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THE USE OF ANTISEISMIC DEVICES

FOR THE REDUCTION OF THE EARTHQUAKE ACTIONS ON THE STRUCTURES

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Tehran, 13 July 2016

How to protect a structure from the earthquake?

There are 2 systems

1. First system is to design the structure strong enough to resist the earthquake (like the Inca wall)

➢ In case of earthquake structural damages are admitted but not the collapse of the structure

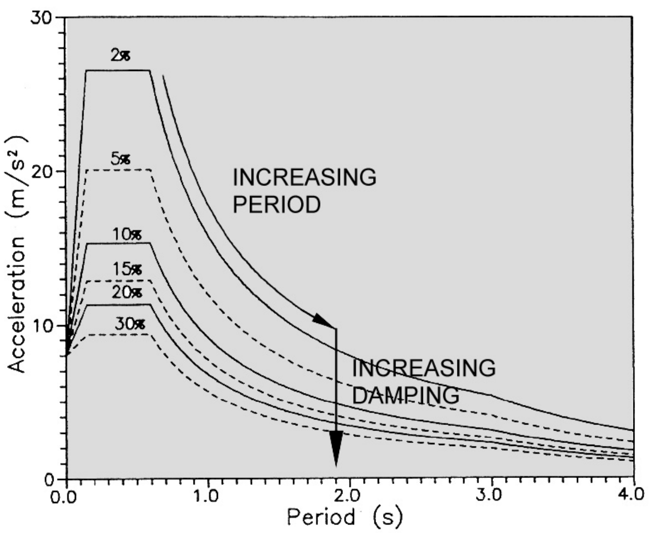
How to protect a structure from the earthquake?

2. Second system (SMART SYSTEM or TECHNOLOGIC ADVANCED SYSTEM) is to reduce the seismic action.

- The seismic action in the structure is reduced
- Damages, if any, will be concentrated in the antiseismic devices
- The structure and its content are protected from any damage

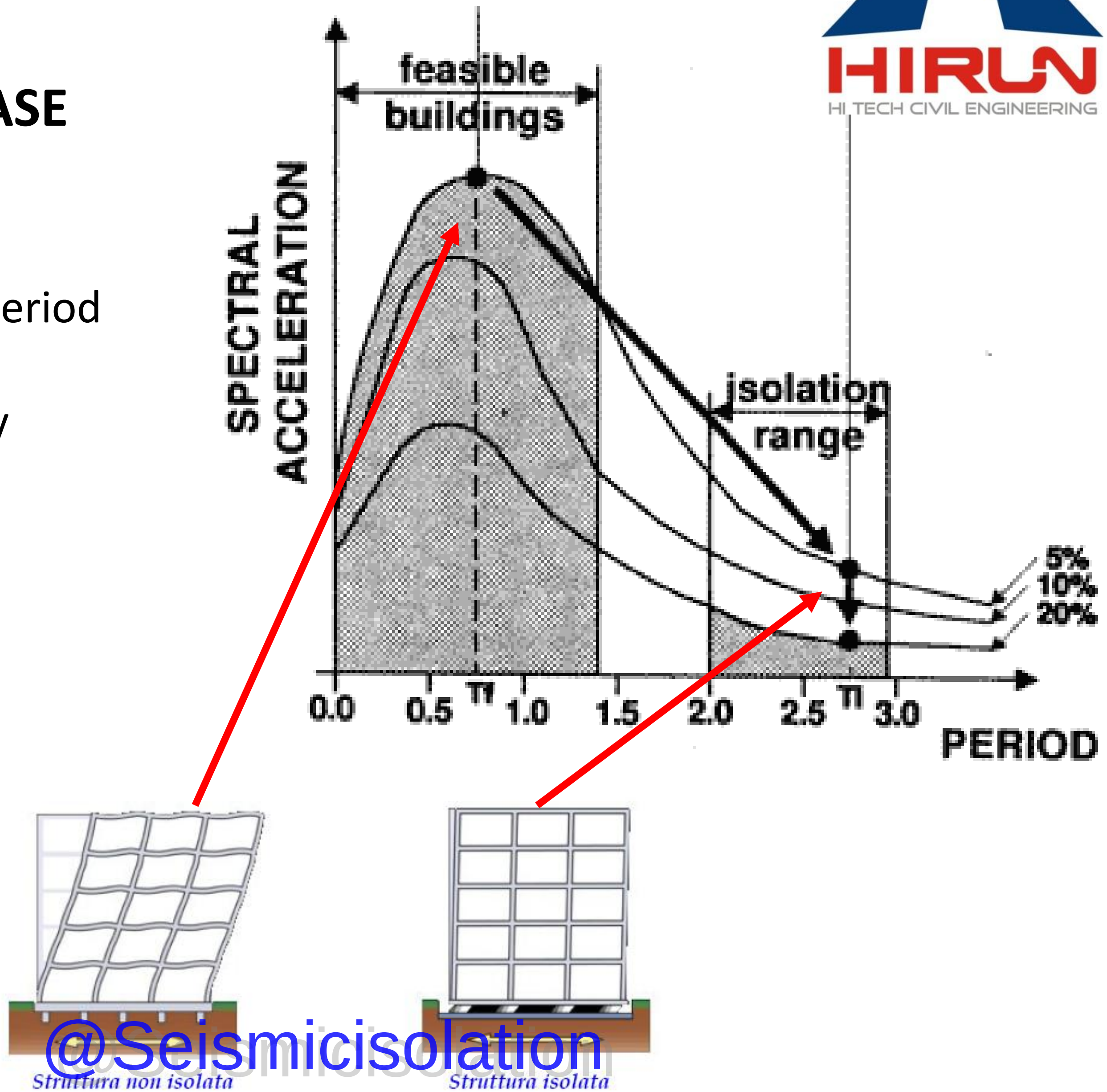
How to reduce the seismic action?

- Increasing the natural period of the structure
- Increasing the damping (dissipating energy)
- By a combination of the 2 systems



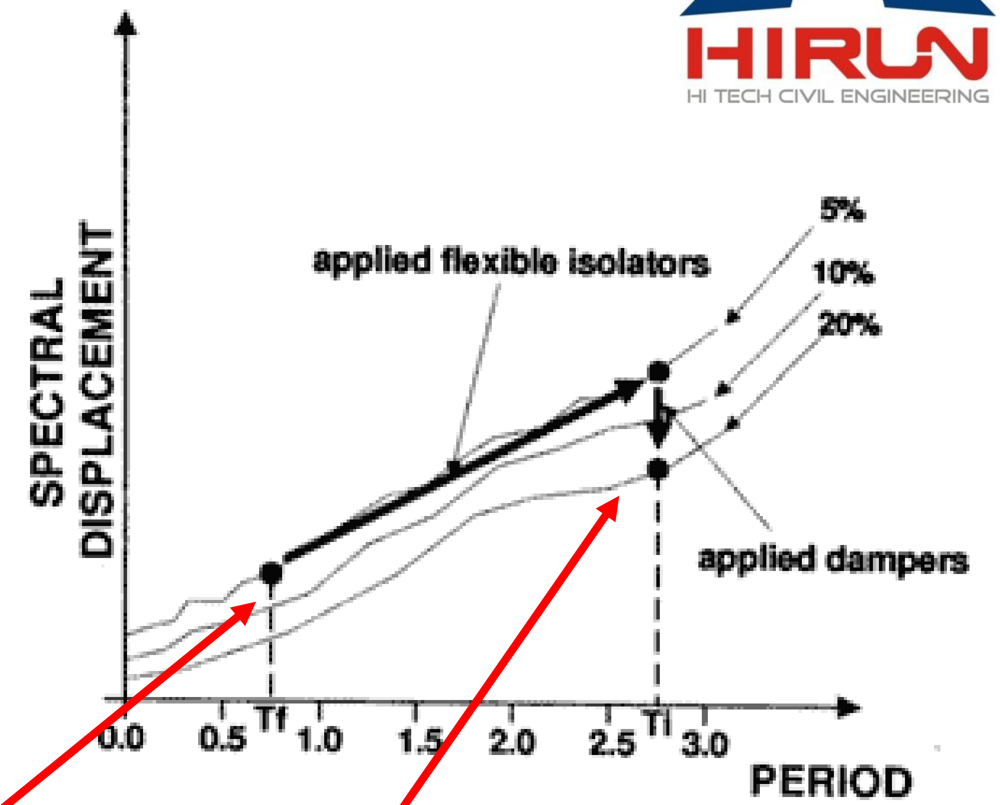
TARGET OF THE BASE ISOLATION

- Shifting the natural period
- Increasing the energy dissipation

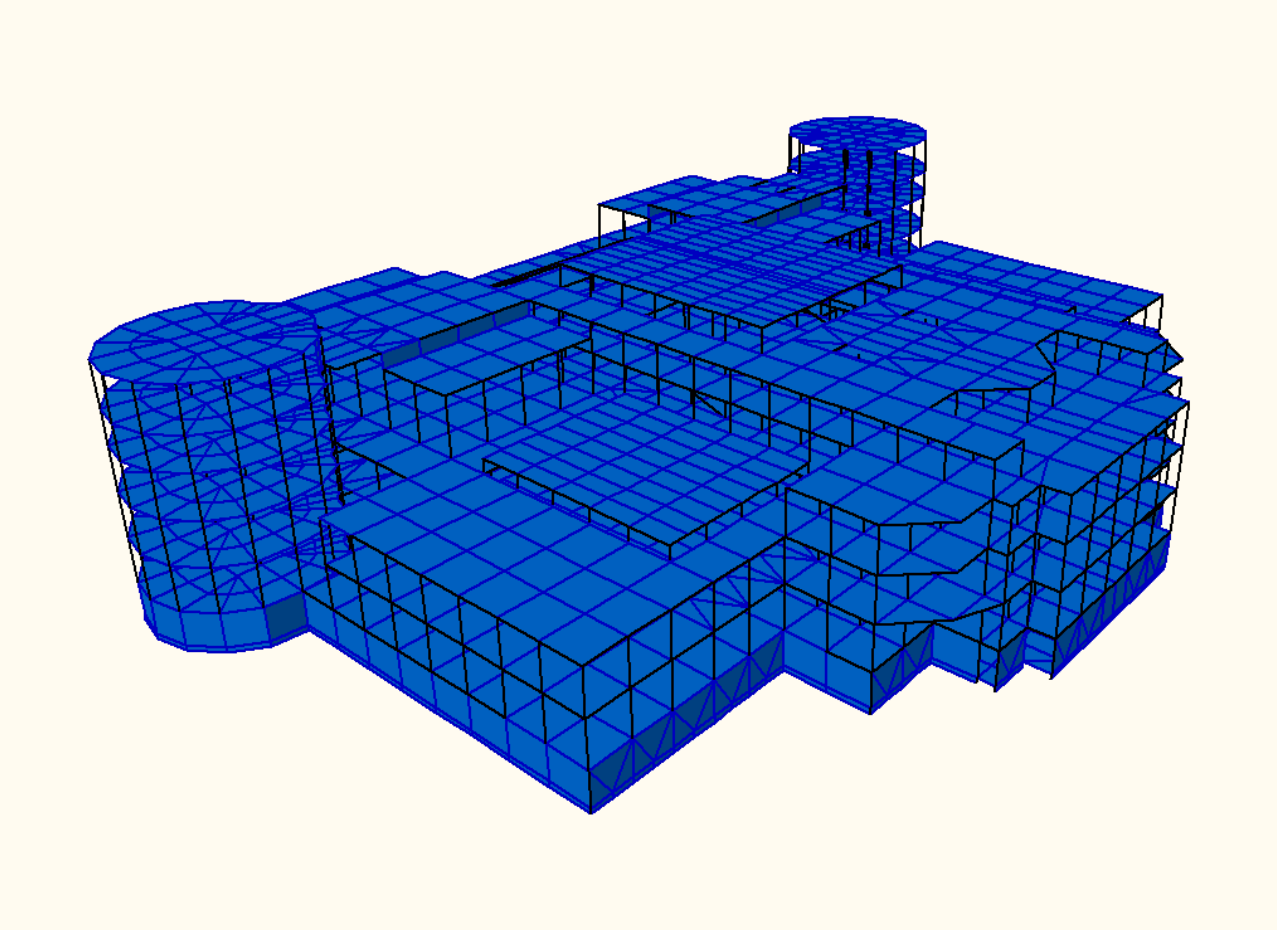


CONSEQUENCES OF THE BASE ISOLATION

•Significant increase of the displacement
•Energy dissipation will reduce the displacement



FIXED BASE BUILDING



BASE ISOLATED BUILDING

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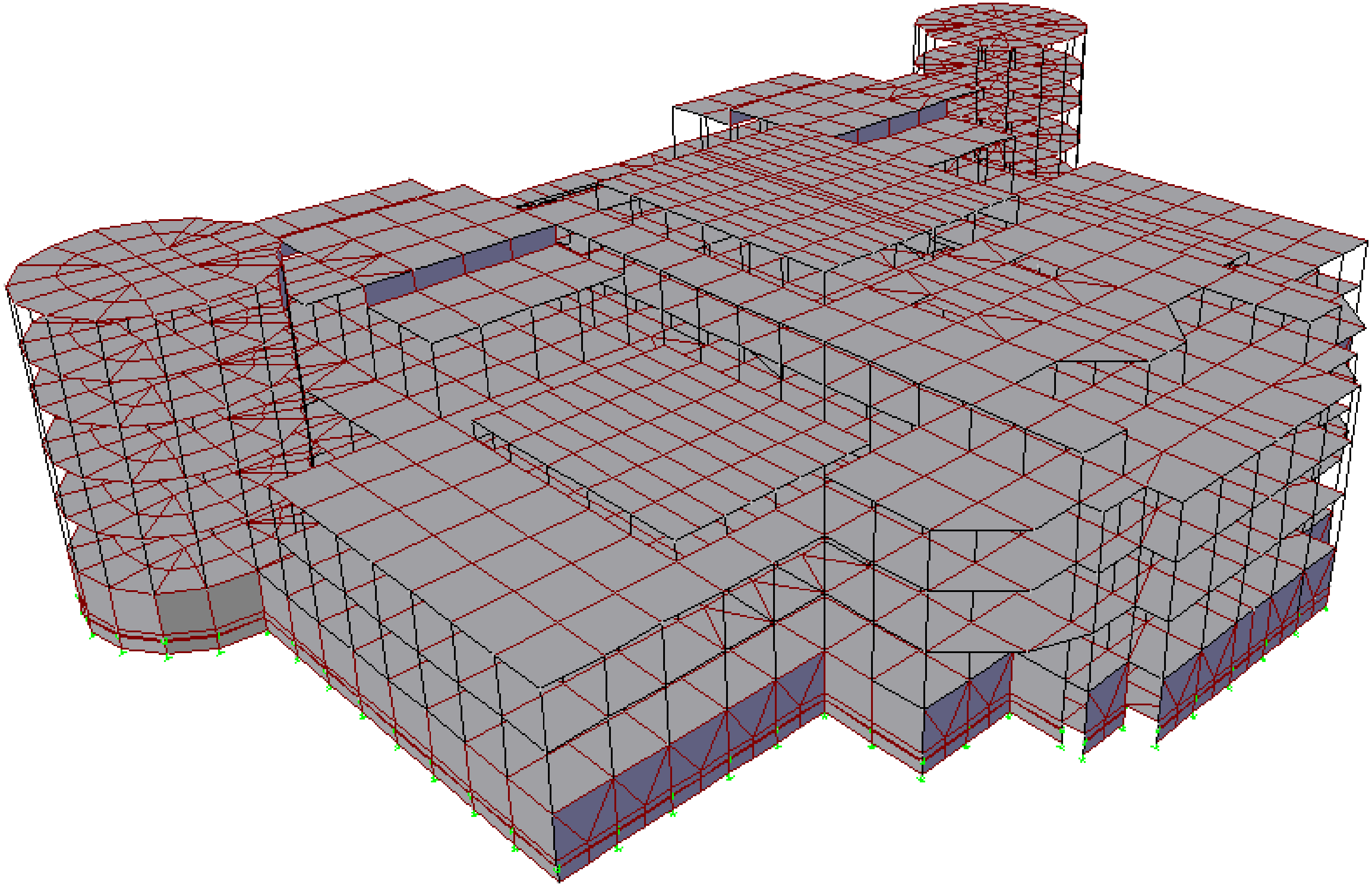

How to increase the natural period of a structure?

- Placing between the structure and the foundations a harmonic oscillator forcing the structure to swing according to the period of the oscillator

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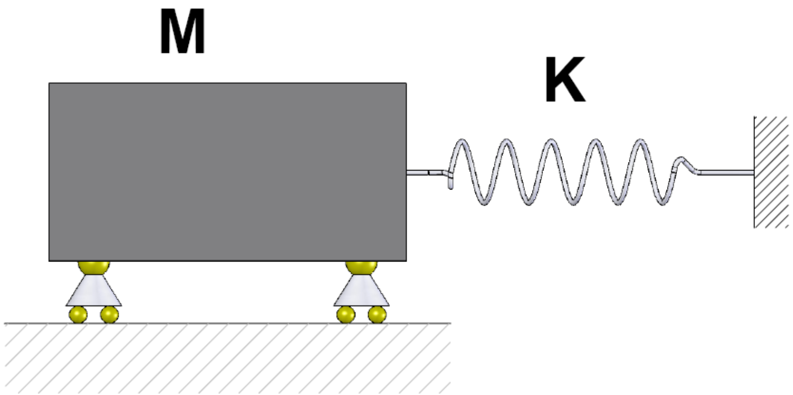
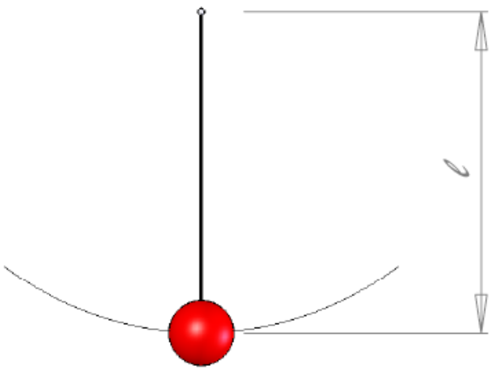
Harmonic oscillators

- Spring with stiffness K
- Pendulum with length l





$$T = 2\pi\sqrt{\frac{M}{K}}$$

$$T = 2\pi\sqrt{\frac{l}{g}}$$

How to dissipate energy?

- Friction
- Yield of metals
- Viscosity of fluids or rubbers

In any case an amount of heath equivalent to the dissipated energy is generated

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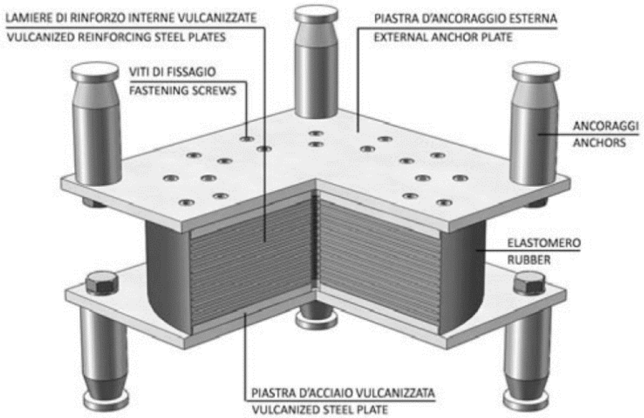
Main types of Isolators

- High Damping Rubber Bearing
  - The spring effect is given by the rubber elasticity (elastic energy storage)
  - The energy dissipation is given by the rubber viscosity



Main types of Isolators

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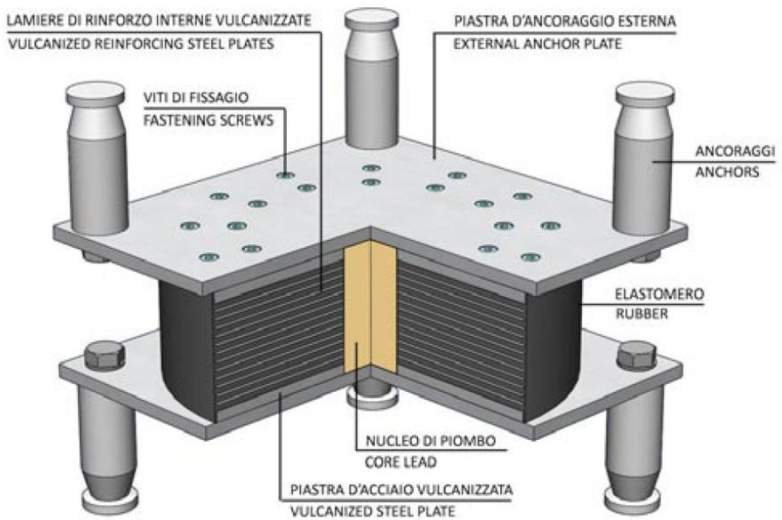
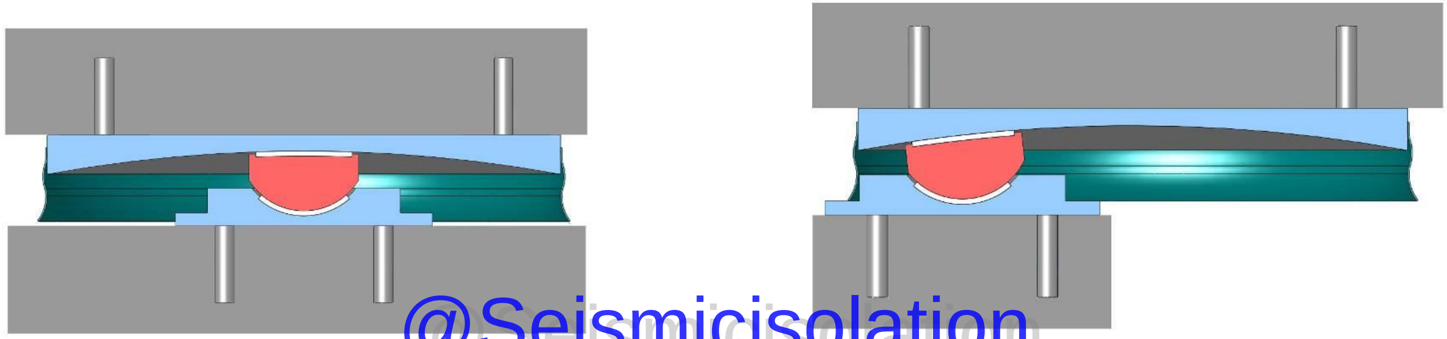
- Lead Rubber Bearing
  - The spring effect is given by the rubber elasticity (elastic energy storage)
  - The energy dissipation is given by the yield of the lead core



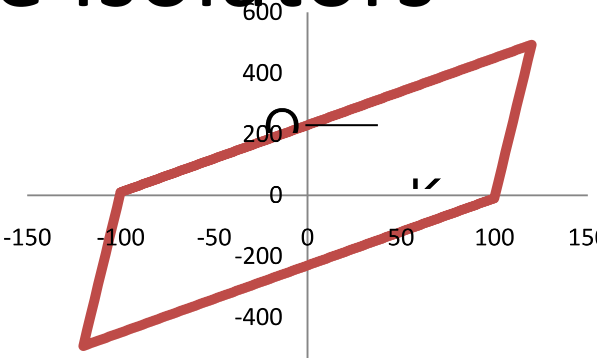
Main types of Isolators

- Sliding Pendulum
  - The spring effect is provided by the potential energy storage
  - The energy dissipation is provided by the friction of the sliding material

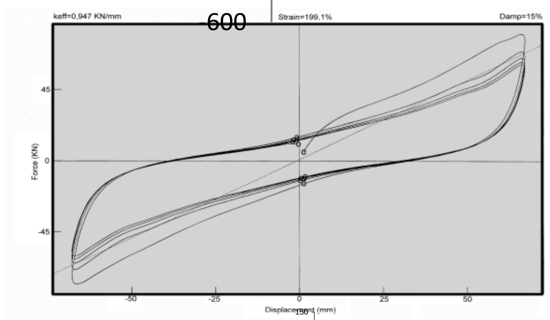


Hysteresis Cicles of the Isolators

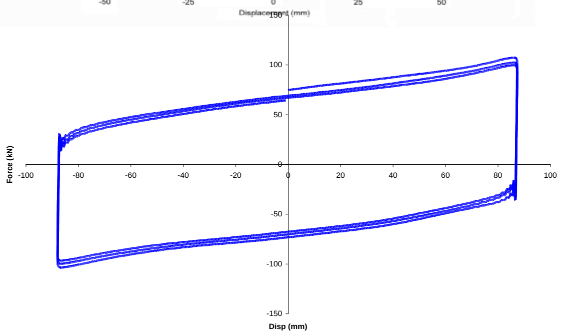
- LRB



- HDRB



- Sliding Pendulum



The Standards for the Antiseismic Devices

In Europe:

- EN 1998 (Eurocode 8)
- EN 15129 European Standard for Antiseismic Devices

In USA:

- AASHTO Guide Specification for Seismic Isolation Design

The Standards for the Antiseismic Devices

In China:

- GB 50011 Seismic design for buildings
- GB 20688.1 Test method for rubber isolators
- GB 20688.2 Rubber isolators for bridges
- GB 20688.3 Rubber isolators for buildings
- JT/T 852 Friction pendulum
- JT/T 3320 Double spherical isolators
- TB/T 3320 Spherical bearings for railway bridges

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Type oriented classification of anti-seismic devices

