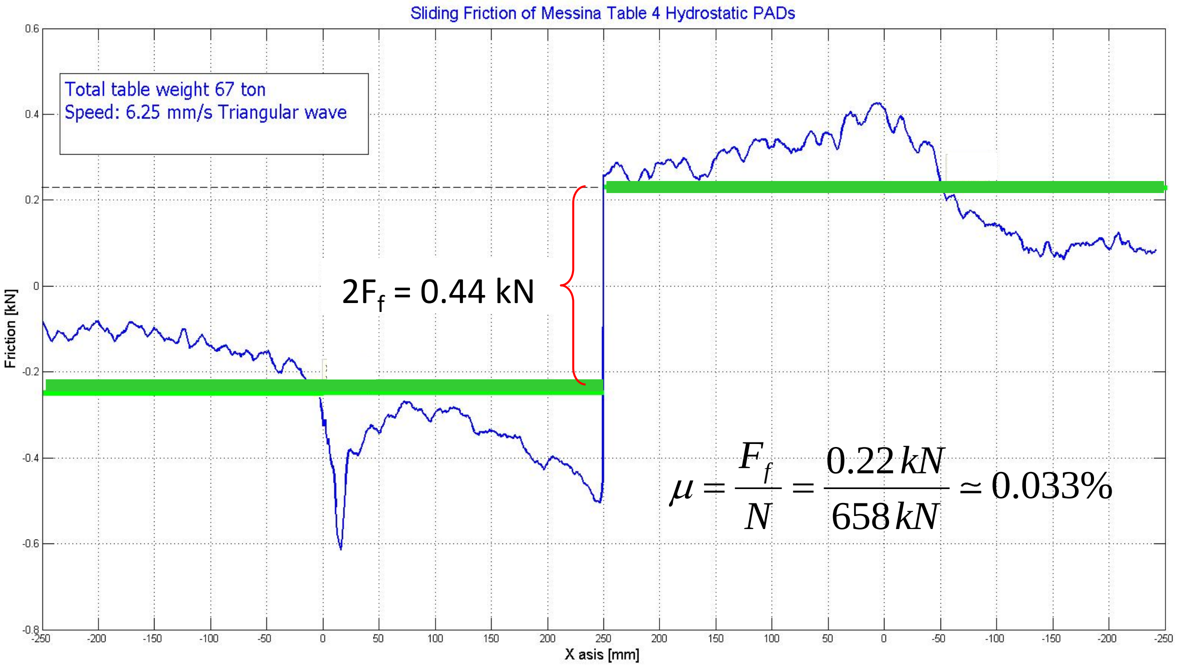
- 4 hydrostatic pads, with special oil pumped at high pressure inside it, connected to the load cell of each actuator, make "float" the sliding table on a film of oil (with high viscosity).



- The lubrication system allows an exceptional dynamics.

Anti-seismic device test facility of CERISI





$$2F_f = 0.44 \text{ kN}$$

$$\mu = \frac{F_f}{N} = \frac{0.22\,kN}{658\,kN} \simeq 0.033\%$$

Anti-seismic device test facility of CERISI

$$F_i + \cancel{F_f} + F_c = F_a \qquad m_p\ddot{u} + \cancel{\mu N} + F_c = F_a$$

$F_i = m_p\ddot{u}$ inertia force of the shaking table

$F_f = \mu N$ friction exerted by hydrostatic pads

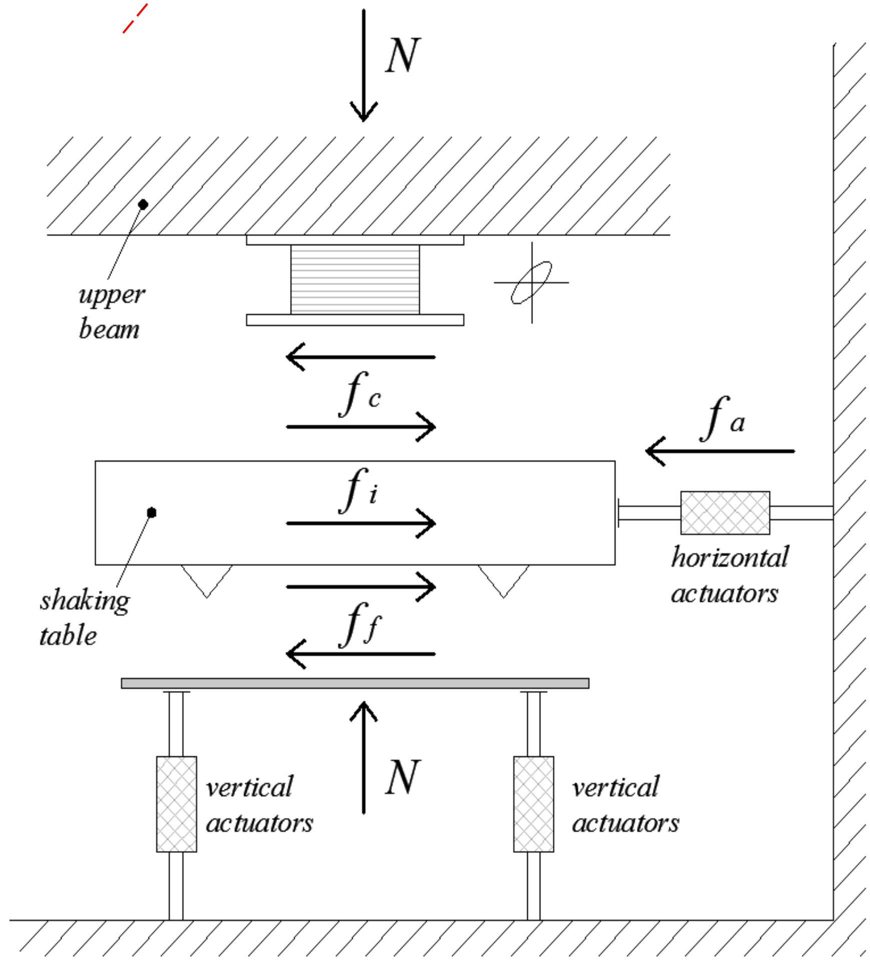
F_c corrected force applied to the specimen

