Application of Seismic Isolation in China

Professor ZHOU Fu Lin

Division of Civil, Hydraulic and Architectural Engineering,
Academician, Chinese Academy of Engineering, Earthquake Engineering Research & Test Center,
Guangzhou University, China

Application on Seismic Isolation in China

Fu Lin ZHOU, Ping TAN & Wen Liuhan HEISHA
Earthquake Engineering Research & Test Center
National Key Lab. On Seiemic Isolation and Control
Guangzhou University, CHINA

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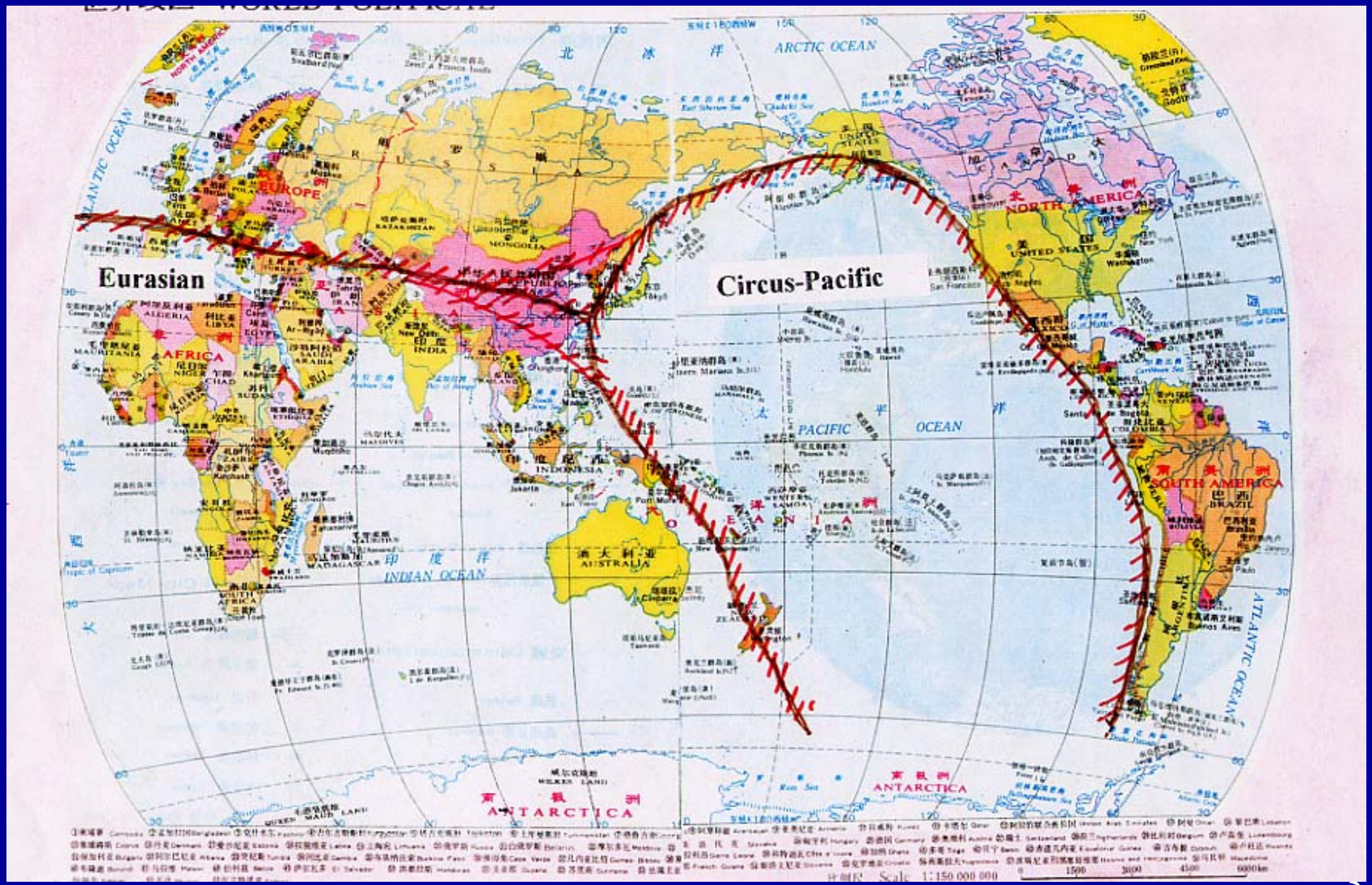
1. Earthquakes hazard and countermoves in China
2. Concept design and isolation of buildings
3. Mechanism and test for isolation system
4. Testing of property and durability of isolators
5. Application and Real earthquake experience of isolation in China
6. Isolation for low cost rural buildings
7. Technical maturity of isolation technique
8. Future development tendency of isolation

1. Earthquakes hazard and countermoves in China

Two main seismic zones in the world
Circus-Pacific zone & Eurasian zone



Serious Threaten of Earthquake for China

China -- a very Frequently seismic country

- Located in the Cross Area of
  Two main seismic zones in the world
- Over 80 % of national land is seismic area
- 85 % of large cities are located in seismic area
- Most of EQ are stronger, over prediction
- Many buildings are lack of capacity for anti-Earthquake,
  People urgently require living in houses,
  that are ensured to be safe in strong EQ

China Tanshan Earthquake

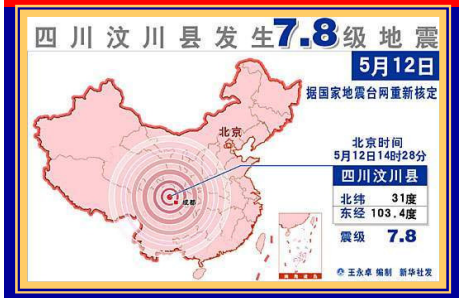
1976.7.26 3:15 240,000

China Yushu (YS) Earthquake M7.1

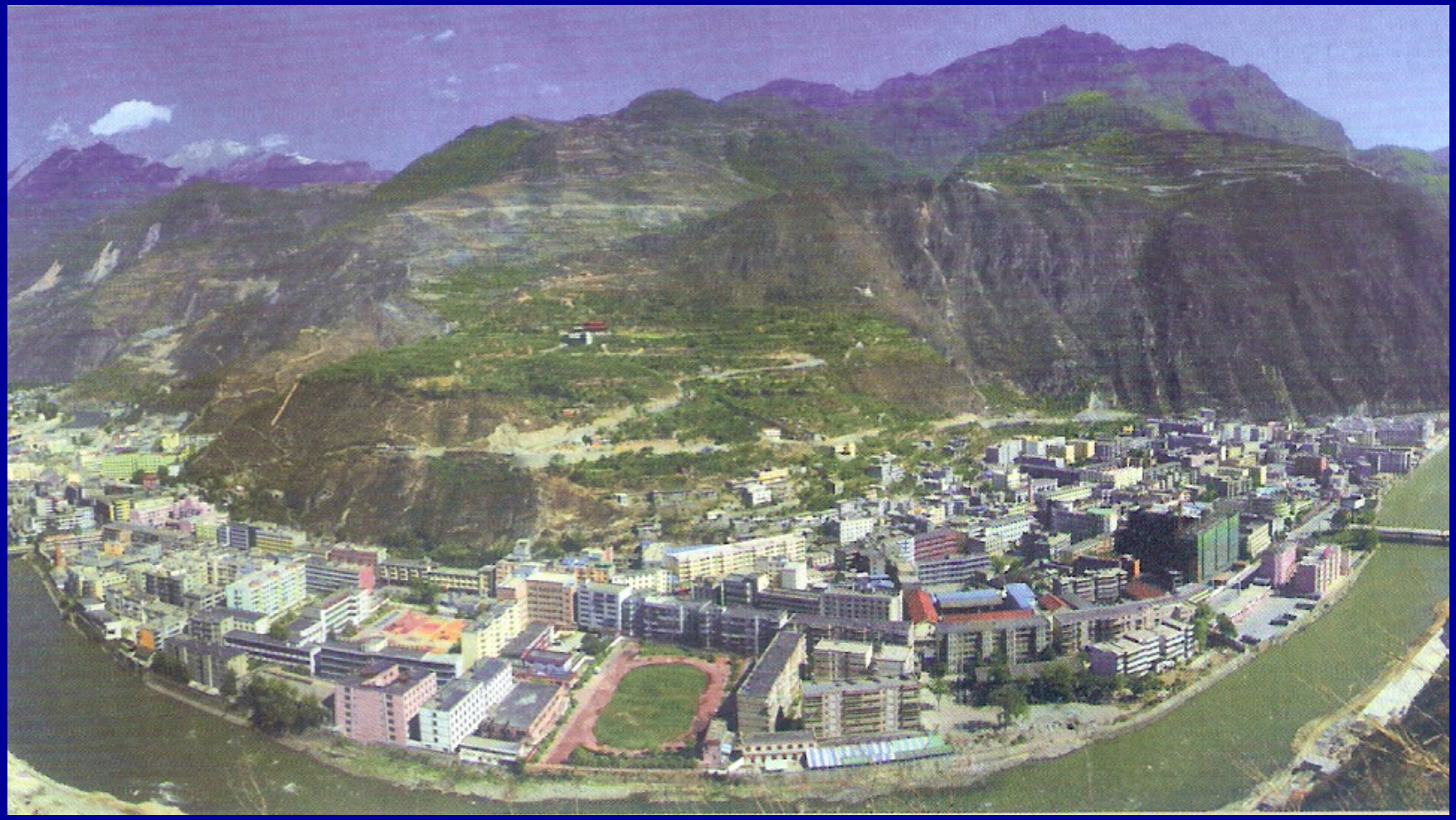
2010.4.14 Dead 2500 people

China Wenchuan (WC) Earthquake

2008.5.12 M=8.0 90,000 died or lost



A beautiful county before EQ
Wenchuan Area



The county Become a ruin after EQ

512地震 超烈度 汶川县城成一片废墟

A great number of buildings collapse

房屋整体倒塌,512地震超烈度,汶川县城 残垣断壁

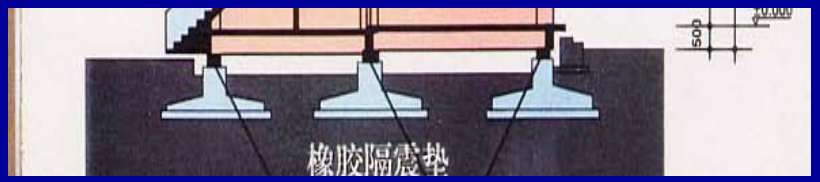
After EQ, Mother was finding her son in school ruin
妈妈找孩子,地震超烈度,学校一片废墟

In the EQ site, People sorrowfully ask a requirement to the Engineers:

"Can we live in a really safe house in strong E.Q. ? ! "

Just after EQ,
A surprise message comes:
There are 3 buildings with isolation
with 6 stories masons structures
In northern Sichuan
陇南武都县 (A=0.18g)

performance very well !



Well performance of Isolation buildings
in Wenchuan EQ 2008.5.12

There are 3 buildings with isolation,6 stories brick St.

(1) Only feel slowly vibration T=2.6s , A=0.18g,

(2) No any facilities inside fall down

(3) No any cricks on brick wall after EQ

Serious damaged of no-Isolation buildings in this same area

(1) People feeling shake very seriously
(2) Most facilities fall down inside
(3) Serious cricks on brick wall after EQ

China Lu Shan(芦山)Earthquake
April 20. 2013 M7.0

Lu Shan(芦山)Earthquake in China

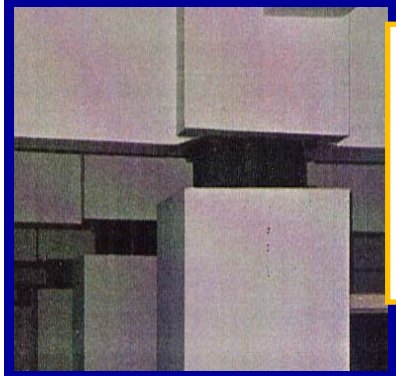
Lu Shan(芦山)Earthquake in China

Concrete buildings

Brick buildings

Lu Shan(芦山)Earthquake in China

Just after EQ, A surprise message comes: One Isolation Hospital is perfomance very well in China Lu Shan(芦山)Earthquake April 20. 2013 M7.0



+7 story

-1 basement

- 3 hospitals building with base fixed.
  shaking severely in building
  Damage both structure and facilities
  3 hospitals are all break down
- 1 hospital Building with isolation
  No any damage for struc. & deco.
  No any fall down for Facilities & equipment inside the building
  persons, no any feeling

This Isolation Hospital become unique rescue Center

Thousands of injured people in it.

Lu Shan(芦山) isolation hospital

The lessons learn from E.Q. in China

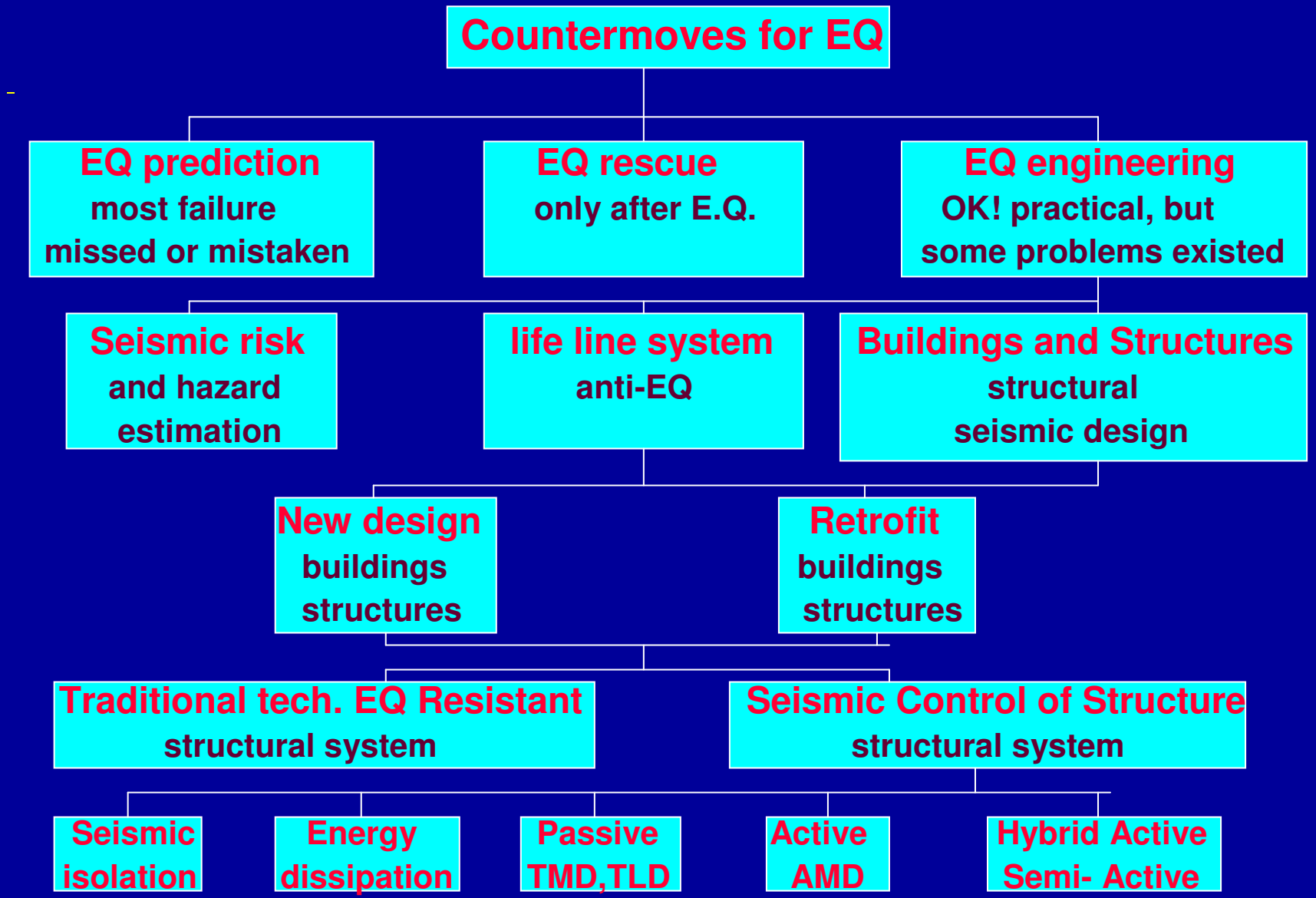
1. Most people dead caused by buildings collapse

2. EQ Cause severe damages of both buildings structures and inside facilities, stop city's life.

3. Most of strong EQ are over prediction in China
   2008.05.12 Wenchuan EQ 0.10g →0.96g, 10 times
   2010.04.14 Yushu EQ 0.10g →0.65g, 6 times

4. Isolation technique is an effective Technique to protect people life & both the building structures and inside facilities in strong earthquake.

Three countermoves for EQ disaster mitigation

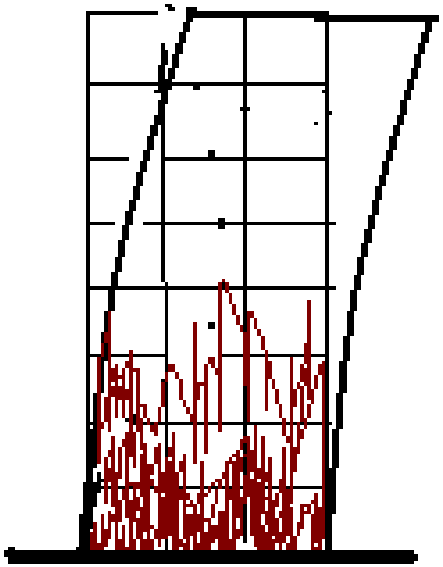


2. Concept design and isolation of buildings

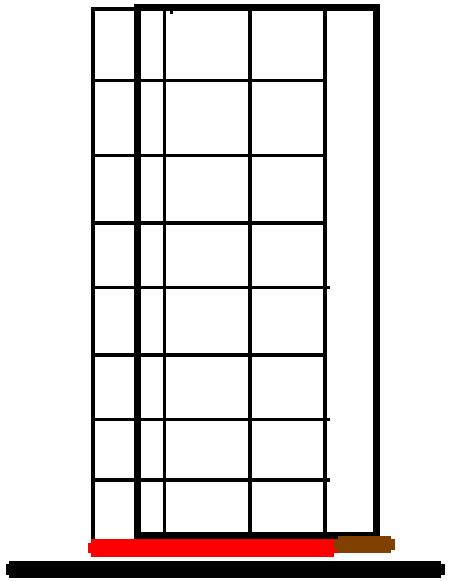
Concept 2.1

Large shear force on the bottom

Base isolation



底部固定
结构弯剪摆动
结构底部破坏



底部柔软层隔离
结构平动
结构完好

Large shear force on the button of building in E.Q.

The 1st story of house collapse

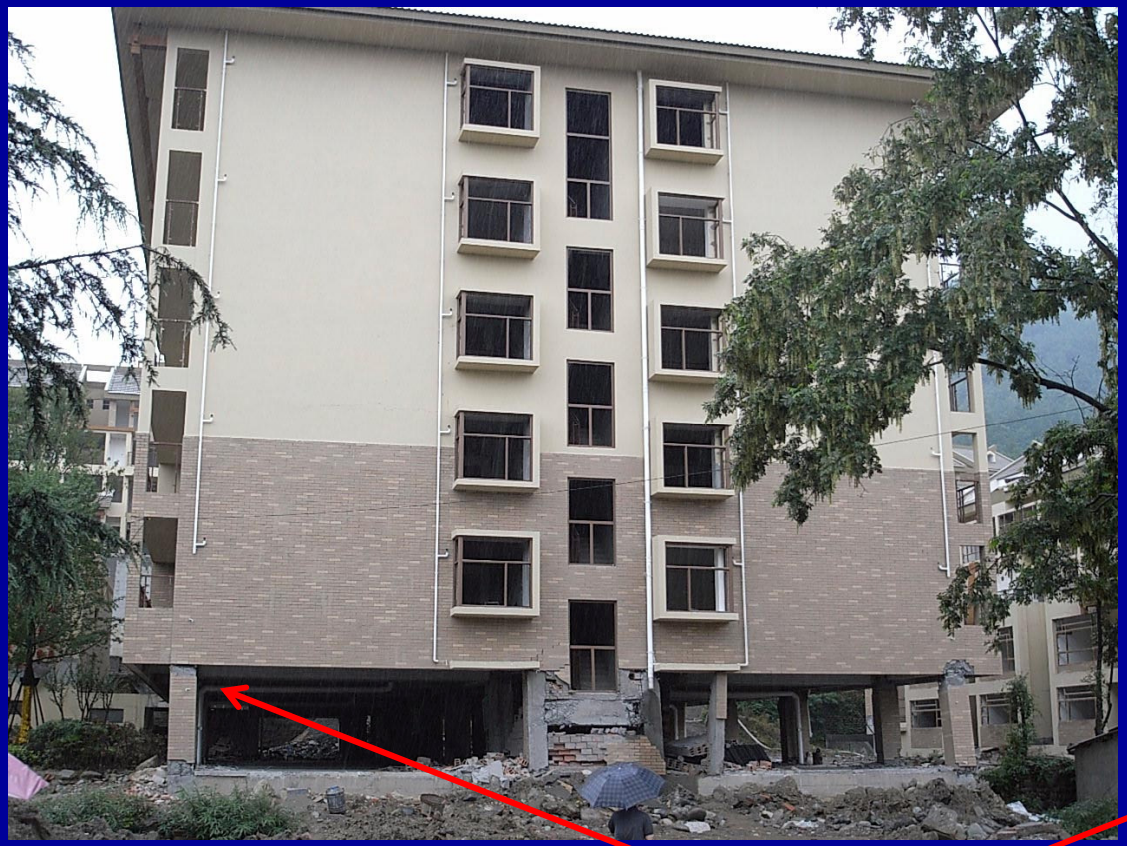
柔性底层,底层塌落

The 1st story of house collapse

damage by weak first story

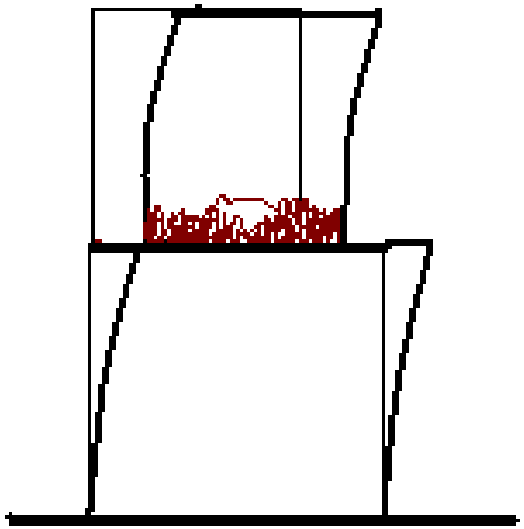
The weak 1st story of house collapse

Plastic hinges 框架住宅形成”柔性底层”