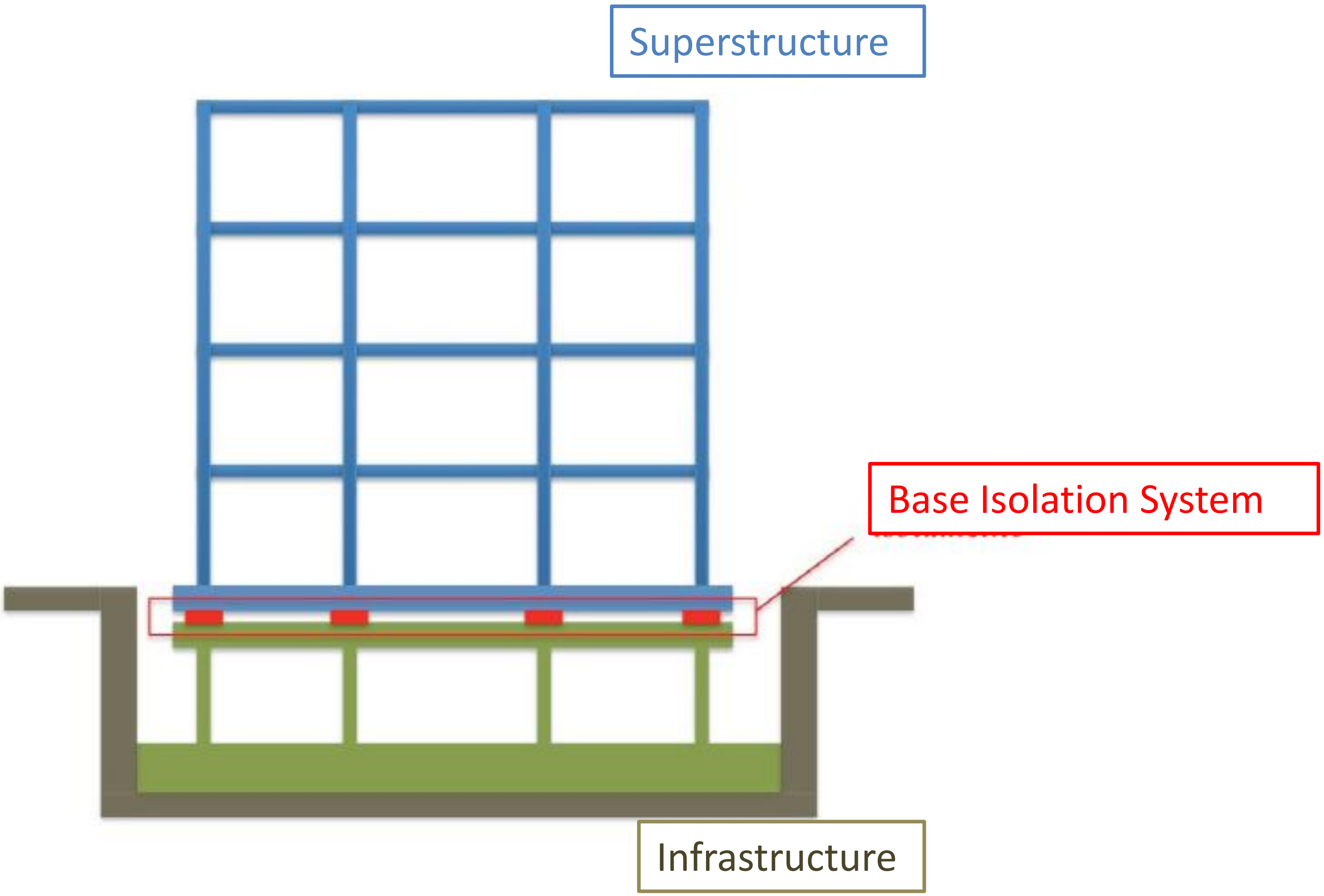
- HDRB (High Damping Rubber Bearings)
- LRB (Lead Rubber Bearings)
- Hysteretic Dampers
- Sliding Pendulum Isolators
- Hydraulic Devices
  – Viscous Dampers
  – Shock transmission units - STU

Functions of a base isolation system

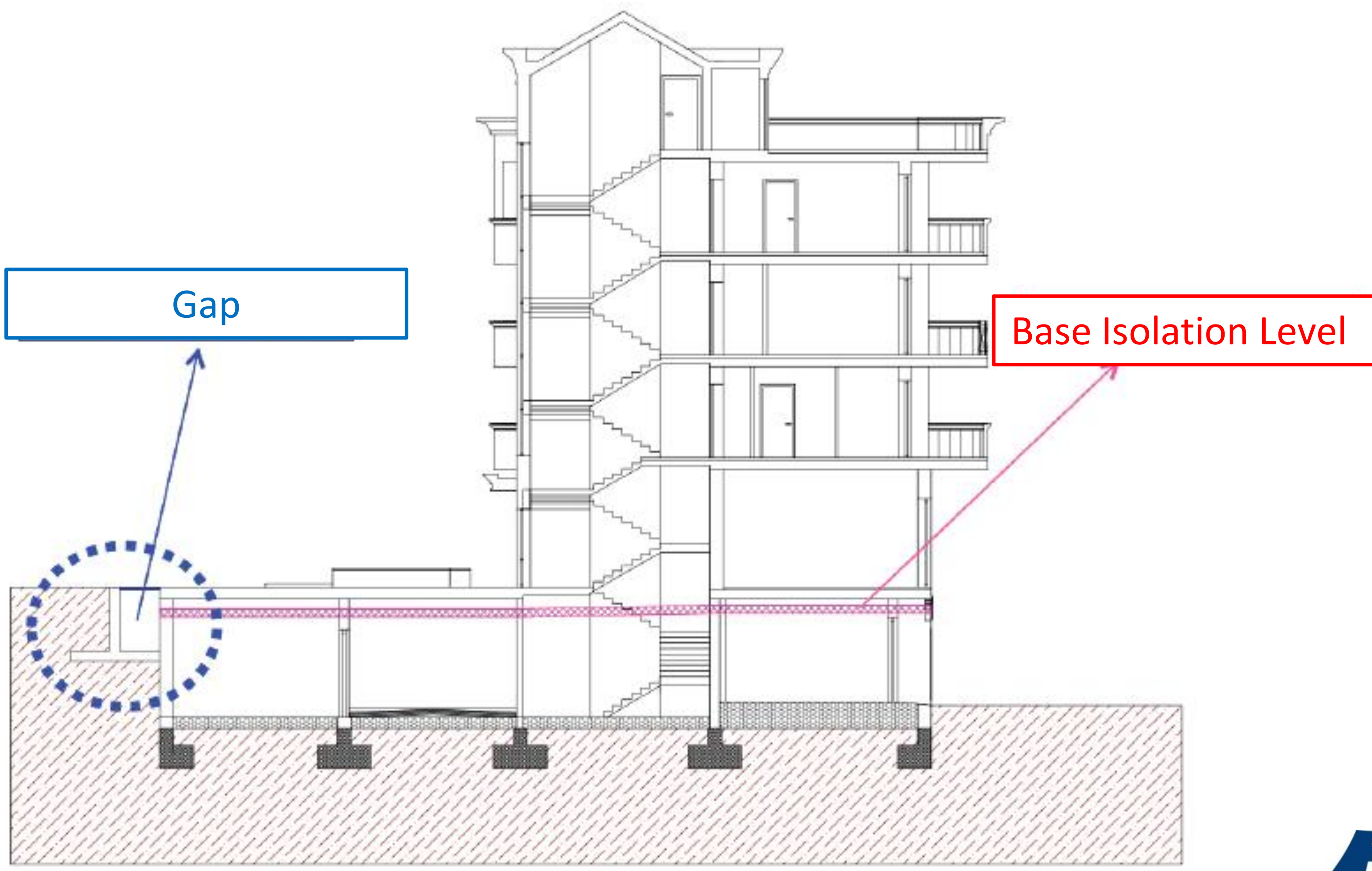
- Support the vertical load
- Provide lateral flexibility
- Provide a restoring force
- Damp the energy

Isolators are devices providing the four functions

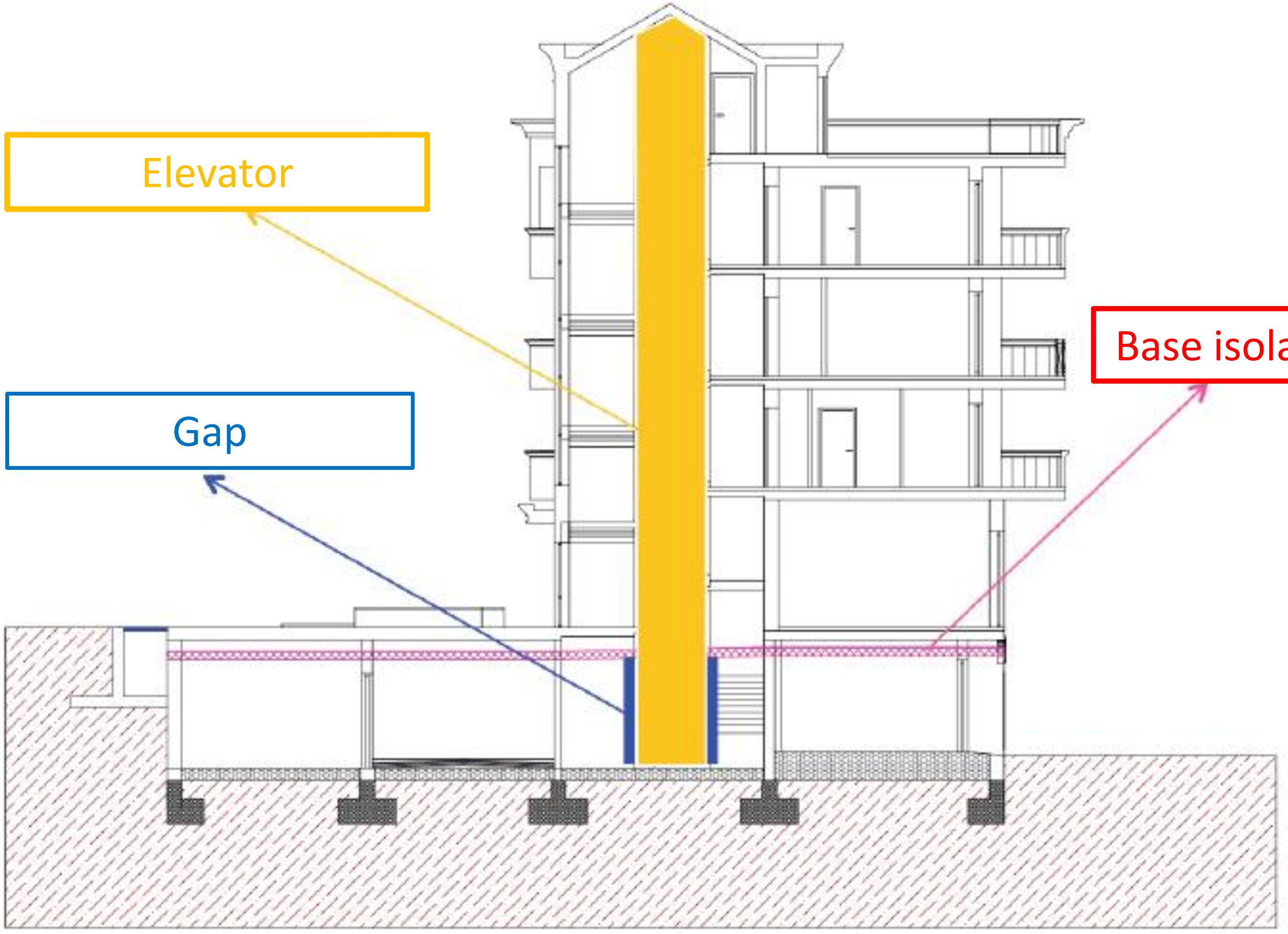
General rules for a base isolated building



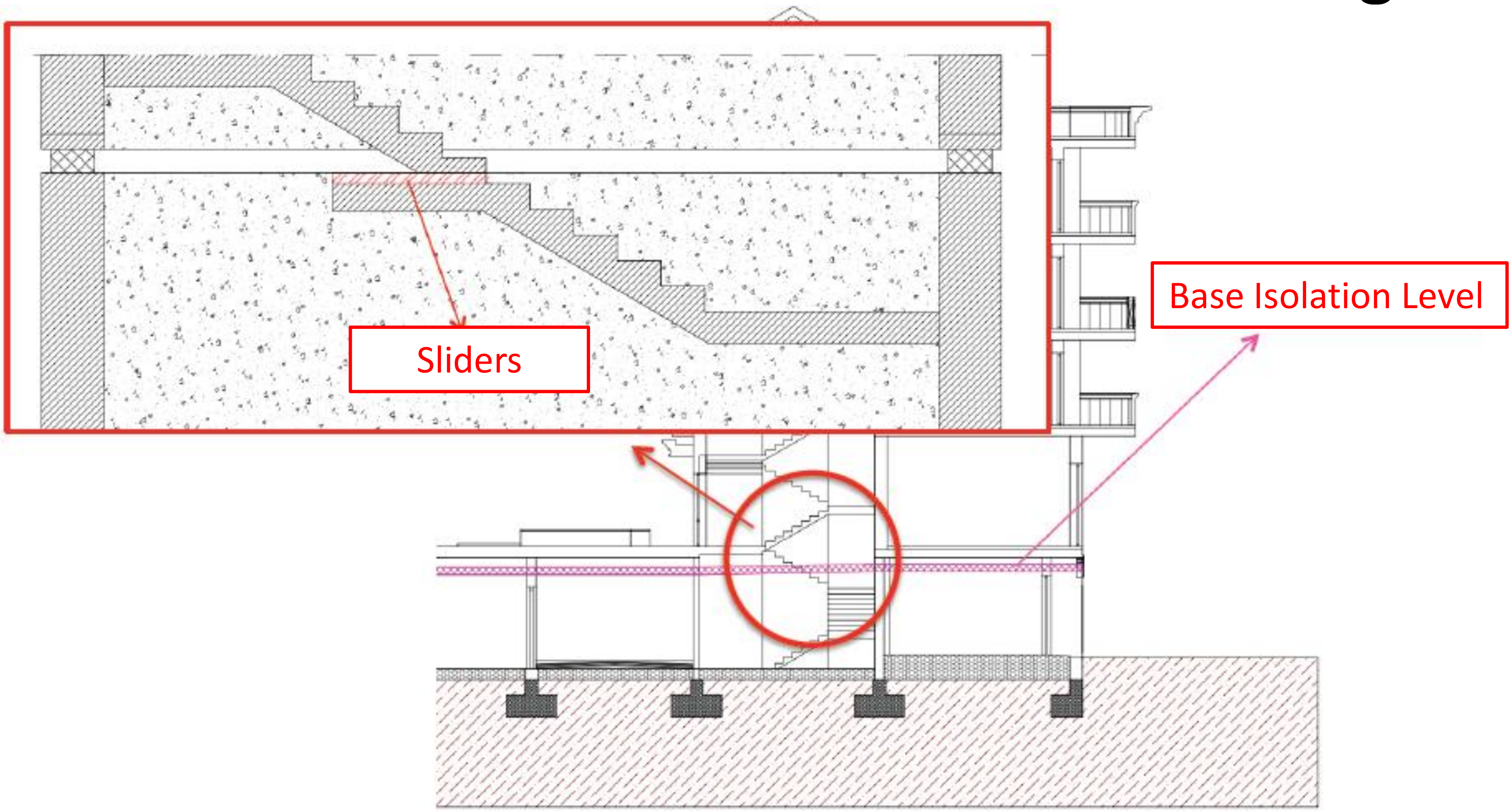
General rules for a base isolated building



General rules for a base isolated building

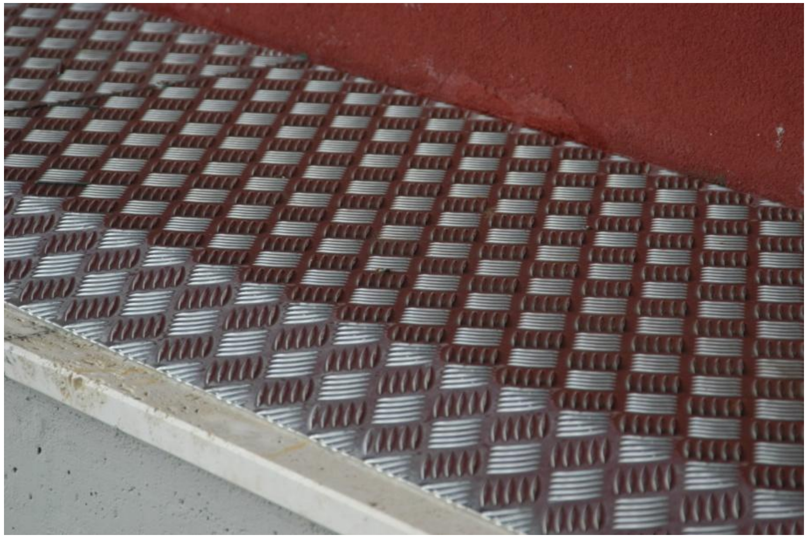


General rules for a base isolated building



Construction details

Fire protection for HDRB and LRB



Gap cover for pedestrian transit

Construction details

All piping and cables crossing the base isolation level shall be provided with flexible connections

Design procedure for a base isolated structure

There are 3 possible design approaches:

1. Static Linear Analysis
2. Dynamic Linear Analysis
3. Dynamic non linear analysis

Approaches 1 and 2 require that the structure and the antiseimic devices can be modelled as linear

Further requirements to apply the static linear analysis (according to EN 1998)

1. The period of the isolated structure shall be $\geq 3T_0$, where T_0 is the period of the non isolated structure and $\leq 3{,}0$ s. This means the structure shall not be too flexible
2. The vertical stiffness of the isolators is 800 times greater than the horizontal stiffness
3. There are no isolators under traction
4. ...

Static linear analysis

- It is always suitable to perform the static linear analysis, even if not all the requirements are met.
- Static linear analysis can always give a useful indication to select the appropriate isolation system

Example of static analysis for a building

We will consider a real project:

Gurgaon Building in India

We will consider 3 alternative base isolators:

- HDRB
- LRB
- Pendulum

Gurgaon Building

Gurgaon building is a 6-story building including 304 columns.

The dead load is DL = 895.000 kN

The Live load is LL = 108.000 kN

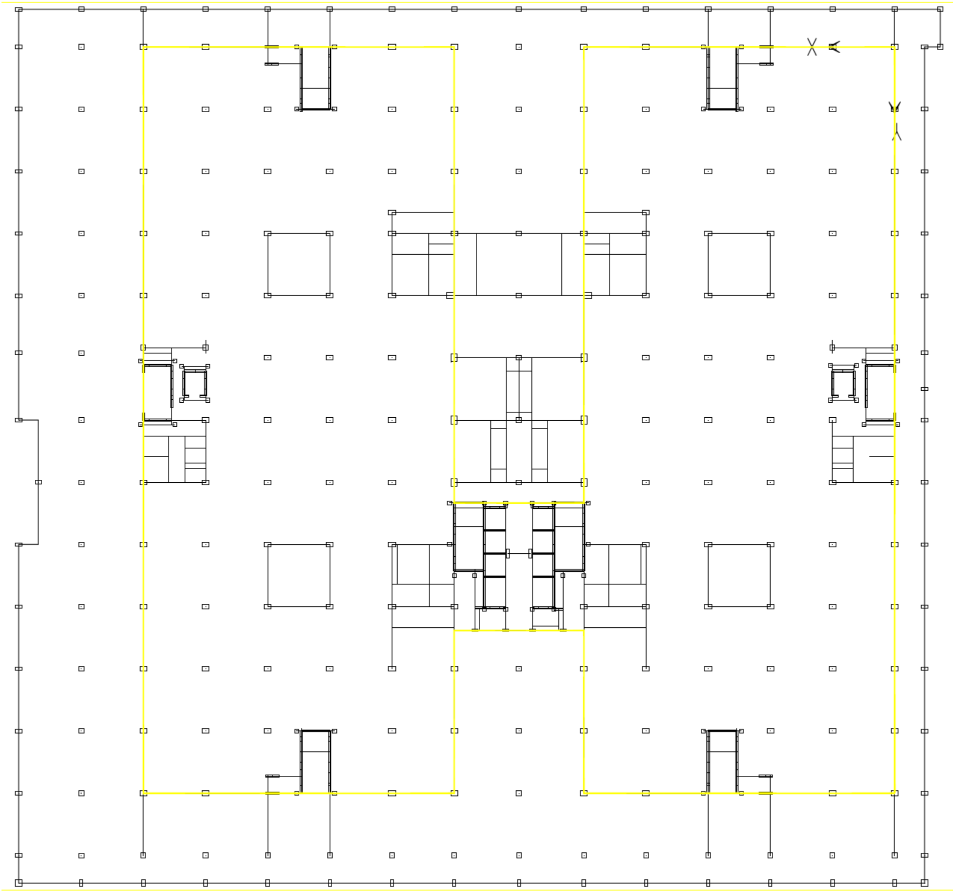
The total load is DL +LL = 1.003.000 kN

For the seismic analysis we consider

DL + 0,3LL = 927.400 kN

Corresponding to a mass M = 927.400/9,81 = 94.536 t

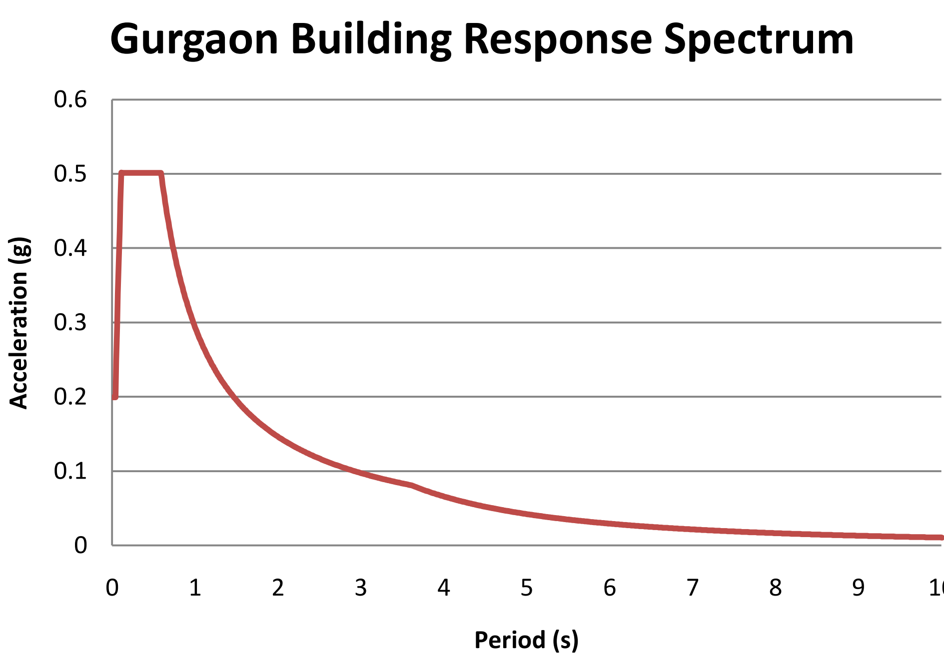
Gurgaon Building



Section at isolation level

Example of static analysis for a building

1. First step is to examine the response spectrum



The spectrum is defined as follows:

$A=0,199g$ for $0 \leq T \leq 0,03$

$A=0,199(T/0,3)^{0,768}$ for $0,03 \leq T \leq 0,1$

$A=0,501$ for $0,1 \leq T \leq 0,58$

$A=0,291/T$ for $0,58 \leq T \leq 3,6$

$A=1,048/T^2$ for $3,6 \leq T \leq 10$

Wit A in g and T in s

For our example we can consider always $A = 0,291/T$

Example of static analysis for a building

2. Second step is to define the mathematical model of the isolators
   - HDRB can be modeled considering 2 parameter only
   - K the stiffness
   - ξ the equivalent viscous damping

Equivalent Viscous Damping

ξ

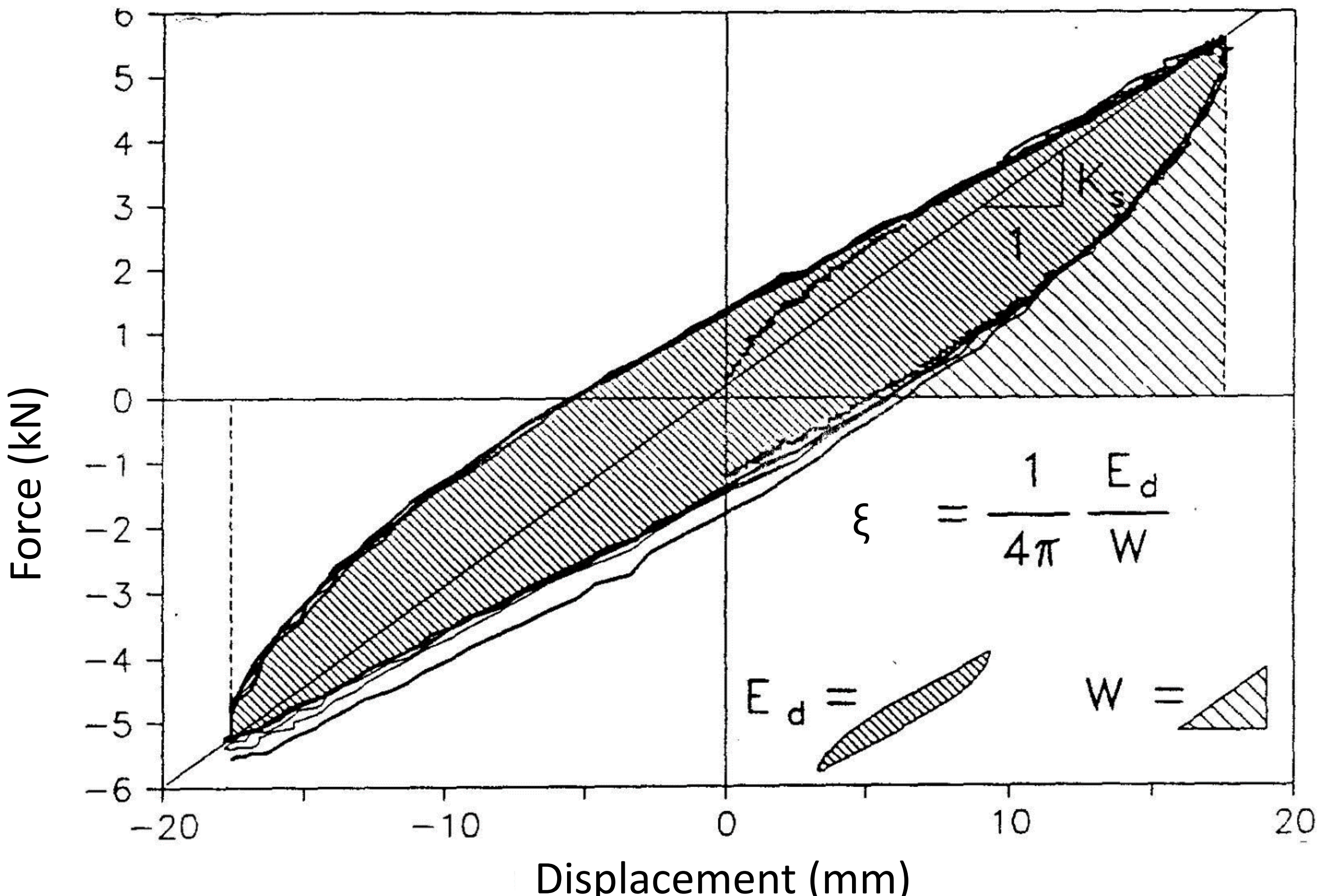
Equivalent viscous damping

E_d

Energy dissipated per cycle

W

Elastic stored energy



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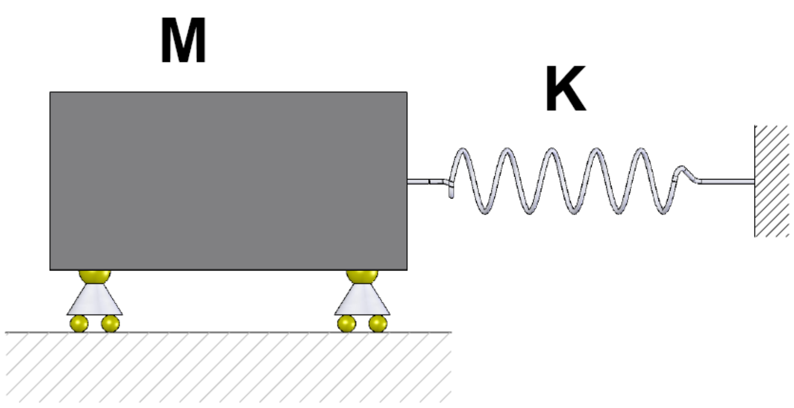
Gurgaon building with HDRB

For the static analysis the building is considered as a rigid mass with 1 degree of freedom connected to the ground by a spring of stiffness K.