F_a force applied by the horizontal actuators

m_p mass of the shaking table

$\ddot{u}$ acceleration of the shaking table

N vertical load



$$\boxed{F_c = F_a - m_p\ddot{u} - \mu N}$$

Collaborations and customers

C.M.M.
F.LLI RIZZI SRL
STEEL CONSTRUCTION

POLITECNICO DI MILANO

UC San Diego
Jacobs School of Engineering

JSSI

Rexroth
Bosch Group
The Drive & Control Company

MAURER SÖHNE
forces in motion
Since 1876

BRIDGESTONE

mageba
mageba-group.com

JRMA
Japan Rubber Manufacturers Association

TENSA

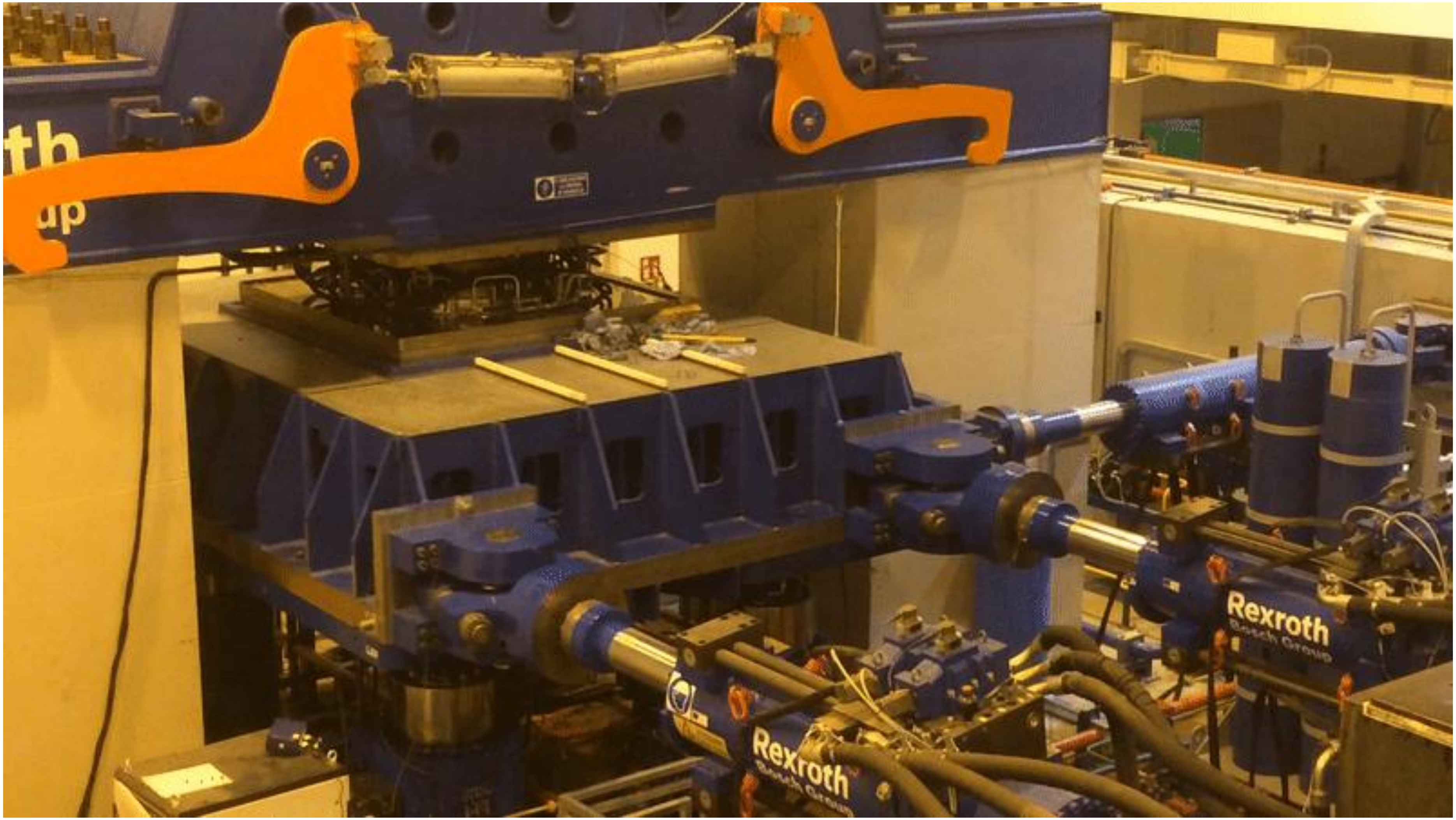
Redaelli

FIP INDUSTRIALE
leading technologies

Some experimental tests…

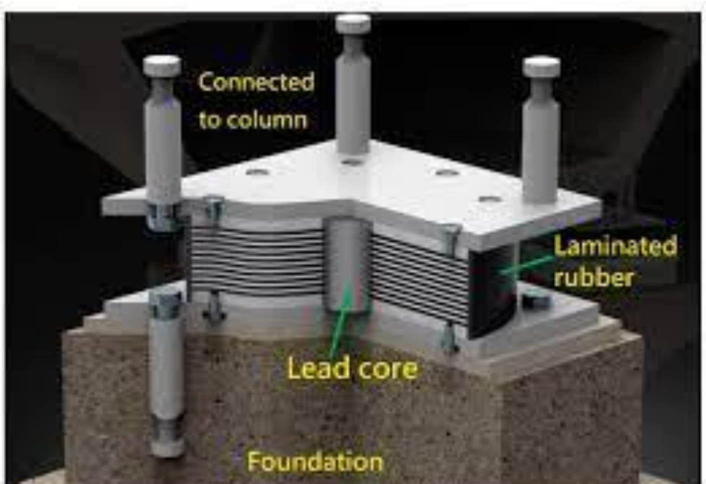
*Full-scale **3D** tests of isolators, and dissipation devices*

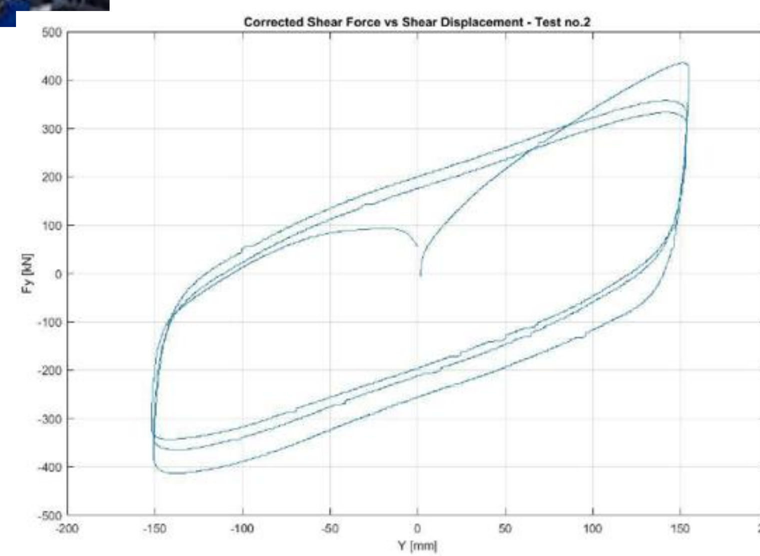
Load capacity 3100kN
Stroke of actuators 550mm
Maximum velocities 1100 mm/s