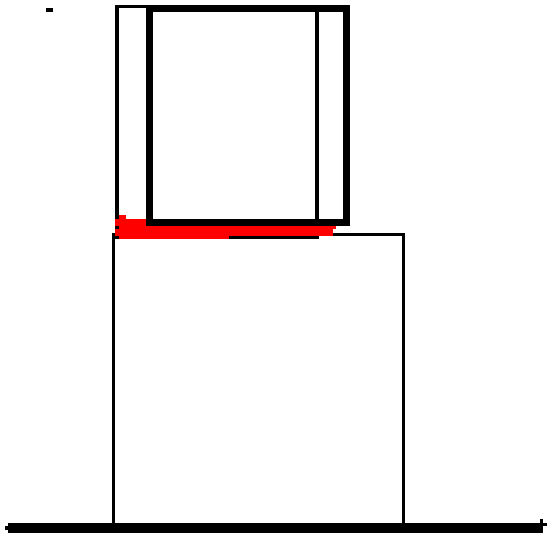


Plastic hinges

Concept 2.2
damage by weak story in middle height of bld. Middle isolation



刚度突变处
形成结构薄弱层
结构破坏



刚度突变处
设置柔软隔离层
结构平动，完好无损

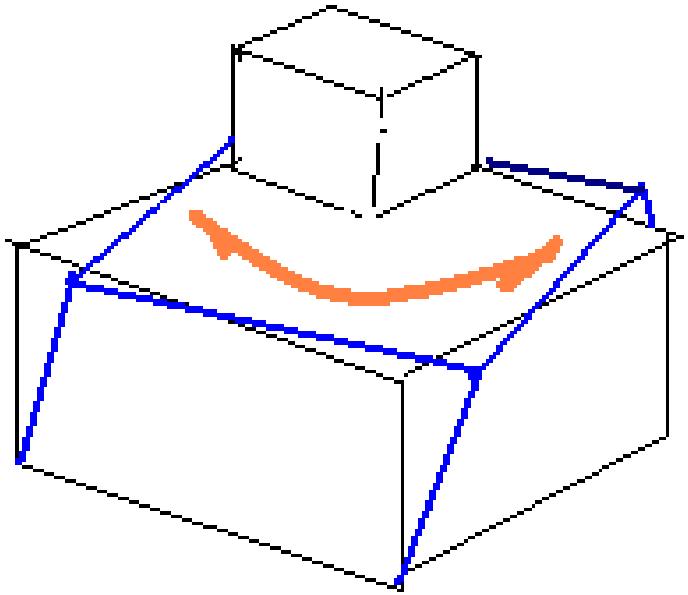
damage by weak story in middle height

damage by weak story in middle height

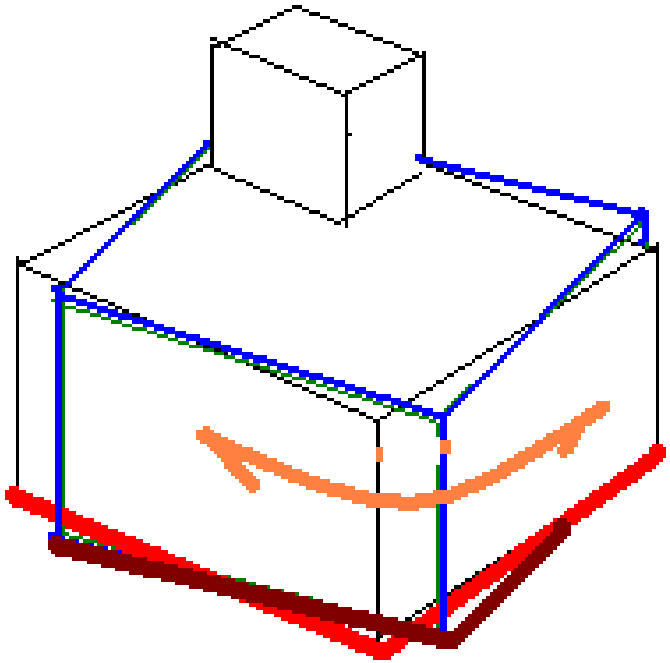
weak story in middle height collapsed

Ask design to be "Stronger Column,weaker Beam"
Really happening is " Weak column, Strong beam"
Plastic hinges(塑性铰)appear on the end of column

Concept 2.3
Structural torsion Isolator's torsion



基础固定
上部结构弯扭
结构破坏

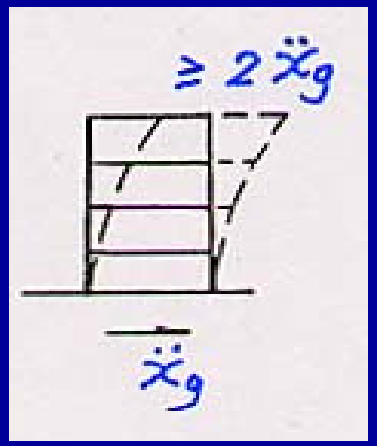


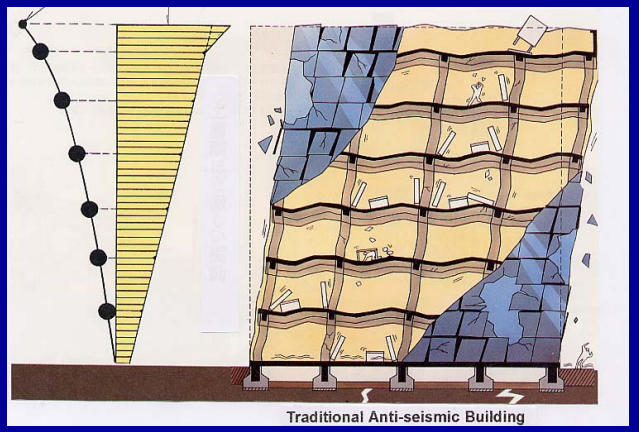
基础柔软隔离层
上部结构整体平动
结构完好

Torsion by eccentric stiffness in plan

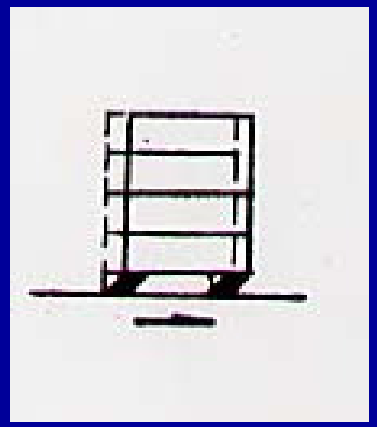
Concept 2.4 Amplify and Reduce structural response — Horizontal move

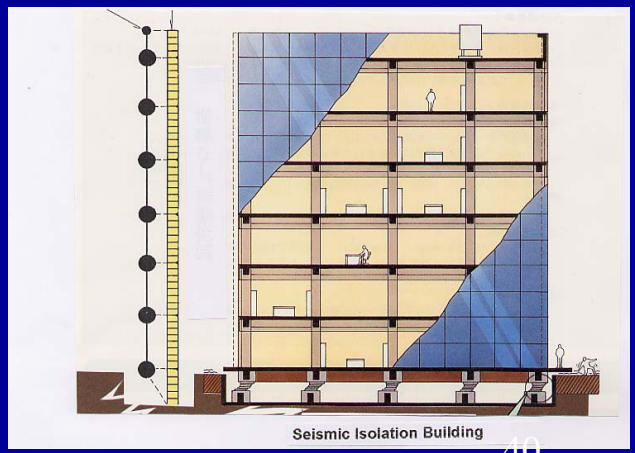
Amplify:
Fix base str.
Amplify structural response





Reduce:
Isolation str.
Reduce resp.
Horizontal move
No any damage





Taiwan Earthquake

台湾大地震 1999.9.21 1:47 2,300

Some Highrise buildings though do not collape
But inside damage are very serious

主体结构破坏轻微,但装修严重破坏,修复难

Serious damage in masons structure buildings

Church is damaged

历史文物建筑严重破坏或倒塌 教堂建筑

Buddhist temple is damaged

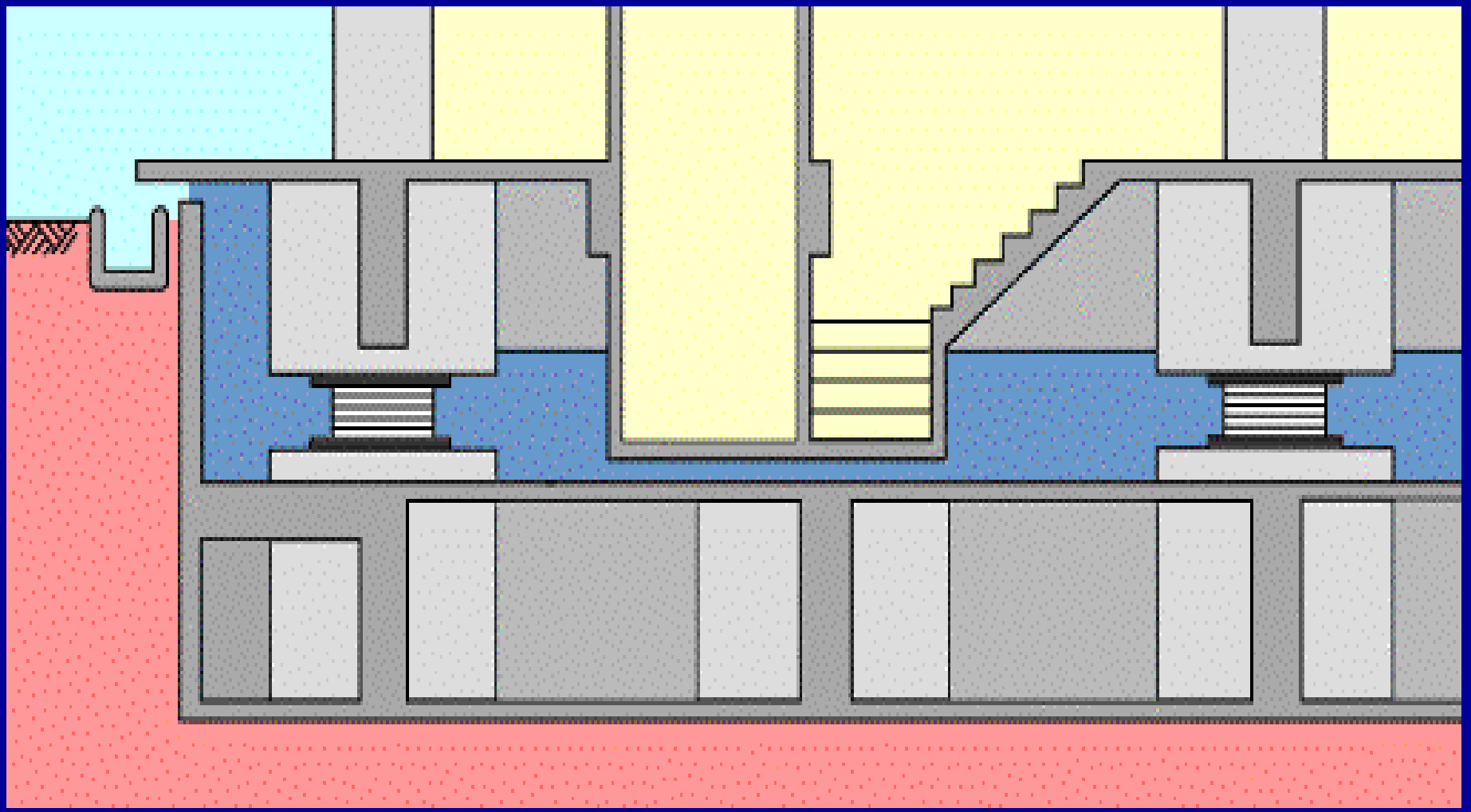
The Chengdu airport stopped 17 Hours by facilities fall down inside the tower

生命线系统指挥中枢

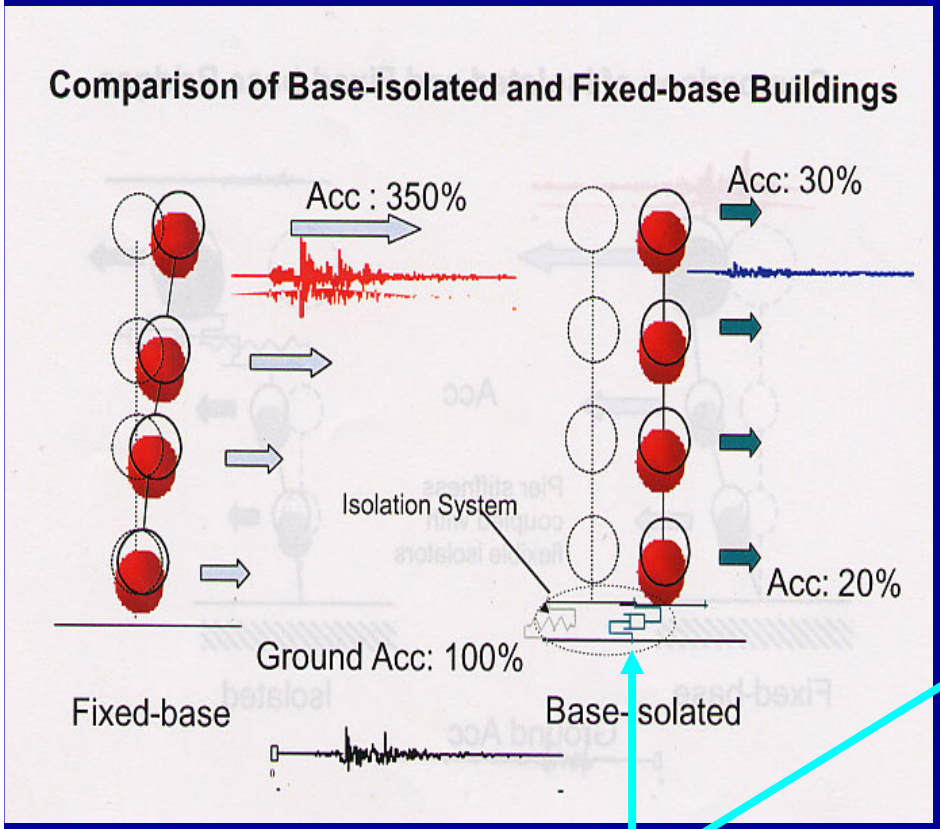
1. 机场新塔台于2002年5月启用，地震中振动摇摆剧烈，仪表、控制设备易损坏
2. 供电系统的调度中心也是如此
3. 机场中断 17 小时

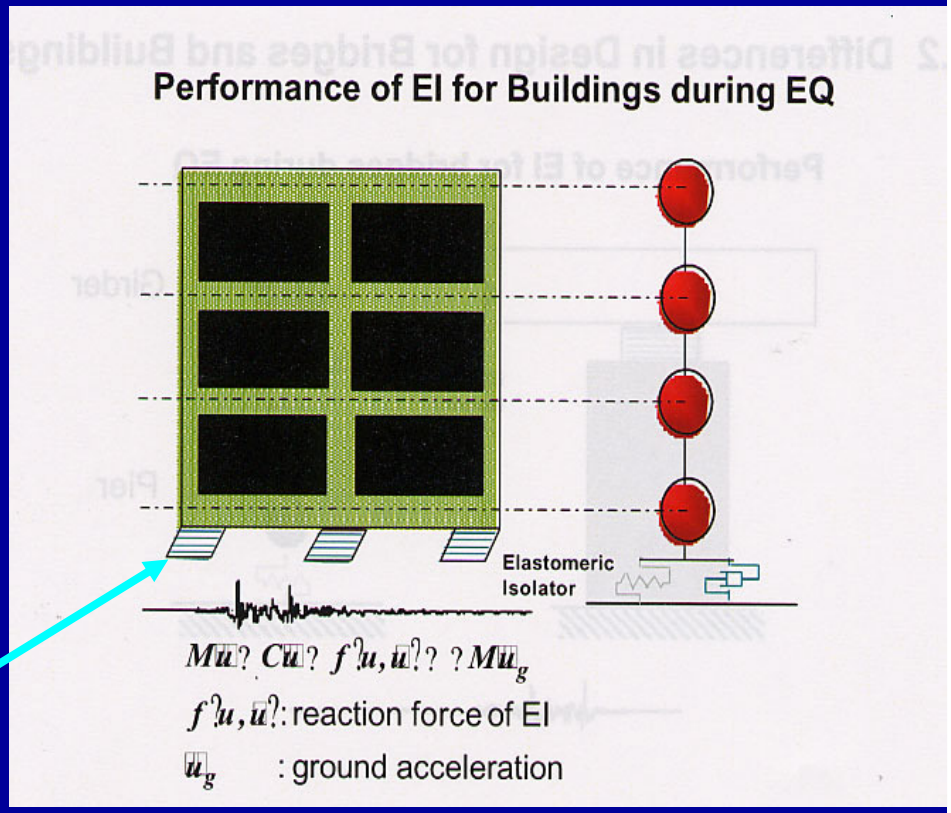
3. Mechanism and test for isolation system

(M) put a soft isolation layer under structure, could isolate Strong EQ



Model of Isolation for Buildings



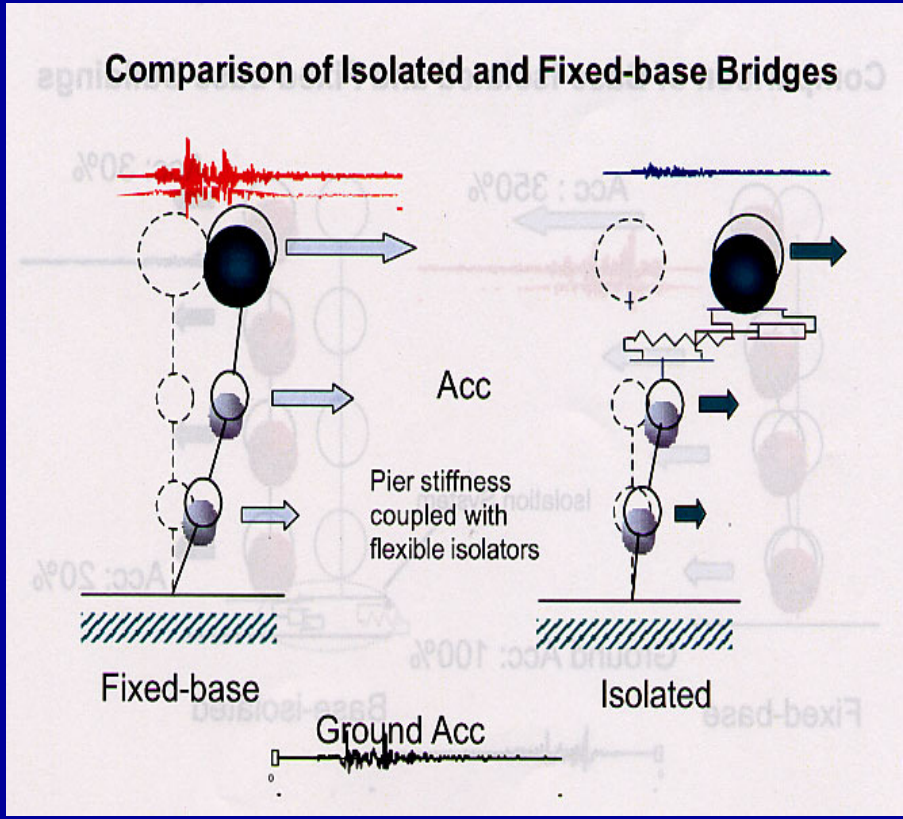


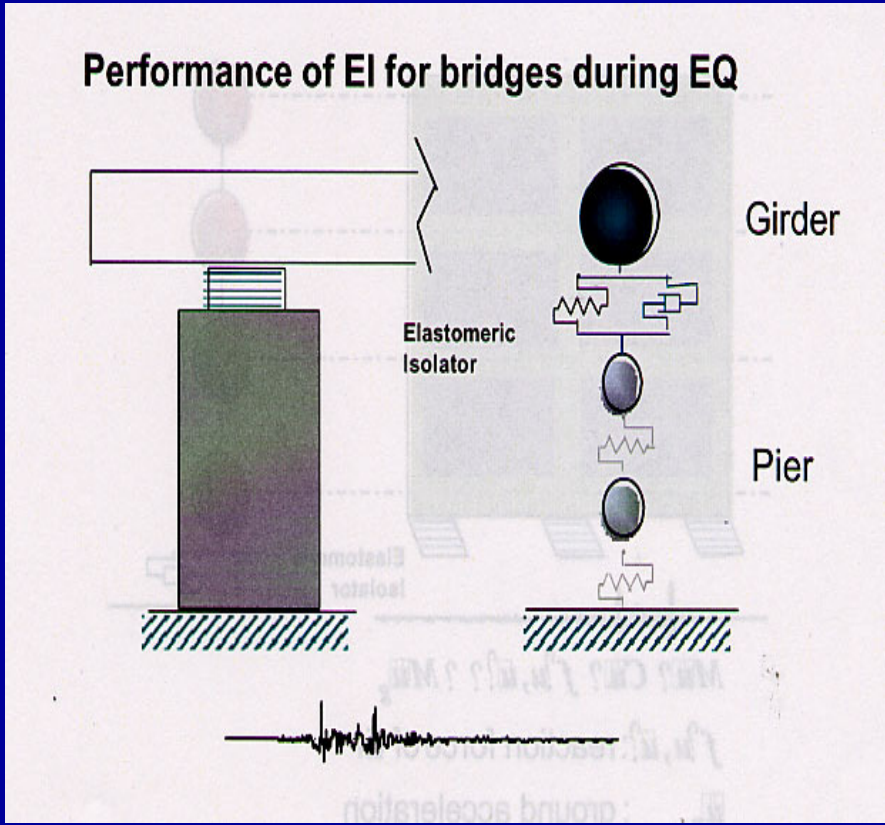
Soft isolation layer (with small stiffness), Reduce response