The period can be computed by the formula:



$$T = 2\pi\sqrt{\frac{M}{K}}$$

Gurgaon building with HDRB

In our case we assume as target period T = 3s

And we deduct the horizontal stiffness of the isolation system:

$$K = \left(\frac{2\pi}{T}\right)^2 \times M = \left(\frac{2\pi}{3}\right)^2 \times 94536$$
$$= 414681\ kN/m = 414{,}7\ kN/mm$$

Corresponding to an average stiffness of the individual isolator $k = \frac{414{,}7}{304} = 1{,}36\ kN/mm$

Gurgaon building with HDRB

- The equivalent viscous damping of the isolators can be taken into account (in accordance with EN 1998) applying a reduction factor η to the spectrum
- $\eta = \sqrt{\frac{10}{5+\xi}} \geq 0{,}55$
- Adopting HDRB with ξ = 10% we get η = 0,816

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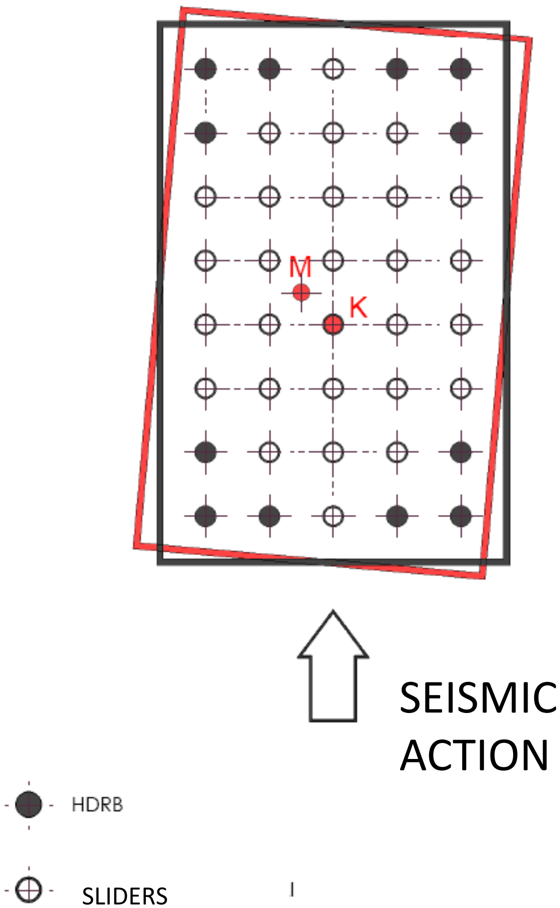
Gurgaon building with HDRB

- From the spectrum we can now compute:
- Acceleration A=0,816 x 0,291/3 = 0,079g = 0,777 m/s^2
- Displacement $D = \left(\frac{T}{2\pi}\right)^2 \times A = \left(\frac{3}{2\pi}\right)^2 \times 0{,}777 = 0{,}177m = 177mm$
- This is the displacement at the gravity center

Gurgaon building with HDRB

- The next step is now to select the isolators in function of the actual loads for each column, taking care of the following:
- The average stiffness of the isolators shall be the same as computed: 1,36 kN/mm each
- The center of the stiffness shall be as close as possible to the center of mass

Gurgaon building with HDRB



The condition of coincidence may not be met: we don't exactly know where are the mass and the live load.

EN 1998 recommend to increase the displacement of the isolators 30% to take into account the uncertainty.

Therefore the design displacement of the isolators become

D = 177 x 1,3 = 230 mm

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LRB Mathematical Model

- LRB also can be modelled by 2 parameters only
- Effective stiffness

$$K_{eff} = \frac{GA'}{t_e} + \frac{A_p \tau_y}{D}$$

- Equivalent viscous damping

$$\xi = \frac{E_D}{2\pi F D} = \frac{4 A_p \tau_y D}{2\pi K D^2} = \frac{2 A_p \tau_y}{\pi K D}$$

- D is the displacement: this implies that the model is not linear.
- The other symbols are explained in the next slides

LRB Mathematical Model

$$K_{eff} = \frac{GA'}{t_e} + \frac{A_p \tau_y}{D}$$

PLASTIC TERM = Q_d

A_p = Area of the lead core

τ_y = Yield shear stress of the lead = 10 Mpa

D = displacement

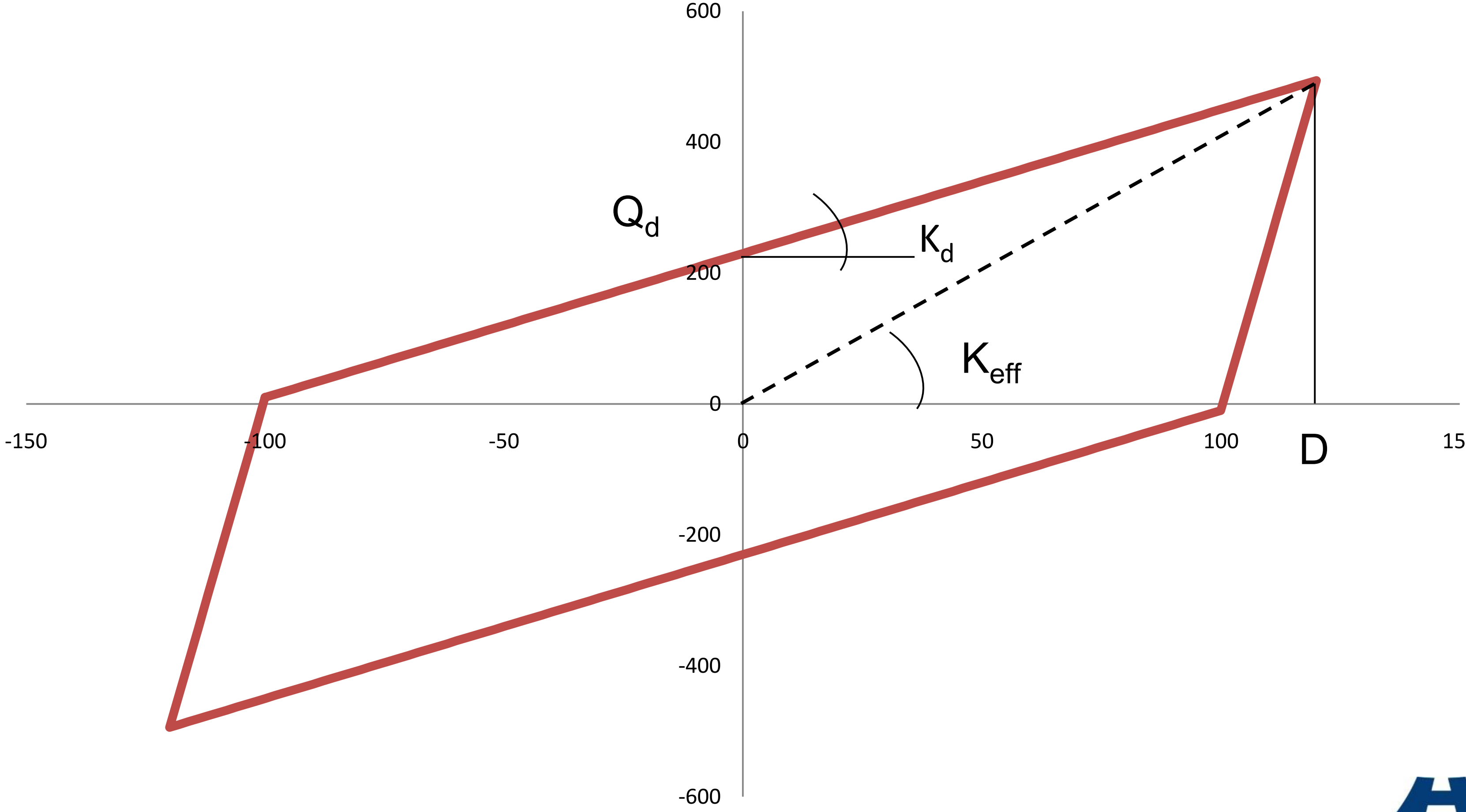
ELASTIC TERM = K_d

G = Shear Modulus of the rubber

A' = Net area of the rubber

t_e = net rubber thickness

LRB Mathematical Model



Gurgaon building with LRB

- The mathematical model of the LRB is not linear because is depending from the displacement D that shall be the result of the computation.
- It is possible to perform the linear static analysis by iteration method as shown in the following table based on a very simple software
- Utilizing LRB we will put as target values:
  - Period 3 s
  - Equivalent viscous damping 30%

Gurgaon Building with LRB

LRB ITERATIVE COMPUTATION			1	2	3	4
Vertical load	V	kN	927400	927400	927400	927400
Mass	M	t	94536	94536	94536	94536
Elastic stiffness	Kel	Kn/mm	220	220	220	220
Yield force	Qd	Kn	23000	23000	23000	23000
Displacement	D	mm	100	114.5	118.4	119.4
Effective stiffness	K_{eff}	kN/mm	450.00	420.81	414.19	412.66
Period	T_{eff}	s	2.88	2.98	3.00	3.01
Equivalent viscous damping	x		32.5%	30.4%	29.8%	29.7%
Damping factor	h		0.550	0.550	0.550	0.550
Acceleration	a	m/s^2	0.545	0.527	0.523	0.522
Displacement	D	mm	114.5	118.4	119.4	119.6
Horizontal load	H	kN	51541	49841	49447	49356
Response spectrum	S_{D1}	g	0.291			

TENTATIVE VALUE

FINAL VALUE

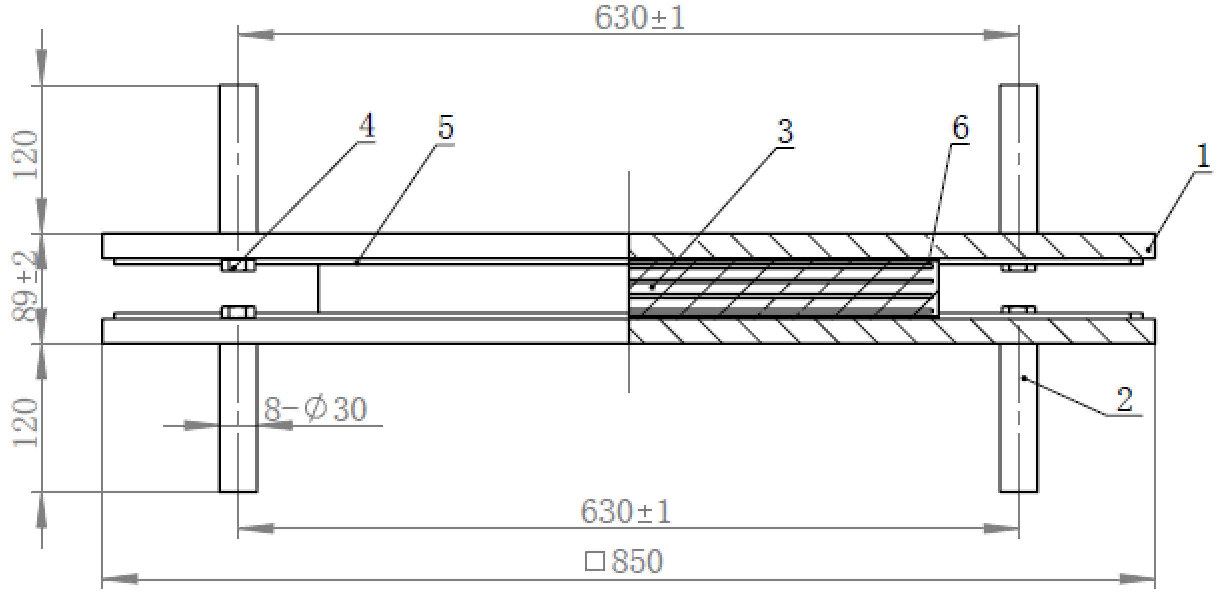
Gurgaon building with HDRB

- The results of the computation, adopting:
  - Yield force of the lead Q_d = 23000 kN
  - Elastic stiffness K_d = 220 kN/mm
- are the following:
  - Acceleration = 0,522 m/s^2 = 0,053g
  - Displacement = 120 mm. This value also shall be amplified by 30% to take care of torsional effects so d=156 mm shall be considered

Gurgaon building with HDRB

- The total stiffness of the LRB is 220 kN/mm, Corresponding to 0,72 kN/mm for each LRB.
- This stiffness is far too low for a LRB that shall carry, in the average, over 3000 kN. A LRB with such stiffness will for sure buckle under the design load.
- What is the solution?
- We combine LRB with suitable stiffness and sliders which are devices supporting the vertical load with zero stiffness

Gurgaon building with HDRB



- Typical feature of a slider is a rubber bearing with PTFE with two stainless steel sliding plates

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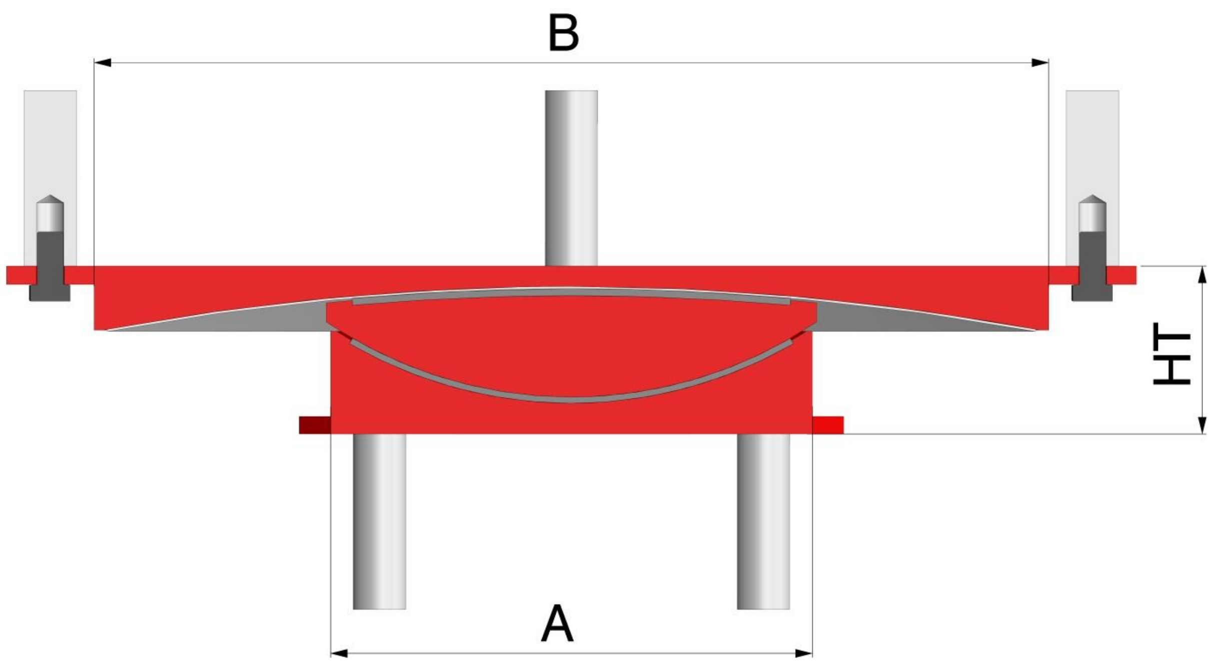
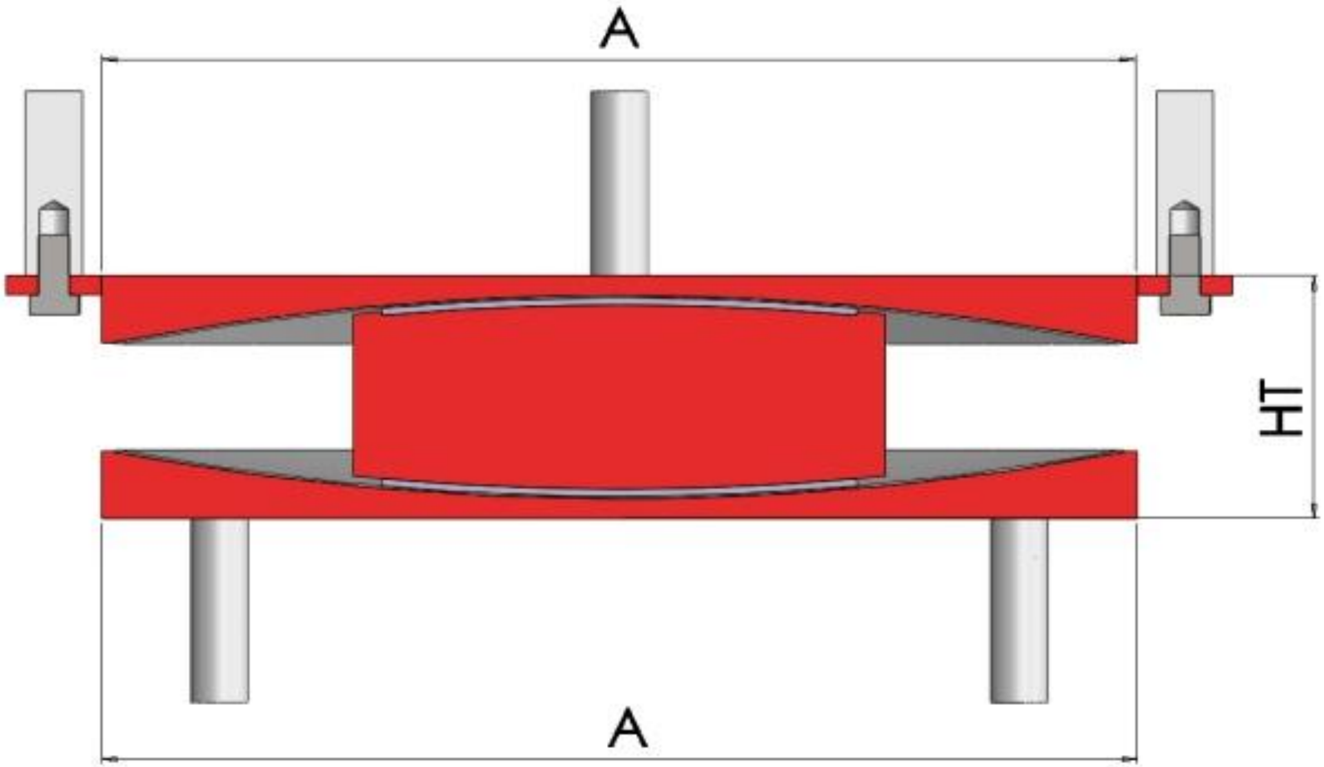
Gurgaon building with HDRB

- In summary we adopt for the Gurgaon building:
- 215 sliders
- 89 LRB with individual stiffness 2,24 kN/mm
- This solution however has the disadvantage that the seismic action is concentrated in 89 columns only and not in all the 304

Sliding Pendulum with one spherical sliding surface



Sliding Pendulum with two spherical sliding surfaces



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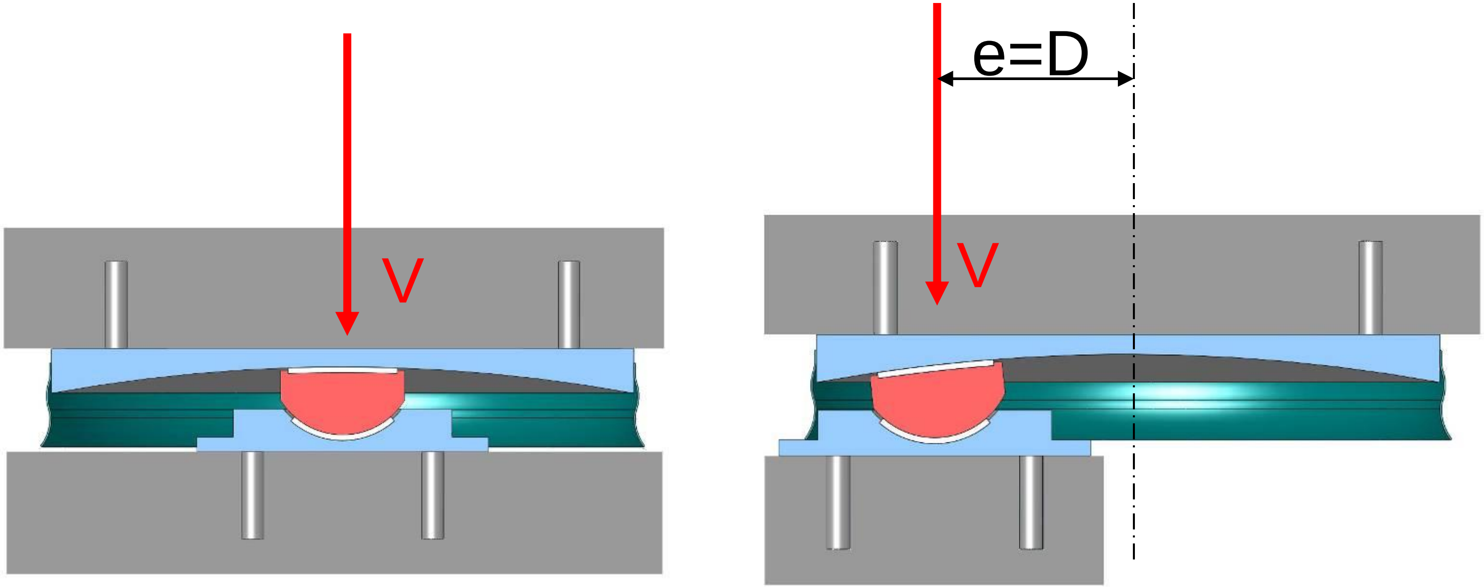
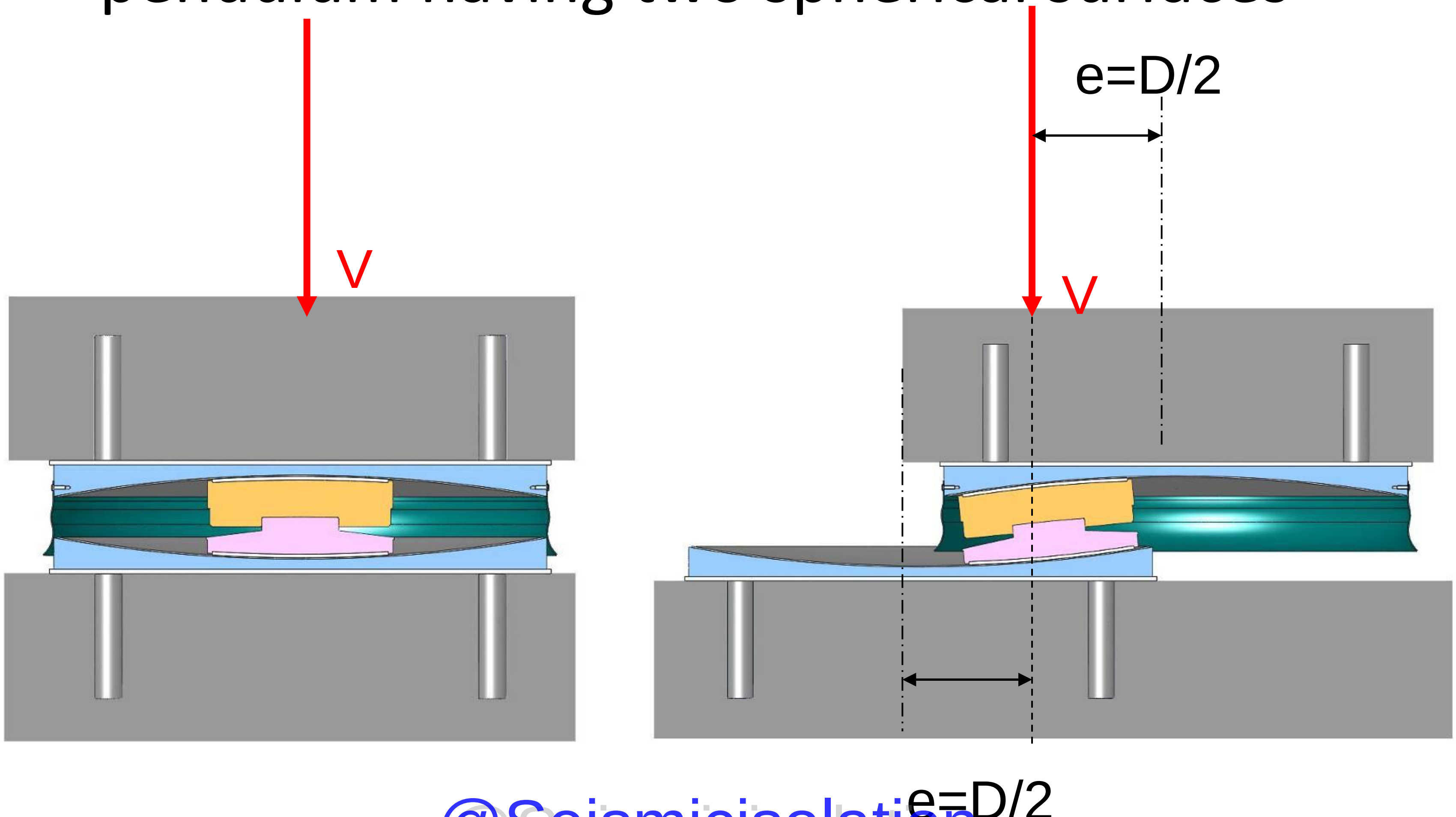
Resultant displacement with sliding pendulum having one spherical surface



Resultant displacement with slidin pendulum having two spherical surfaces



SLIDING PENDULUM ISOLATORS

Their main characteristics are the following:

•They allow the relative displacement of the structure in respect of the foundations following one or two spherical surfaces.