Experimental tests on elastomeric bearings

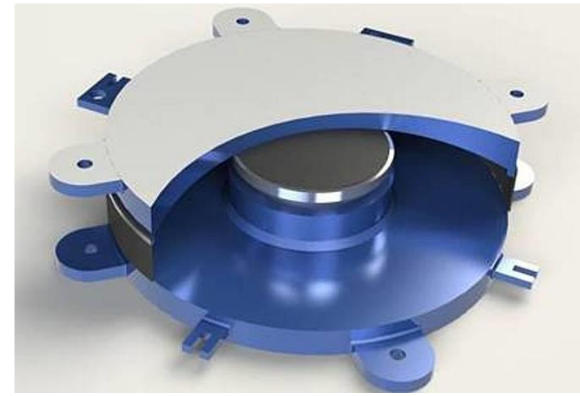
Lead rubber bearing (LRB) isolator



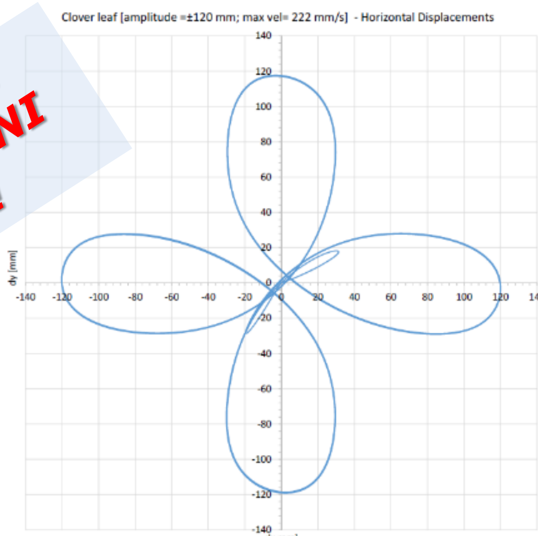


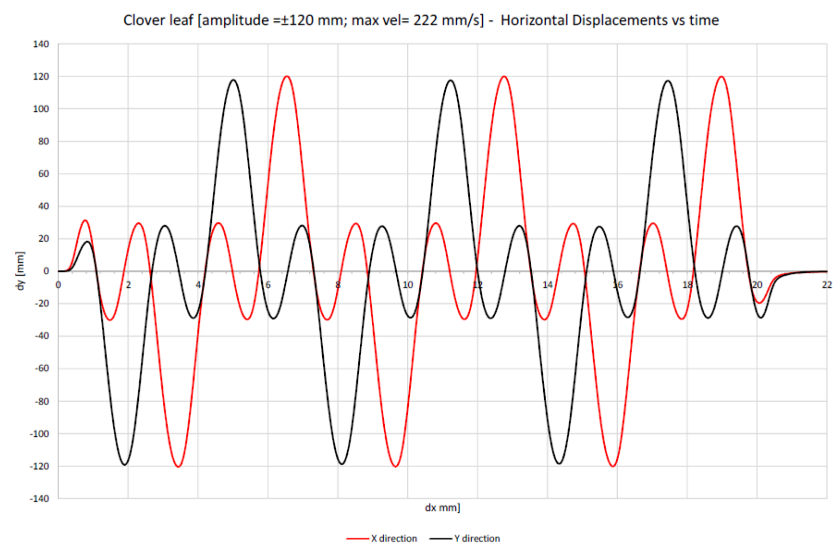
Experimental tests on friction pendulum isolators

Friction pendulum system (FPS)



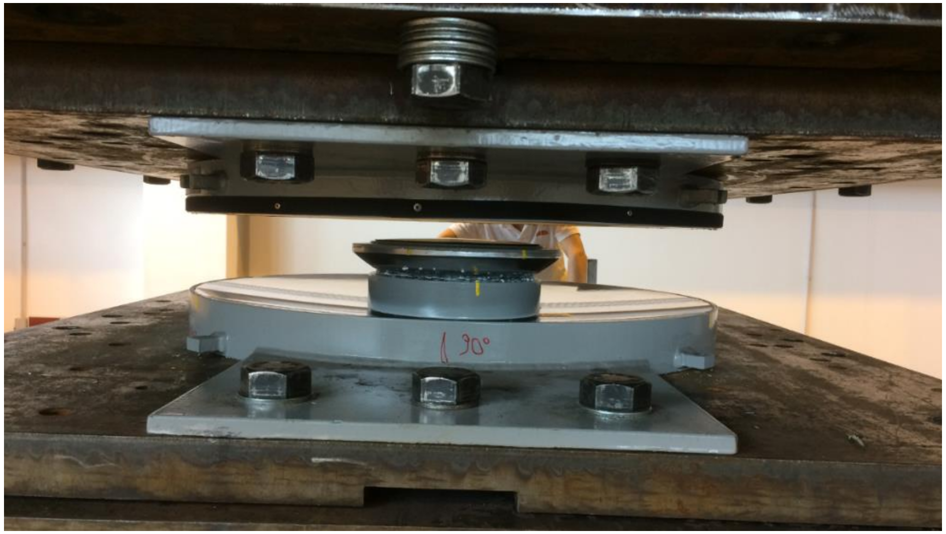
Cloverleaf tests prescribed in UNI EN 15129 !

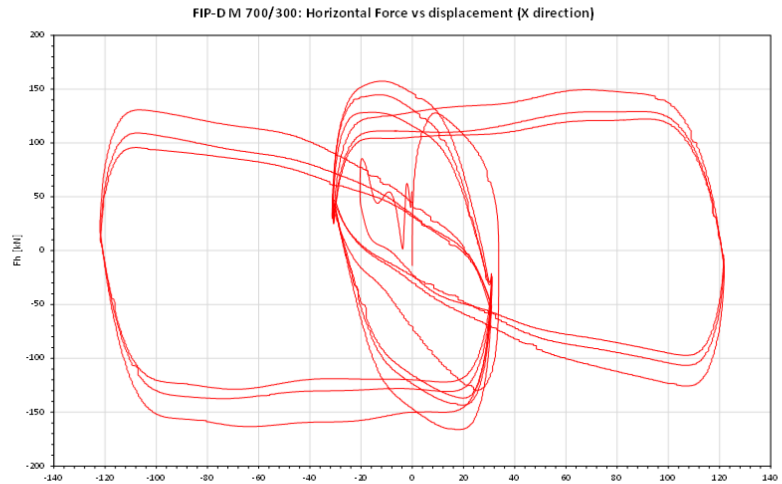


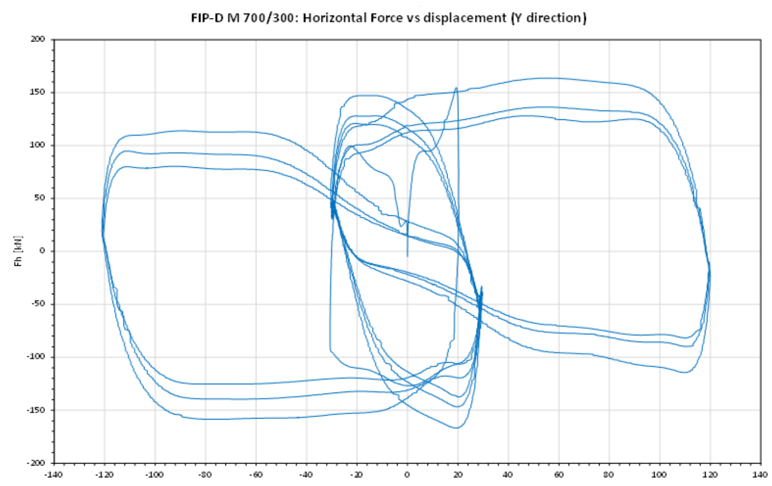


Experimental tests on friction pendulum isolators

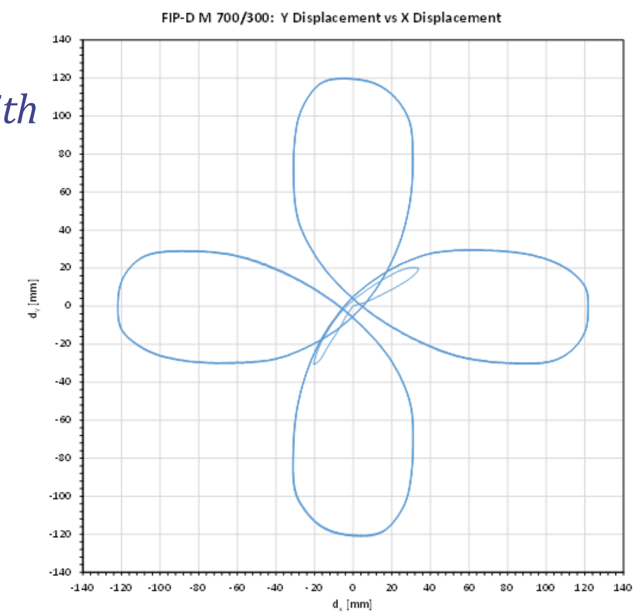
Cloverleaf (bidirectional) tests on double curved surface sliders