Fixed base structure: Ground Acc.100% → Struc. Acc. 200-300%

Base Isolated structure: Ground Acc.100% → Struc. Acc. 30%

Model of Isolation for Bridges





Seismic Isolation-Dynamic Analysis

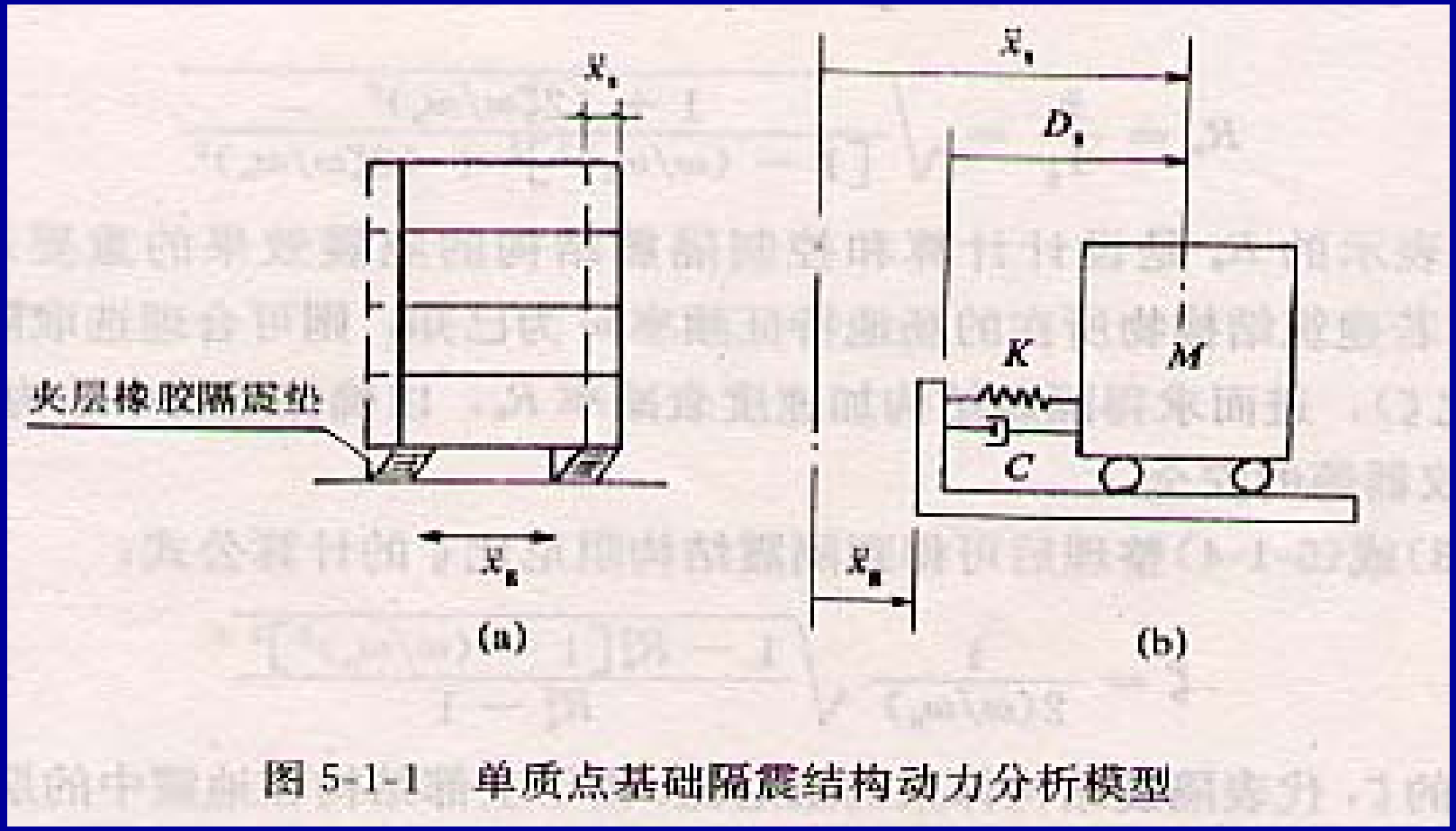


图 5-1-1 单质点基础隔震结构动力分析模型

Model of Single degree of freedom of isolation structure

Seismic Isolation-Dynamic Analysis

$$M\ddot{x}_s + C\dot{x}_s + Kx_s = C\dot{x}_g + Kx_g$$

$$\omega_n = \sqrt{\frac{k}{M}} \qquad \zeta = \frac{C}{2M\omega_n}$$

$$\ddot{x}_s + 2\zeta\omega_n\dot{x}_s + \omega_n^2 x_s = 2\zeta\omega_n\dot{x}_g + \omega_n^2 x_g$$

$$Ra = \frac{\ddot{x}_s}{\ddot{x}_g} = \sqrt{\frac{1+(2\zeta\omega/\omega_n)^2}{[1-(\omega/\omega_n)^2]^2+(2\zeta\omega/\omega_n)^2}}$$

$$\zeta = \frac{1}{2(\omega/\omega_n)}\sqrt{\frac{1-R_a^2[1-(\omega/\omega_n)^2]^2}{R_a^2-1}}$$

$$R_D = \frac{|D_s|}{|D_g|} = \frac{(\omega/\omega_n)^2}{\sqrt{\left[1-(\omega/\omega_n)^2\right]^2+(2\zeta\omega/\omega_n)^2}}$$

Amplify factor Ra --- ω/ ω n

结构地震反应 放大系数 Ra -频率比 的 关系

Fix base 传统结构 水平刚度大

频率比ω/ ω n =0.8 ~ 1.5

地震动放大系数 Ra

Ra=2 ~ 3

Isolation 隔震结构 水平刚度小(柔性支座)

频率比ω/ ω n =3 ~ 8

地震动放大系数 Ra

Ra= 1/2 ~ 1/4

Isolation/Fix base

隔震结构 / 传统结构 ：

理论：Ais/Afs =1/8.6

试验： Ais/Afs= 1/4 ~ 1/12

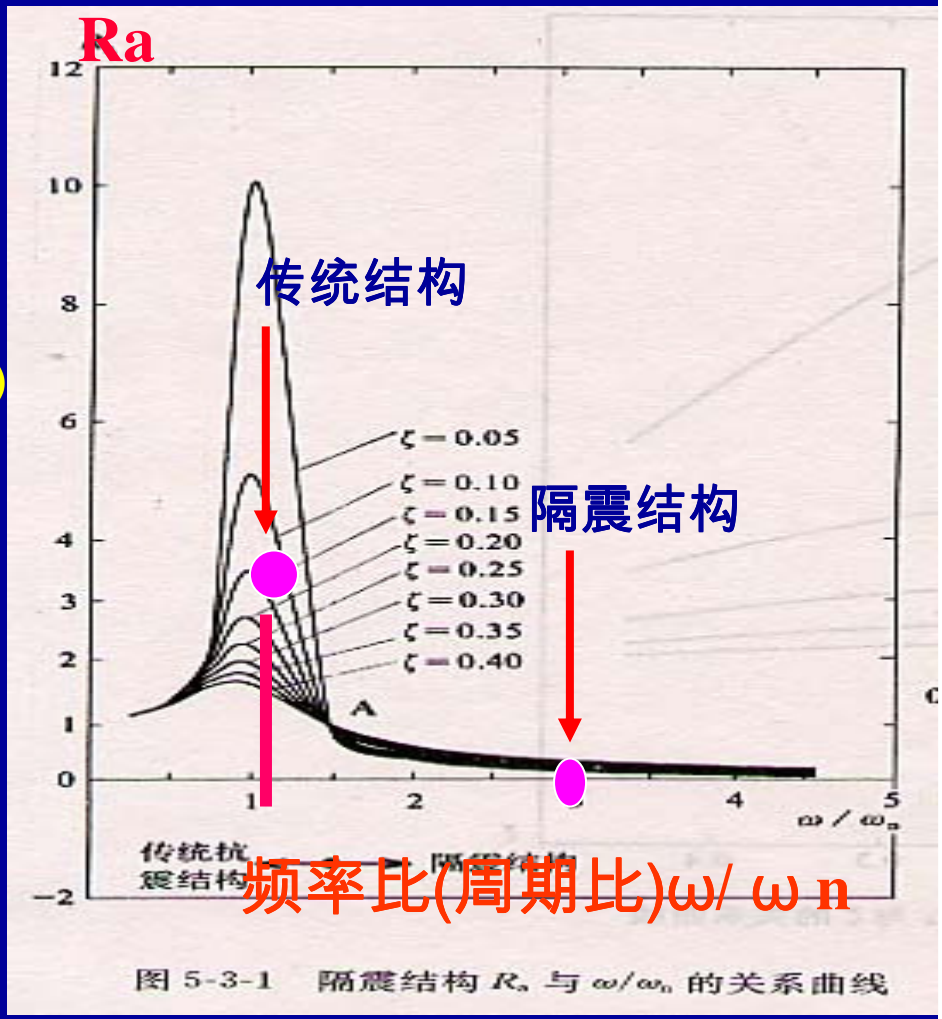
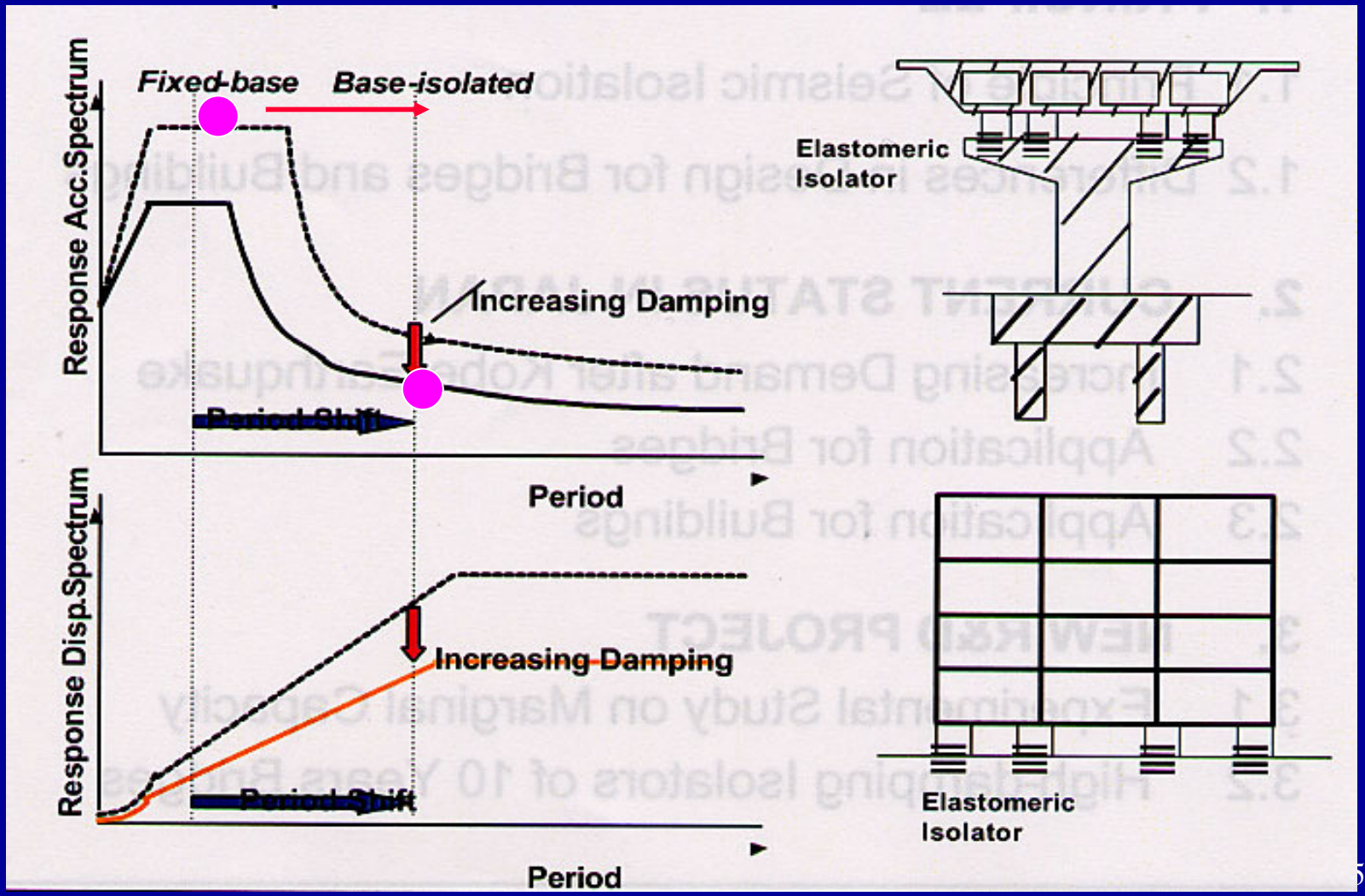


图 5-3-1 隔震结构 R_a 与 ω/ω_n 的关系曲线

From Design Spectrum for structures Isolated structure is long period, effective to reduce the Response to be 1/4- 1/12



(M)实录Iso.Hi. Small shaking table test: Isolation & Traditional Structure

Isolated Struc. Traditional Struc

Shaking table tests for Isolation structures

Base Isolation

Stories Isolation

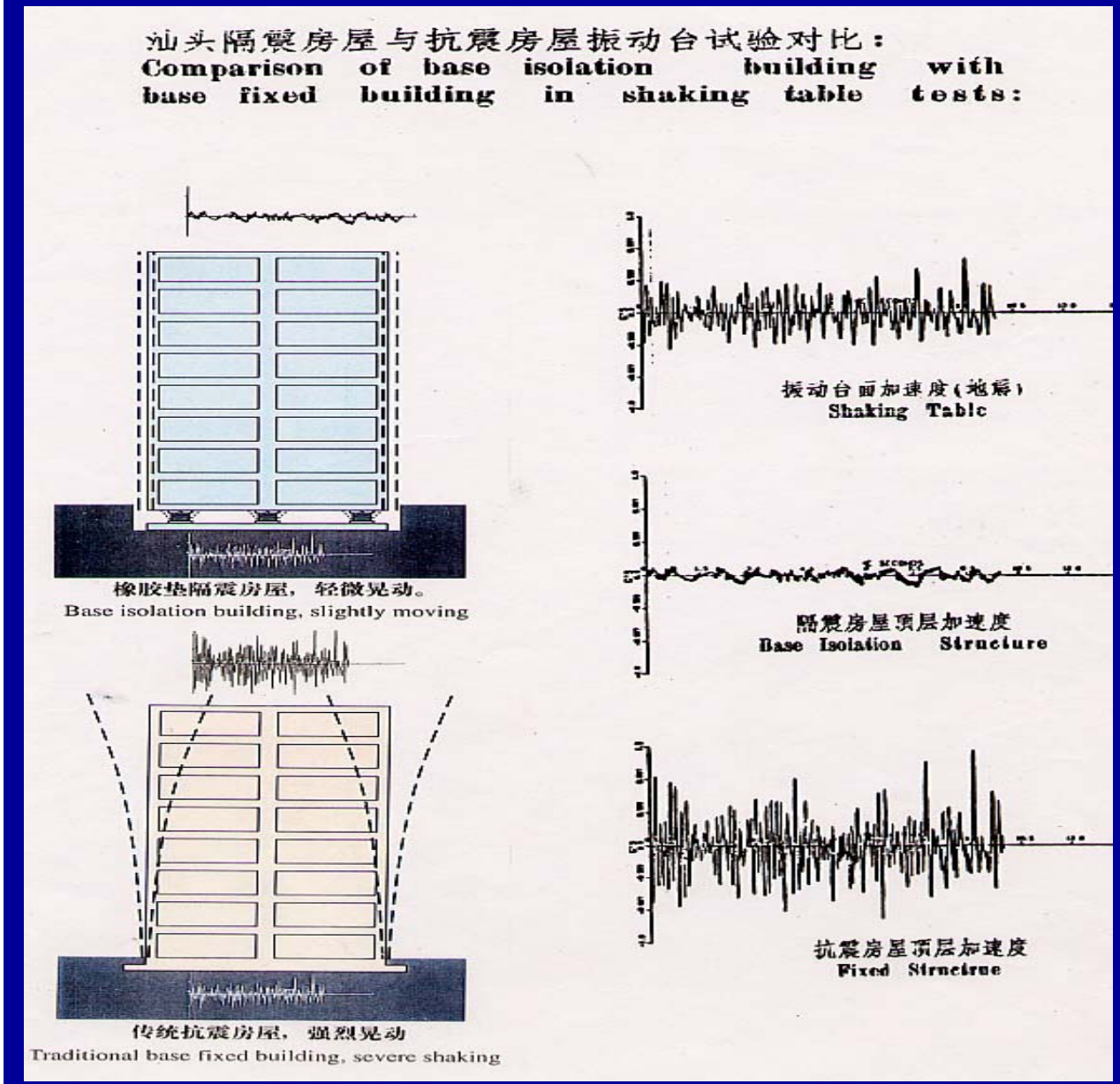
Shaking table tests for Isolation Highrise structures

(M)超高层 隔震结构 振动台试验

CaseR01(TRB+SLD9%)
No64 BCJ L2 x3 1/12

honestech

Shaking table tests to compare Isolation & no iso.



Ground motion 400gal

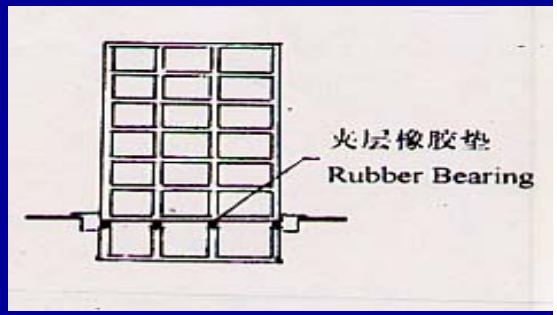
Isolated Struc. 100gal

Tradit. Strct. 800gal

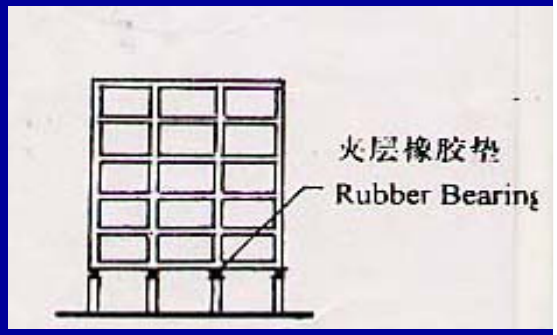
2.1 Base or Middle Stories isolation

Different locations of isolation layer

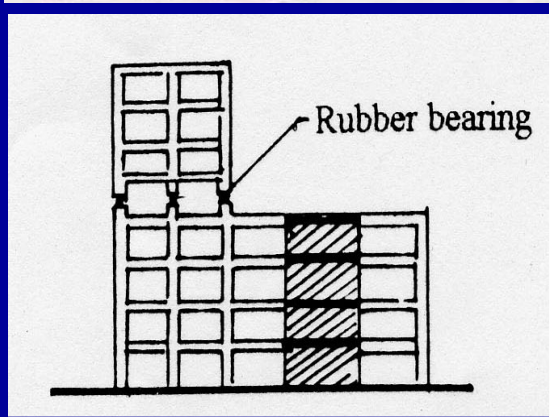
(1) Base isolation
(or Basement)



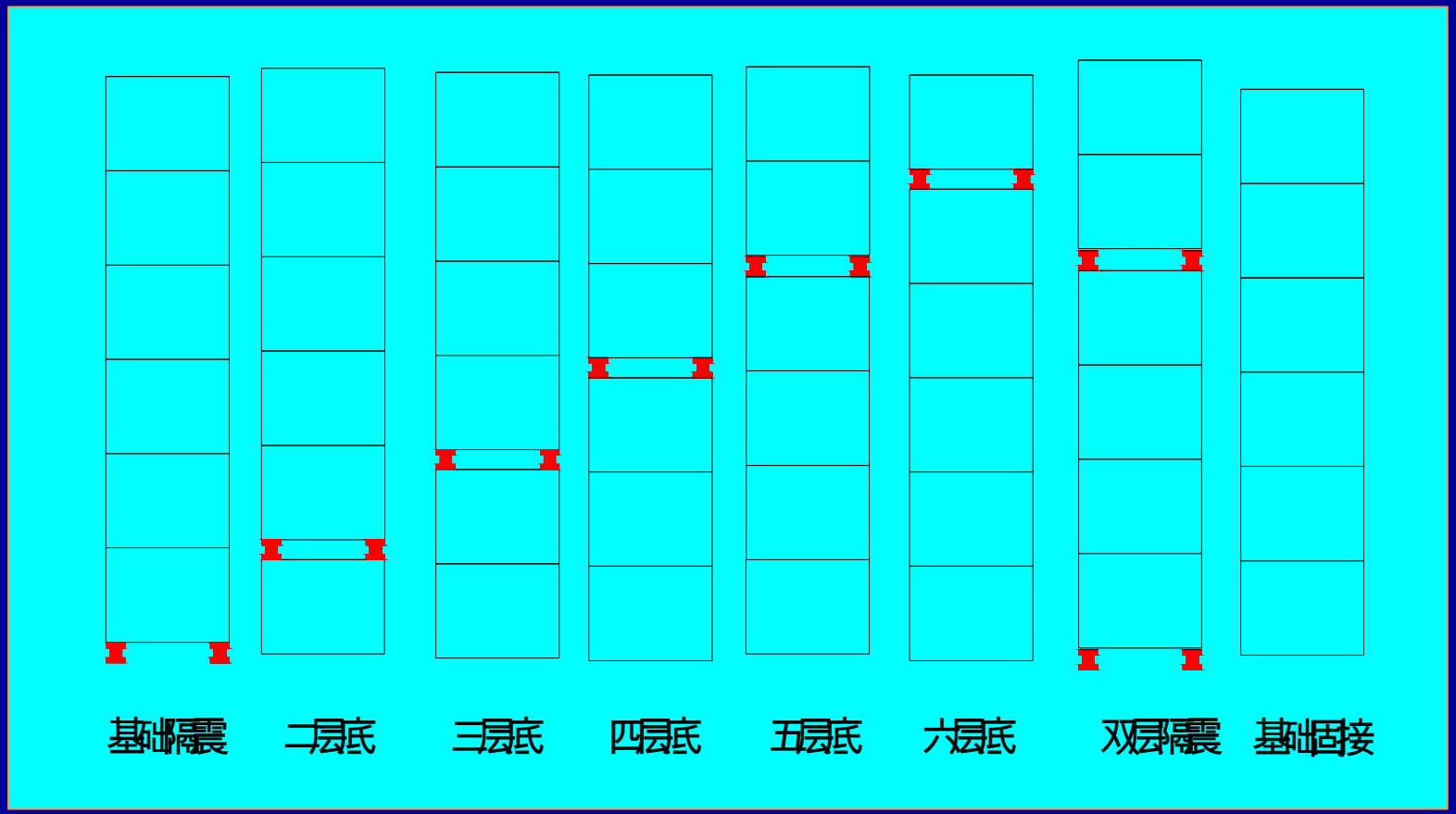
(2) First story isolation
(on the top of 1st story)