•The radius of the spherical surfaces determines the natural period of the structure.

•The natural period is independent from the mass of the structure.

•The friction coefficient of the sliding surface determines the equivalent viscous damping of the isolation system

Gurgaon Building with Pendulum

PENDULUM ITERATIVE COMPUTATION			1	2	3	4
Vertical load	V	kN	927400	927400	927400	927400
Friction	m		0.03	0.03	0.03	0.03
Equivalent radius	R	mm	5000	5000	5000	5000
Displacement	D	mm	100	112.8	116.9	118.1
Stiffness	K_{eff}	kN/mm	463.70	432.06	423.50	421.13
Period	T_{eff}	s	2.84	2.94	2.97	2.98
Equivalent viscous damping	x		38.2%	36.3%	35.8%	35.6%
Damping factor	h		0.550	0.550	0.550	0.550
Acceleration	a	m/s²	0.553	0.534	0.529	0.527
Displacement	D	mm	112.8	116.9	118.1	118.4
Horizontal load	H	kN	48750	49502	49720	49782
Response spectrum						
	S_{D1}	g	0.291			

TENTATIVE VALUE

FINAL VALU

SLIDING PENDULUM ISOLATORS MATHEMATICAL MODEL

Sliding Pendulum also can be modeled utilizing 2 parameters only:

- R is the equivalent radius
- μ is the dynamic friction

In the following formula also:

- W is the weight of the structure
- D is the displacement
- ξ is the equivalent viscous damping
- G the gravity constant 9,81 m/s^2

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SLIDING PENDULUM ISOLATORS MATHEMATICAL MODEL

- Stiffness

$$K = W\left(\frac{1}{R} + \frac{\mu}{D}\right)$$

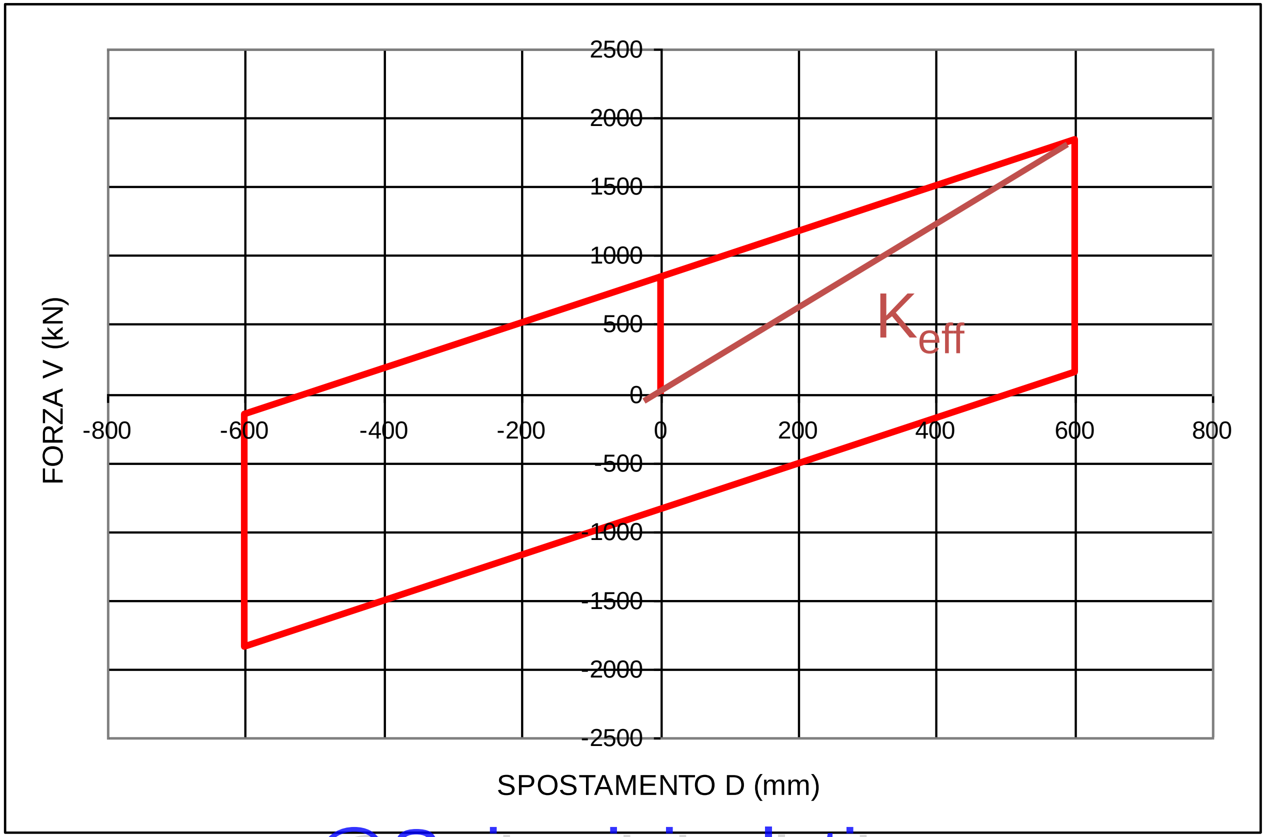
- Period

$$T = 2\pi\sqrt{\frac{RD}{(D + \mu R)g}}$$

- Equivalent viscous damping

$$\xi = \frac{2}{\pi}\left[\frac{\mu}{\mu + \frac{D}{R}}\right]$$

SLIDING PENDULUM ISOLATORS MATHEMATICAL MODEL



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Gurgaon building with Pendulum

- The mathematical model of the Pendulum is not linear also, because is depending from the displacement D that shall be the result of the computation.
- It is possible to perform the linear static analysis by iteration method as shown in the following table based on a very simple software
- Utilizing Pendulum we will put as target values:
  - Period 3 s
  - Equivalent viscous damping ≥ 30%

Gurgaon Building with Pendulum

The requirement of coincidence between the mass and the stiffness barycentre is always automatically satisfied because the stiffness of the sliding pendulum isolators is proportional to the weight and therefore to the mass

$$K_{eff} = W\left(\frac{1}{R} + \frac{\mu}{D}\right)$$

There is no need to amplify the displacement to take care of torsional effects

Gurgaon building with HDRB

- The results of the computation, adopting:
  - Equivalent radius R = 5000 mm
  - Dynamic friction coefficient μ = 0,03
- are the following:
  - Period = 2,98 s
  - Equivalent viscous damping = 35,6%
  - Acceleration = 0,527 m/s^2 = 0,053g
  - Displacement = 118 mm.

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Gurgaon building base isolation

- In the following table are summarized the performances of the different isolators

ISOLATORS PERFORMANCES				
	Unit	HDRB	LRB	Pendulum
Period	s	3,0	3,01	2,98
Equivalent viscous damping	%	10	29,7	35,6
Acceleration	m/s^2	0,777	0,52	0,52
Displacement	mm	230	156	118

RUBBER ISOLATORS OR PENDULUM?

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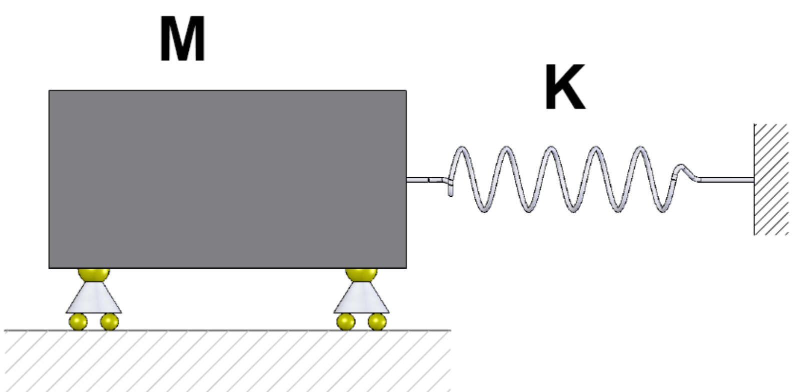
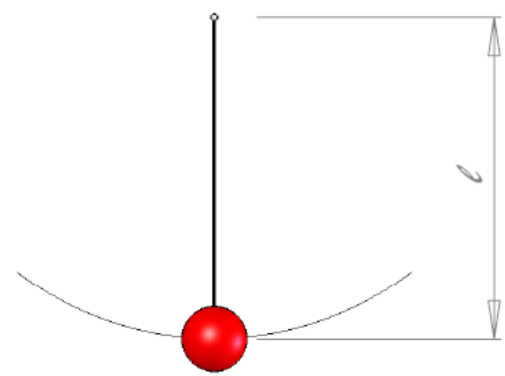
HDRB and Pendulum have similar performances: they shift the period of the structure

- HDRB WITH STIFFNESS K



$$T = 2\pi\sqrt{\frac{M}{K}}$$

- PENDULUM WITH RADIUS L



$$T = 2\pi\sqrt{\frac{l}{g}}$$

ABOUT THE PERIOD T

For the HDRB the period is a function of:

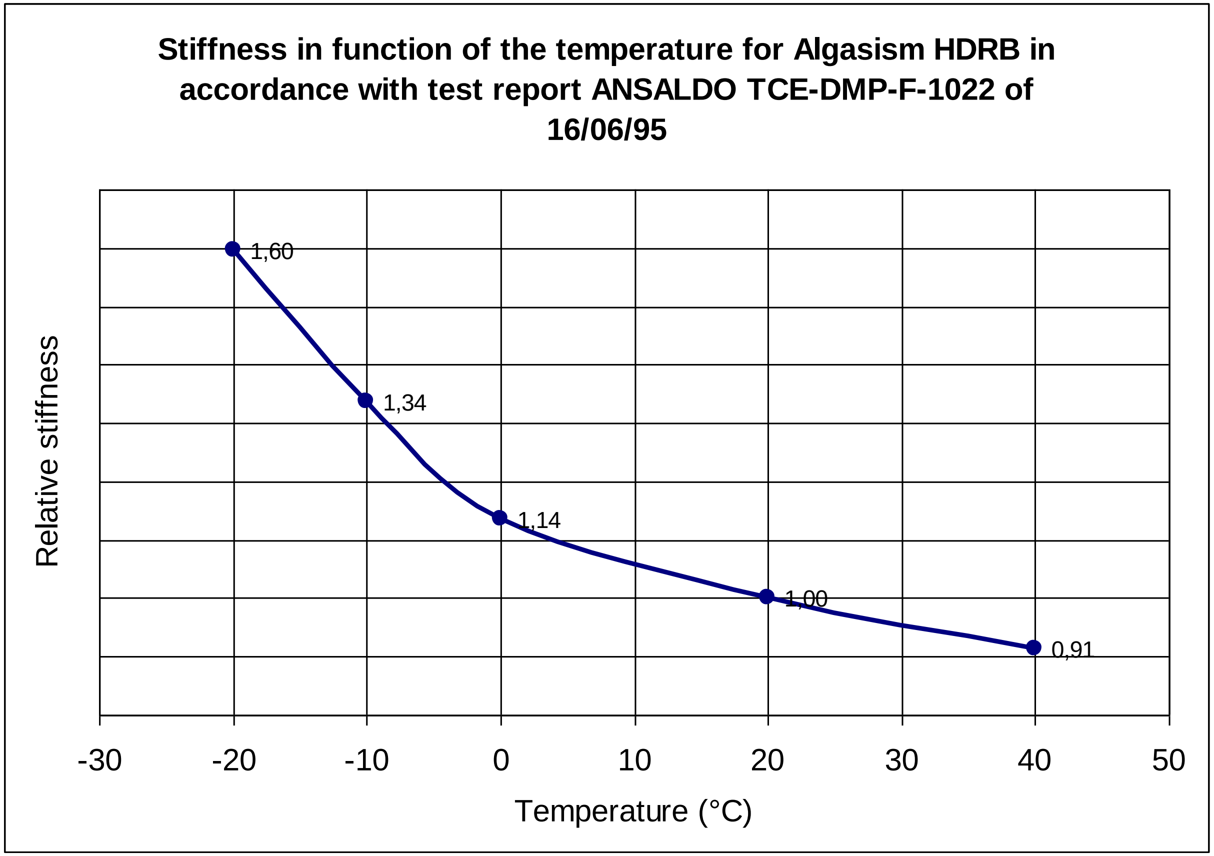
- M = mass
- K = stiffness
- M may vary (LL may change)
- K can vary in function of Temperature and aging

IN CONCLUSION WITH HDRB THE PERIOD T CAN VARY

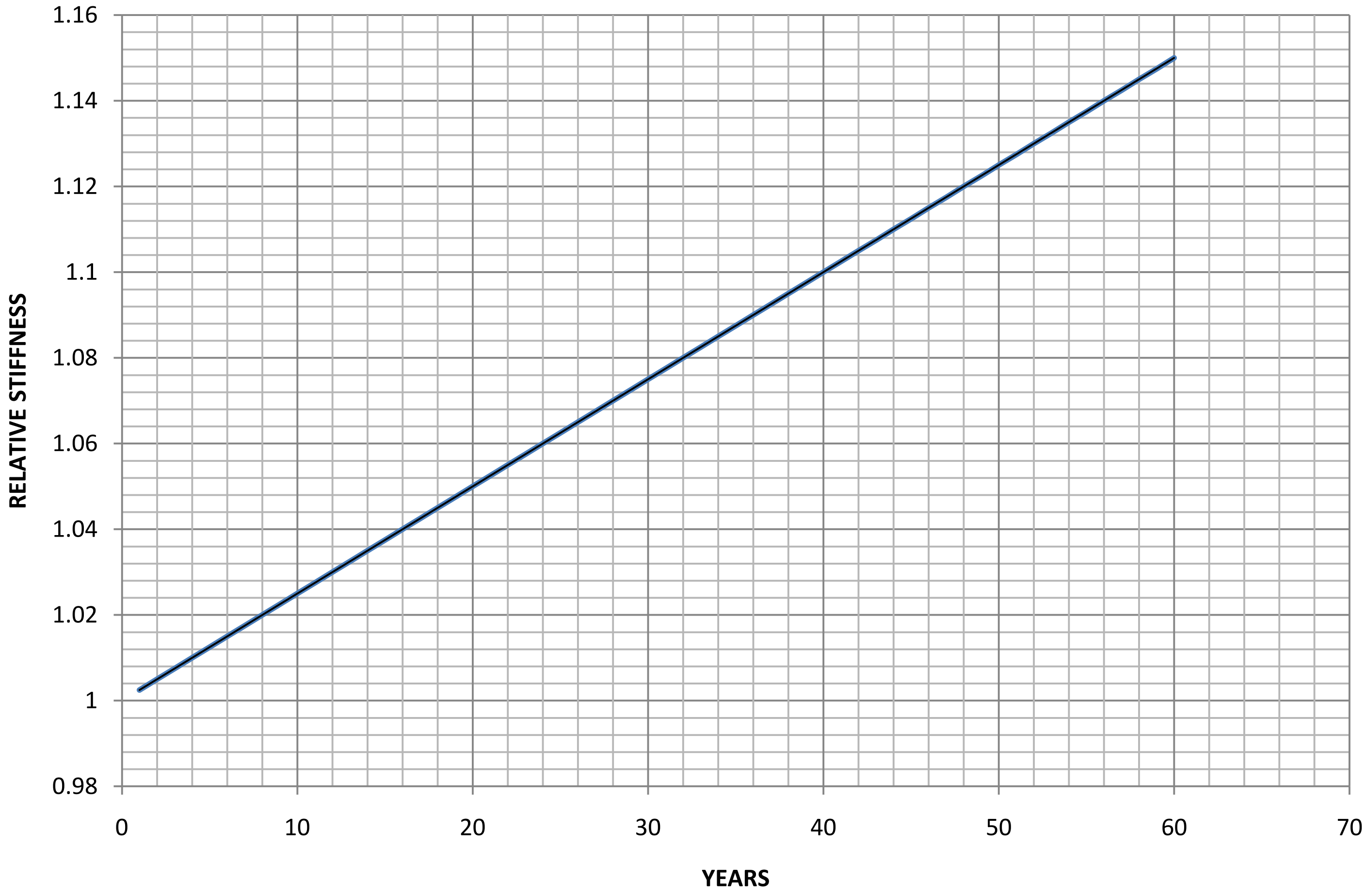
- For the Pendulum the period is a function of:
- g = gravity constant: cannot vary
- R = radius: cannot vary

WITH THE PENDULUM THE PERIOD CANNOT VARY

Variation of stiffness in function of the temperature



Variation of stiffness in function of the aging

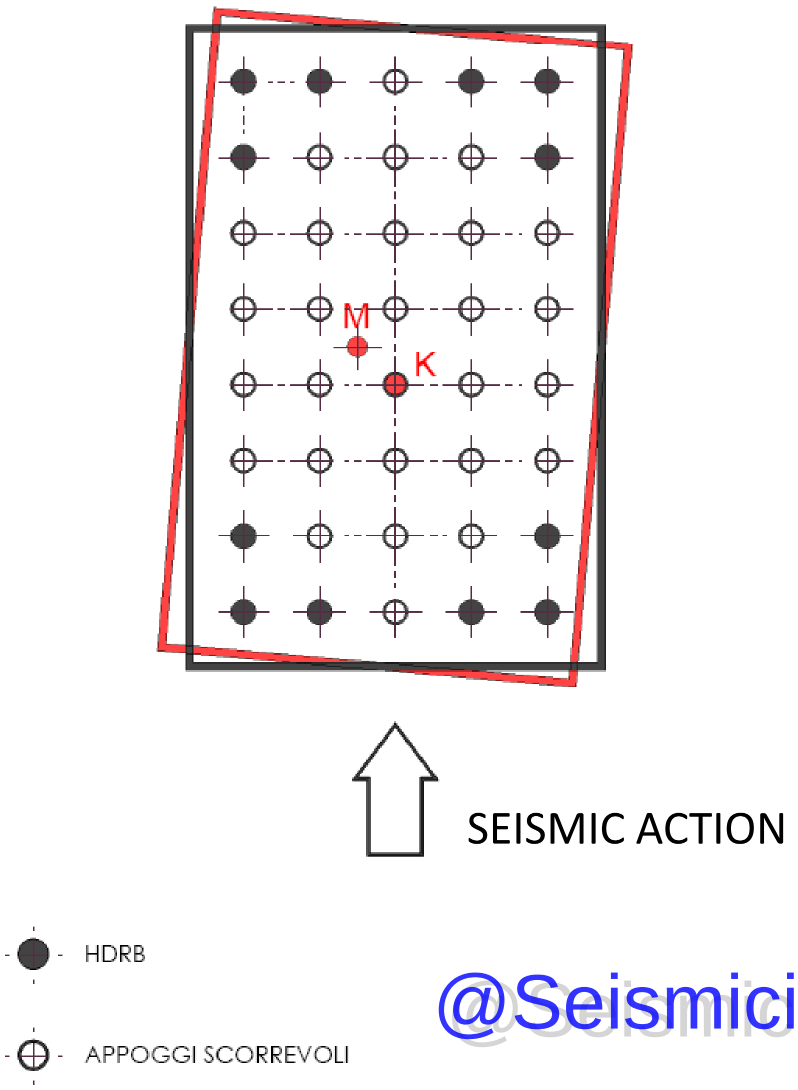


ABOUT THE STIFFNESS K

- For the HDRB the stiffness is an intrinsecal property.
- For the Pendulum the stiffness is proportional to the mass

$$K = Mg\left(\frac{1}{R} + \frac{\mu}{D}\right)$$

- The centre of stiffness may not be coincident with the centre of mass
- The centre of stiffness is always coincident with the centre of mass



What happens if the mass center is not coincident with the stiffness center

The structure may rotate around the vertical axis, amplifying the displacement at the corners

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RUBBER ISOLATORS OR PENDULUM?

PENDULUM

- Service life ≥ 100 years
- Behaviour independent from aging and environmental conditions

RUBBER

- Service life ≤ 60 years
- Behaviour dependent from aging and environmental conditions

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HI TECH CIVIL ENGINEERING

RUBBER ISOLATORS OR PENDULUM?

PENDULUM

- Fire resistant
- Very high performances in terms of:
  - Period shift
  - Energy dissipation

RUBBER

- May be damaged from fire
- Limited performances in terms of period shift

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RUBBER ISOLATORS OR PENDULUM?

PENDULUM

- No maintenance requirements after an earthquake
- Very good cost/efficiency ratio

RUBBER

- Possible maintenance after an earthquake

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RUBBER ISOLATORS OR PENDULUM?

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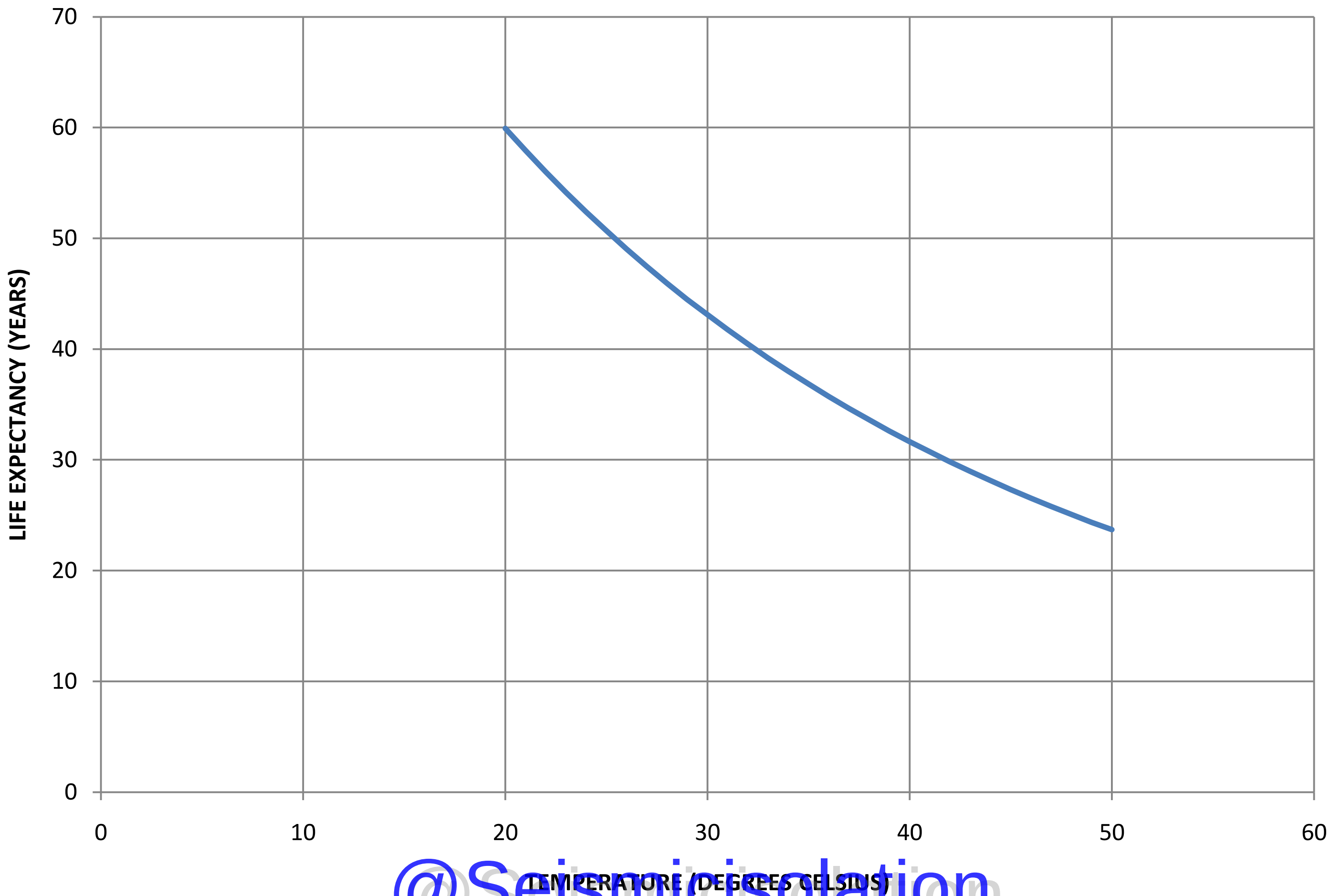
Expected life of rubber isolators in function of temperature



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QUALITY CERTIFICATES

HIRUN
HI TECH CIVIL ENGINEERING

IQNet
THE INTERNATIONAL CERTIFICATION NETWORK

CERTIFICATE

IQNet and
CQC
hereby certify that the organization

WUHAN HIRUN ENGINEERING EQUIPMENT CO.,LTD.
(WUHAN HIRUN ENGINEERING EQUIPMENT CO.,LTD. GUANGZHOU RUBBER FILIALE)

No.9 Wudong Street, Qingshan District, Wuhan, Hubei, China
(Northeast Side of 7431 Factory, Western Side of Guang Hua Road, White Cloud District, Guangzhou, Guangdong, China)

For the following field of activities

Design, Production and Service of Bridge Bearing, Building Bearing, Damper, Anti-seismic Devices, Expansion Joints, Pre-stressing System, Rotational Spherical Hinge, Rubber Goods

Has implemented and maintains a
Management System
Which fulfils the requirements of the following standard

ISO9001:2008

Issued on: May. 05, 2015
Validity date: May. 04, 2018
Registration Number: 00115Q23978R2M/4200

Michael Drechsel
President of IQNet

Wang Kejiao
President of CQC

IQNet Partners*:
AENOR *Spain* AFNOR Certification *France* AIB-Vinçotte International *Belgium* ANCE-SIGE *Mexico* APCER *Portugal* CCC *Cyprus*
CISQ *Italy* CQC *China* CQM *China* CQS *Czech Republic* Cro Cert *Croatia* DQS Holding GmbH *Germany*
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JQA *Japan* KFQ *Korea* MIRTEC *Greece* MSZT *Hungary* Nemko AS *Norway* NSAI *Ireland* PCBC *Poland*
Quality Austria *Austria* RR *Russia* SII *Israel* SIQ *Slovenia* SIRIM QAS International *Malaysia*
SQS *Switzerland* SRAC *Romania* TEST St Petersburg *Russia* TSE *Turkey* YUQS *Serbia*
IQNet is represented in the USA by: AFNOR Certification, CISQ, DQS Holding GmbH and NSAI Inc.
* The list of IQNet partners is valid at the time of issue of this certificate. Updated information is available under www.iqnet-certification.com

CQC

QUALITY MANAGEMENT SYSTEM
CERTIFICATE

Certificate No.: 00115Q23978R2M/4200

We hereby certify that

WUHAN HIRUN ENGINEERING EQUIPMENT CO.,LTD.
(WUHAN HIRUN ENGINEERING EQUIPMENT CO.,LTD.
GUANGZHOU RUBBER FILIALE)

Organization Code Certificate: 27103144-8

No.9 Wudong Street, Qingshan District, Wuhan, Hubei, China
(Northeast Side of 7431 Factory, Western Side of Guang Hua Road, White Cloud District, Guangzhou, Guangdong, China)

by reason of its
Quality Management System
has been awarded this certificate for compliance with the standard
ISO9001: 2008 GB/T19001-2008
The Quality Management System Applies in the following area:

Design, Production and Service of Bridge Bearing, Building Bearing, Damper, Anti-seismic Devices, Expansion Joints, Pre-stressing System, Rotational Spherical Hinge, Rubber Goods

Certified since: Aug. 06, 2009 Valid from: May. 05, 2015 Valid until: May. 04, 2018

After a surveillance cycle, the certificate is valid only when used together with an Acceptance Notice of Surveillance Audit issued by CQC. Please access www.cqc.com.cn for checking validity of the certificate.
This certificate and its relevant information can query in the website of Certification and Accreditation Administration of the People's Republic of China (www.cnca.gov.cn).