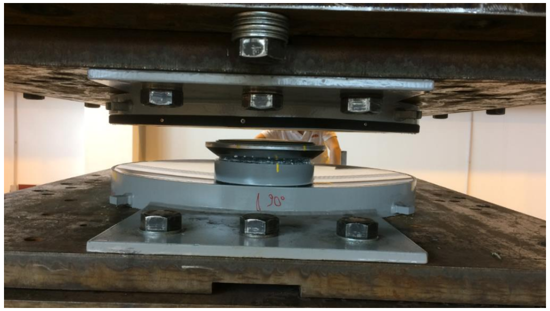




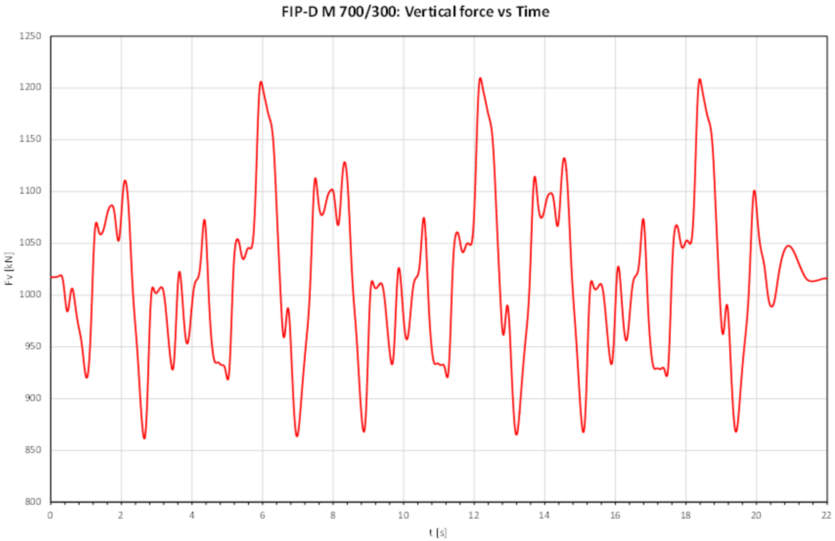
Cloverleaf test with maximum displ. equal to 125mm
3 cycles
Vertical force 1018 kN

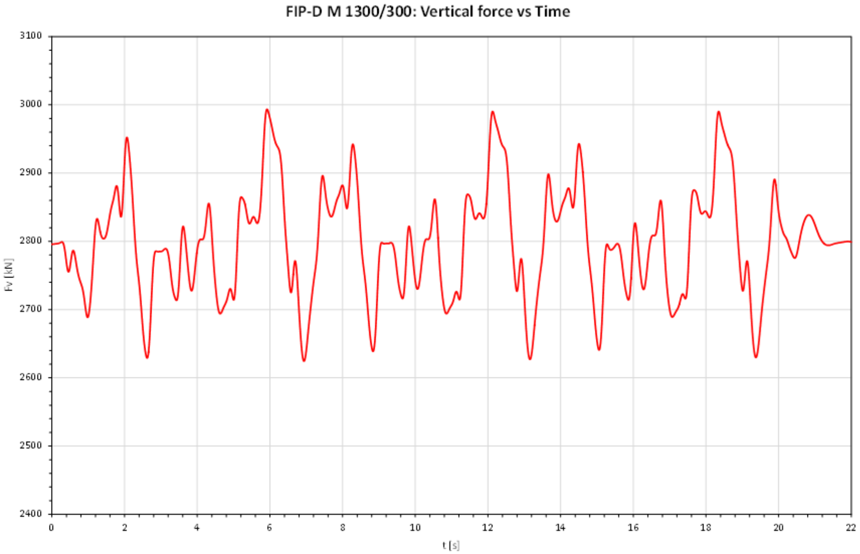


Experimental tests on friction pendulum isolators

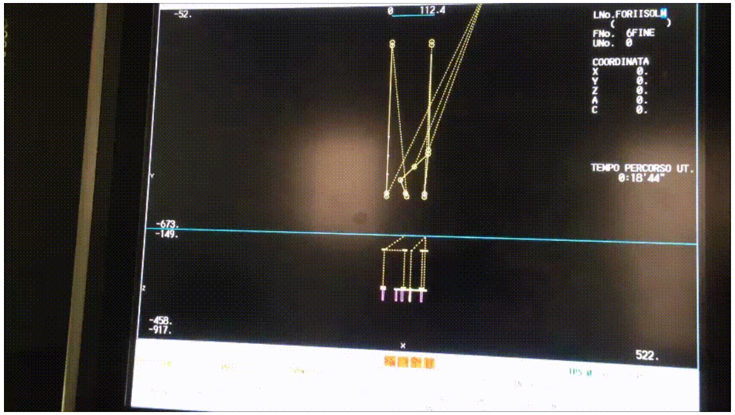


Cloverleaf (bidirectional) tests on double curved surface sliders





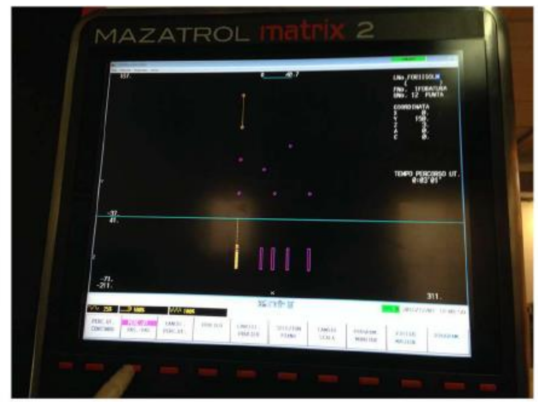
Experiments on thermo-mechanical behavior of FPS

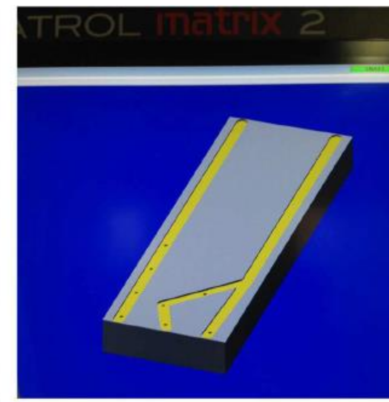


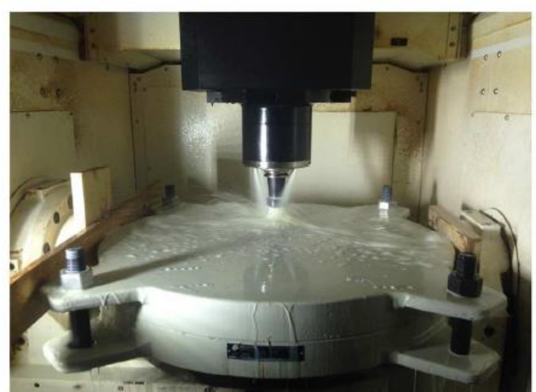
The upper plate of the DCSS prototype is CNC (computer numerical control) machined to create a set of holes that allow the installation of 8 thermocouples

J-type thermocouples are used with temperature range from –60°C to +350°C

Thermocouples installed in contact with the underlying polished stainless-steel sheet of 2.5mm thickness → their measurements representative of the temperature rise at the sliding interface