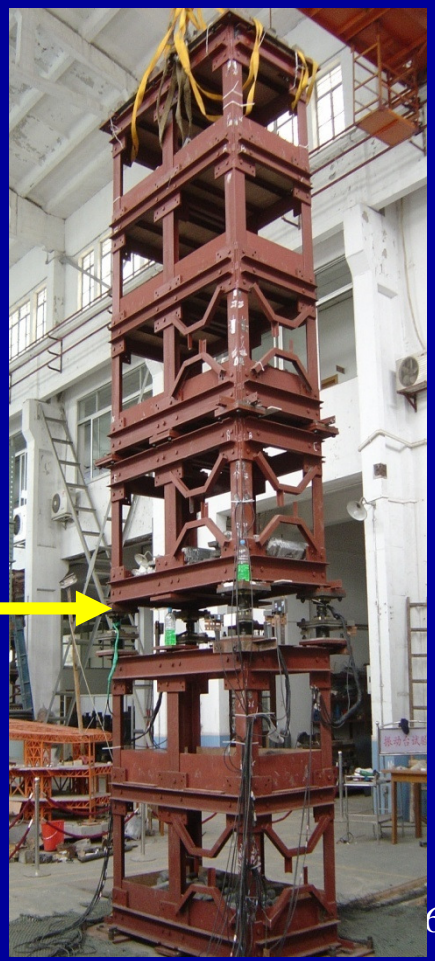
(3) Middle Storied isolation
(on the stories which irregularly)



Stories isolation
Shaking table Tests for Models

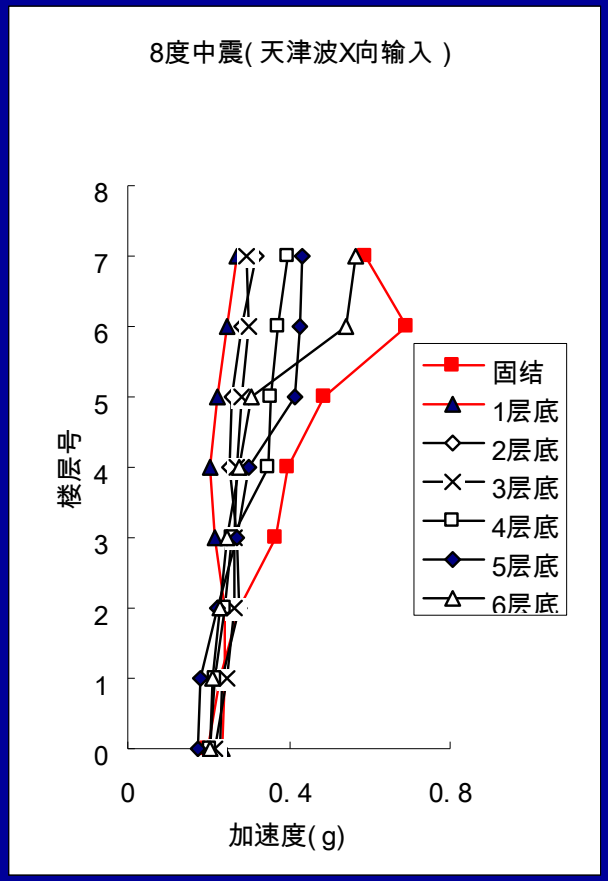


Shaking table tests
for Stories isolation structures
(Guangzhou University) 2003-2007

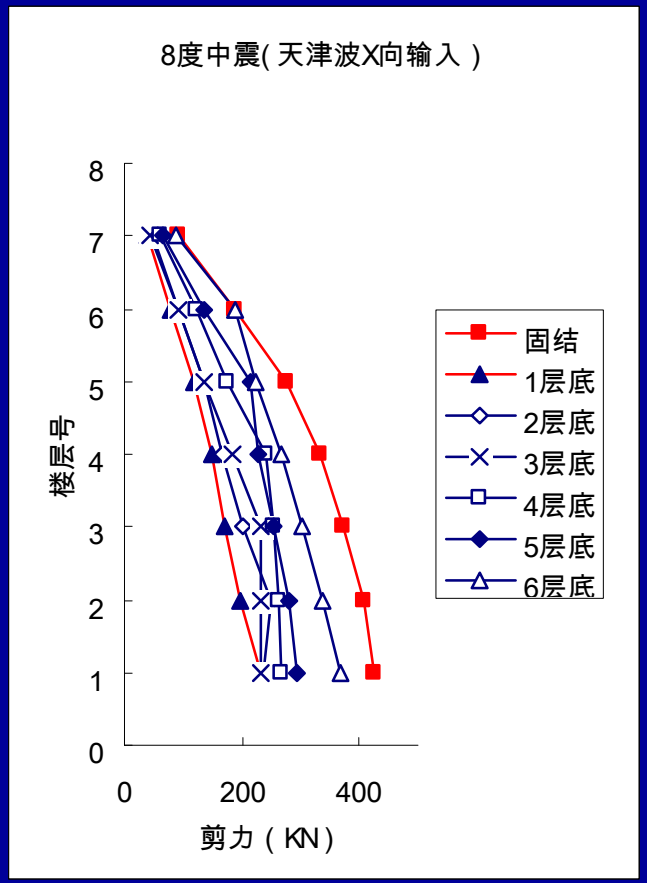


Results of shaking Table Tests
Acceleration A and Shear Force F

A & F will be smaller with iso. Layer location Lower



Acceleration



Shear Force

4. Testing of property and durability of isolators

Classification of isolator devices

(1) Sand layer

(2) Graphite lime mortar layer

(3) Slide friction plate

(4) Laminated steel plate Rubber bearing
--- most popular at the present time.

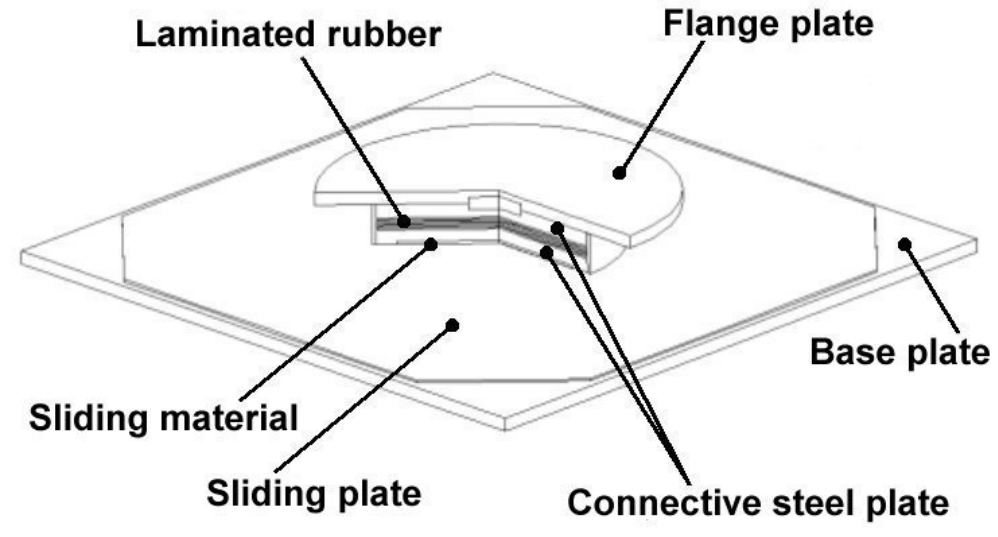
Sand or Graphite lime mortar layer

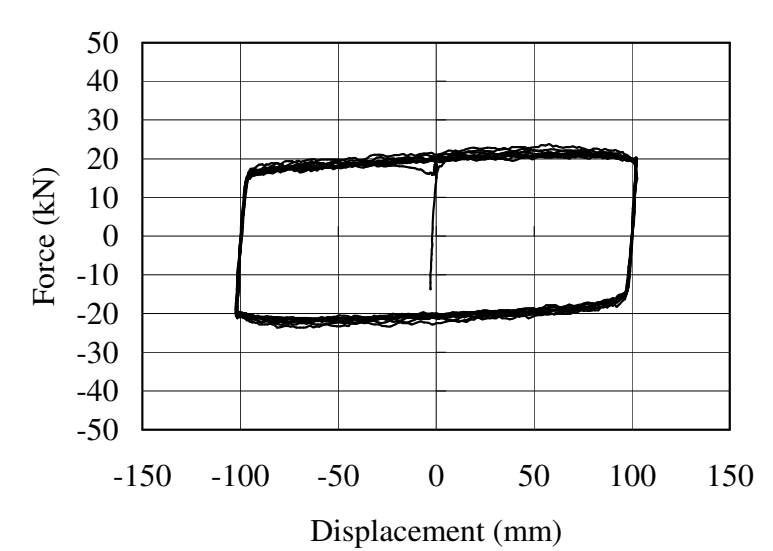
Steel bar damper
(in the layer)

Slide friction plate (1/3)

Slide friction plate (2/3)

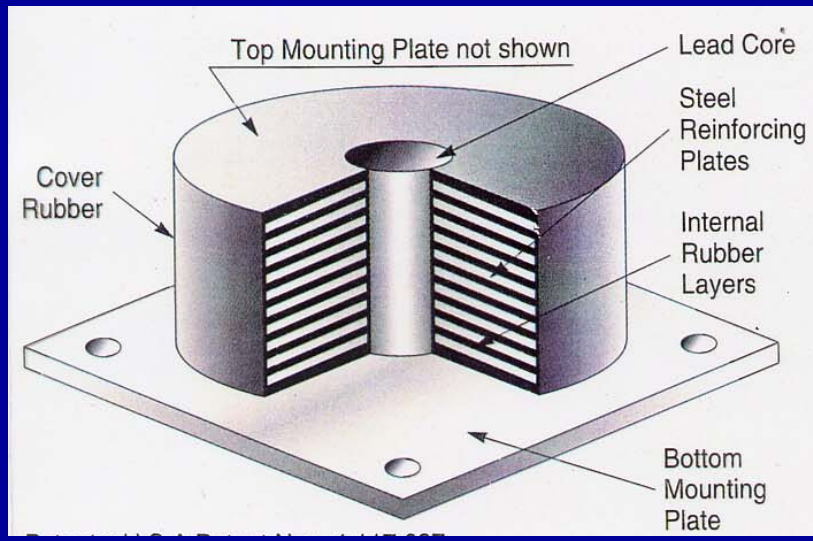
Slide friction plate (3/3)



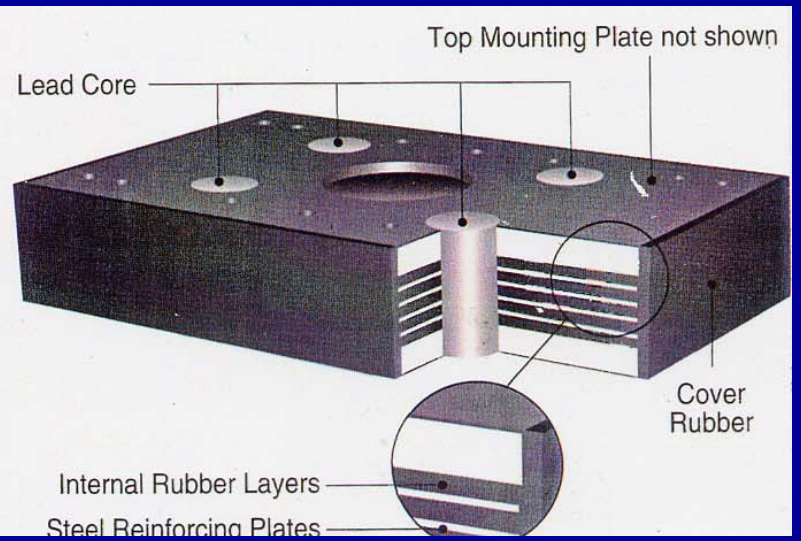


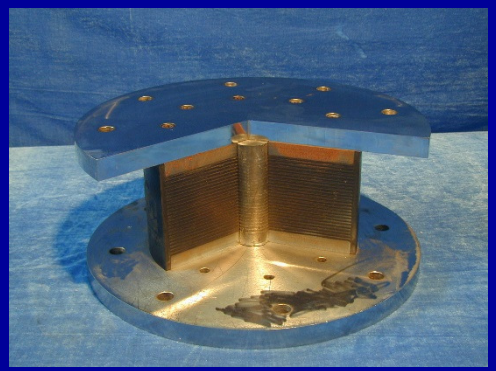
Laminated Rubber Bearing (LNR,LRB HDR)

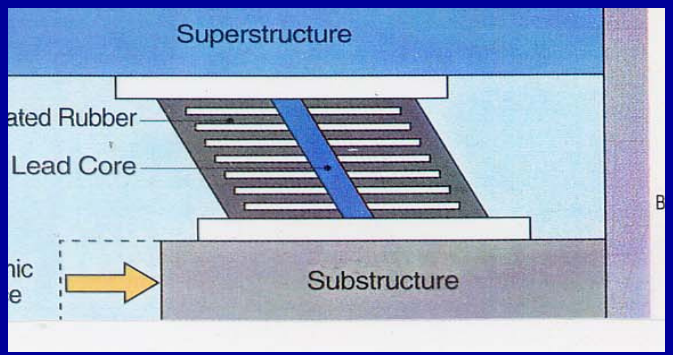
Circular shape



Square or rectangular shape



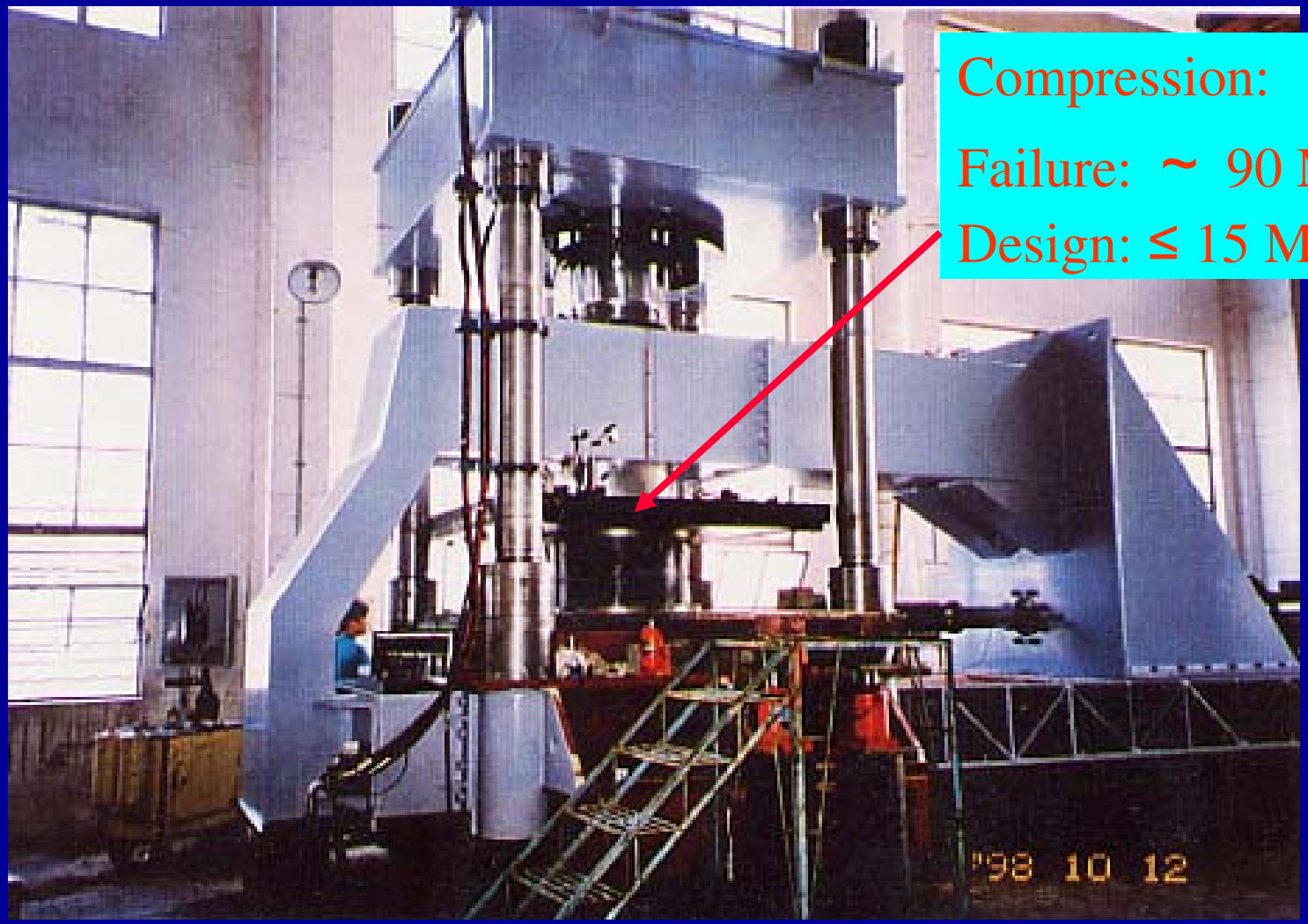




Rubber bearings Compression tests

Earthquake Engineering Research & Test Center (EERTC)

Guangzhou University, CHINA 广州大学 工程抗震研究中心



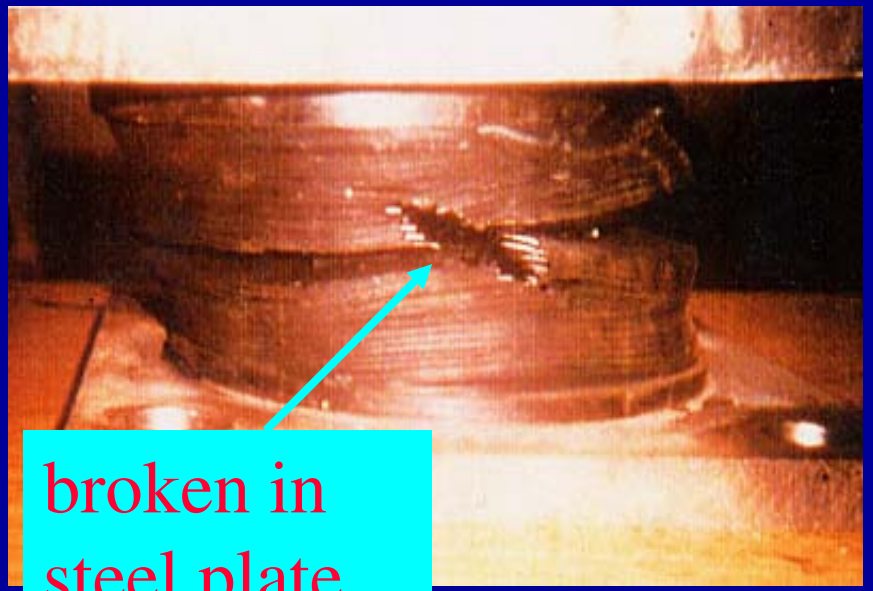
Compression:

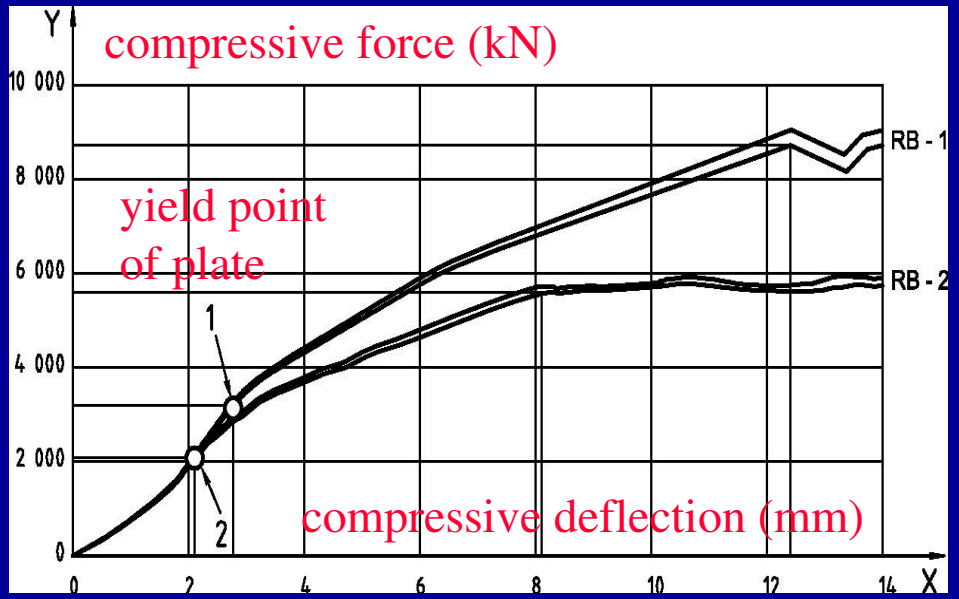
Failure: ~ 90 Mpa

Design: ≤ 15 Mpa

Compression ultimate strength

Compression failure tests





σ_o = 10 ~ 15 MPa 1 / (8-10 σ_u)

σ_u = 80 ~ 100 MPa (broken in steel plate)

The stress of steel can be control:

$\sigma_s = 2\lambda \cdot (P\, t_r / A_e\, t_s) \cdot u \cdot \sigma_{sa}$

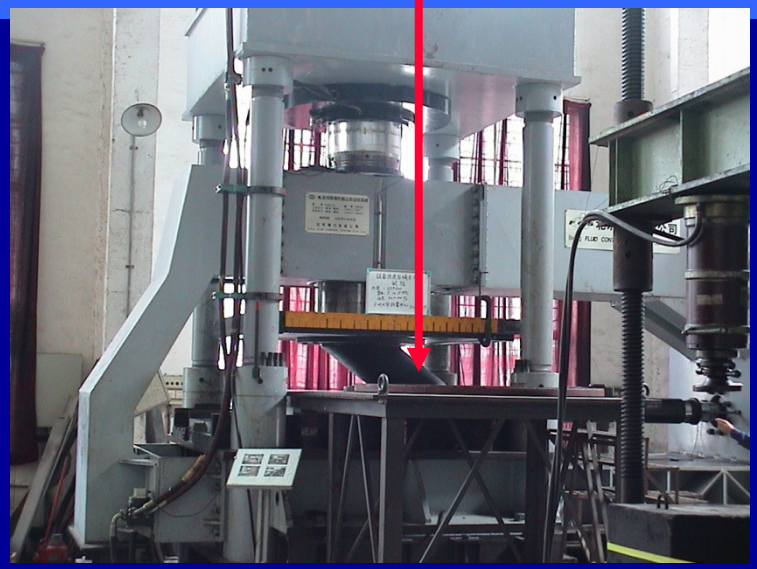
Properties test items for isolator

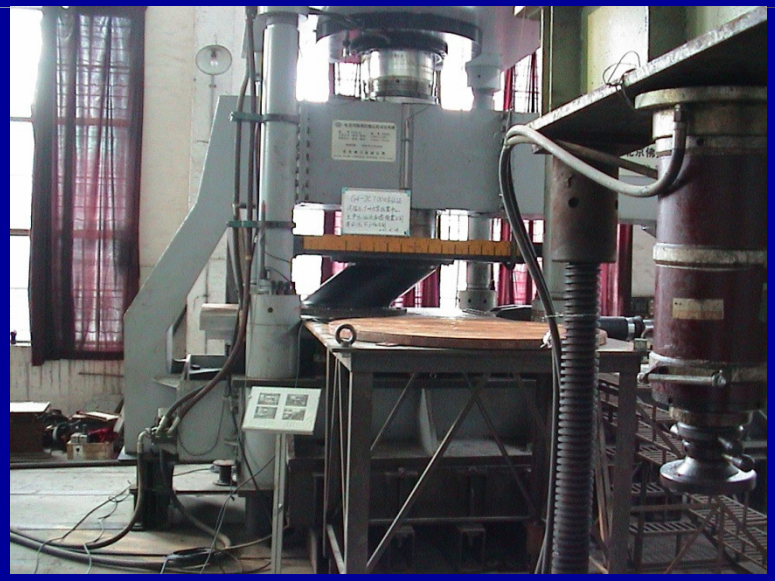
1.2.4 Tensile properties

- Tensile yielding stress $\sigma_y \geqq 2$ MPa
- Tensile breaking stress $\sigma_u \geqq 5$ MPa

Rubber bearings testsVertical compression and shear

Failure: D≧ 4.5Tr (450 mm), Design D ≤ 3 Tr (300 mm)





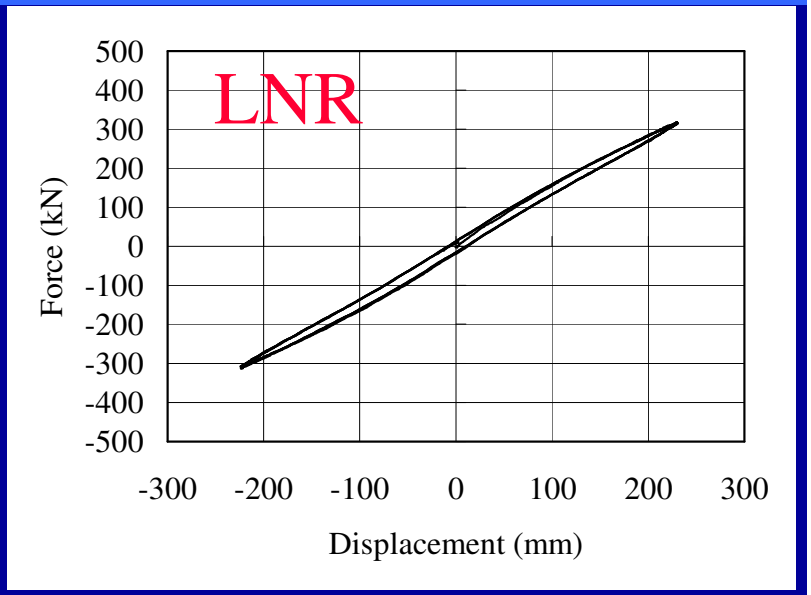
Could get:

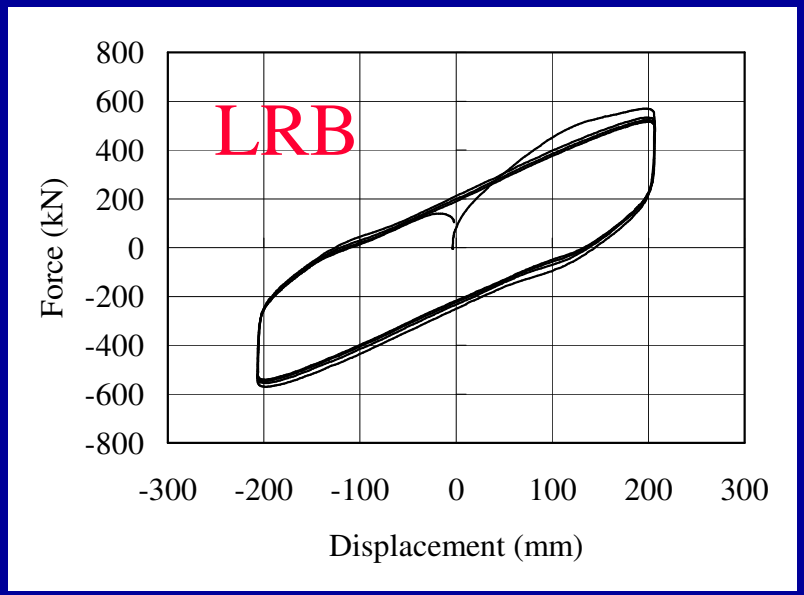
Horizontal Stiffness Kh

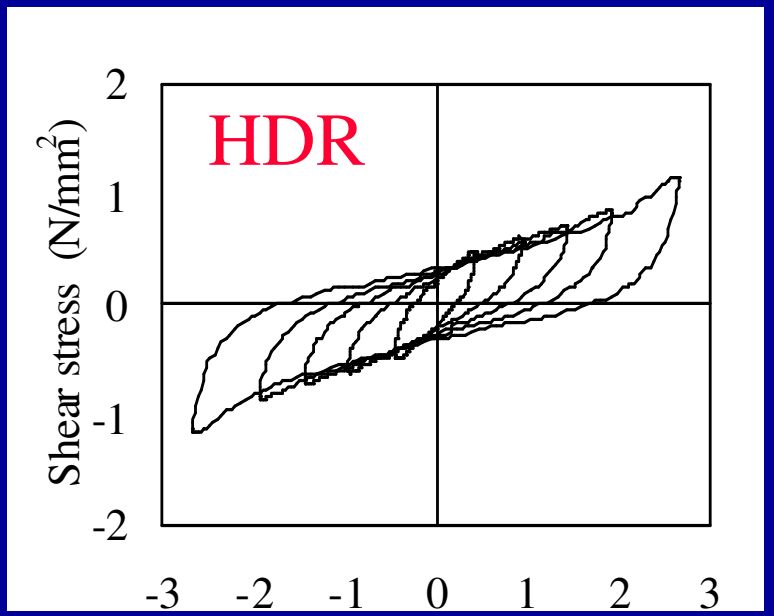
Damping ratio ζ(20-30%)

Compression & Shear test results

Curve Loop of shear force – shear displacement



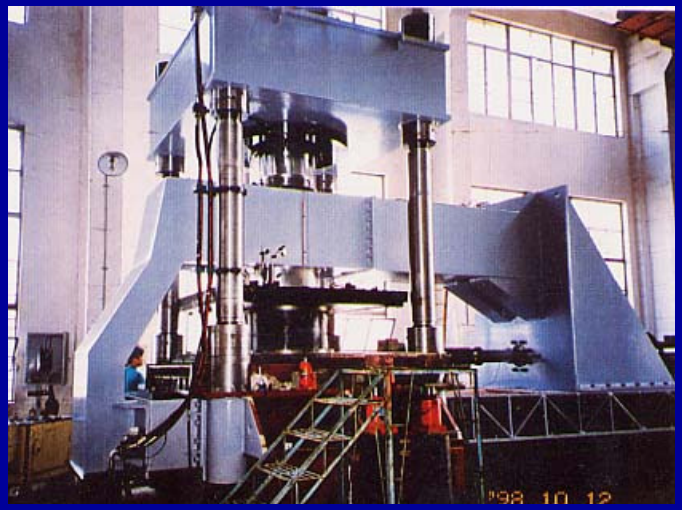


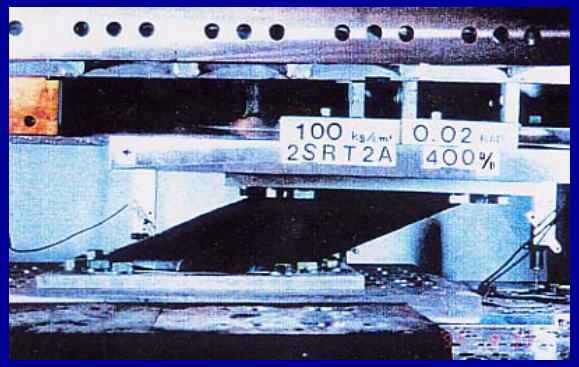


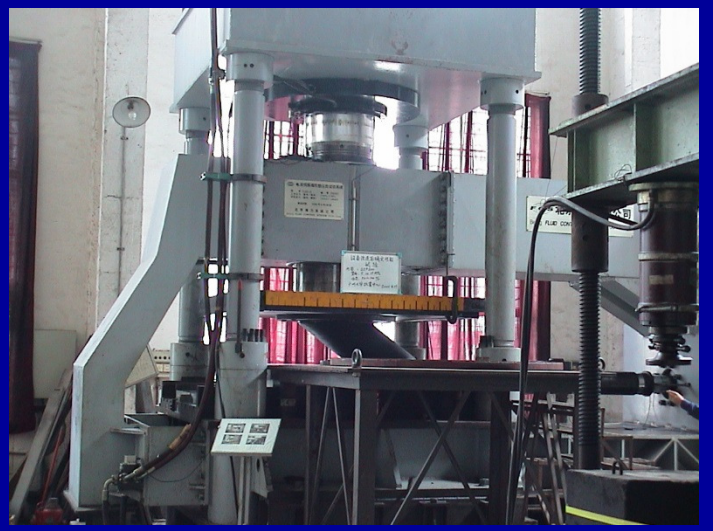
Compression -- shear test

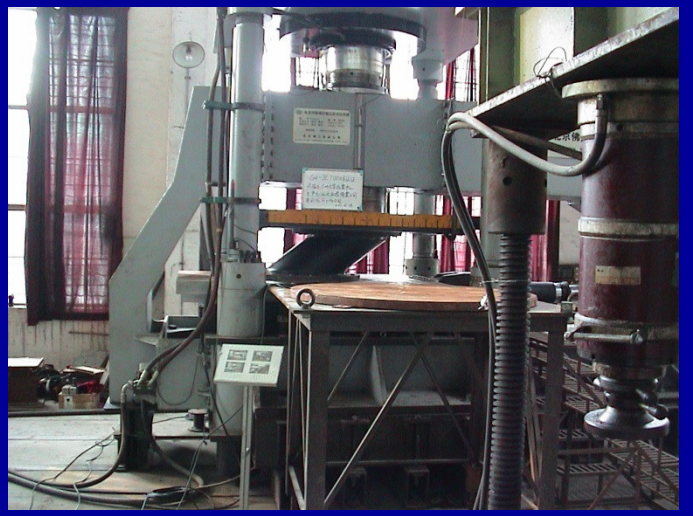
Compression 10-15 Mpa

Shear strain ± 50- 400 %

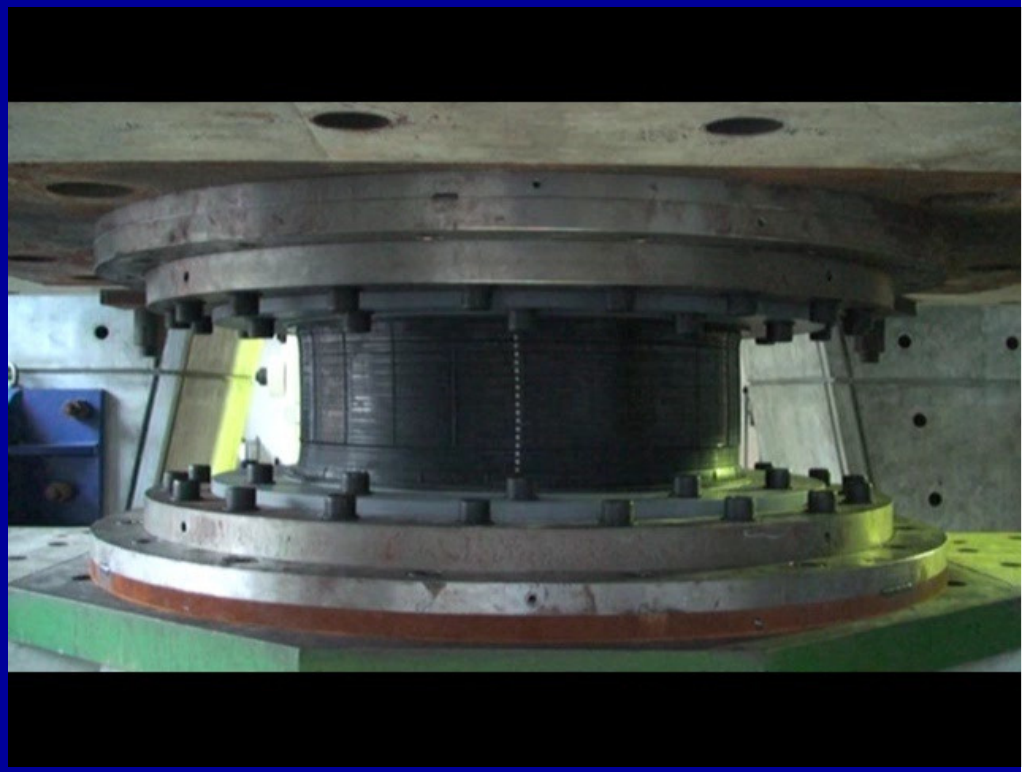


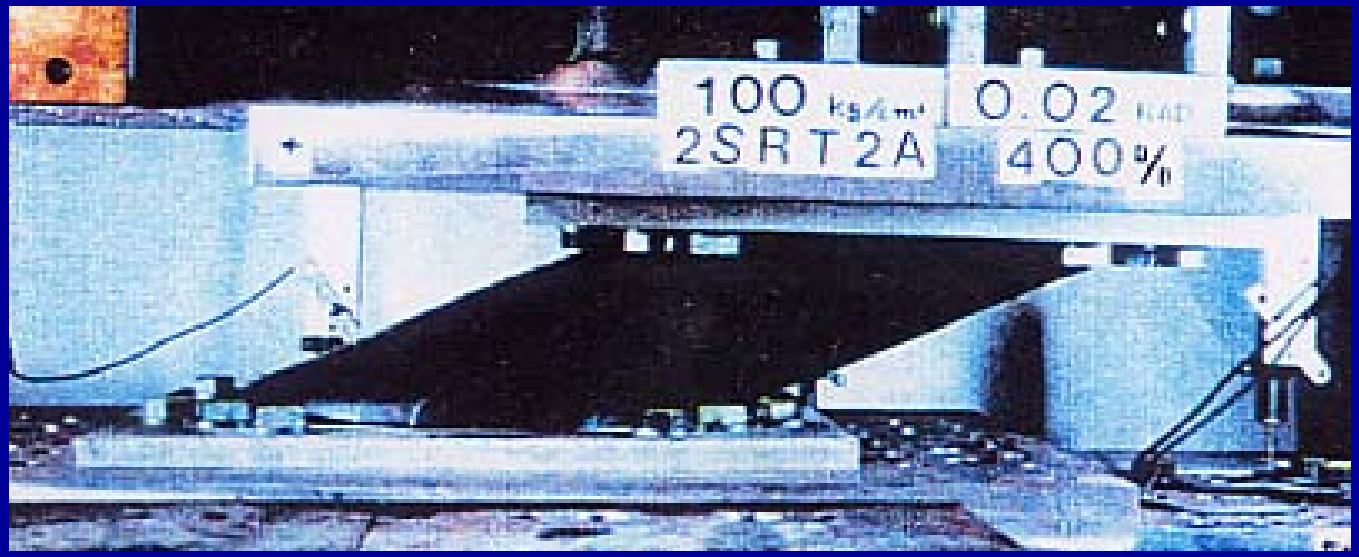


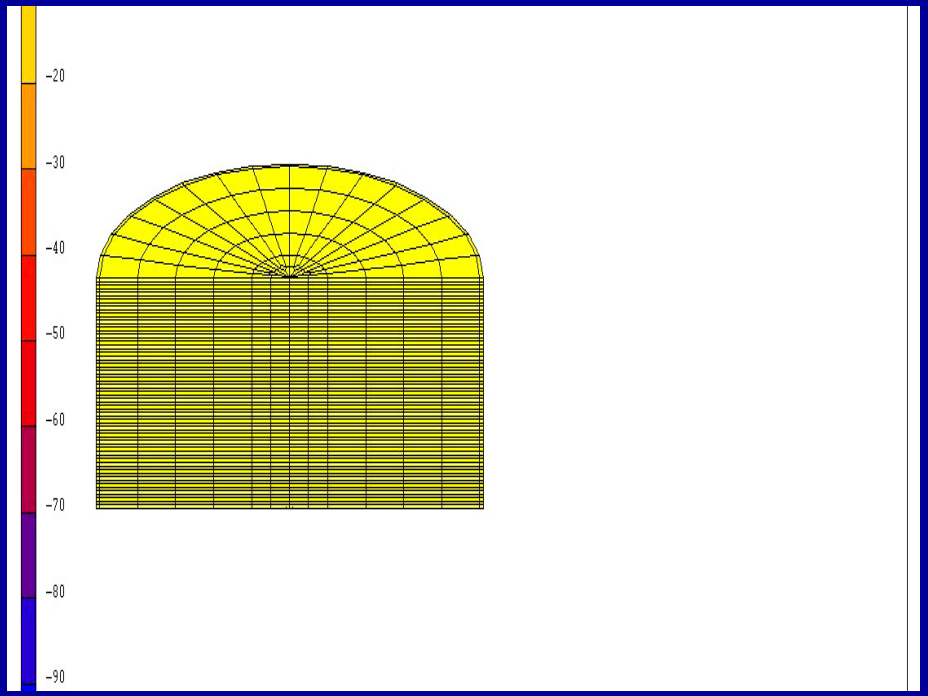




Seismic Isolation-Rubber bearings tests

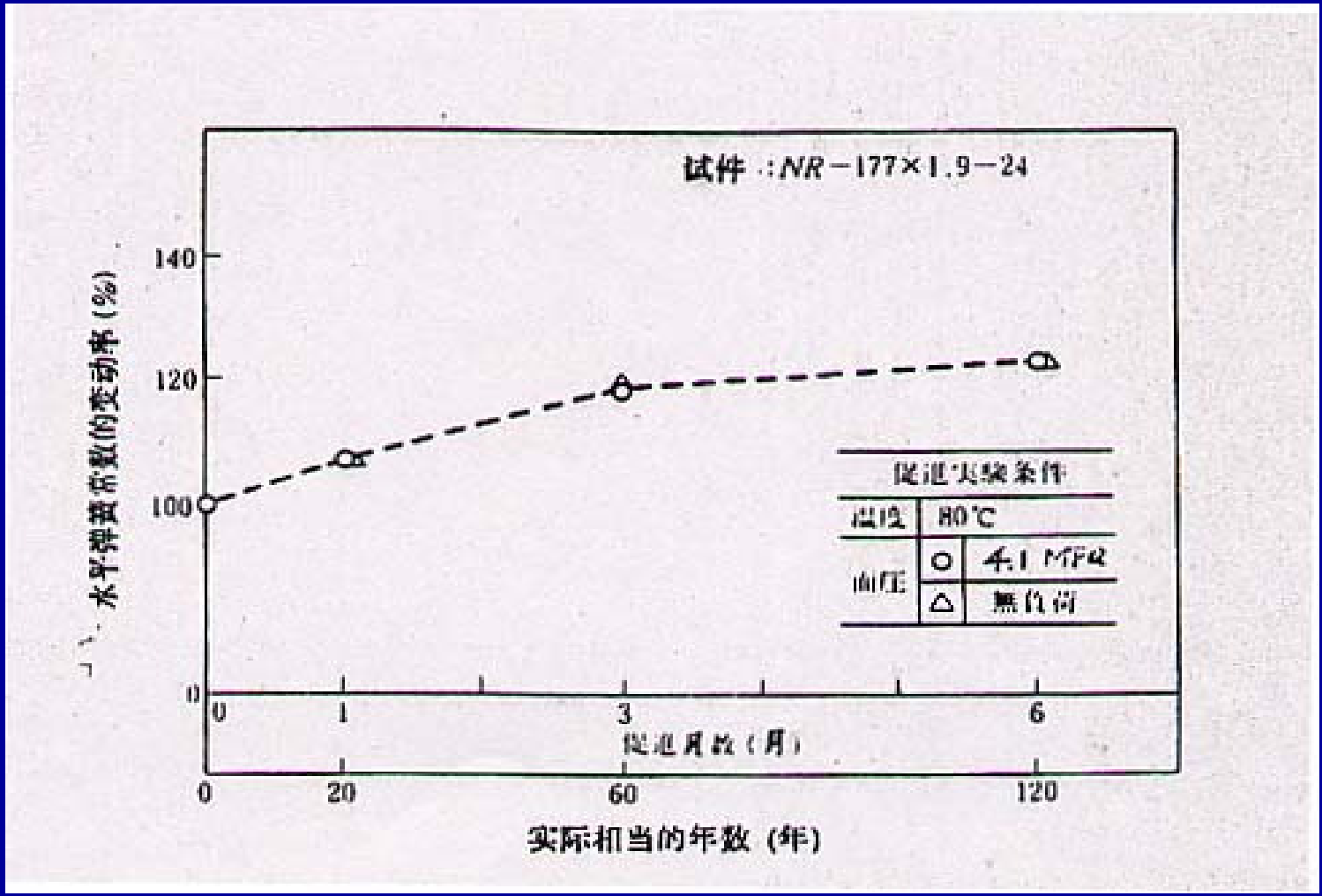



100 kg/cm²
0.02
2SRT2A
400%


-20
-30
-40
-50
-60
-70
-80
-90

Seismic Isolation-Rubber bearings tests
老化 试验 Ozone aging tests 广州大学

Seismic Isolation-Rubber bearings tests
Durability testing results(60-120 ys.)