CNAS
MANAGEMENT SYSTEM
CNAS C001-Q

IAF

Signed by: Wang Kejiao

IQNet

CHINA QUALITY CERTIFICATION CENTRE 中国质量认证中心

CHINA QUALITY CERTIFICATION CENTRE
Section 9, No.188, Nansihuan(the South Fourth Ring Road) Xilu(West Road), Beijing 100070,China
http://www.cqc.com.cn

Q 0198312 2009年版

- Main quality certificates ISO 9001

QUALITY CERTIFICATES

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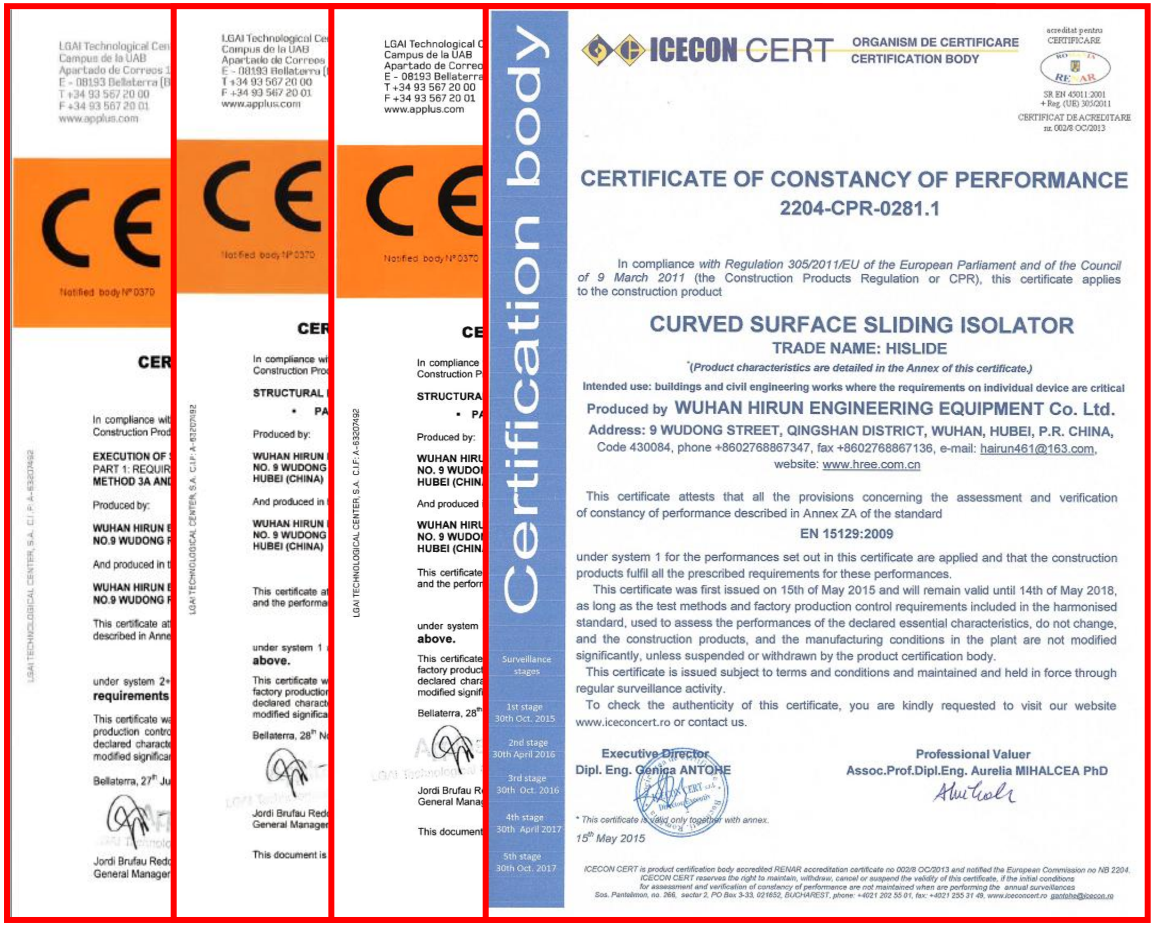

ICECON CERT
ORGANISM DE CERTIFICARE
CERTIFICATION BODY

Certification body

CERTIFICATE OF CONSTANCY OF PERFORMANCE
2204-CPR-0281.1

In compliance with Regulation 305/2011/EU of the European Parliament and of the Council of 9 March 2011 (the Construction Products Regulation or CPR), this certificate applies to the construction product

CURVED SURFACE SLIDING ISOLATOR
TRADE NAME: HISLIDE
*(Product characteristics are detailed in the Annex of this certificate.)

Intended use: buildings and civil engineering works where the requirements on individual device are critical

Produced by WUHAN HIRUN ENGINEERING EQUIPMENT Co. Ltd.
Address: 9 WUDONG STREET, QINGSHAN DISTRICT, WUHAN, HUBEI, P.R. CHINA,
Code 430084, phone +8602768867347, fax +8602768867136, e-mail: hairun461@163.com,
website: www.hree.com.cn

This certificate attests that all the provisions concerning the assessment and verification of constancy of performance described in Annex ZA of the standard

EN 15129:2009

under system 1 for the performances set out in this certificate are applied and that the construction products fulfil all the prescribed requirements for these performances.

This certificate was first issued on 15th of May 2015 and will remain valid until 14th of May 2018, as long as the test methods and factory production control requirements included in the harmonised standard, used to assess the performances of the declared essential characteristics, do not change, and the construction products, and the manufacturing conditions in the plant are not modified significantly, unless suspended or withdrawn by the product certification body.

This certificate is issued subject to terms and conditions and maintained and held in force through regular surveillance activity.

To check the authenticity of this certificate, you are kindly requested to visit our website www.iceconcert.ro or contact us.

Surveillance stages
1st stage 30th Oct. 2015
2nd stage 30th April 2016
3rd stage 30th Oct. 2016
4th stage 30th April 2017
5th stage 30th Oct. 2017

Executive Director
Dipl. Eng. Genica ANTOHE

Professional Valuer
Assoc.Prof.Dipl.Eng. Aurelia MIHALCEA PhD

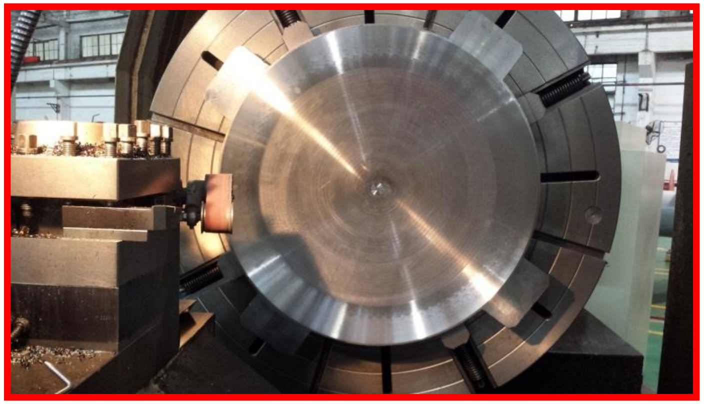
* This certificate is valid only together with annex.
15th May 2015

- CE marking certificates

PRODUCTION PHASES

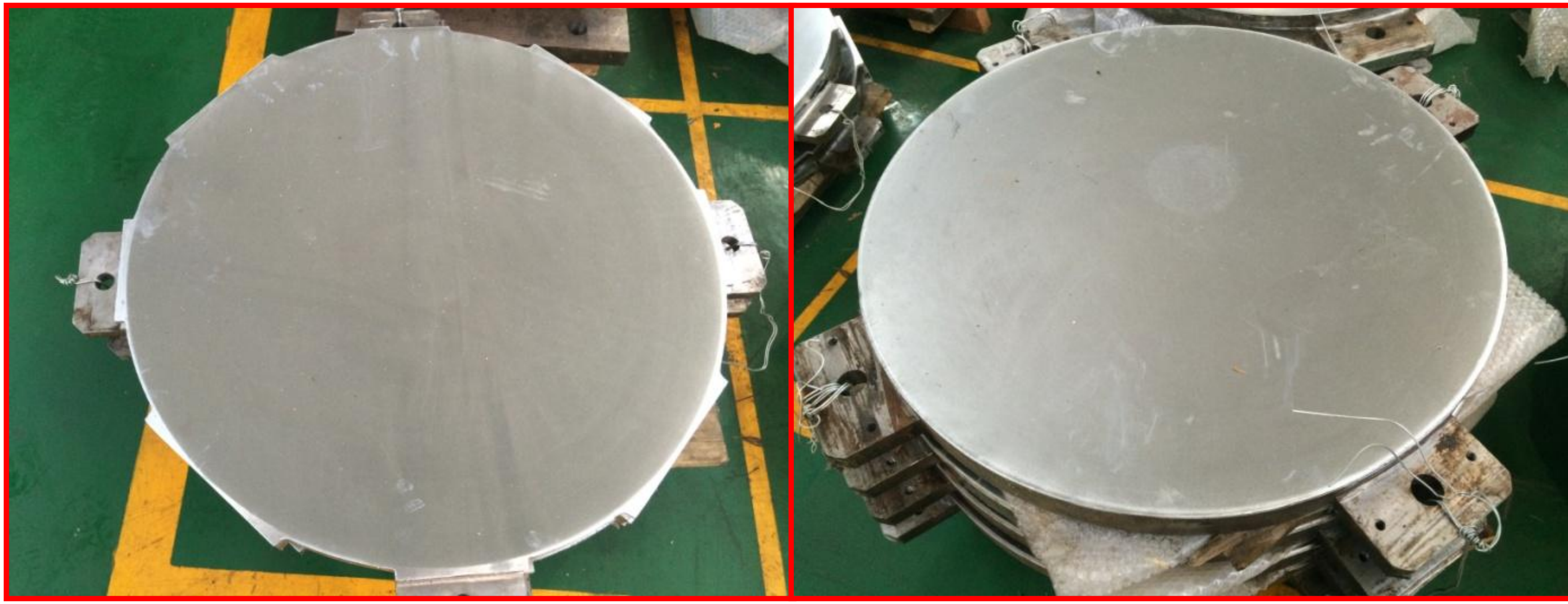
- Preparation of the raw material: steel and sliding material

PRODUCTION PHASES



- Machining

PRODUCTION PHASES

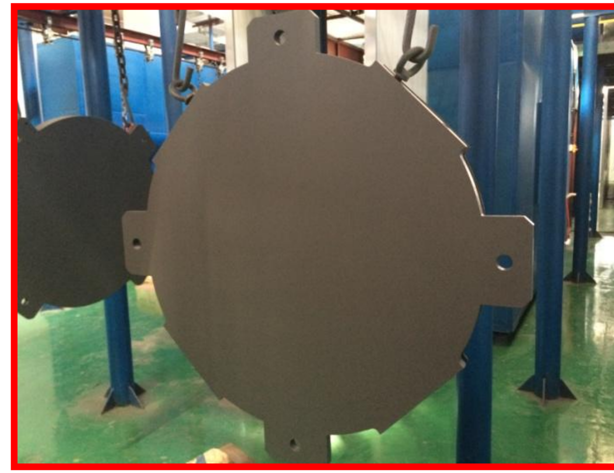


- Chromium plating and polishing

PRODUCTION PHASES

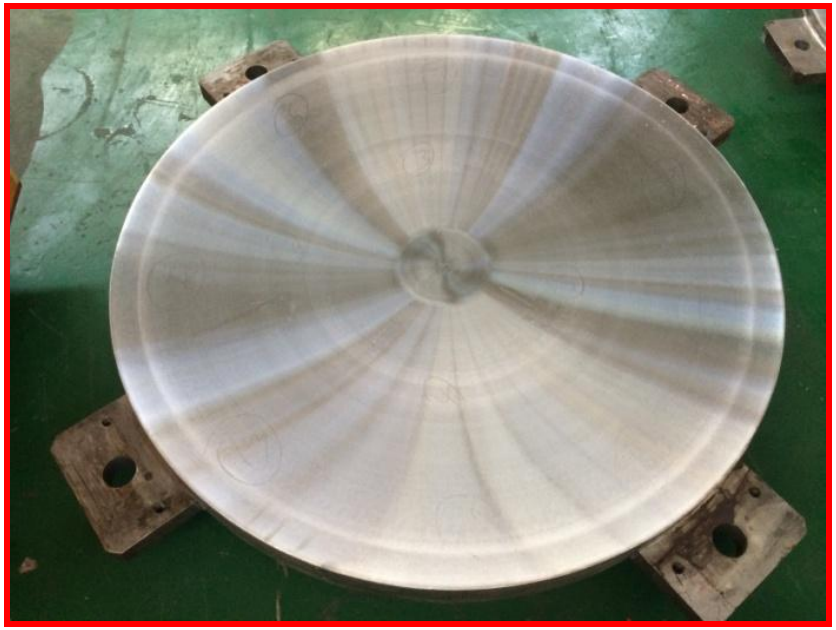
- Polishing

PRODUCTION PHASES



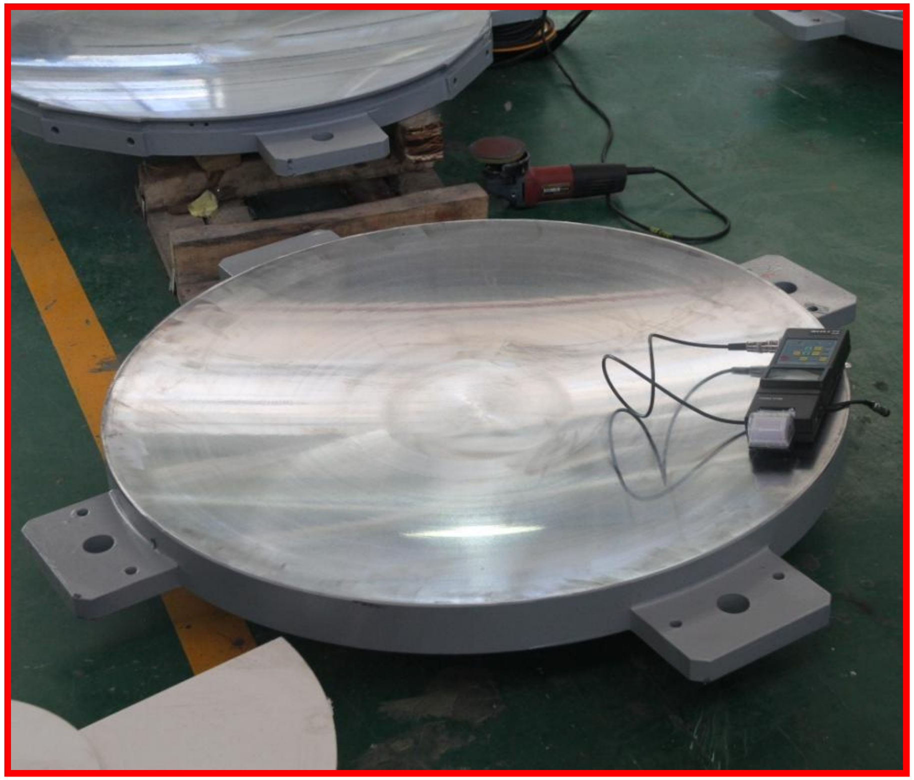
- Sandblasting and painting

PRODUCTION PHASES



- Assembing

PRODUCTION PHASES



- Geometrical check, roughness control

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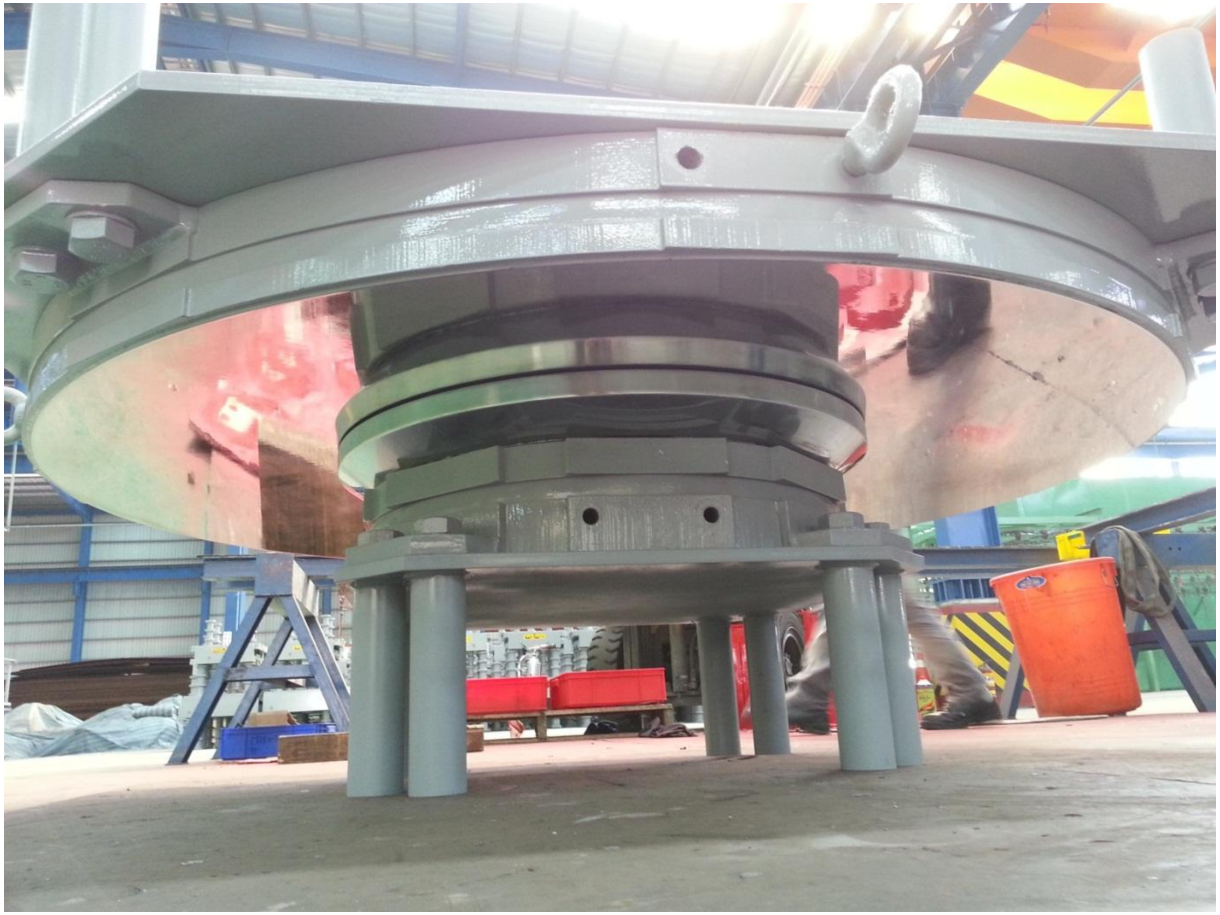
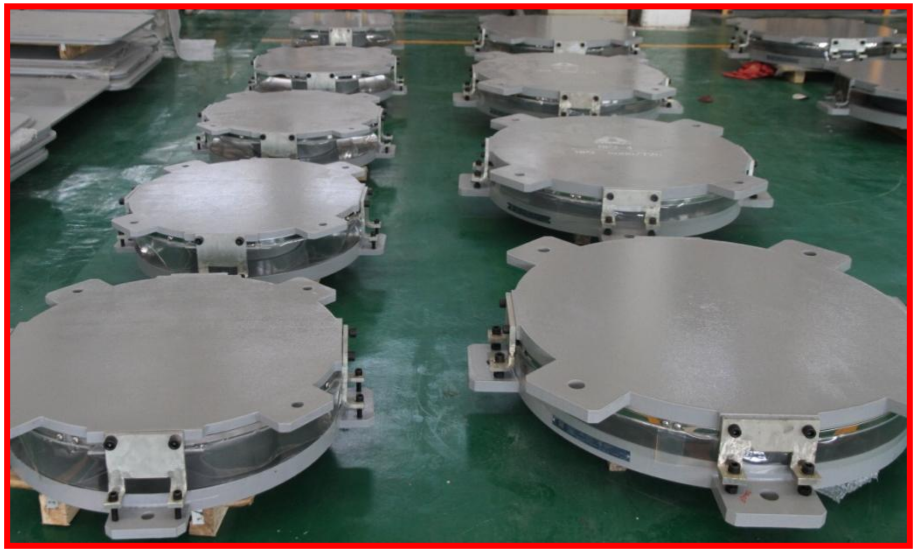
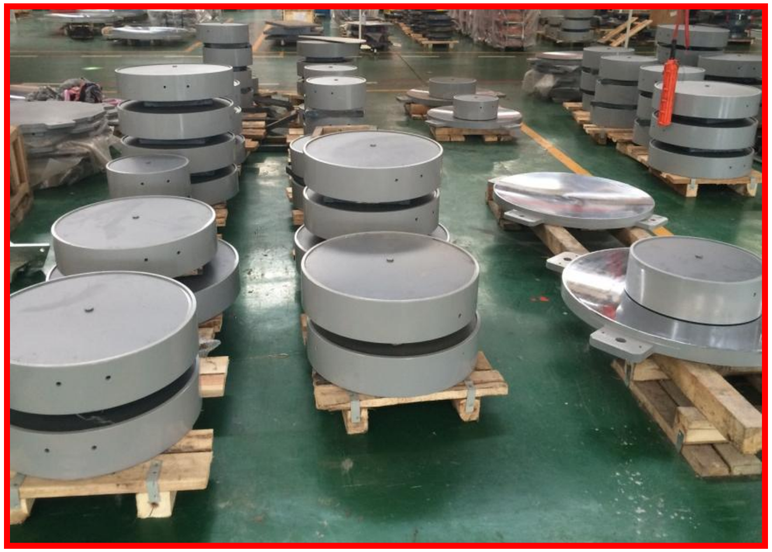
PRODUCTION PHASES



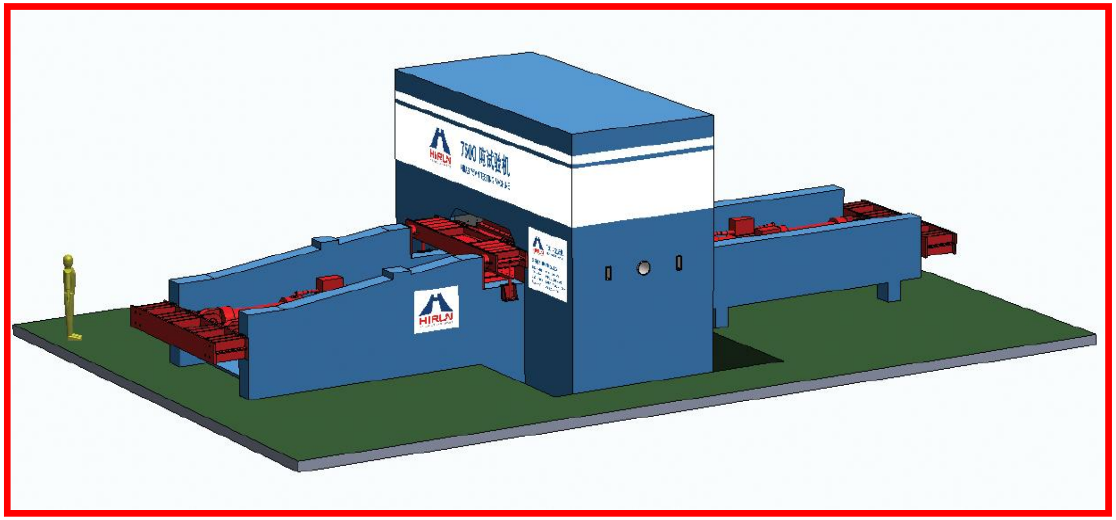
PRODUCTION PHASES





- Preparation for shipment

TESTING PHASES



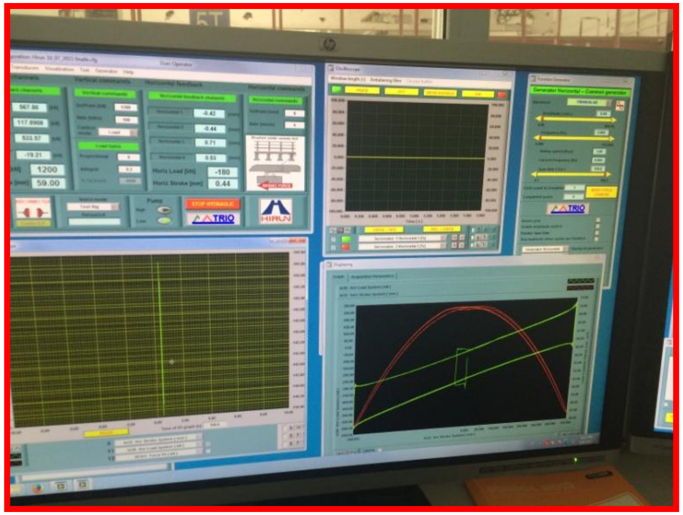
HIRUN TESTING EQUIPMENT

- Vertical load, dynamic, 50 MN
- Vertical displacement 120 mm (dynamic)
- Horizontal load, dynamic, 6000 kN
- Horizontal displacement 1200 mm
- Horizontal peak velocity 1000 mm/sec