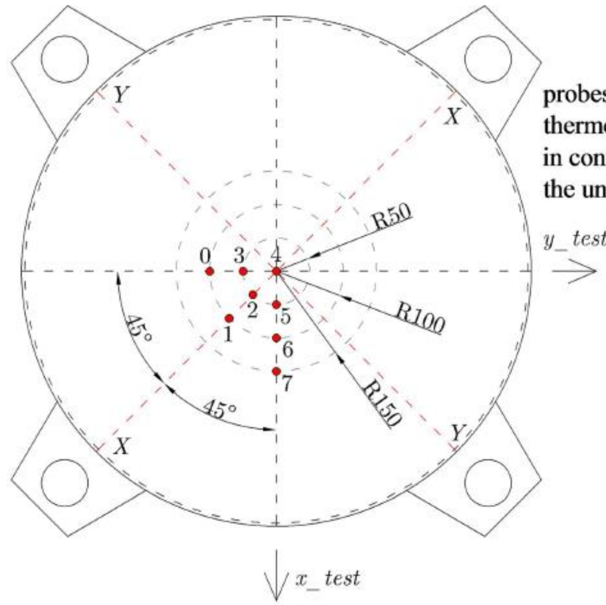


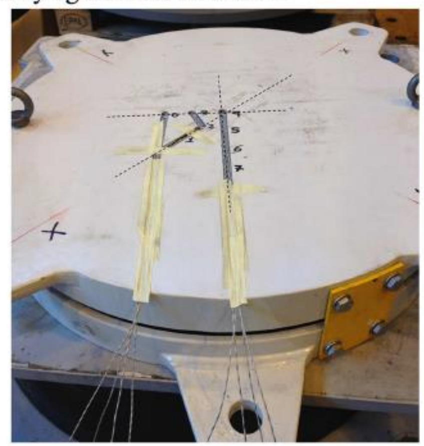


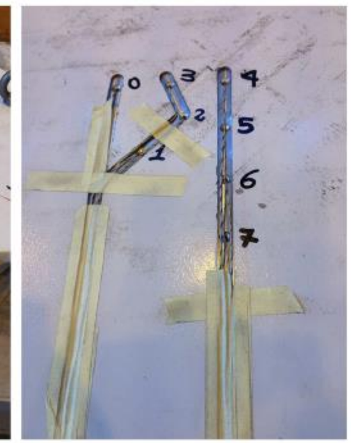


Experiments on thermo-mechanical behavior of FPS

The position in plan allows the evaluation of temperature rise in different points (the heating phenomena depends upon the sliding motion)