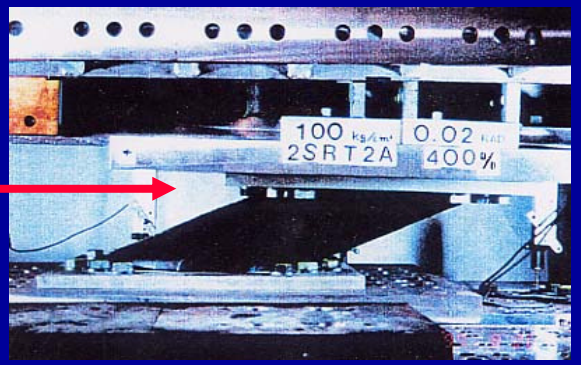
Durability tests for isolators

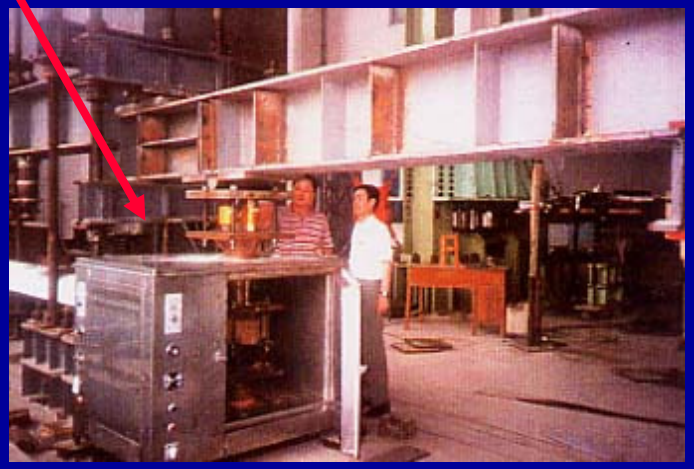
(1) low cycle fatigue test (180 cycle)

(2) Ozone Ageing test (60ys)

(3) Creep test 50 yr.

(2010-2050)





Site Investigation of Ageing of real Rubber Bearing:

Site Investigation of Ageing of real Rubber Bearing:

Countries	Structures	Working life (yr.)	Thickness of ozone
China	Bridge	1956-1996 (40yr.)	3mm
UK	Bridge (Pelham)	1954-1995 (41yr.)	3mm
UK	Building (London)	1934-1996 (62yr.)	3.5mm
Australia	Bridge	1889-1995 (106yr.)	4- 5mm

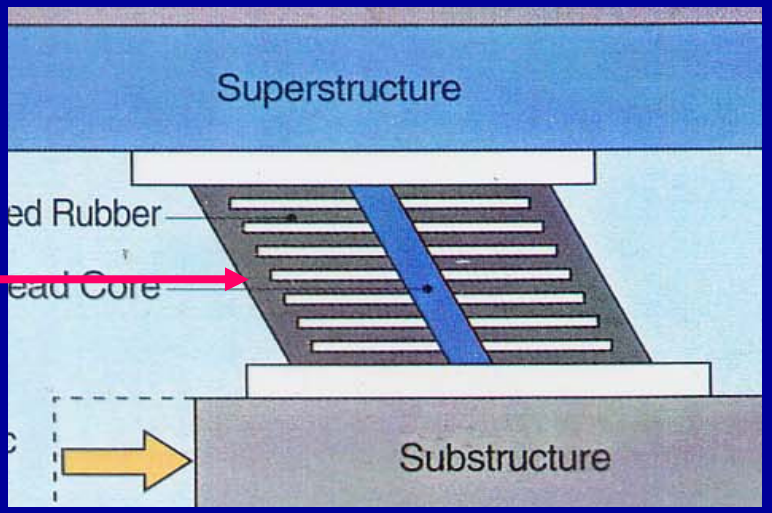
Conclusion : Real working life > 100 yr.

Thickness of ozone: 4-5 mm

How to reach the working life > 100 yr

Add resistant ozone material to rubber

Cover layer 10mm



Conclusion : Real working life > 100 yr
for rubber bearings

5. Application and real earthquake experience of isolation in China

UNIDO Held International Workshop on Isolation May 20, 1994 Shantou, China

Prof. Emanuel Csorba

Summing up and Closing Statement

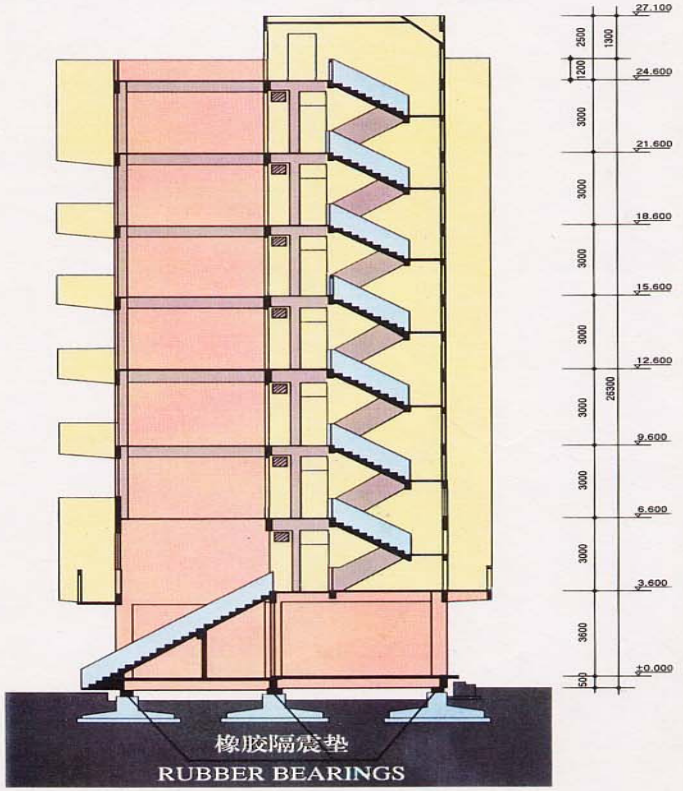
The 1st Isolation building in China (UNIDO Project)

RC frame, 8 stories, Shantou City (1989-1993)

工程应用实例

中国汕头夹层橡胶隔震垫已成功应用于全国各地的房屋建筑之中。先后应用于汕头市、广州市、澄海市、西昌市、大理市等近二十幢房屋。其中汕头博物馆是目前国内采用隔震技术进行设计的最高和最大公共建筑，共十二层，42米高，建筑面积18000m²。此外，隔震垫还用于地下铁道结构的隔震和工业设备的减振、减噪等，并应用于其他国家和地区的建筑隔震工程项目中。

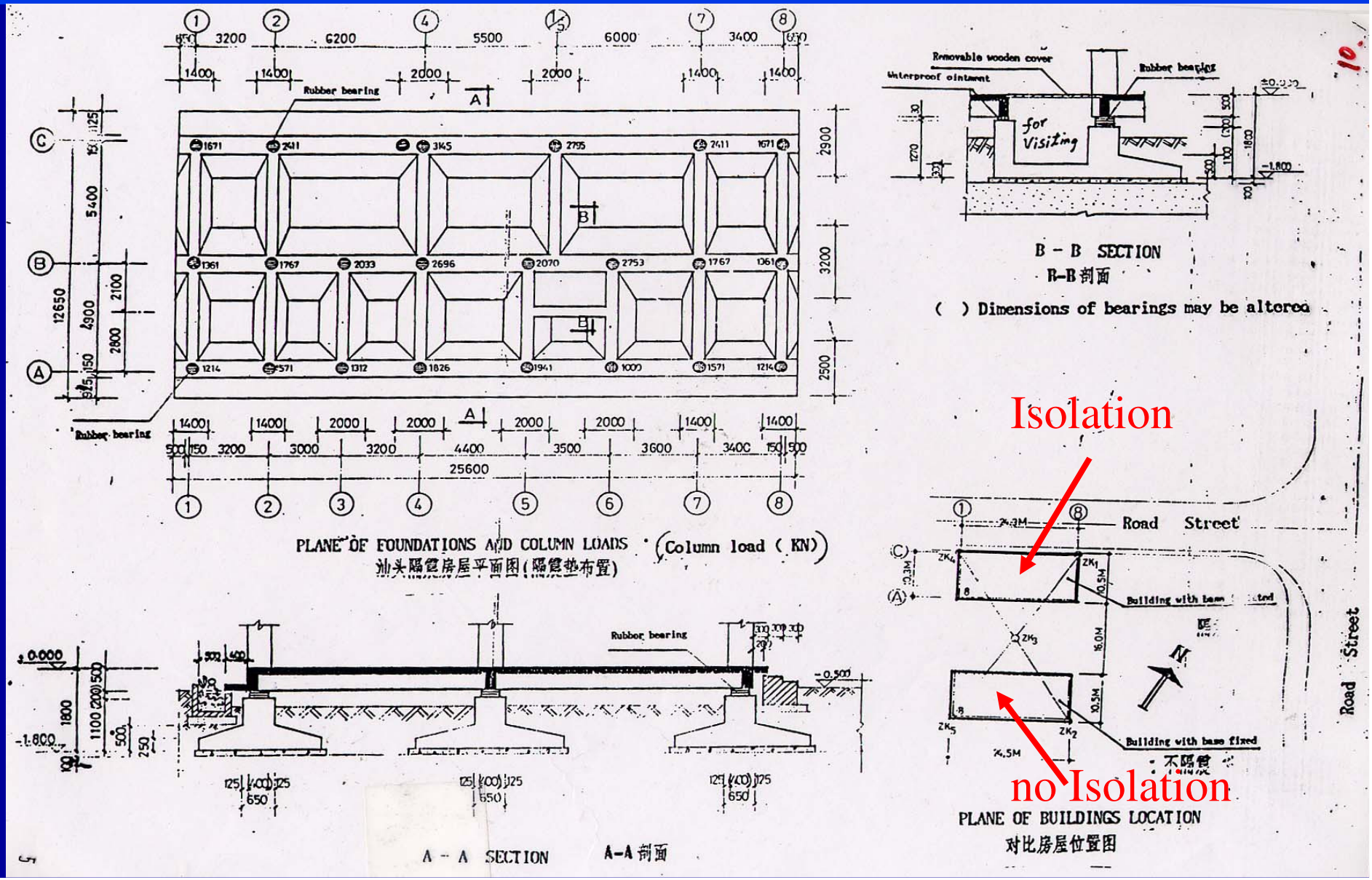
汕头市陵海大路住宅楼
Eight stories house building with base isolation in Shantou, China



中国首幢橡胶隔震房屋
The first multi-stories house building with Rubber Bearings

隔震垫节点大样
Detail of base isolation with Rubber Bearings made in Vibro-Tech

Want to compare two buildings (Isolation & no Iso.)
RC frame, 8 stories, Shantou City (1989-1993)



Earthquake experience (1994.9.16)

Shantou project -- UNIDO, two buildings for comparing in EQ
Same structure (8 stories RC frame house) on same site
one is base isolated, another is base fixed
1994.9.16 Southern China sea Earthquake (M 7.3)
Shantou City: ground A = 0.11 g

- **Building with base fixed**
  - person difficult to stand
  - shaking severely in building
  - slip down on floor
  - people jump out from window
  - water in bucket, shaking, spatter out 1/ 3
- **Building with base isolation**
  - persons, no any feeling

Widely application of isolation in China (from 1994)

5.1 House and buildings (about 3500)

5.2 Large or complex structures

5.3 Bridges (about 150)

5.4 Historical or cultural relic

5.5 facilities, oil tanks

5.6 NPP Nuclear power plant

5.7 Seismic Retrofit (about 100)

5.1 House and buildings (about 3500)

5.1 House and buildings (about 3500)

Isolation Houses group in west China

38 buildings, Floor area 200.000 M^2,

Seismic Isolation Houses buildings in southern China

Stories Isolation--Top of first story

Isolation houses in South-west China

Seismic Isolation Houses group (云南 安晓文)

72 buildings (4-16 stories) , Floor area 210.000 M^2

Isolation houses in South-west China

Seismic Isolation Houses group (云南 安晓文)

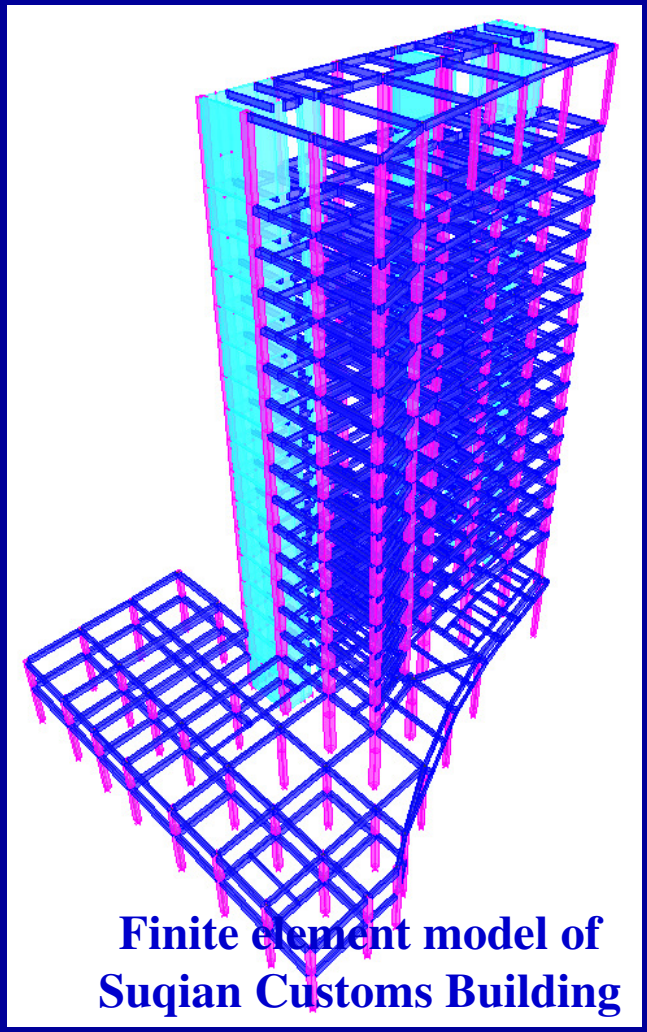
94 buildings (4-6 stories) , Floor area 280.000 M^2

Isolation Houses
(28 buildings)
Yunnan Province
Kunmin city
云南宜良明良
矿职工住宅

Isolation hounses
Yunnan,
Jiansui
(12 buildings)
云南建水
广池宫住宅区

High-Rise (31 stories) Isolation Building in Shandong, China

Floor area is 18,230 square meters



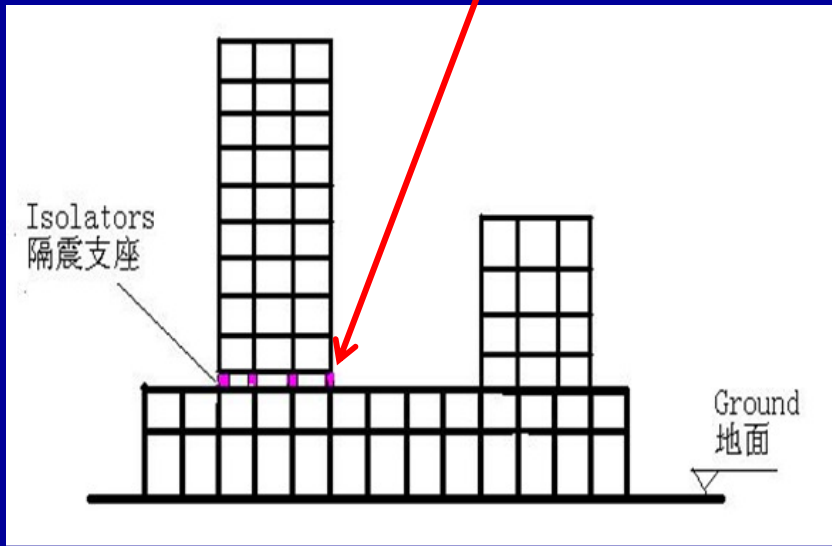
Finite element model of Suqian Customs Building

Stories isolation building
Isolated buildings group – Beijing House group

Subway Hub in Beijing

- Platform (2 storie RC frame) 1500m × 2000m
- 30 isolation buildings (9 stories RC frame) on top of the platform
- floor area of isolation buildings is 240,000 M^2

Rubber Bearings



Isolated buildings -- the largest area in the world

One part of view

Isolation RB Layer

Another part of view

Shaking table tests– 1/25 scale model

(M) 17p04 BJ ISO 01
Stories-isolation Shaking table tests)

Isolation 隔震

El Centro (N-S)

(Transverse) X

Ground Motion

地面 Ag= 0.366 g

Isolation

Structural Acc.

结构 As= 0.122 g

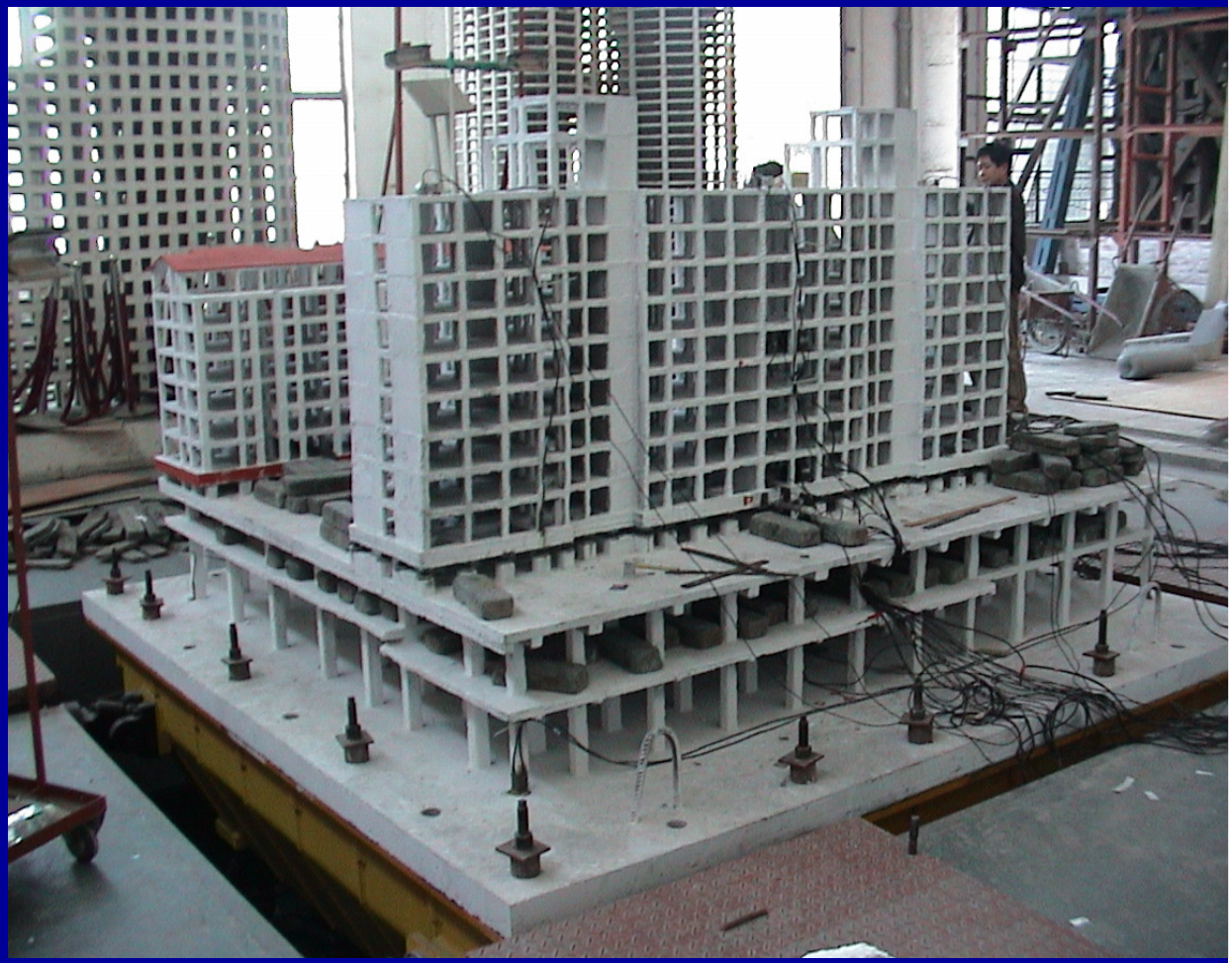
Stories-isolation

Isolation 隔震

no any damage

El Centro wave
Tianjing wave
Local Site wave
Ground Motion
地震 Ag= 0.60 g

Isolation
Structural Acc.
结构As= 0.11 ~ 0.16 g



(M) 17p04 BJ ISO 07

Stories no- isolation Shaking table tests)

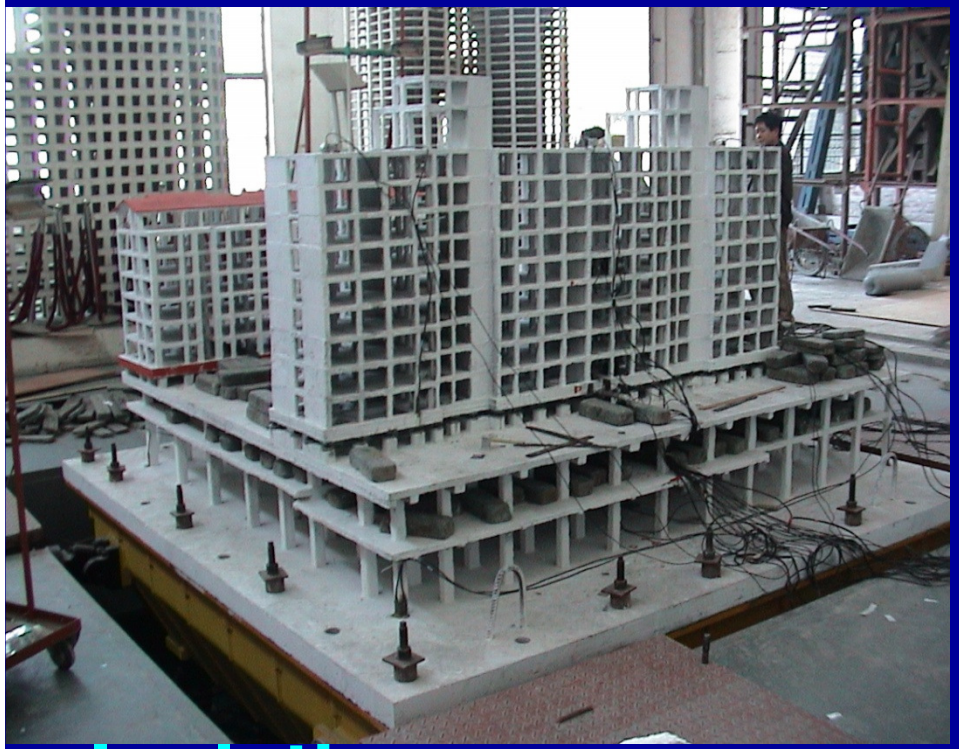
No- Isolation不隔震
(Fixed base)
Damage, Collapse
El Centro (N-S)
(Transverse)
Ground Motion
地震 Ag= 0.366 g