TESTING PHASES

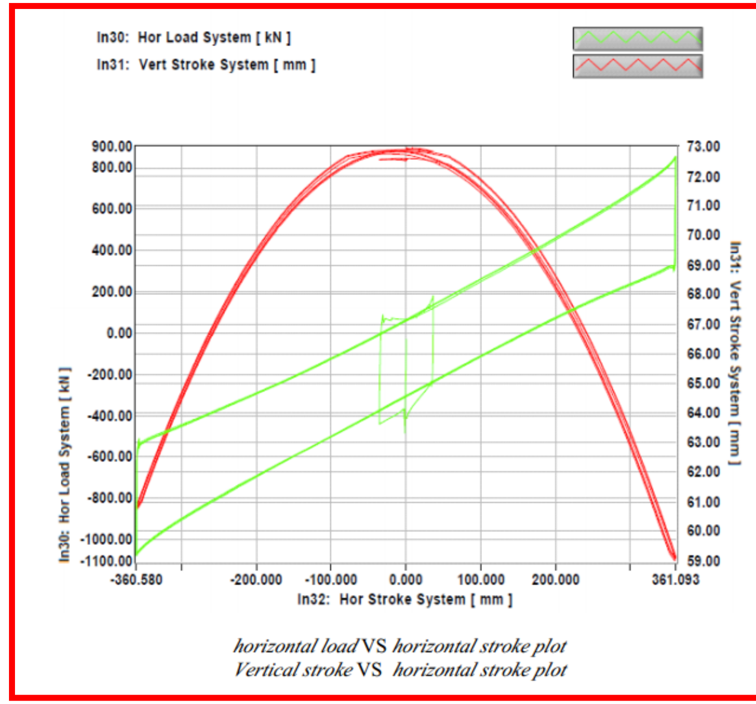
- HIRUN TESTING EQUIPMENT

TESTING PHASES



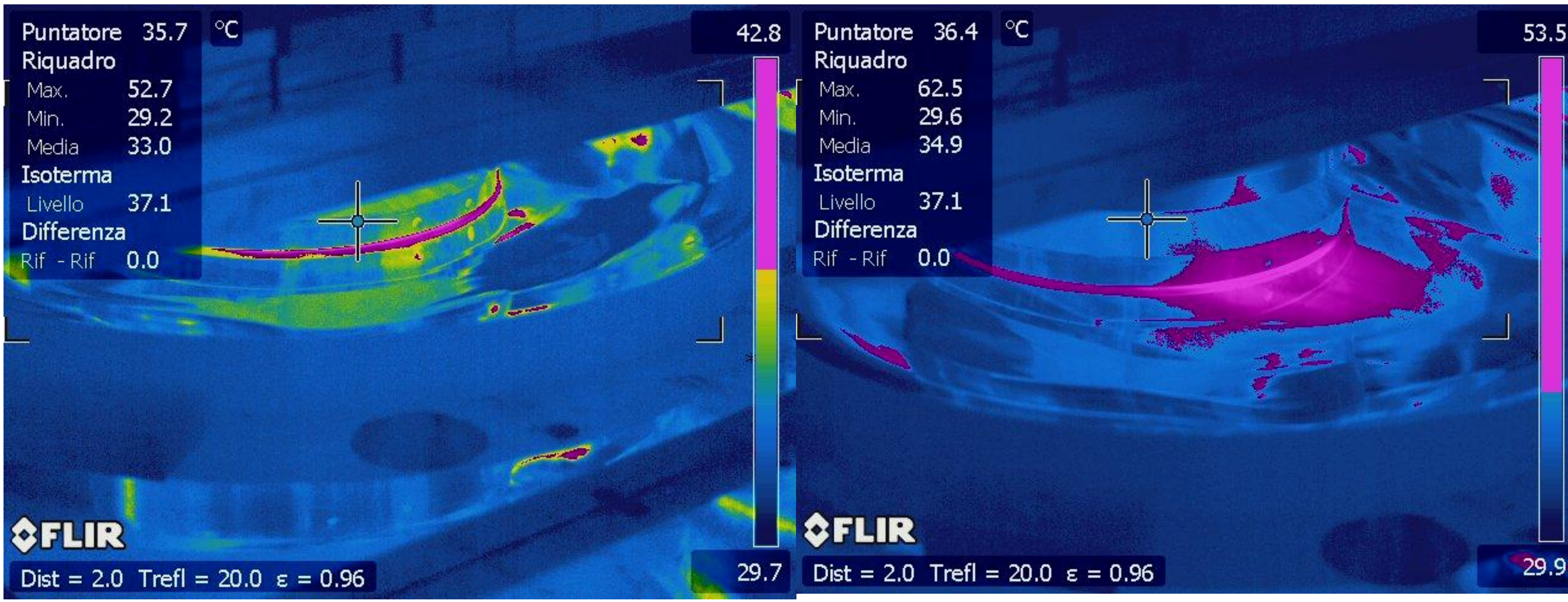
- HIRUN TESTING EQUIPMENT: control room

TESTING PHASES



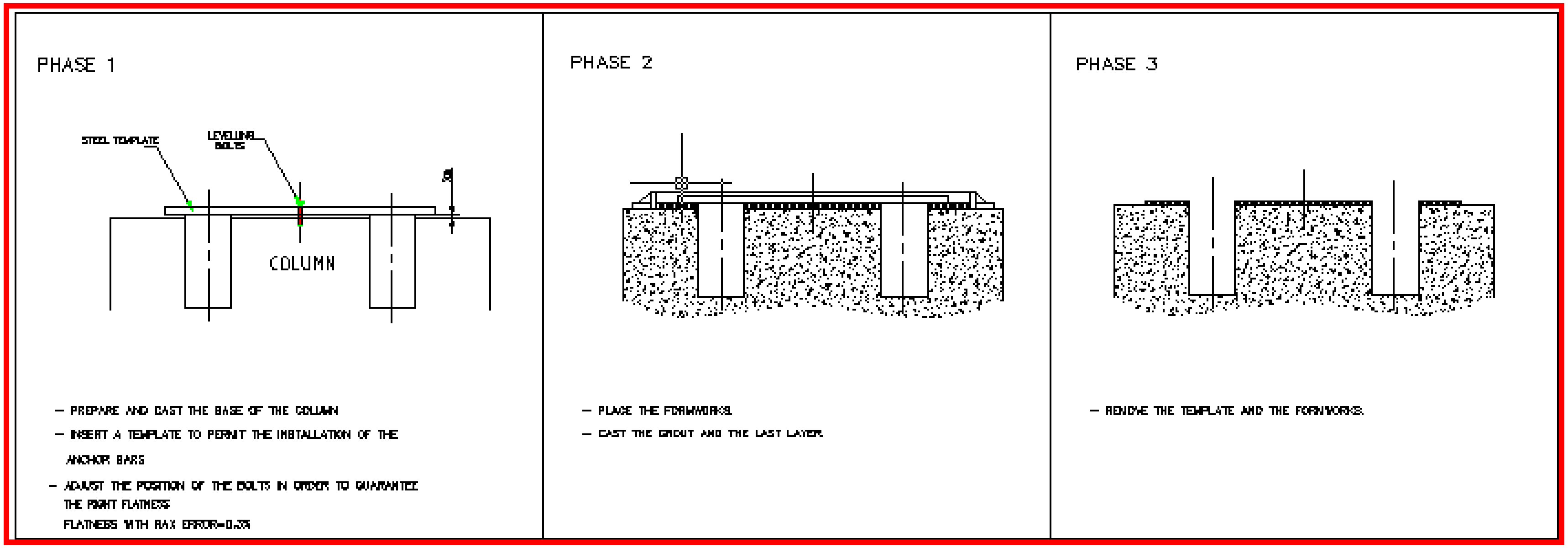
- Test execution and output

TESTING PHASES

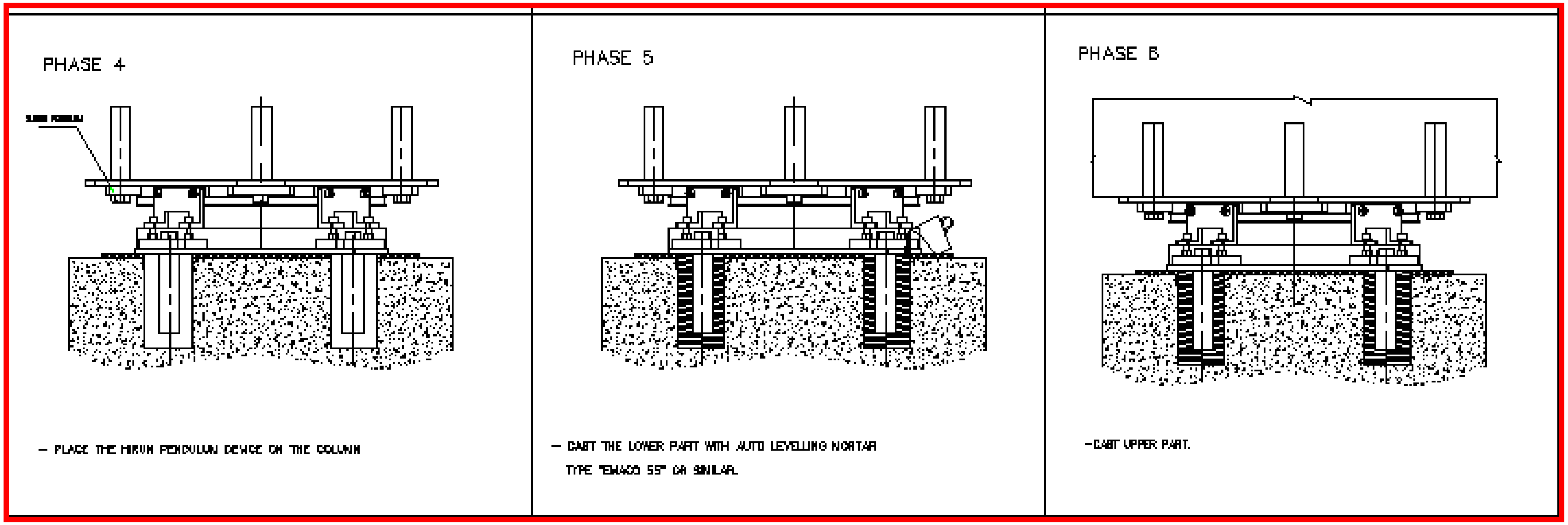


- Temperature check

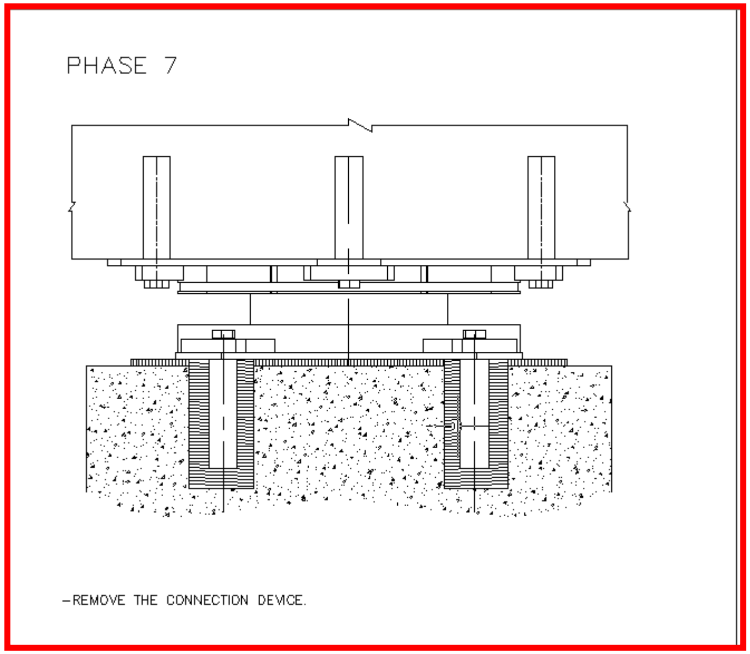
INSTALLATION



INSTALLATION



INSTALLATION



Golden Ears Bridge – Canada - 2007

HIRUN REFERENCES

HISLIDE SLIDING PENDULUM ISOLATORS

Dayue highway,
Hunan ,China

HIRUN
HI TECH CIVIL ENGINEERING

HIRUN REFERENCES
HISLIDE SLIDING PENDULUM ISOLATORS

- Hong Kong Macao Zhuhai Bridge

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HIRUN REFERENCES

HISLIDE SLIDING PENDULUM ISOLATORS

- Bursa Hospital, Turkey

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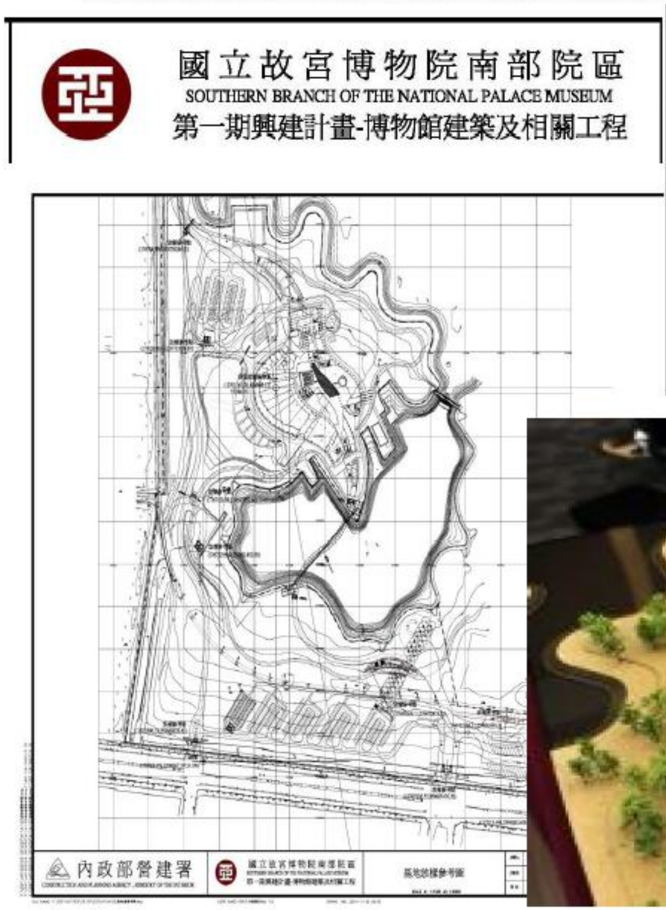
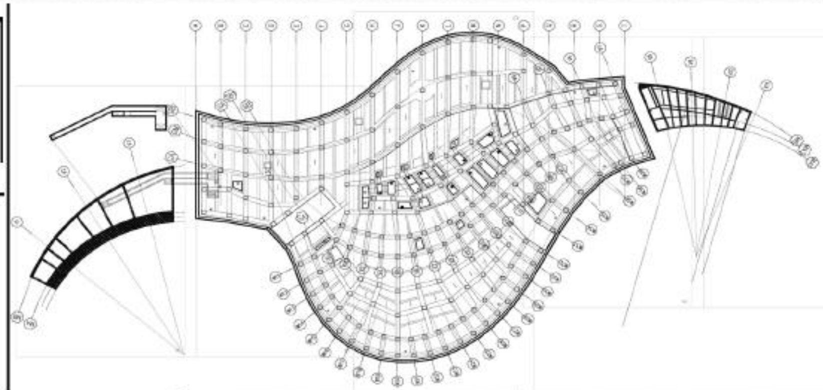
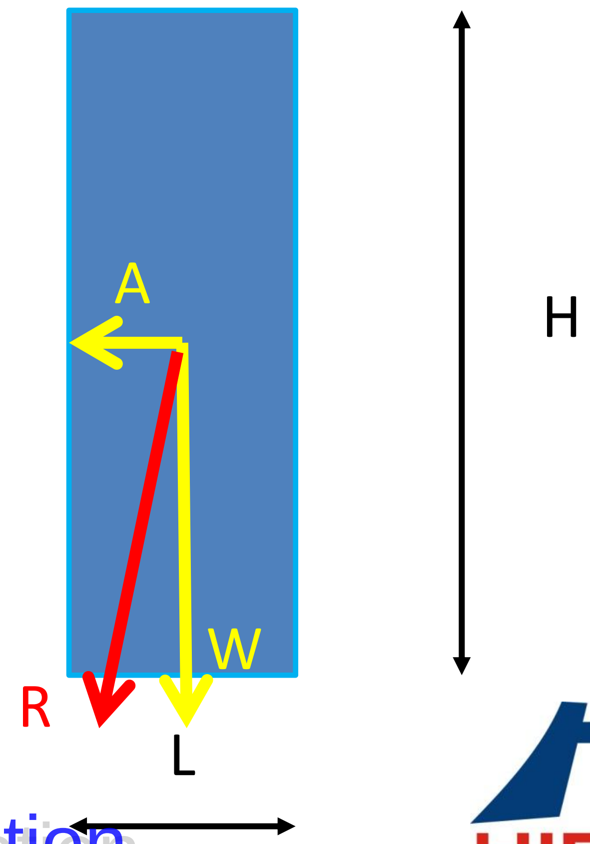
Base isolation for tall buildings
South Palace,TAIWAN 2013



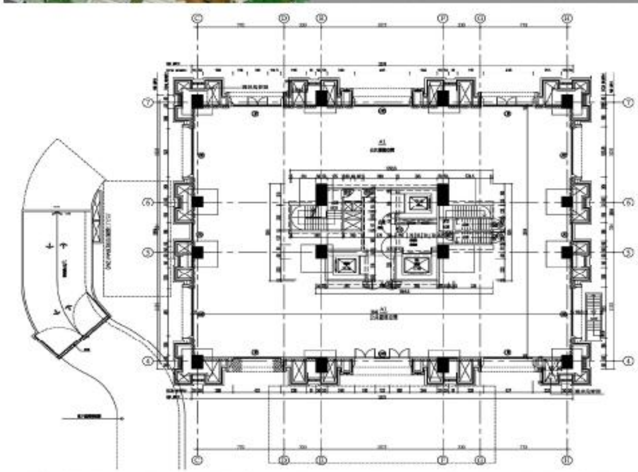


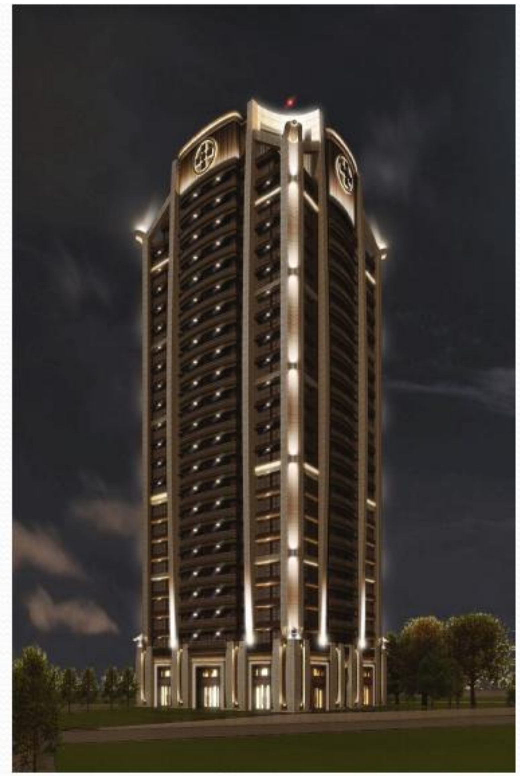
IS BASE ISOLATION SUITABLE FOR TALL BUILDINGS?

- No problem if the ratio H/L is smaller or equal to 4 or 5 (the exact value depends on the seismicity grade of the area)



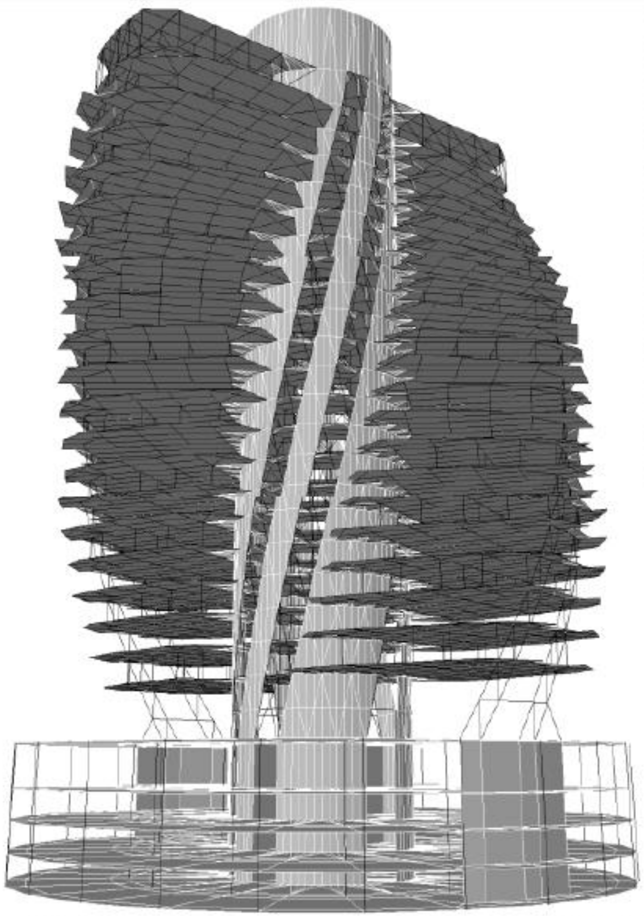
Base isolation for tall buildings
DINTAI apartment building, 25 floors TAIWAN 2013





Base isolation for tall buildings

Agora Building, 30 floors,TAIWAN 2013



IF THE BUILDING IS TOO TALL

One possible solution is to apply a TMD on top of the building

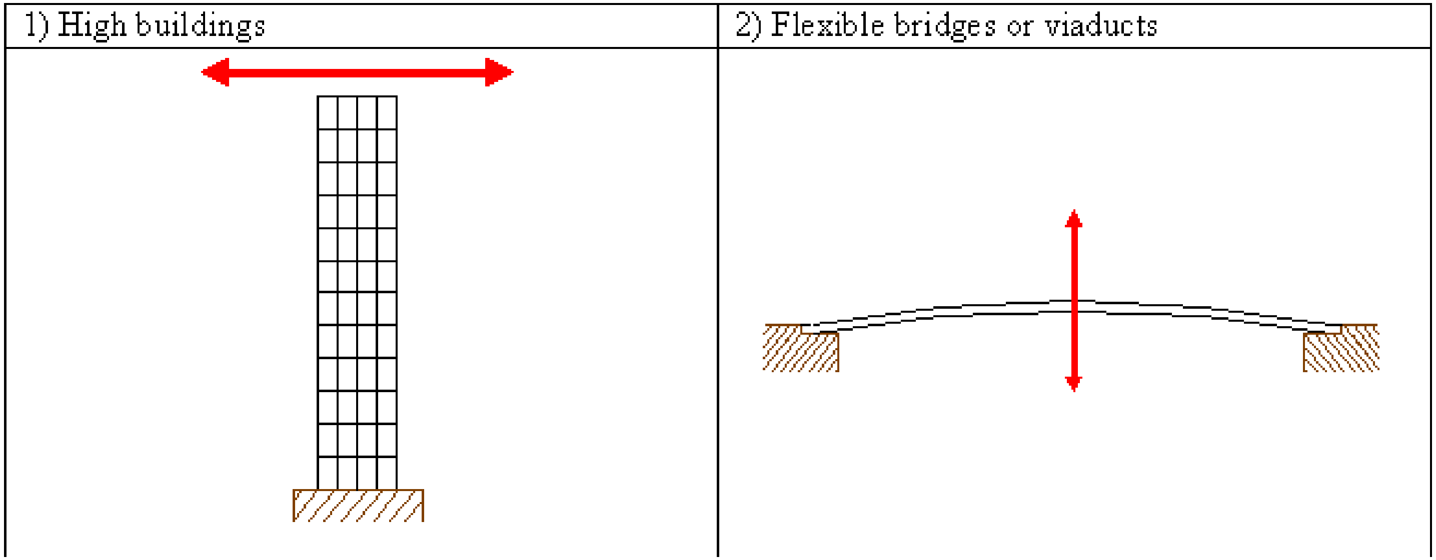
WHAT IS A TMD

- TMD is a mass that is connected to the structure by a spring and a damping element without any other support, in order to reduce the vibration of the structure
- The frequency of the TMD is tuned to a particular structural frequency so that it will resonate out of phase with the structure

MAIN USES OF TMD DEVICES

The TMD devices are used in tall or flexible structures in order to prevent structural problems due to the vibration of the structure

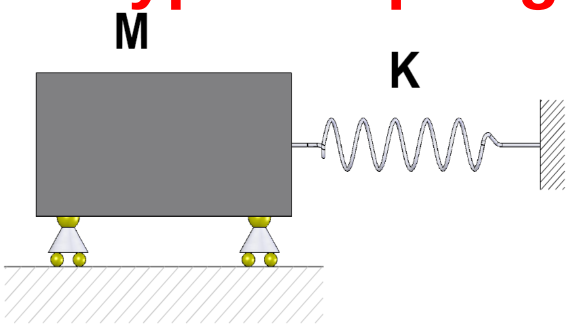
TYPICAL CASES:



MAIN FEATURES OF A TMD SYSTEM

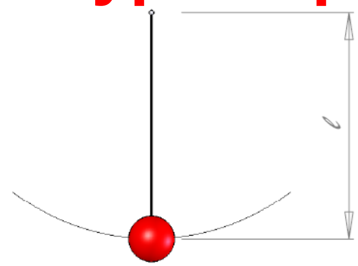
insert a linear harmonic oscillator in order to reduce the vibrations of the structure

Type 1: spring



$$\frac{1}{f} = 2\pi\sqrt{\frac{M}{K}}$$

Type 2: pendulum

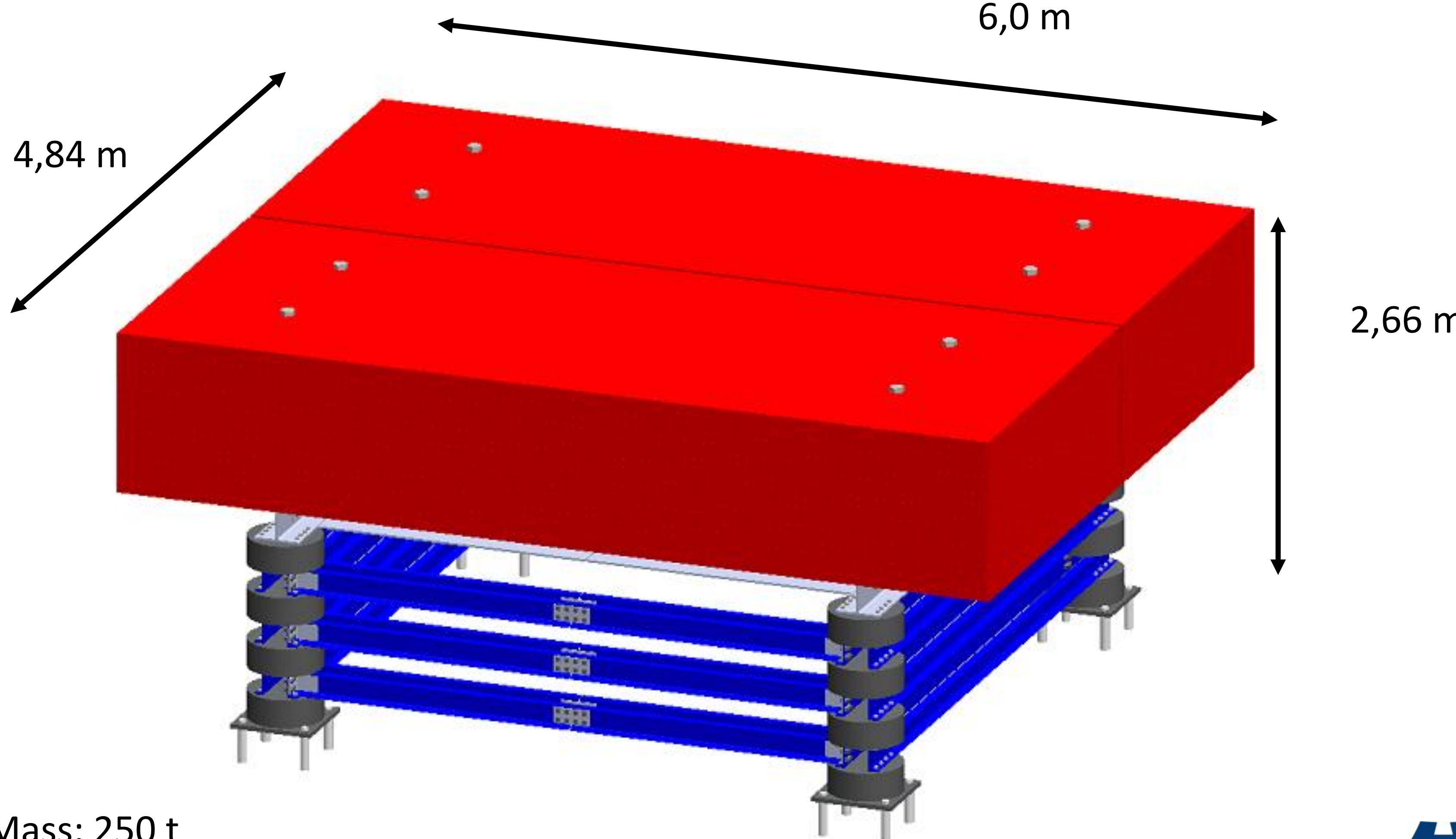


$$\frac{1}{f} = 2\pi\sqrt{\frac{l}{g}}$$

In order to optimize the functionality of the TMD is possible to add a damper system:

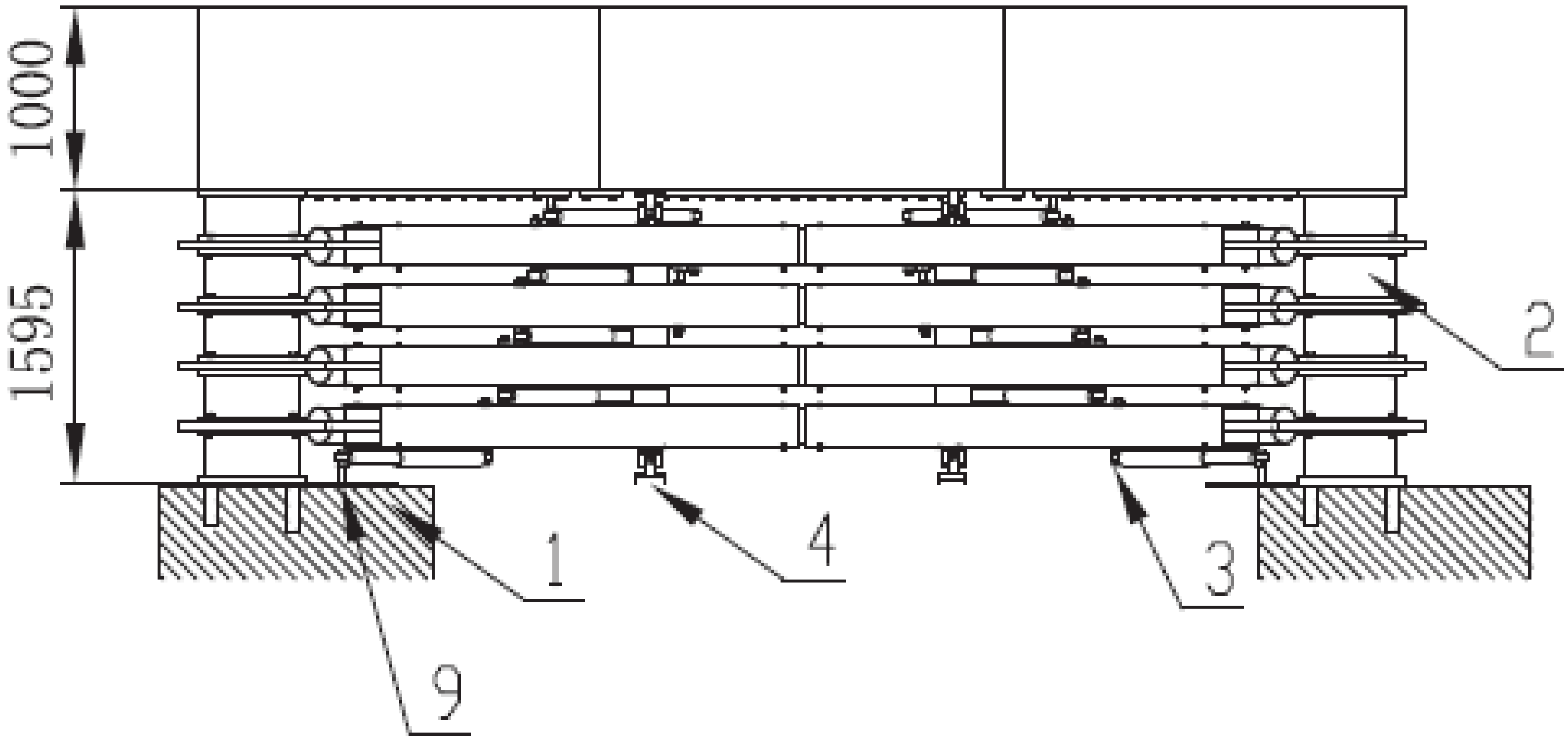
- **Fluid damper**
- **Electro inductive damper**

EXAMPLE OF A BI-DIRECTIONAL TMD FOR TALL BUILDINGS

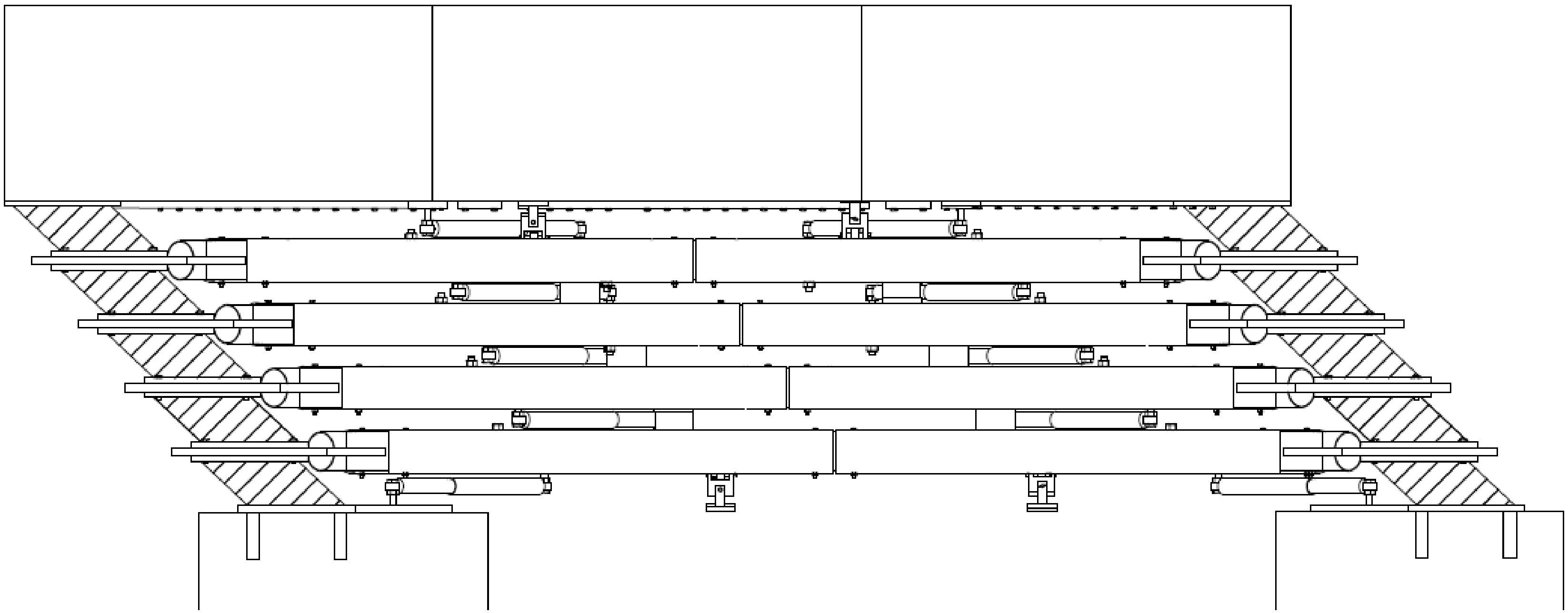


Mass: 250 t
Weight: 2500 kN

LATERAL VIEW OF THE TMD



TMD AT MAXIMUM DISPLACEMENT



SEISMIC RETROFITTING

OF AN EXISTING BUILDING

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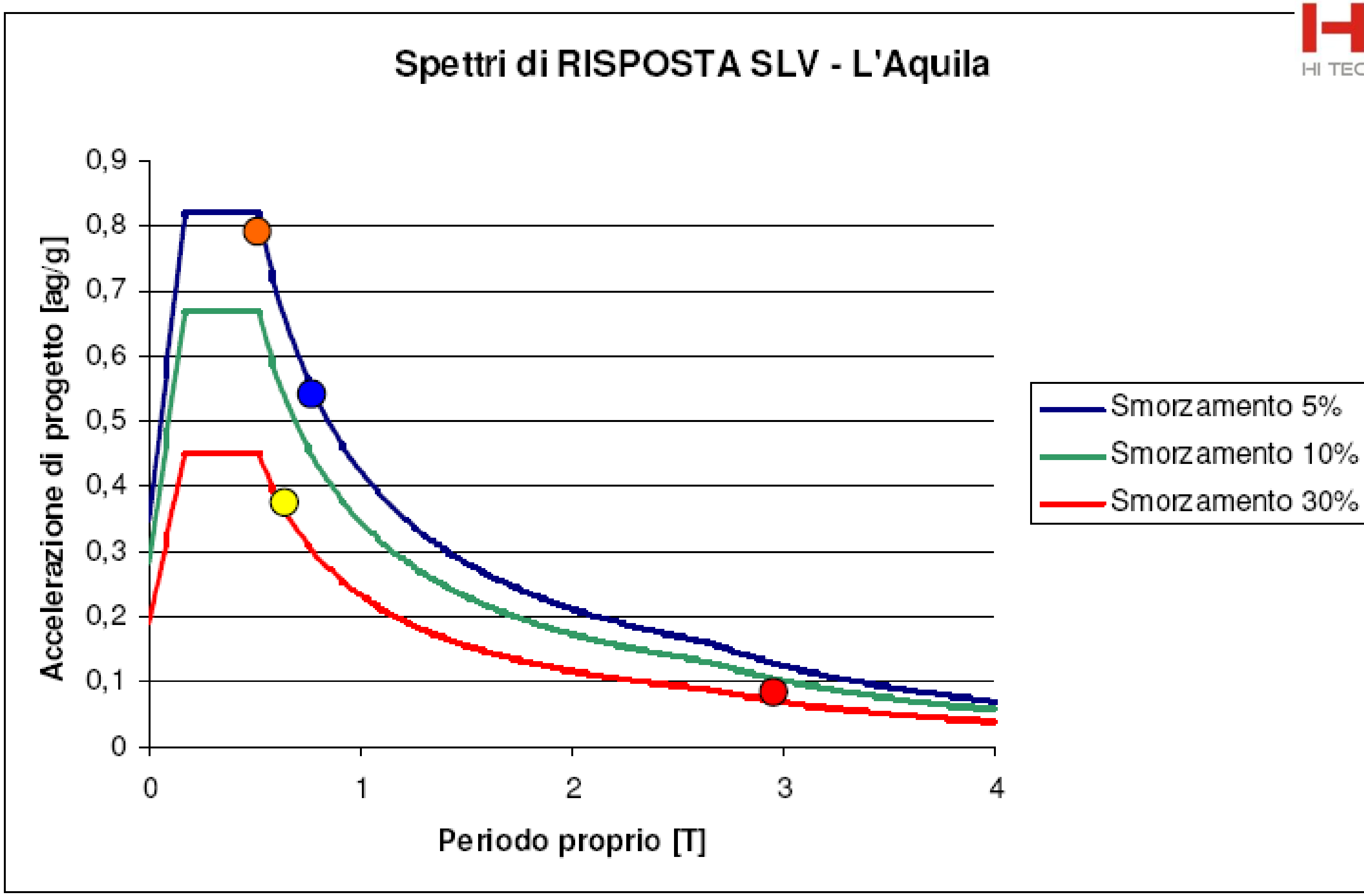
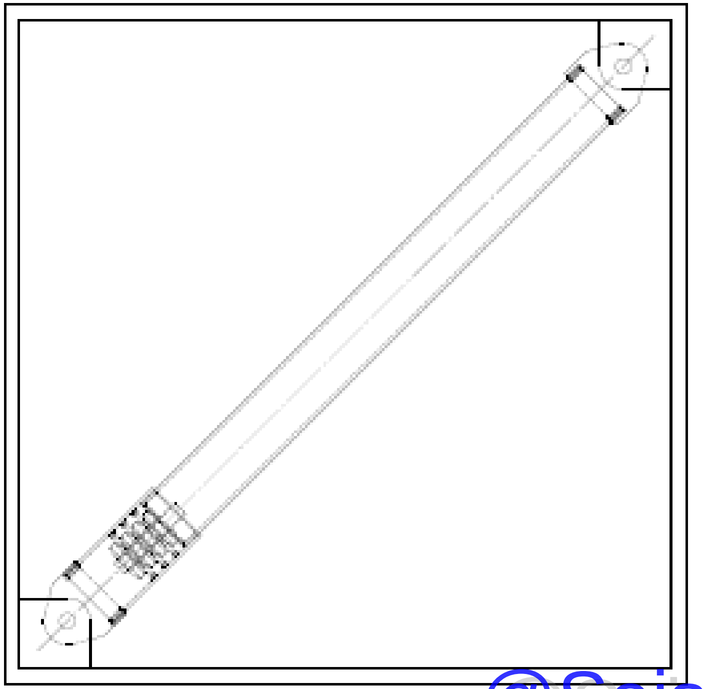
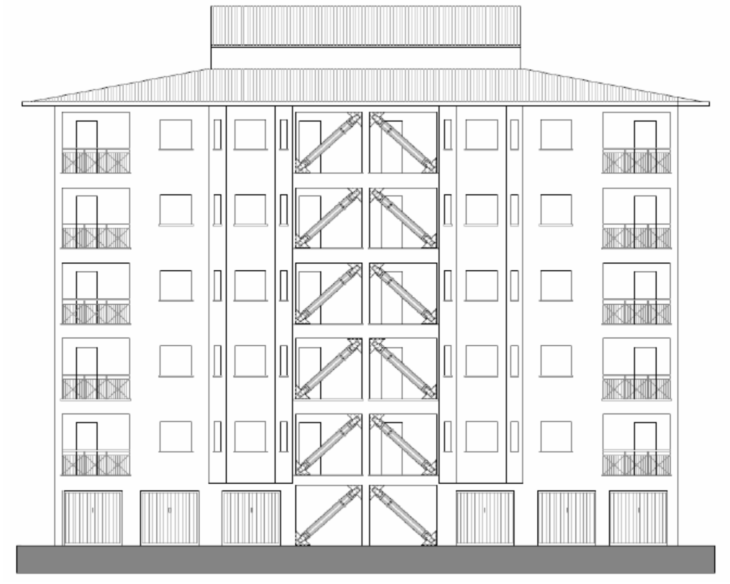


Existing building
Structural strenghtening
Dissipating bracings
Seismic islolation

The use of hysteretic bracing for seismic retrofitting of a building





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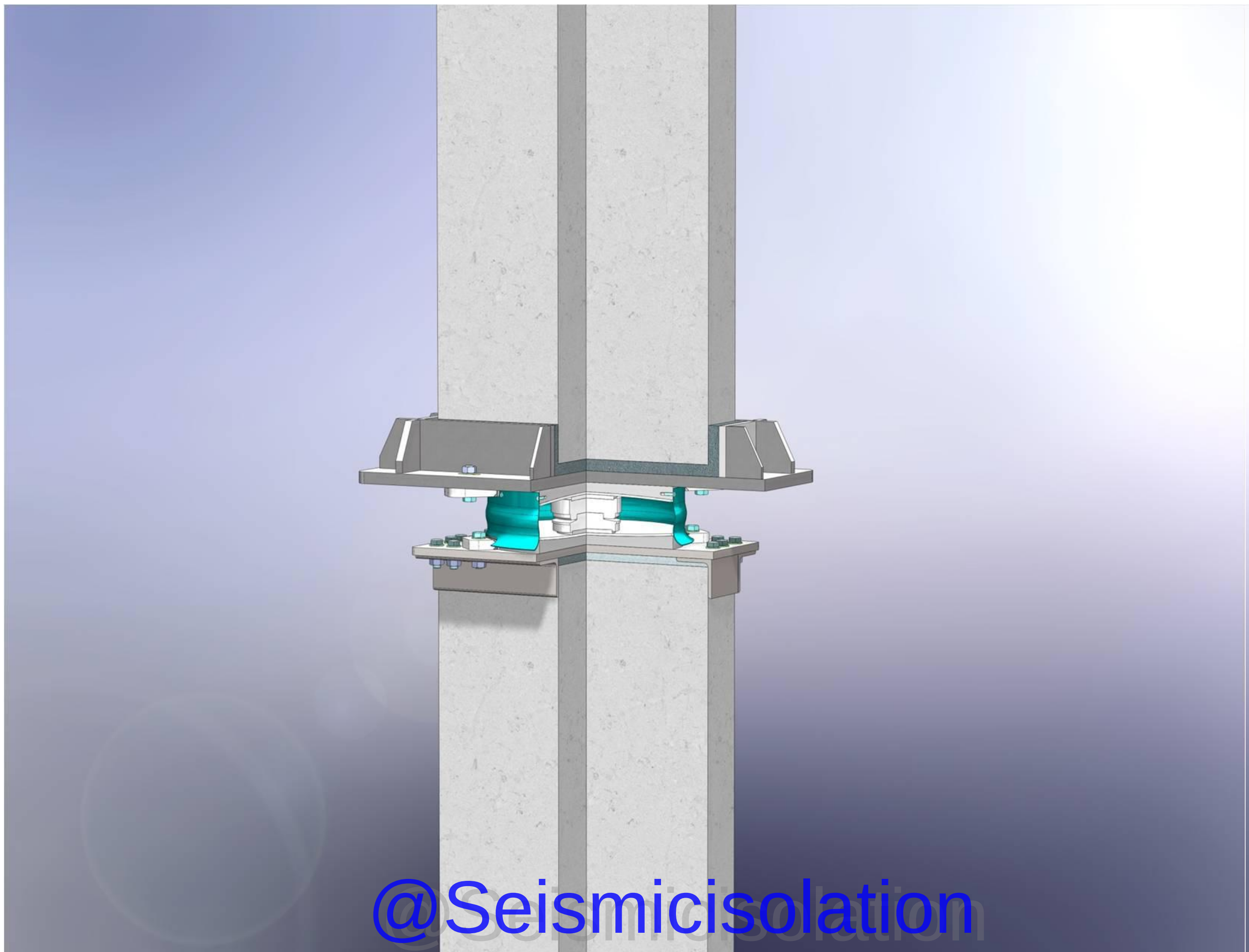
HOW TO PLACE THE ISOLATORS IN A CONCRETE COLU



Details or the reinforcements applied to the column

PLACING THE SUPPORTS

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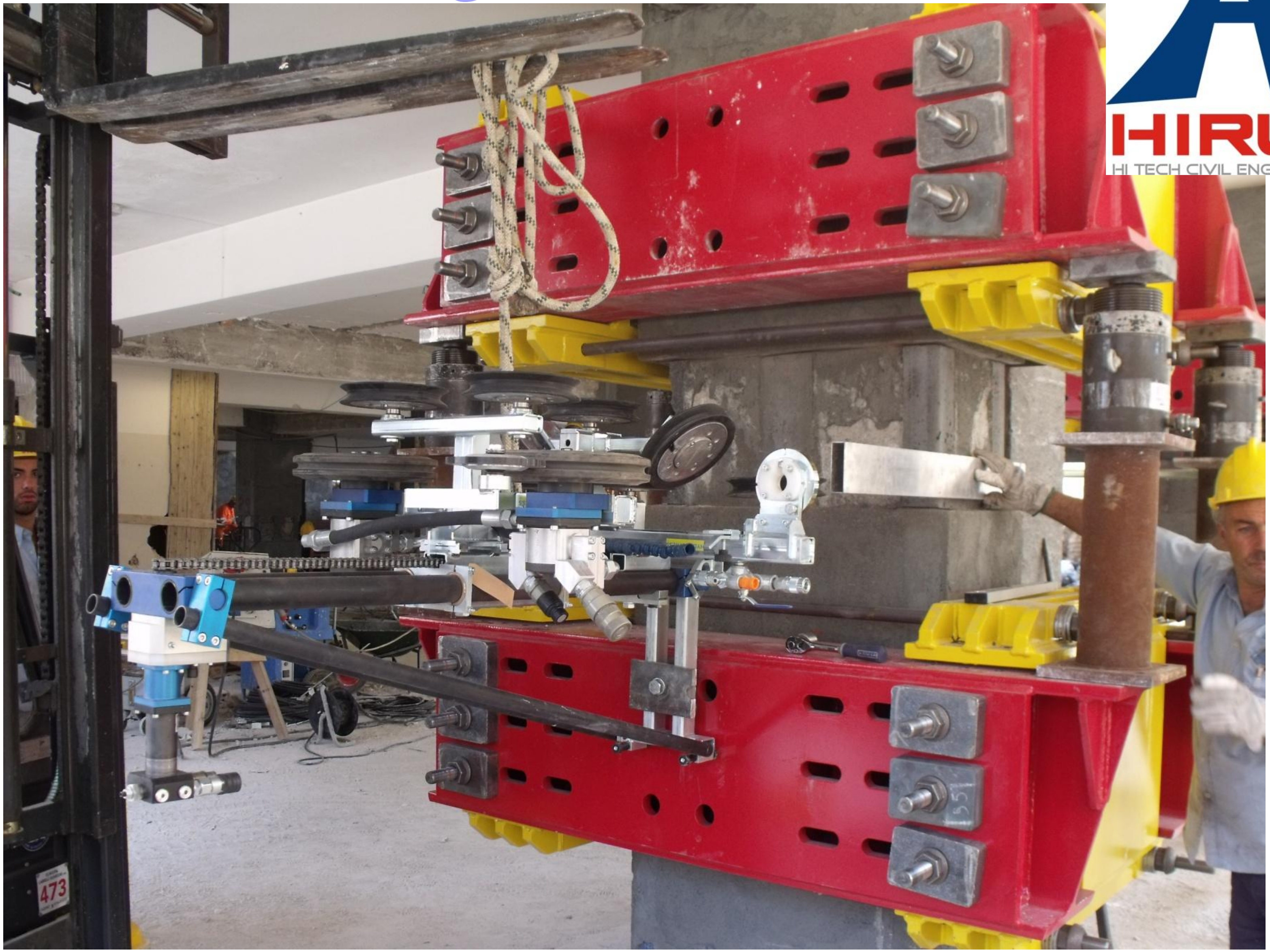
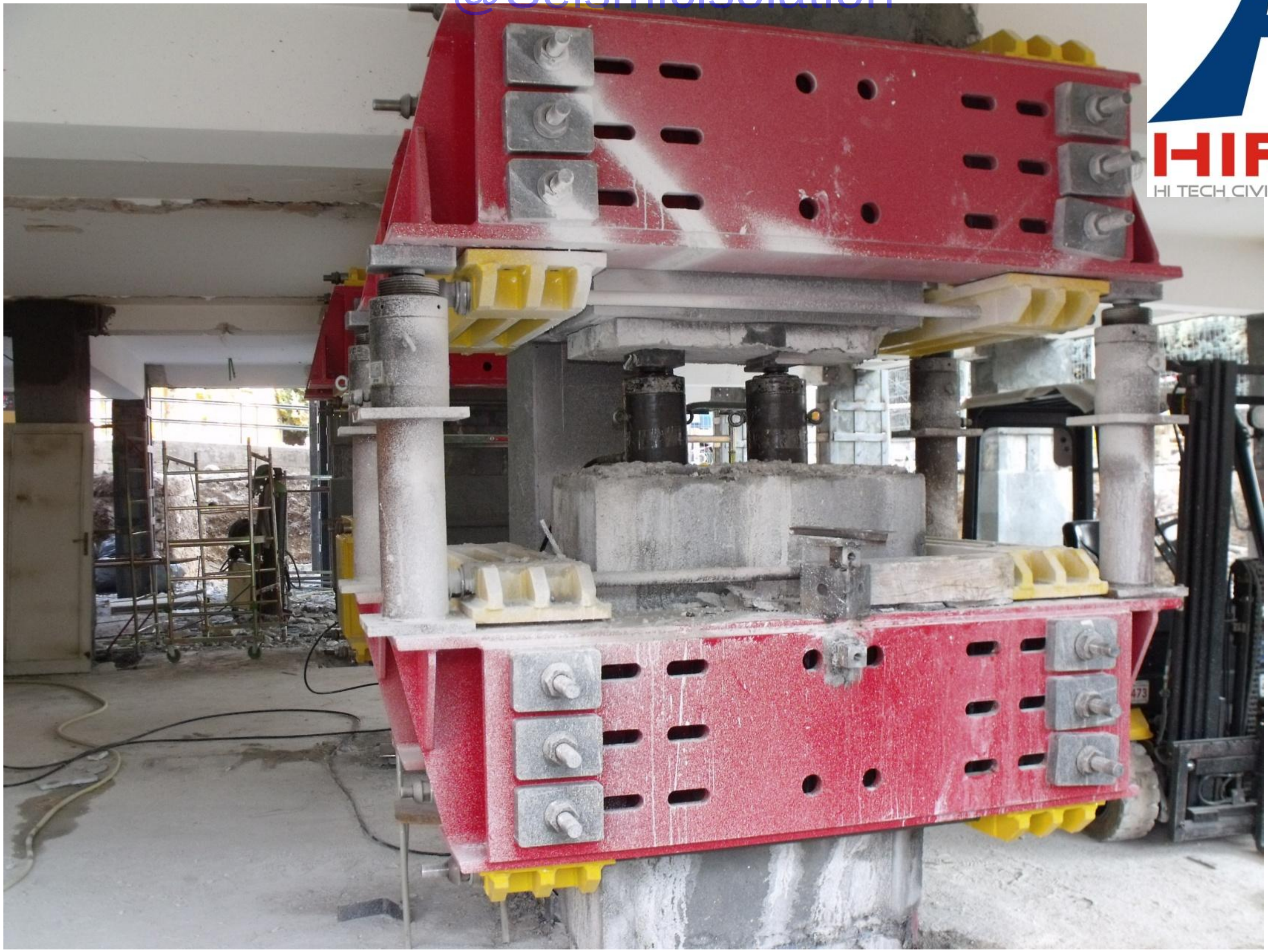
Placing the beams