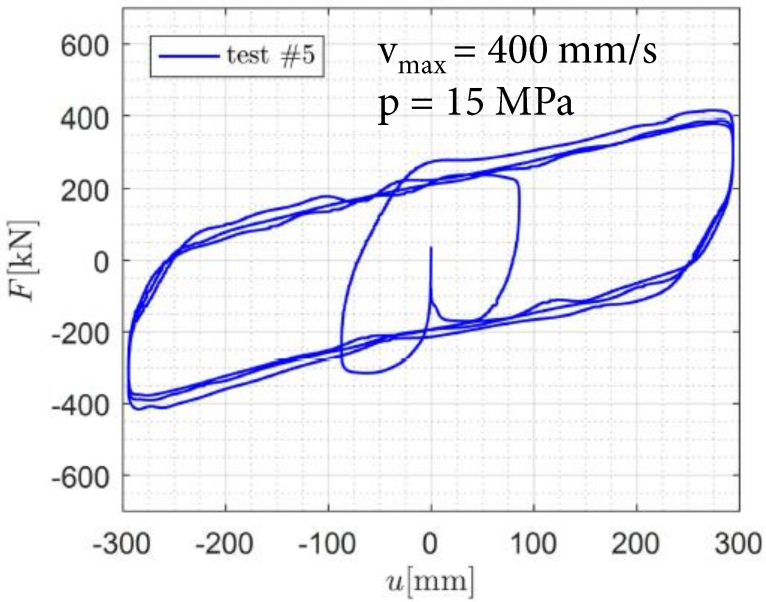


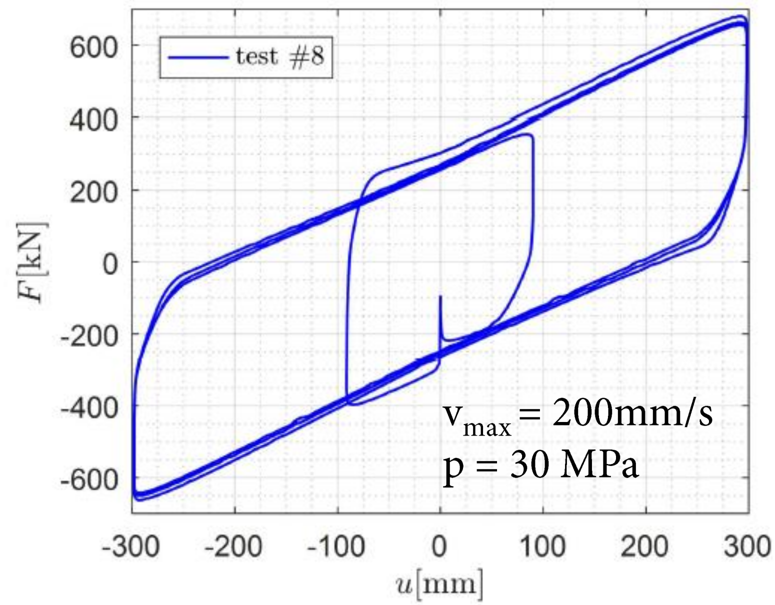


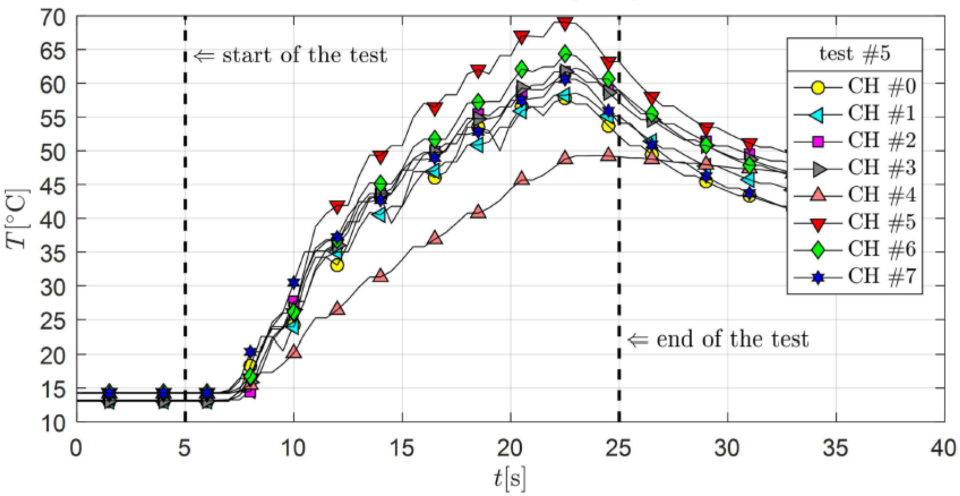


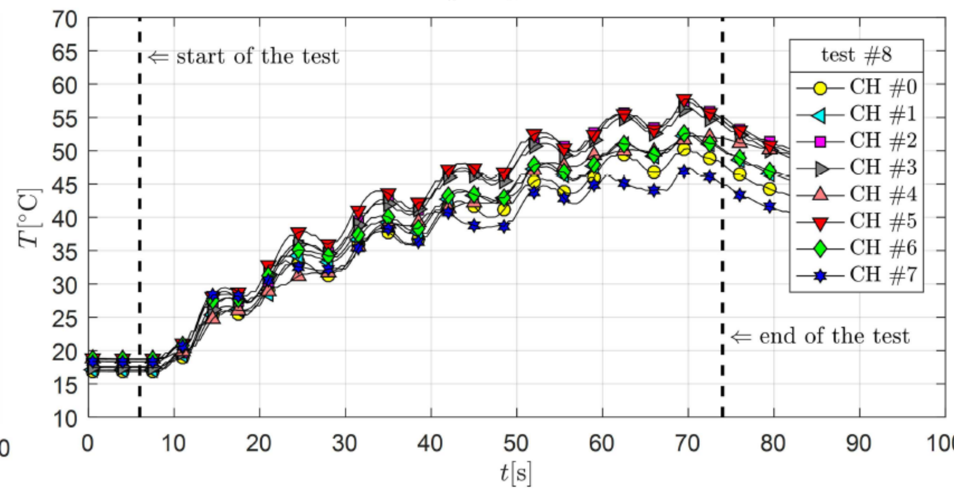
Special care has been taken in order to allow the conductors to come out from the device via two properly realized routes

Experiments on thermo-mechanical behavior of FPS



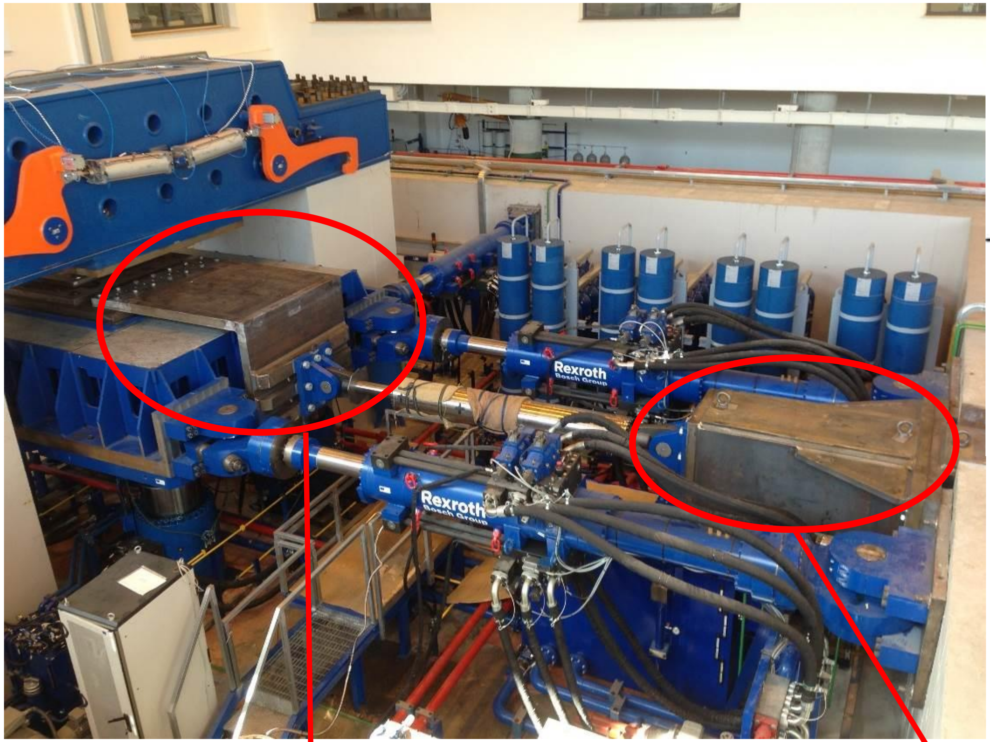




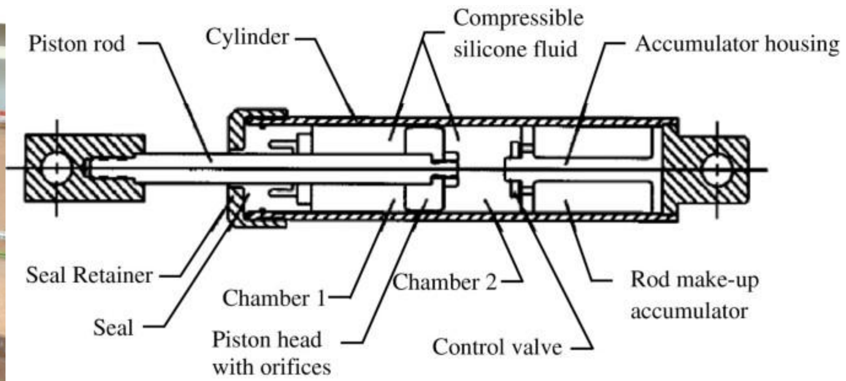


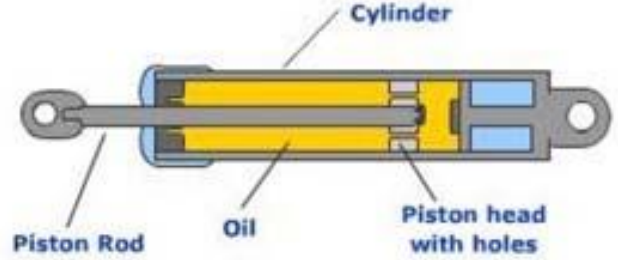
The loops are narrowing after repetition of cycles, which is due to the friction variation induced by the temperature rise

Experimental tests on fluid viscous dampers



Fluid viscous dampers





Experimental tests on fluid viscous dampers

Fluid viscous dampers

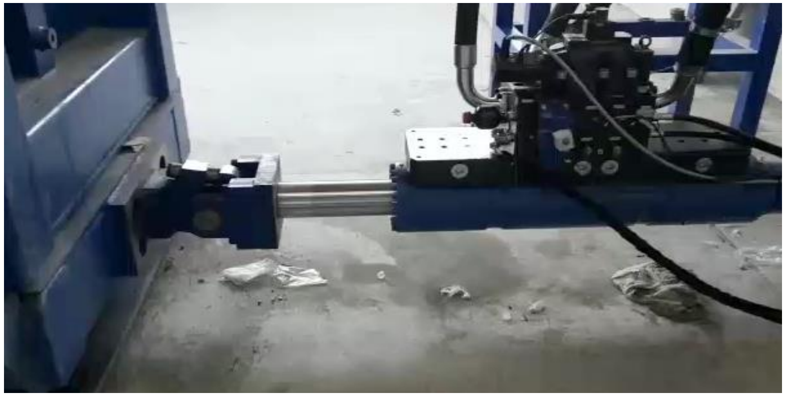
During the tests, the damper experiences a significant temperature rise due to the viscosity of the silicone oil. European regulations UNI EN 15129:2009 prescribe that the test can be started provided that the temperature of the device is below 35°C. The damper was wrapped with wet clothes to speed up the cooling process during the testing protocol…

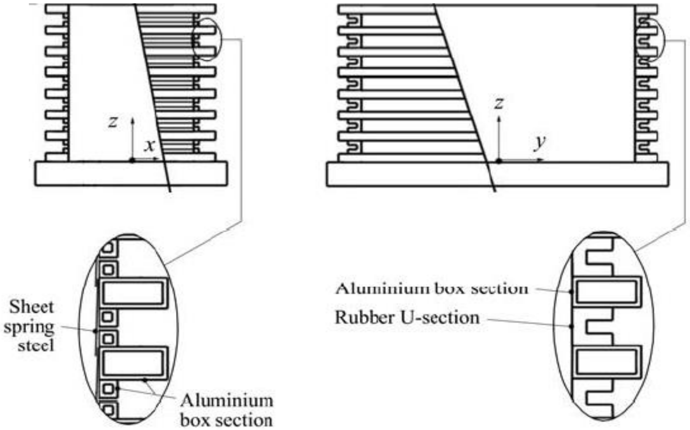
Laminar box – shear stack

- A shaking table equipped with a "laminar box" allows in-scale tests in the field of geotechnical seismic engineering, for studying <u>local amplification phenomena and soil-structure interaction</u>.