Structural Acc.
结构 As= 0.834 g

Comparison:
隔震/不隔震 = 1/4

Shaking table tests –Fixed base, no isolation (300gal), nearly collapse

Shaking table tests Isolated buildings group
Beijing House group



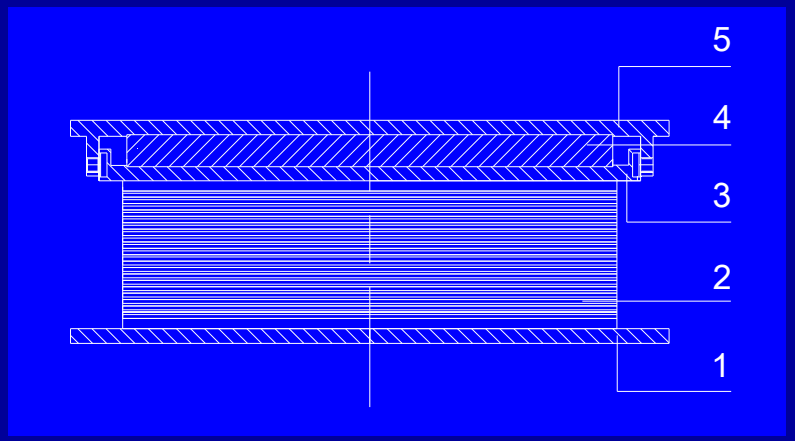
Isolation
Input 300 gal
Response 140 gal **1/5**
Input 600 gal
no any damage

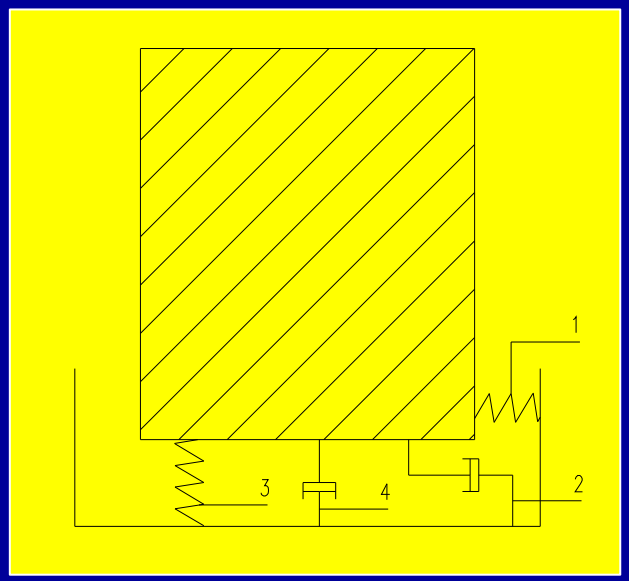
no-isolation
Input 300 gal
Response 720 gal
Input 400 gal
Nearly collapse

Three directions (3D) isolation
Horizontal Seismic Isolation & Vertical Vibration

Model and Device

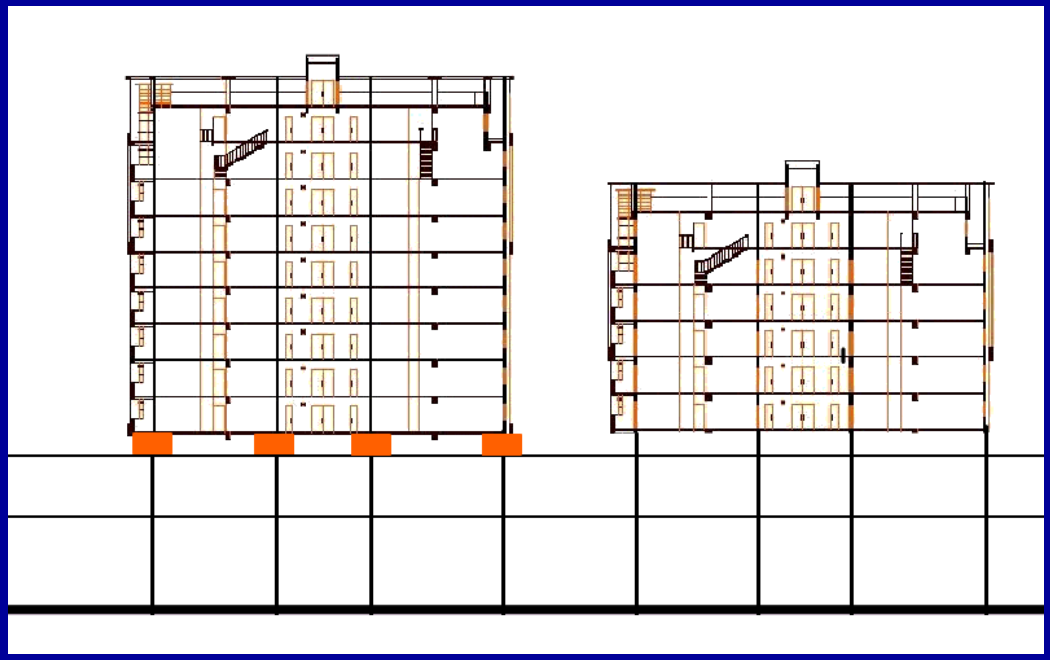
- Decouple of Horiz.-- Verti. Vibration
- High effect of isola. 3D
- Low Cost, install easily

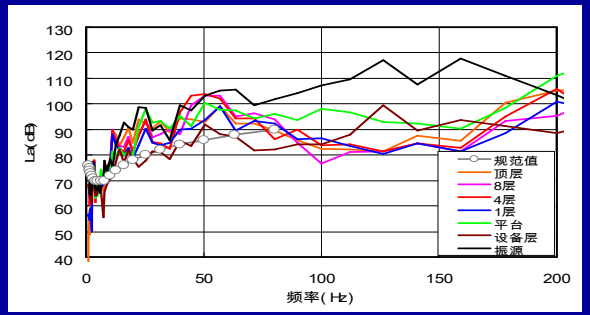




Application of 3D Isolation in China

(Beijing and Guangzhou)





3D isolator

- If no-isolation, Vibra. be amplified
- 3D reduce 90% of Verti. Vibra.

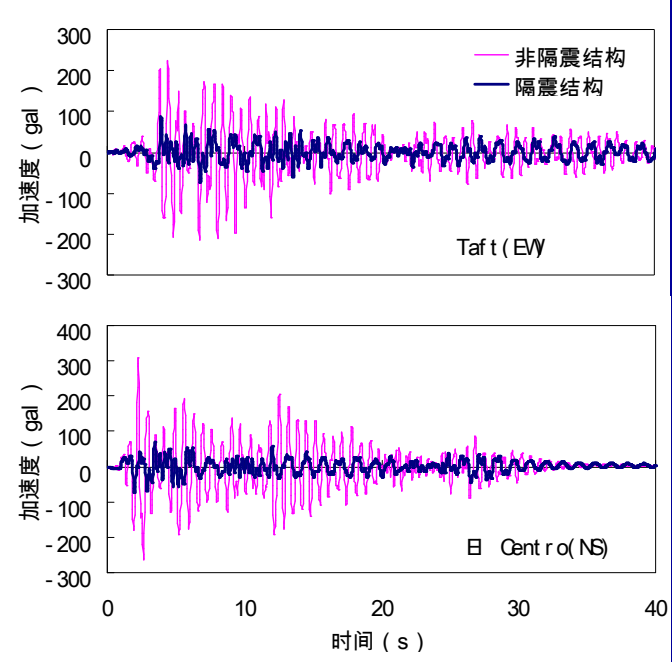
Significant benefits of using Stories Isolation for this project

1. Seismic safety increases to 4 times.
2. Construction cost save 7 %.
   (in normal case ±5%)
3. Environmental problems railway vibration could be solved, using 3D isolators

Isolation for Re-const. After W.C EQ

School, Hospital, House
Use isolation Technique

2nd primary school with Isalation W.C Sichuan after E.Q.



Accel, Iso/no Iso =1/6

Teacher say to students: when E.Q.

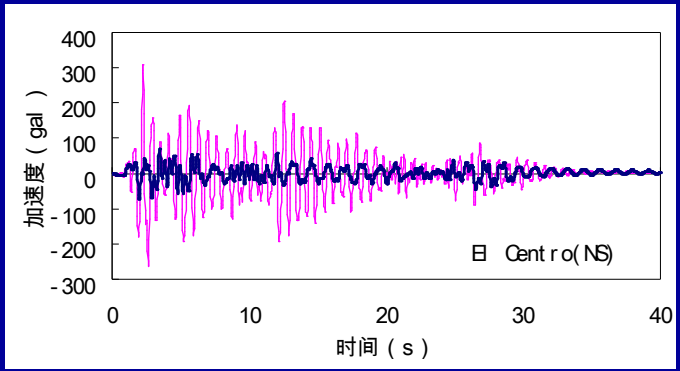
Staying at room is more safe than outside

地震时,不外跑,屋里比屋外更安全!

Record in E.Q. in 20 April 2013

2nd primary school (Isalation)

1st primary school (no Isalation)



School	iso	Ground A	Building A
2nd primary school	Isal.	0.20	0.12
1st primary school	no Isal.	0.20	0.72

Isolation / no isolation 1/6

Isolation for Reconst. After WC EQ

Hospital

House buildings

First story isolation
(on the top of 1st story)
Guangzhou City E.Q. Observing Center

Isolators 首层隔震

Earthquake Bureau building

Fujian Province, China.

Isolation Building

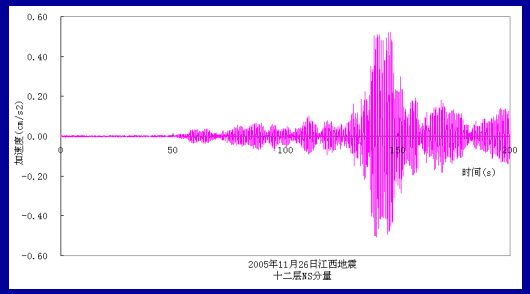
2005

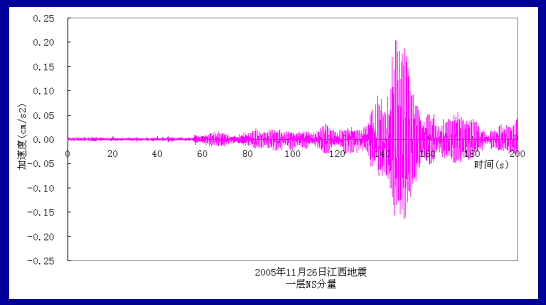
RC Structure

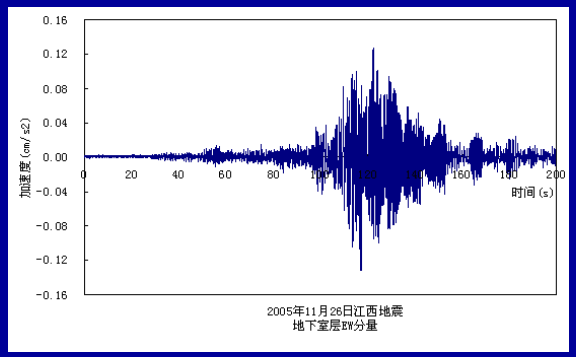
+11 stories,

-1 basement

Earthquake Bureau of FuJian Province, Isolation Building Earthquake Experience in 2005.11.26 Jianxi EQ(M 5.7) Structural Response







	Isolat.	no Isola.	Iso / no iso.
12 story	0.14	0.59	1 / 4.2
1st story	0.10	0.12	
Ground	0.12	0.12	

5.2 Large or complex structures

Centro Government Building for Observing Center Isolation building in Beijing,

北京中央 7 个部委联合办公大楼 2004（隔震大楼）

A Central Government
(7 Ministries) Office Building

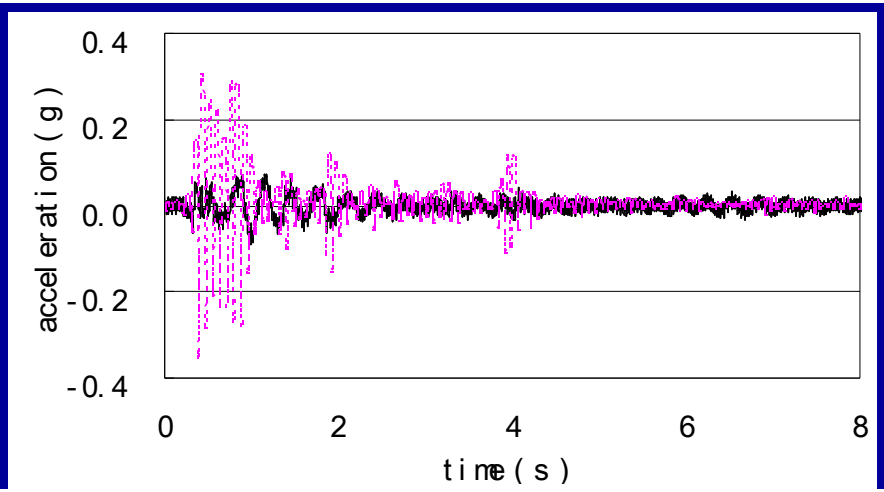
- + 11 stories
  - 3 stories
  basement
- reinforced concrete frames and shear walls
- Base-isolated building

Shaking table test

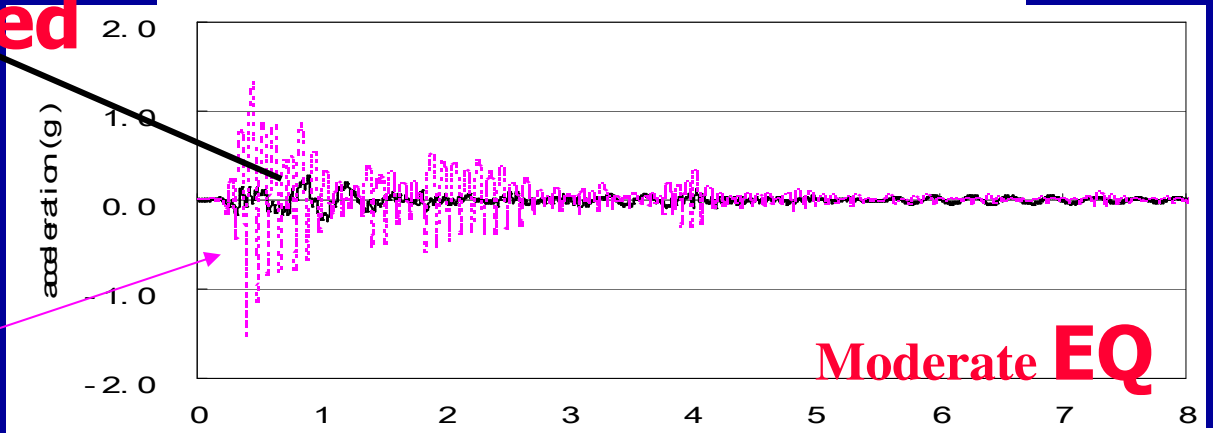
with and without isolators

Isolated building

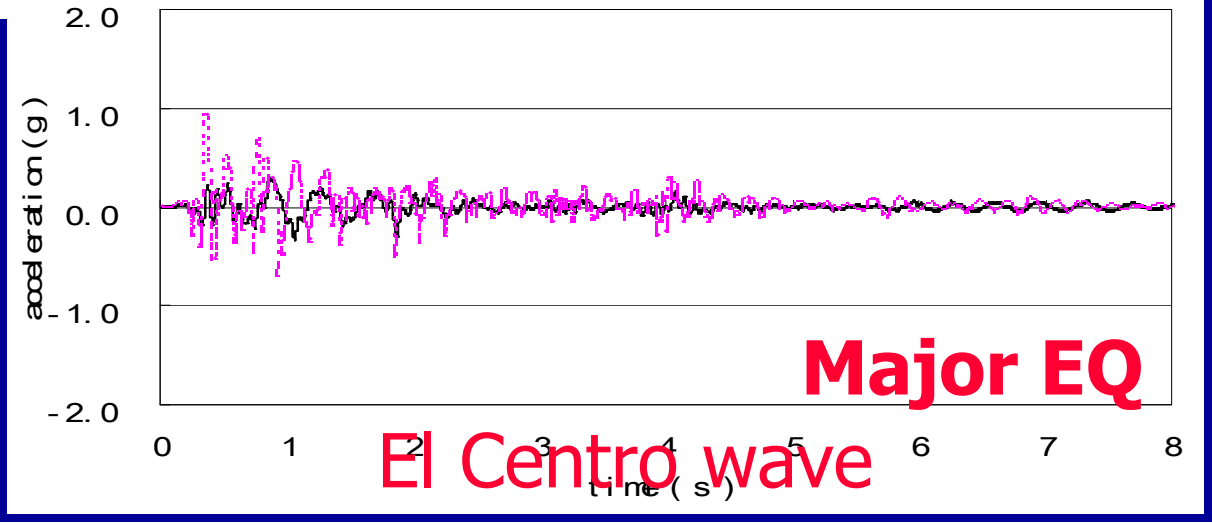
Non-Isolated building



Isolated



Non-Isolated



El Centro wave

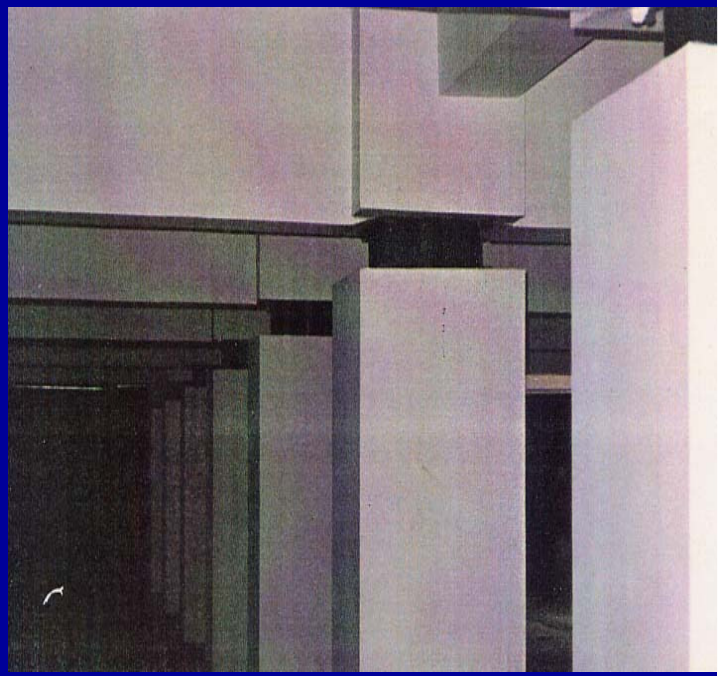
Office Building of Guangzhou University
(广州大学.办公楼)

滑板支座 elastic slide bearings

橡胶支座 Rubber bearings

Seismic Isolation-Application in China

Office buildings in Xinjian,westhern China (4)



IT center of Shimao, Yunnan China

Guangdong S. & T. center

广东省科学中心 隔震结构

整体设计(中南院)

隔震设计 振动台试验

(广州大学,张季超 等)

地震反应 隔震/不隔震=1/6

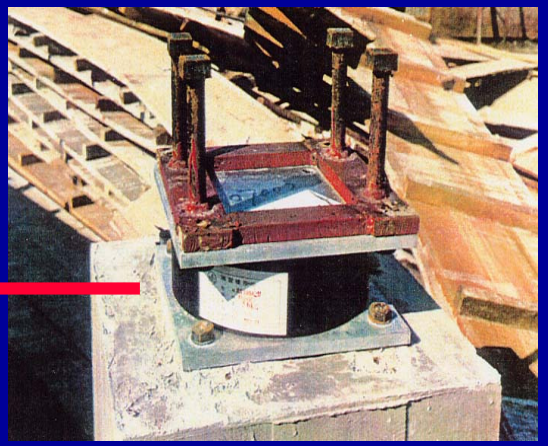
Seismic Isolation Library building in Taiyuan City,northern China

Basement Isolation

Seismic Isolation Museum in southern China

Stories Isolation--Top of first story

isolators



Isolation hotel buildings group in Yunnan

海埂会议中心--商务型酒店

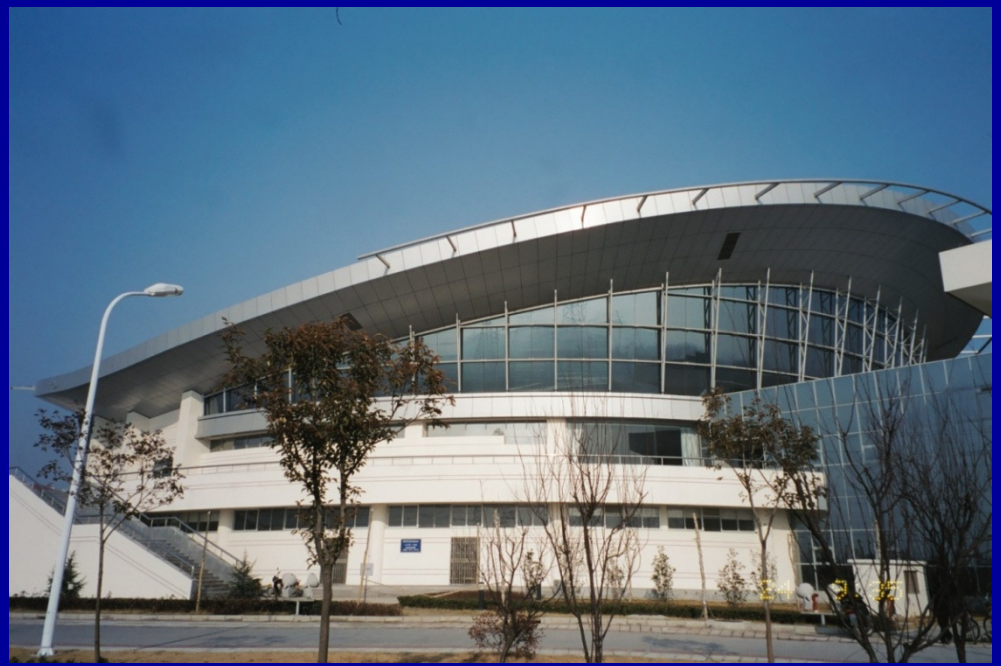
Base Isolation

A sport stadium with isolation (Prof. W.Q.Liu)