Stressing the beams

Loading the vertical jacks



Cutting the column by diamond wire saw



The cut completed

Placing the isolator

Isolators and steel strengthening placed

The job almost completed

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Detail of the external walls

Detail of the external walls and gap

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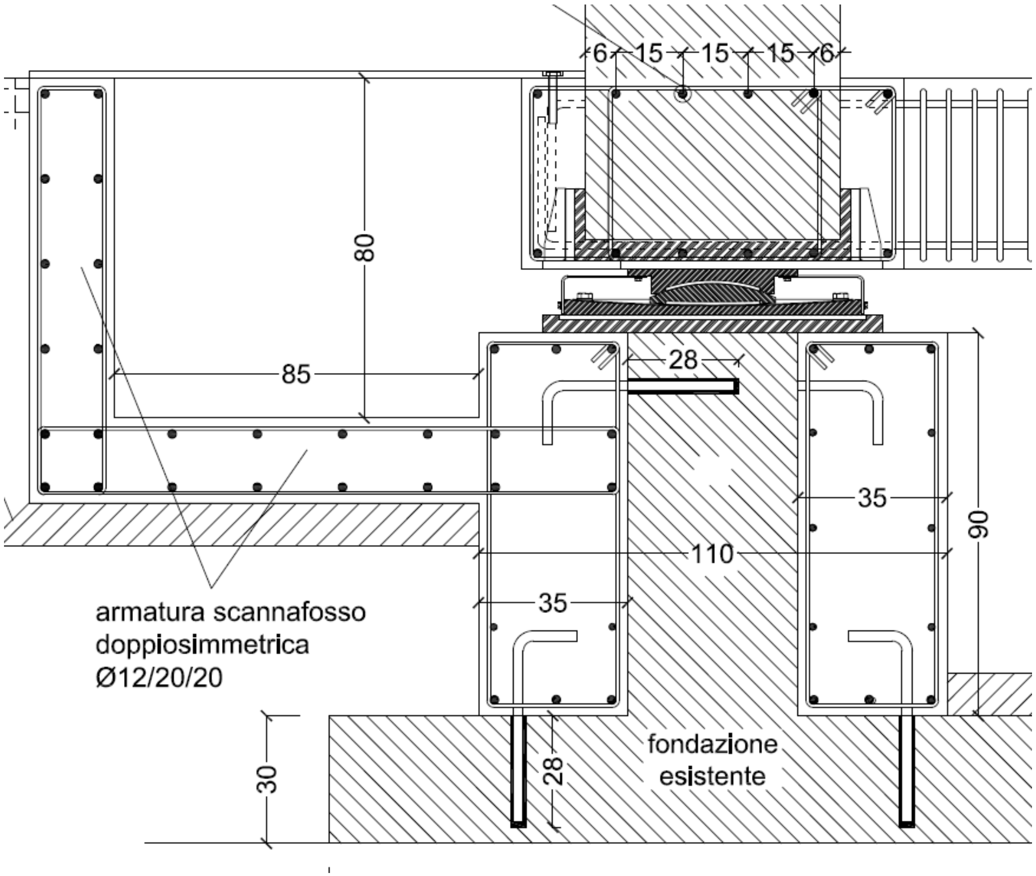
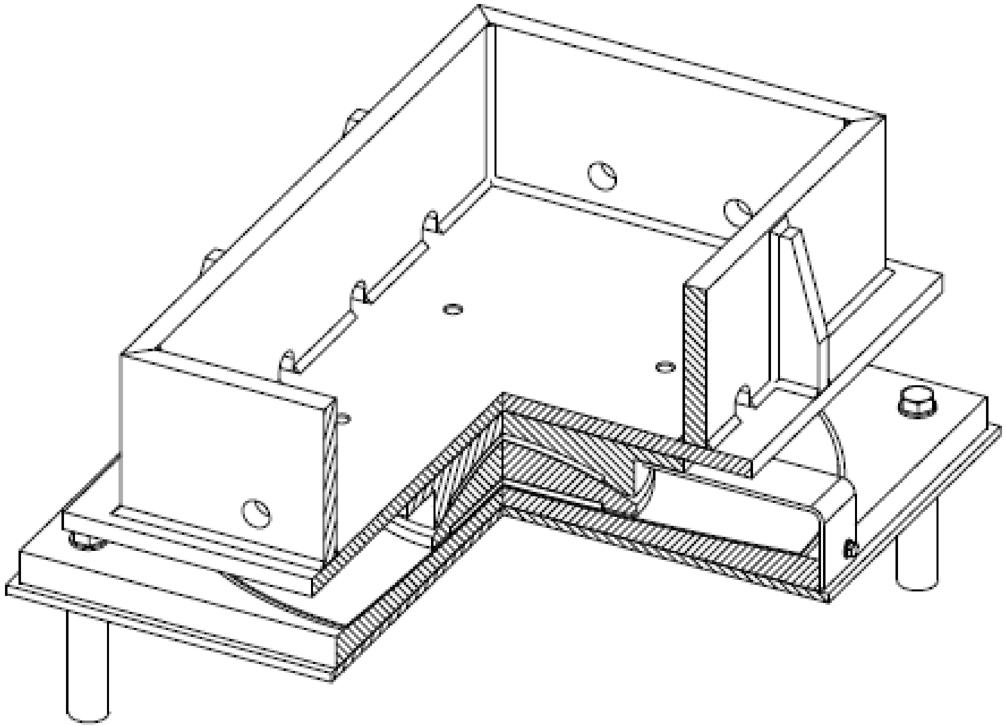
Detail of the external walls

Cover of the isolators (optional)

TYPICAL DETAIL OF THE STRUCTURE ADD TO THE ISOLATOR



TYPICAL DETAIL OF THE CONNECTING PLATES ISOLATOR TO THE STRUCTURE



THE AIRPORT OF ANTALYA, TURKE

19 million passengers per year

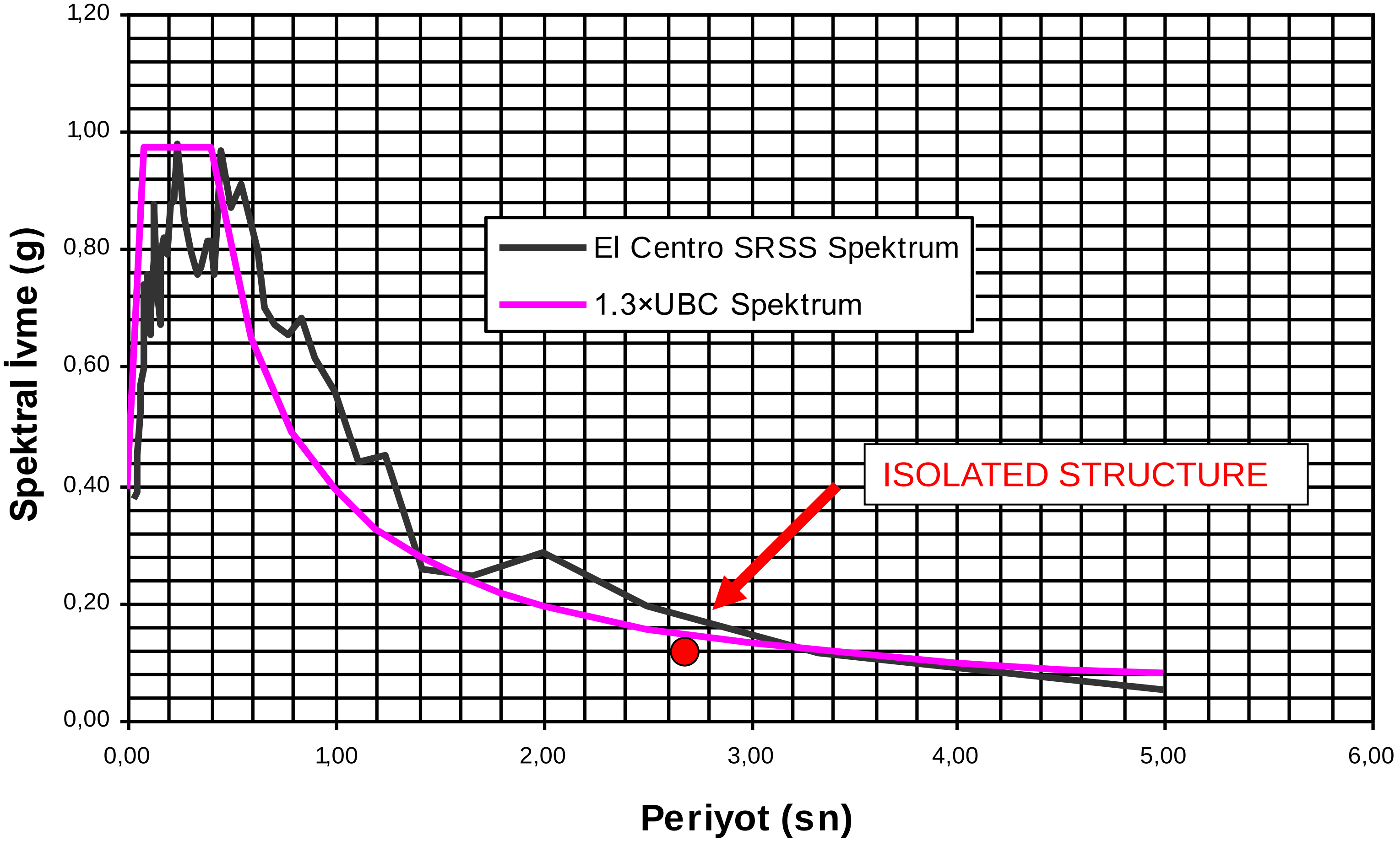
The Airport of Antalya

SEISMIC RETROFITTING OF THE ANTALYA AIRPORT

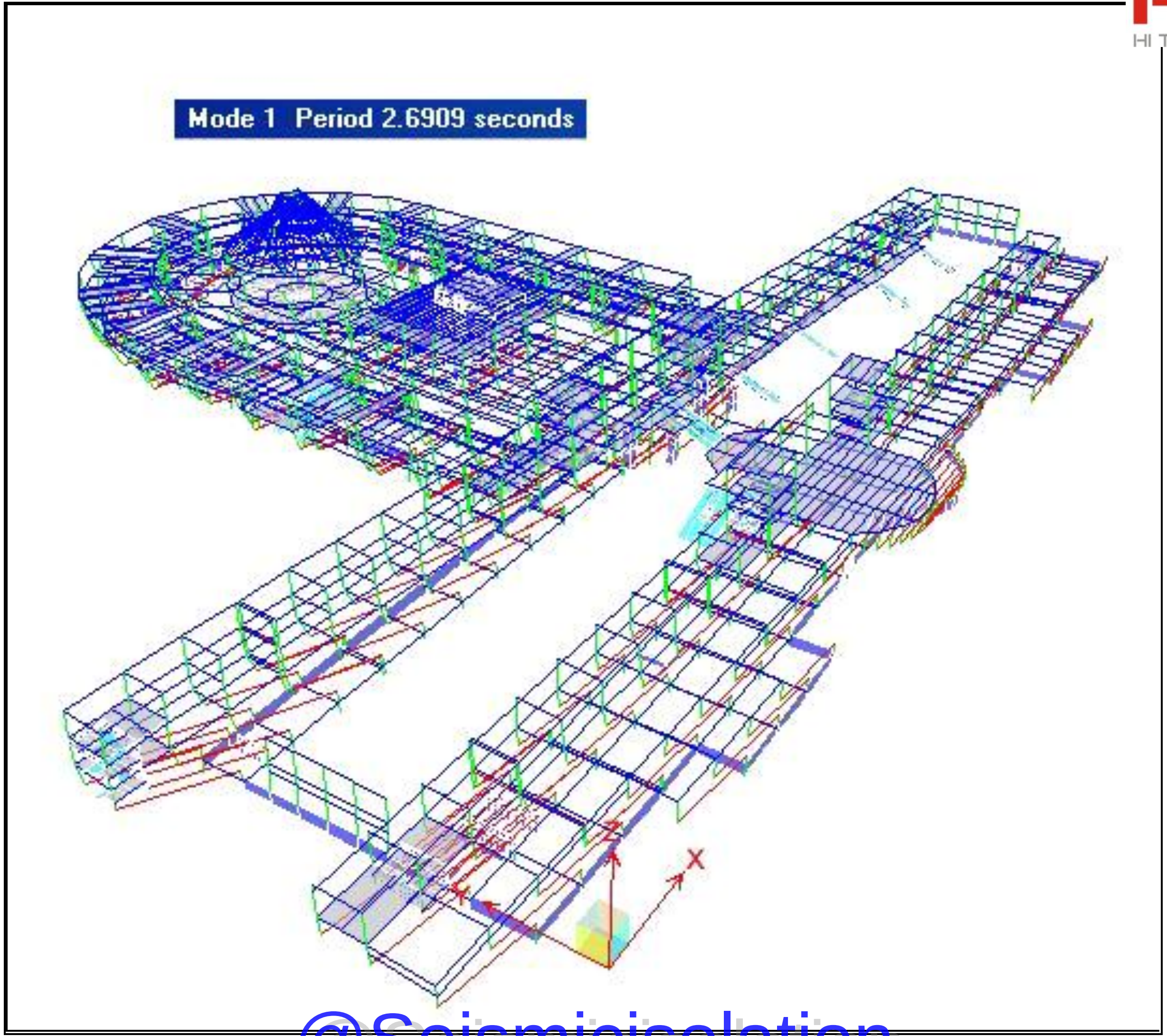
MAIN TECHNICAL DATA

- PGA = 0,4 g
- Design Spectrum: UBC x 1,3
- Soil Type B
- Period of the isolated structure T=2,69 s
- Design displacement D=300 mm
- 358 LRB with equivalent viscous damping 28%
- Dynamic analysis with 7 real accelerograms scaled at the design spectrum

Design spectrum and of one of the consid earthquakes



ANTALYA AIRPORT, FIRST VIBRATION MODE T=2,6



OPERATION SEQUENCE

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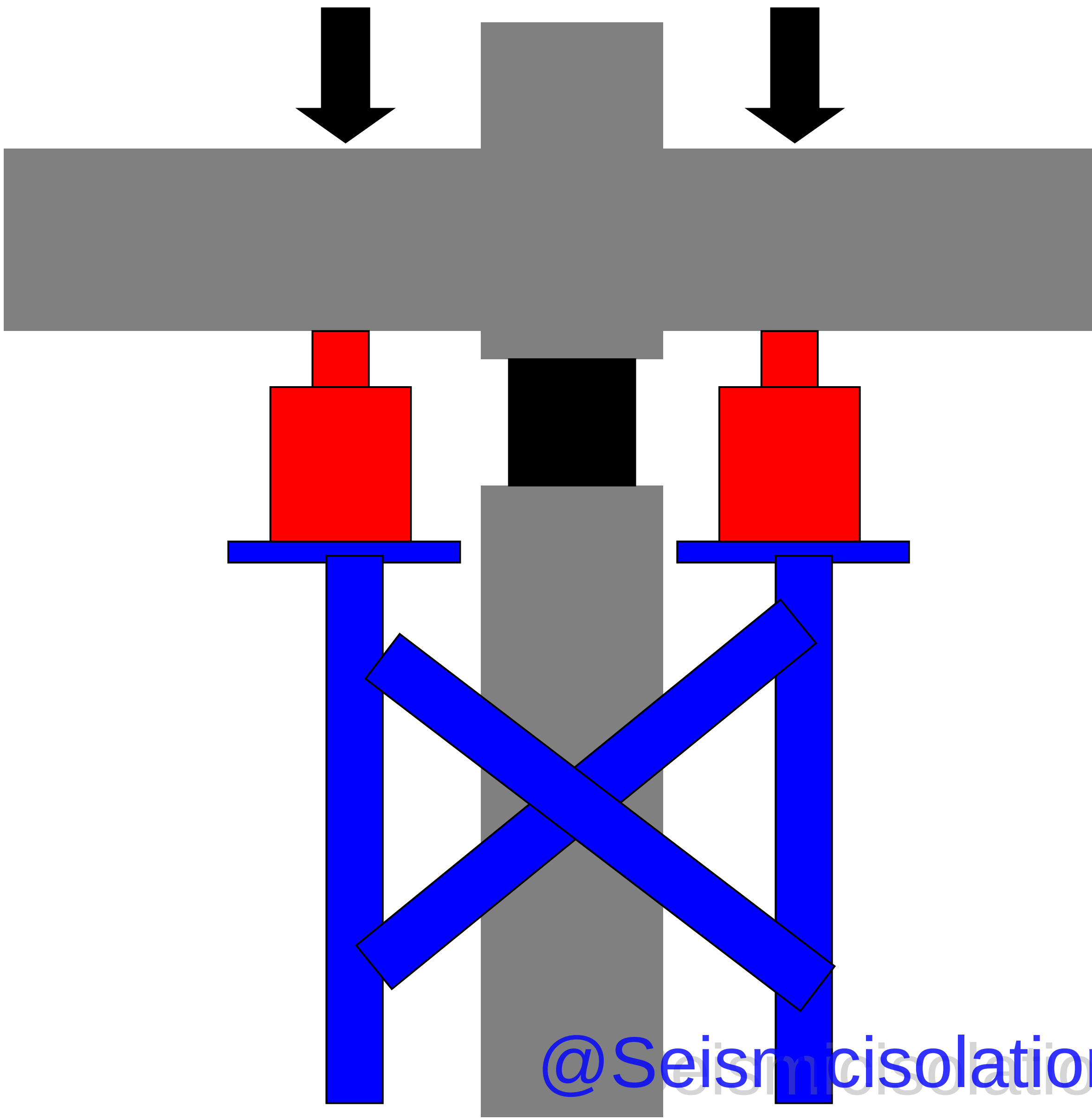
HI TECH CIVIL ENGINEERING

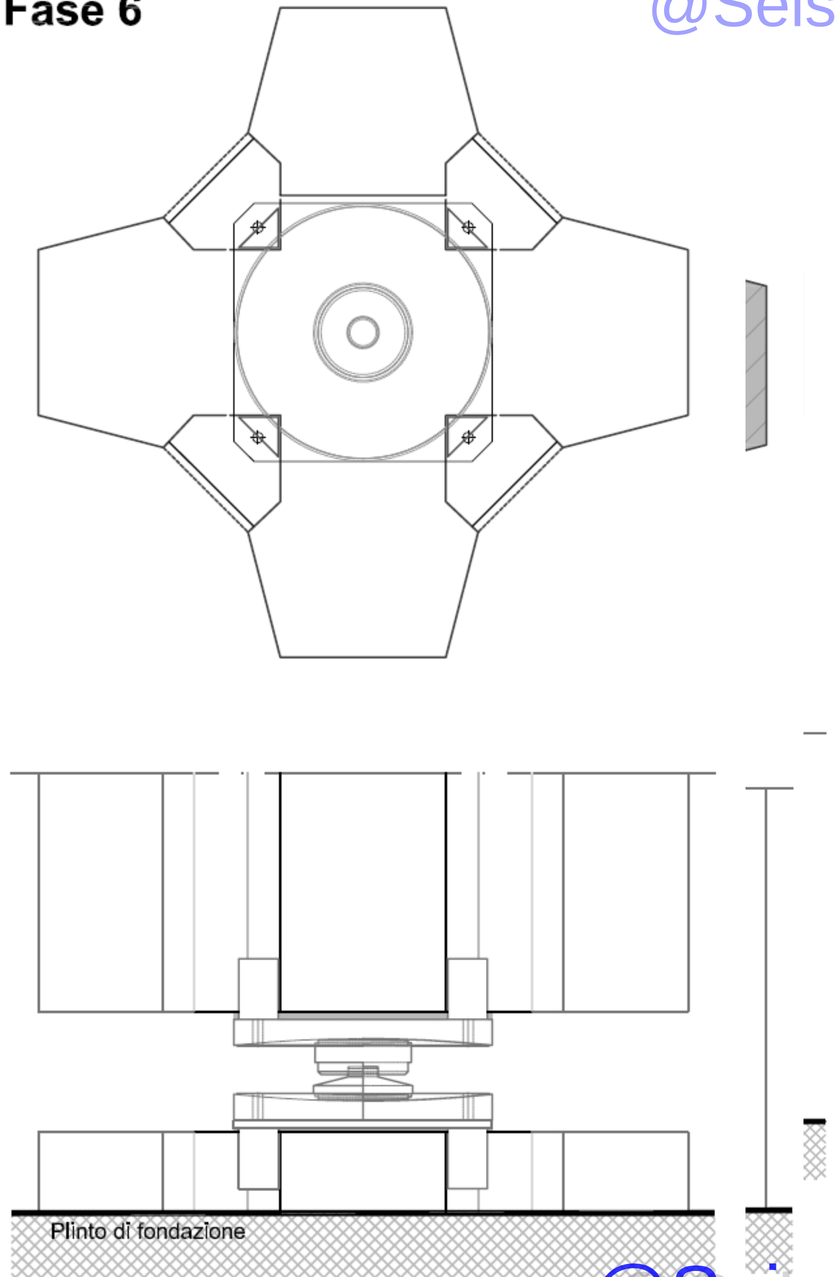


1. Application of the steel columns
2. Application of the jacks
3. Stressing of the jacks
4. Cutting of the concrete
5. Installation of the isolator

CUTTING OF THE COLUMN

DETAIL OF THE LRB

Fase 6



Carico trasferito sull'isolatore a pendolo

- INSTALLATION PROCEDURE WITHOUT JACKING FOR WALLS OR BIG COLUMS

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Partial cutting of the concrete

Placing of the isolator

The job completed

Viscous dampers acting in parallel with the iso increase the energy dissipation

IS IT DIFFICULT TO DESIGN A BASE ISOLATED STRUCTURE?

The contrary is true: it is much easier than a traditional structure.

The whole structure remains in the elastic field and a linear analysis is sufficient

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HOW MUCH DOES IT COST?

RELATIVE COSTS FOR A BRIDGE CONSTRUCTION		
	NON ISOLATED	ISOLATED
BRIDGE DECK	49	49
BEARINGS	1	2
PIERS, FOUNDATIONS	50	30
TOTAL	100	81

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HOW MUCH DOES IT COST?

HIRUN
HI TECH CIVIL ENGINEERING

TYPE OF ISOLATOR	INDICATIVE PRICE IN USD
Isolator for buildings 1000 to 10000 kN	2000 - 10000
Isolator for bridges 50000 to 50000 kN	5000 - 30000
Seismic retrofitting (per column)	8000 - 15000

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CONCLUSION

- Seismic isolation is the most effective system to protect a structure from the earthquake
- Sliding pendulum isolators are the most efficient and the most cost/performance effective
- Retrofitting existing buildings by base isolation is possible
- Retrofitting by base isolation has a very low impact on the activity performed inside the building and may be performed also without stopping it
- Base isolation greatly simplifies the design

Thanks for your attention!

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