- Rectangular aluminum rings stacked alternately with rubber profiles.

- Shaking table moved horizontally by a servo hydraulic actuator, maximum load 33 ton at 1g and 40 ton at 0.75g. The table operates up to 40 Hz.





Laminar box – shear stack

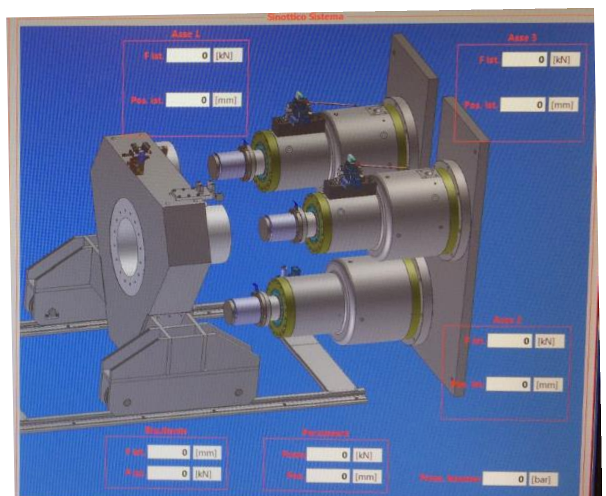
Cables test bench

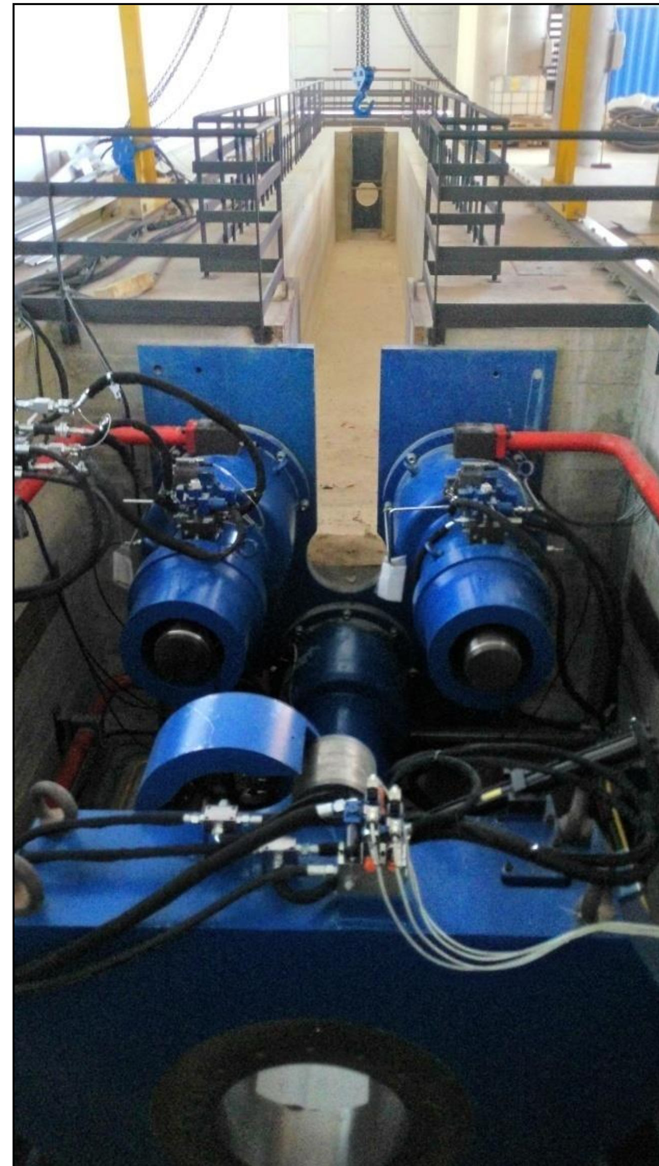
- A test bench for the characterization of cables and stay cables for long-span bridges allows to perform failure tests and fatigue tests on full-scale components of large infrastructures.

Maximum static force:	31,000 kN
Dynamic force superimposed:	3,300 kN
Trench length:	30.6 m
Stay cables length under test (max):	22 m
Stay cables can be tested:	up to 109 wire strands
Transversal dynamic force:	280 kN

3 servo hydraulic actuators in parallel

Patent Bosch Rexroth





Cables test bench

Suspension bridges

Cable-stayed bridges

Arch suspended bridges

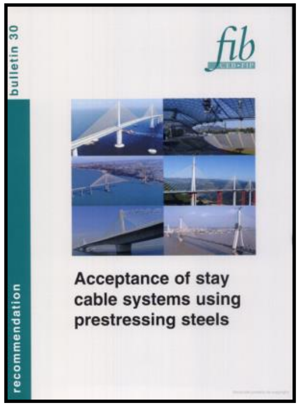
Cableways

Post-tensioned cables

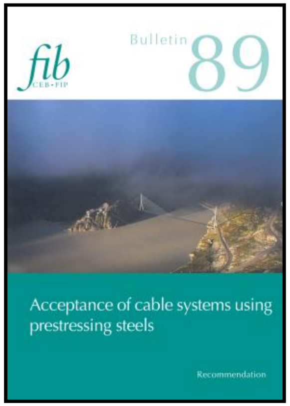
Cables test bench

Tests are performed in accordance with fib Bulletin "Acceptance of cable systems using prestressing steels"

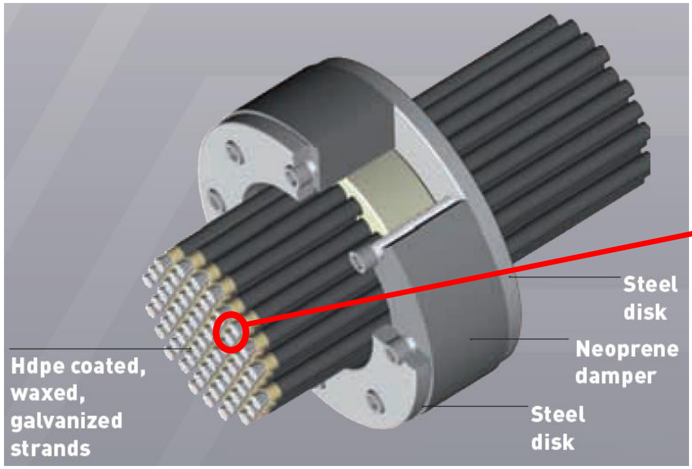
2005



2019



N° of strands	Nominal breaking load Fpk [kN]	Maximum working load 45%Fpk [kN]	Maximum tested fatigue load range (200 MPa) [kN]
31	8.649	3.892	930



Characteristics of the tested cable:

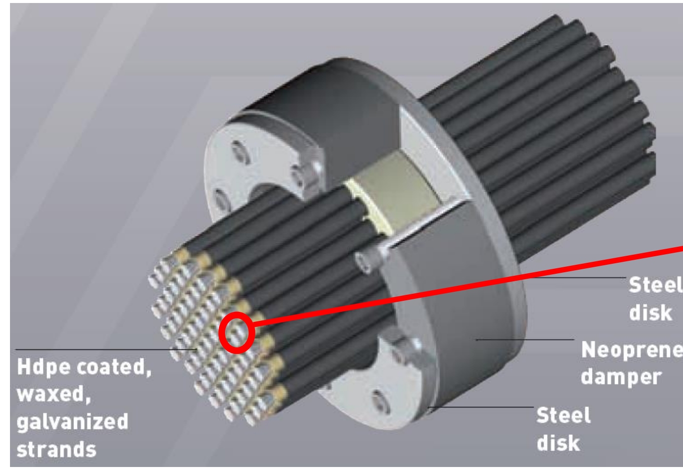
***n. 31** galvanized , waxed and hdpe coated seven-wire low-relaxation steel **strands** with 15.7 mm nominal diameter*

high-density polyethylene

At the end of fatigue test, it shall be verified that:

- "not more than 2% of the number of individual wires (rounded to the nearest whole number) or not more than 2 wires, if the number of wires is less than 100, may fail": so, since the total number of wires is 7 x 31 = 217, it is allowed to have not more than 4 wire breakages during the fatigue test;
- "no failure shall occur in the anchorage materials or in any component of the anchorage during the fatigue test"; this requirement does not apply to cracking of wedges.

Cables test bench



Characteristics of the tested cable:

n. 31 *galvanized seven-wire low-relaxation steel* ***strands*** *with 15.7 mm nominal diameter*

Nominal steel strand area:	150 mm^2
Area of the cable A_{pk}:	31*150 = 4650 mm^2
Steel grade f_{ptk}:	1860 MPa
Mean force (**45% f_{ptk}** = 837 MPa):	≈ 3427 kN
Variation of force (**$\Delta\sigma$ = 200 MPa**):	± 465 kN
Elastic elongation due to mean force:	78 mm
Variation of elongation due to $\Delta\sigma$:	± 10.5 mm
Number of cycles:	**2*10^6 cycles**

If frequency is 1 Hz → 23 days test duration!!

…Messina Strait Bridge ???

World's Largest Suspension Bridge

main span	3 300 m
total length	5 070 m
sag:span	1:11
span lengths	183 m - 3 300 m - 183 m
suspended length	3 666 m

cables	total length	5 300 m
	cable diameter	4 × 1.24 m
	number	4

9TH INTERNATIONAL WORKSHOP ON RELIABLE ENGINEERING COMPUTING
Risk and Uncertainty in Engineering Computations
Virtual Conference: May 17-20, 2021
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UNIVERSITY OF MESSINA
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Thank you for your kind attention!

Further information at:

http://cerisi.unime.it/en.html

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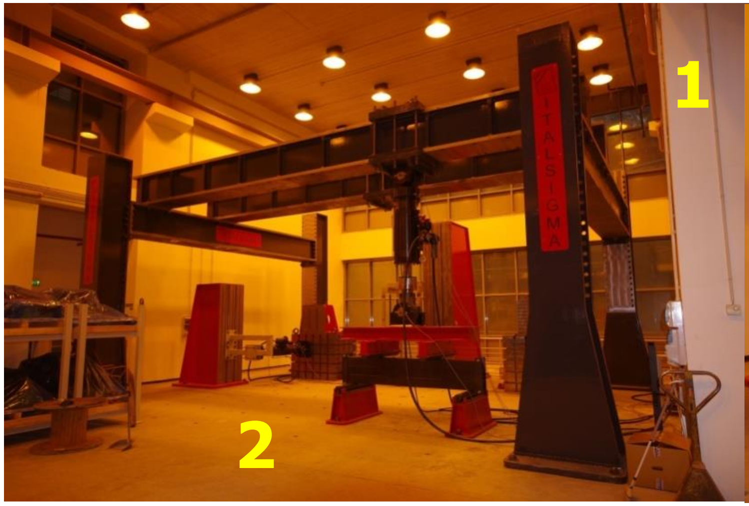
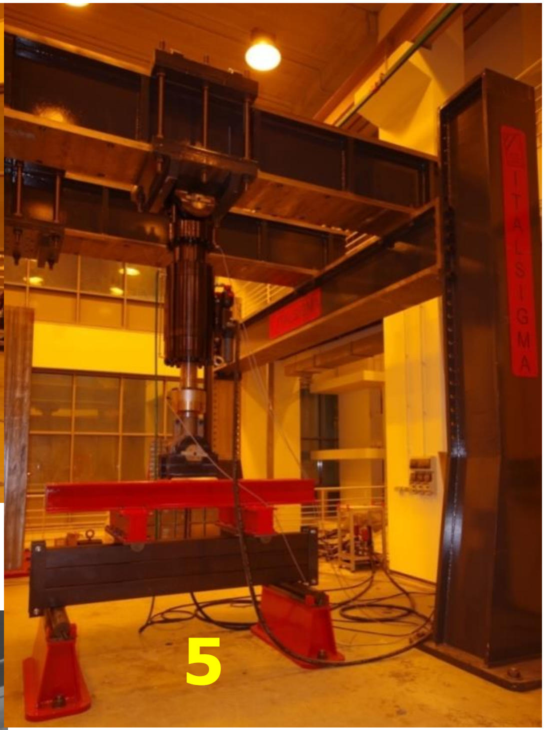
Structural laboratory for large-scale tests

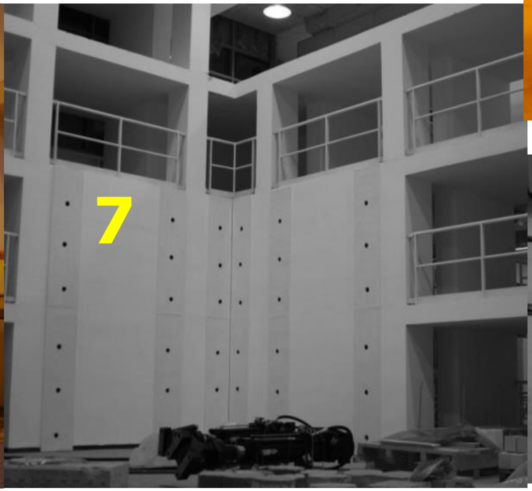
Laboratory for large-scale tests includes the following facilities :

1. Two frame structures (9x7x5 m, 6x6x5 m);
2. Strong floor
3. Movable test benchs
4. Movable reaction arms (H=4 and 2m)
5. Accessories for bending tests
6. Hydraulic actuators
   - load: +/- 1000 kN, +/- 500 kN. +/- 250 kN; +/- 100
   - displacement: +/- 100 mm);
7. L-shape strong wall for bi-directional testing
8. Extensometers

Structural laboratory for large-scale tests







Structural laboratory for large-scale tests

- Seismic retrofitting/upgrading of civil structures;
- Seismic load and deformation capacity of building elements.

Dimensions (W x L): 9 x 7m – H = 5m

The system of the strong floor/reaction wall can be used for cyclic or pseudo-dynamic testing of earthquake-resistant components and small structures.