Floor Area 23,000 M^2

Response:

isolation / no isolation 1 / 4.2

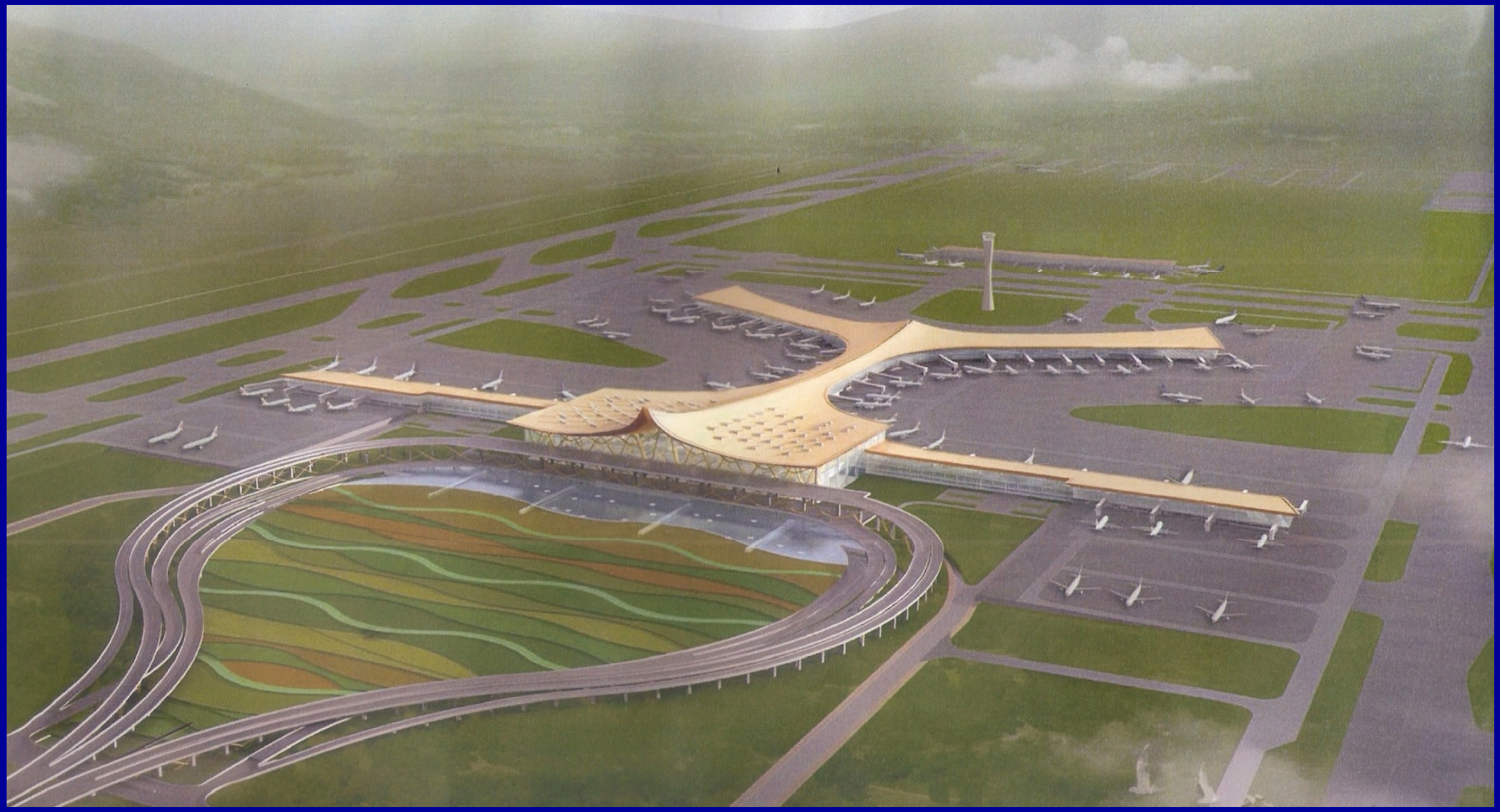


Base Isolation

Kunmin Isolation New Airport (2011)

Floor Area: 500,000 M^2

(Design by Beijing Architectural Design Institute)



昆明新机场航站楼

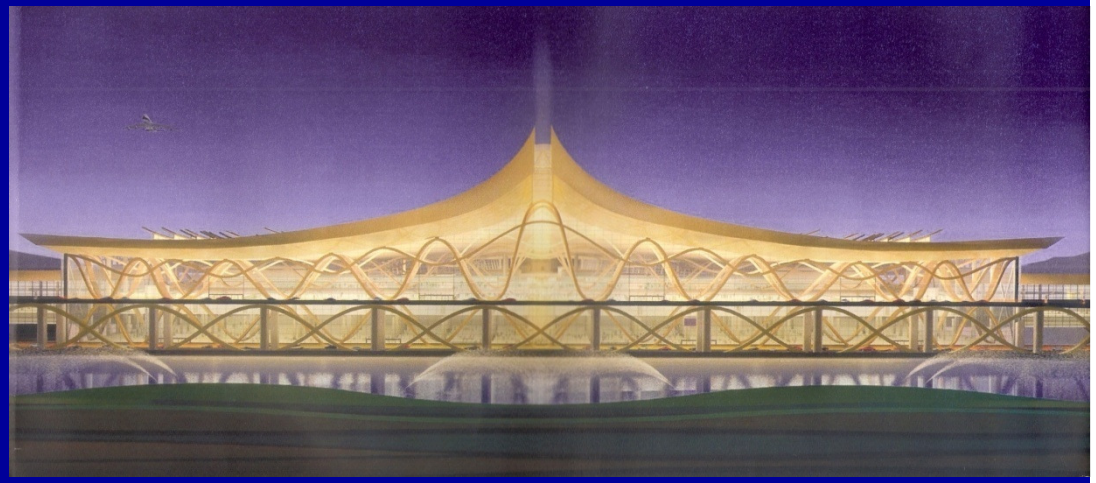
Base Isolation Kunmin Isolation New Airport (2007-2012)

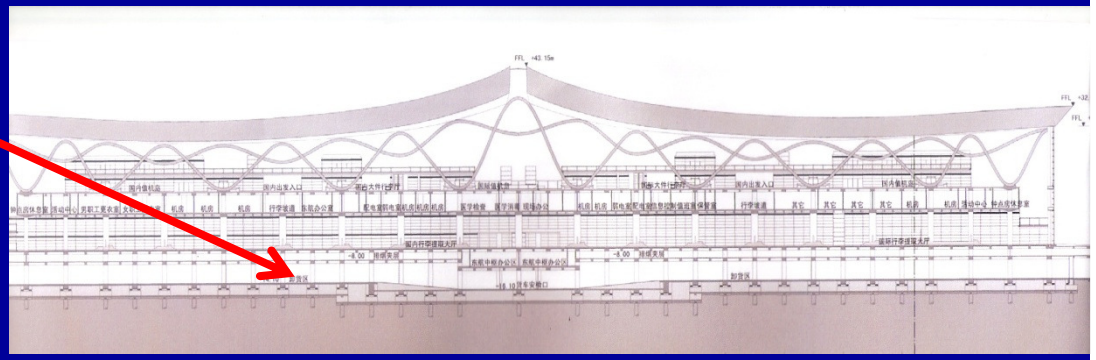
Base Isolation

Rubber Bearings ：

隔震支座 1892 RB

(∮1000)

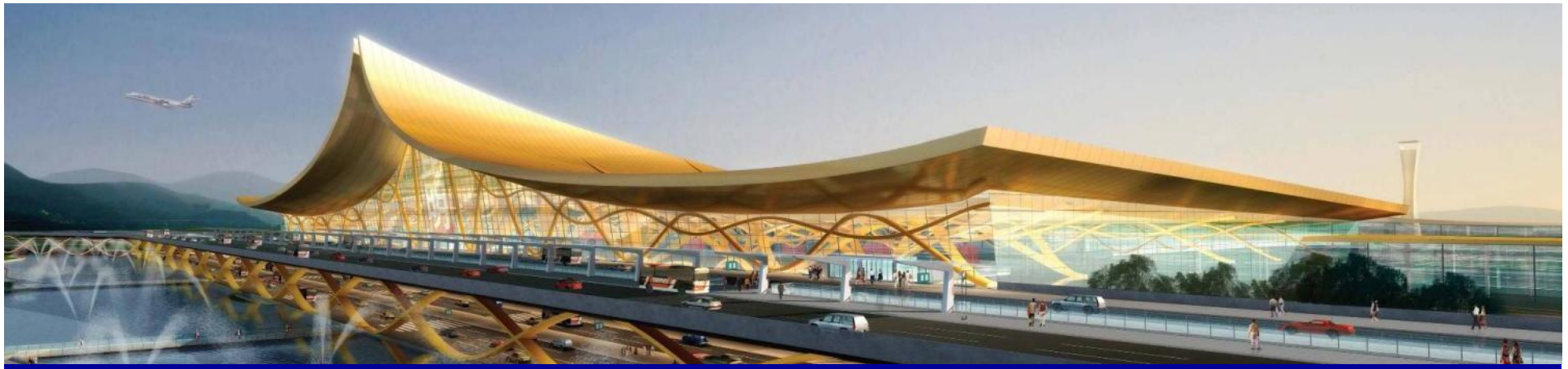




Oil Dampers 油阻尼器

108 OD

(D= ±600mm, F=150T)



Beautiful Arch. Design

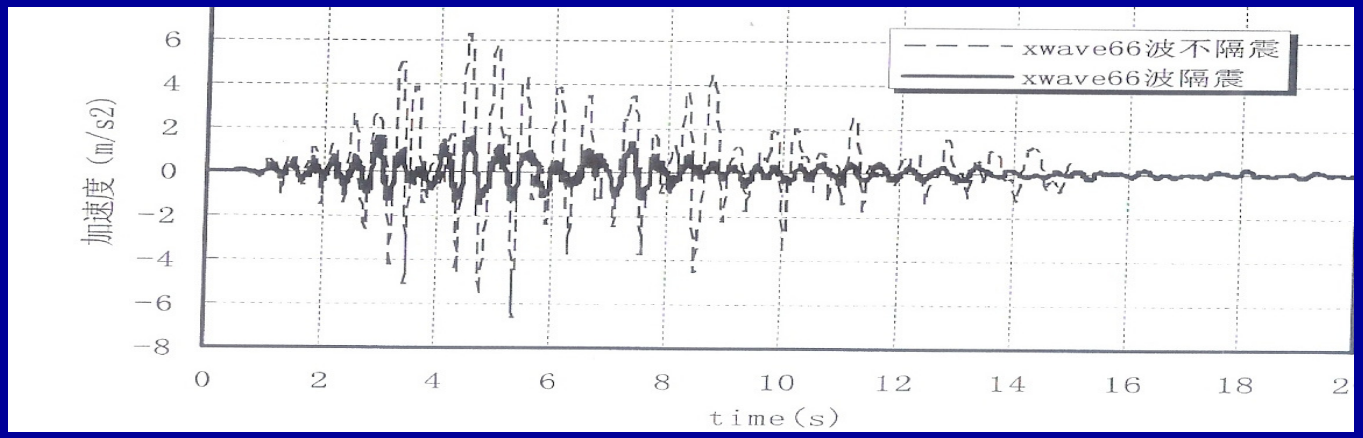
Need to protect:

1. Complex structure
2. Facilities inside
3. Curve column and large glass
4. Large Ceiling

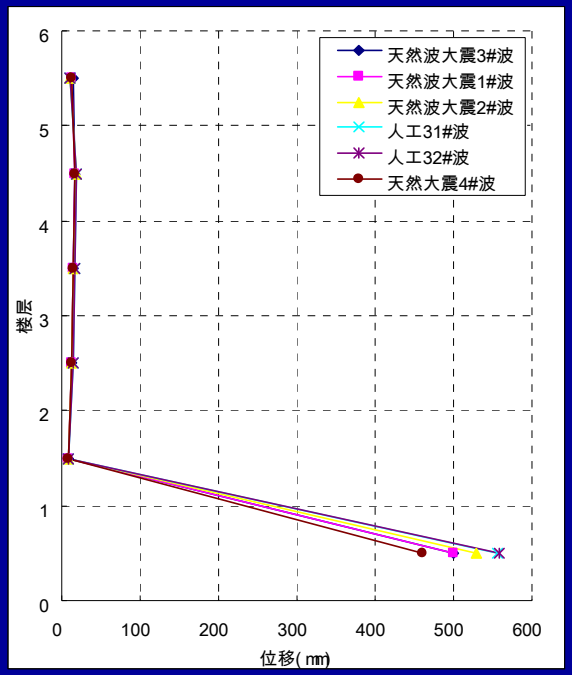
So,
only use Isolation!

Shaking table test (2008) for Isolation Kunmin New Airport

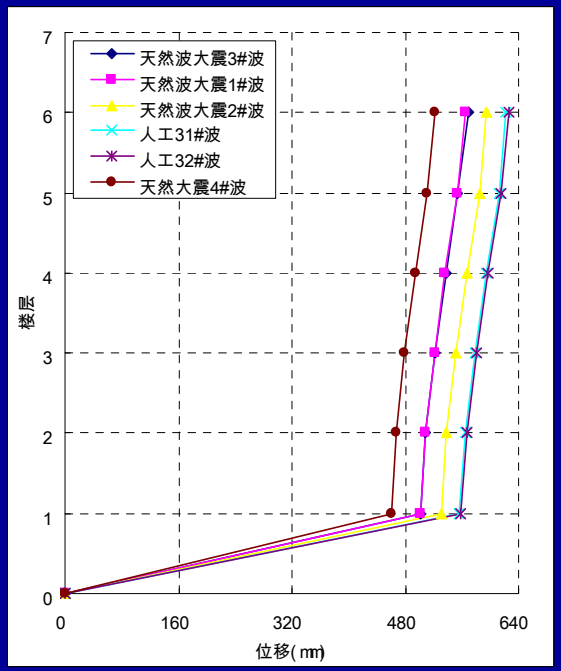
Testing and analysis results



Acceleration - Time



Model shape 楼层位移

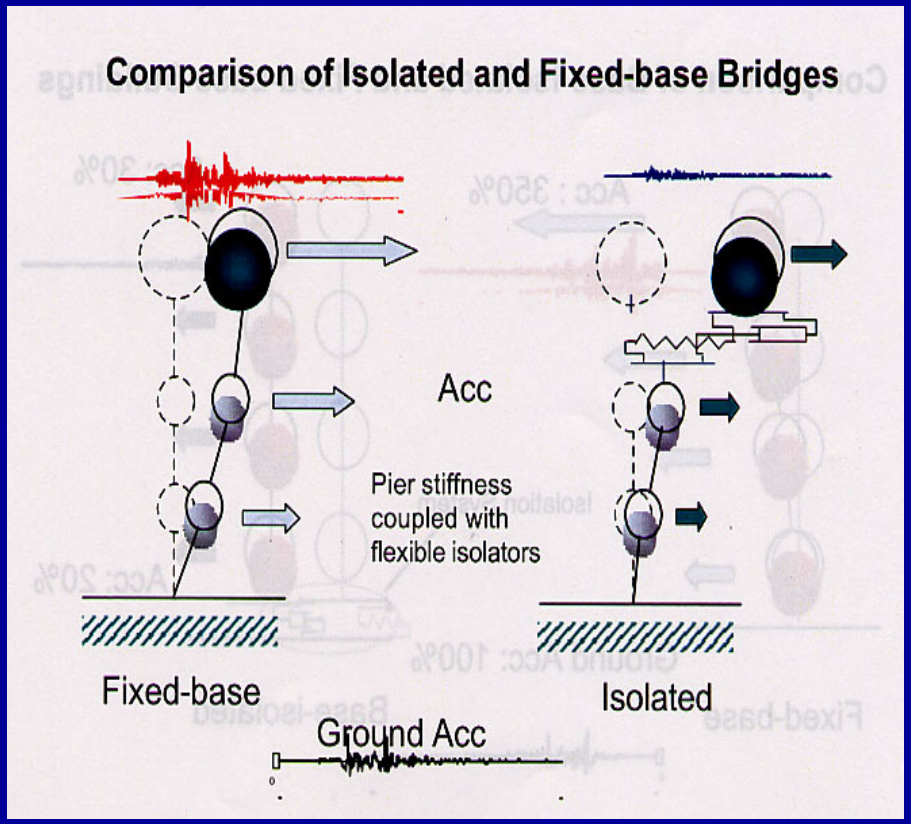


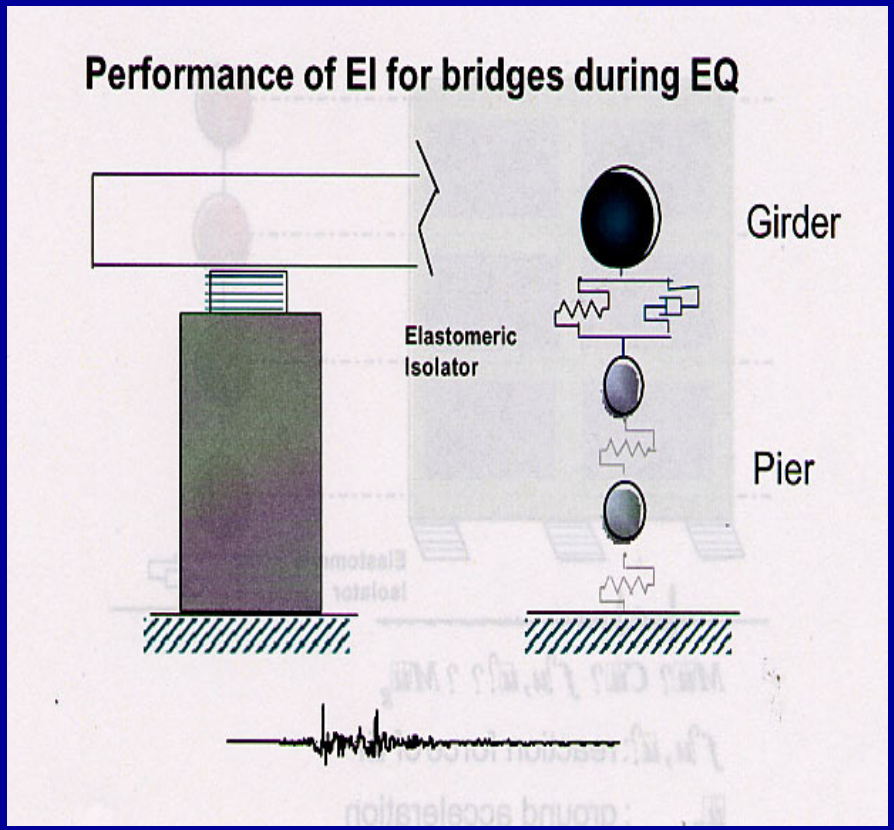
Story drift 楼层层间位移

5.3 Bridges (about 150)

6.1.8. 隔震桥梁 (柱墩顶,底部)

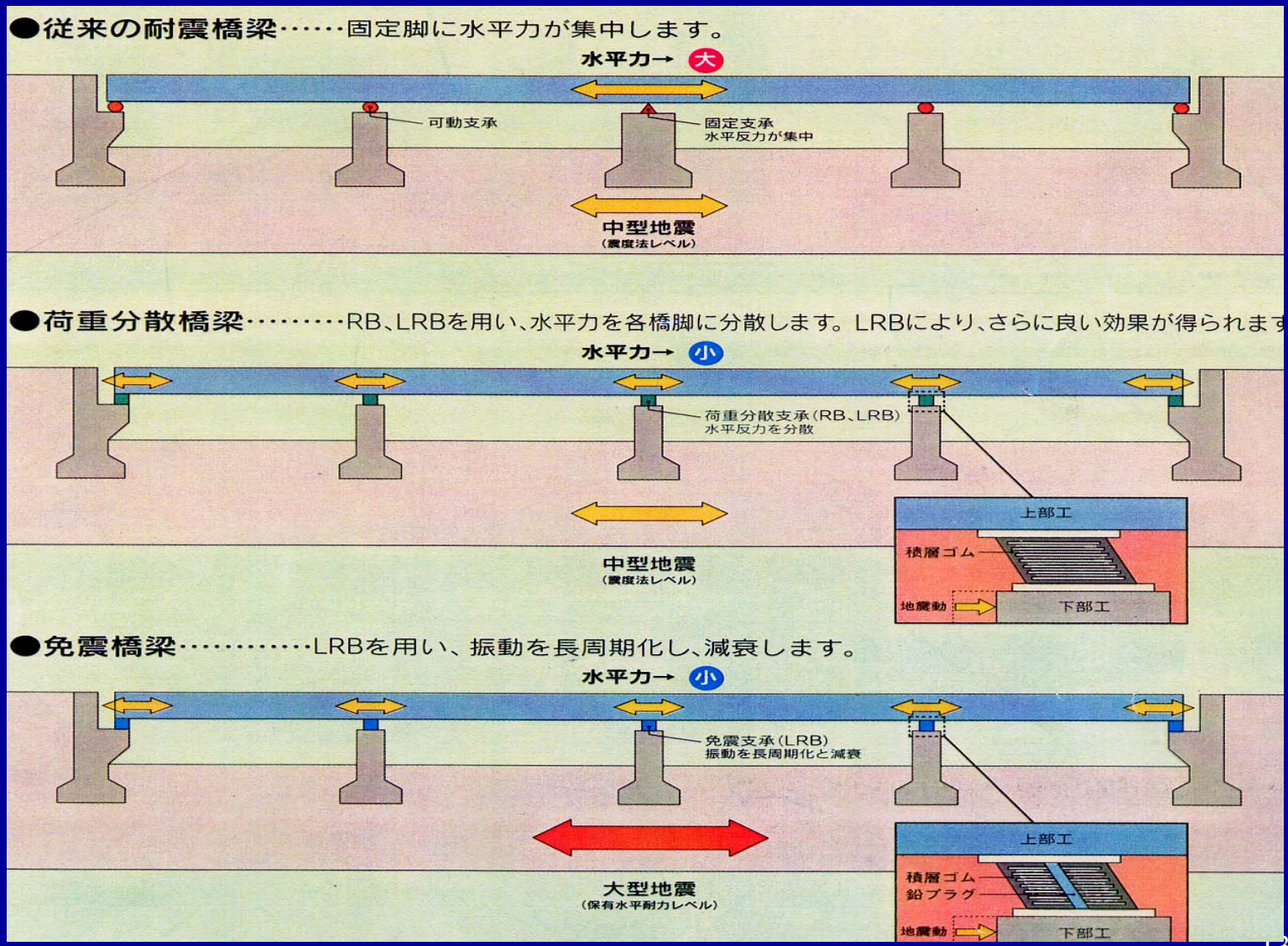
桥梁 隔震机理





Seismic Isolation-Application in Bridges

Concept of reducing response for using isolation in bridges



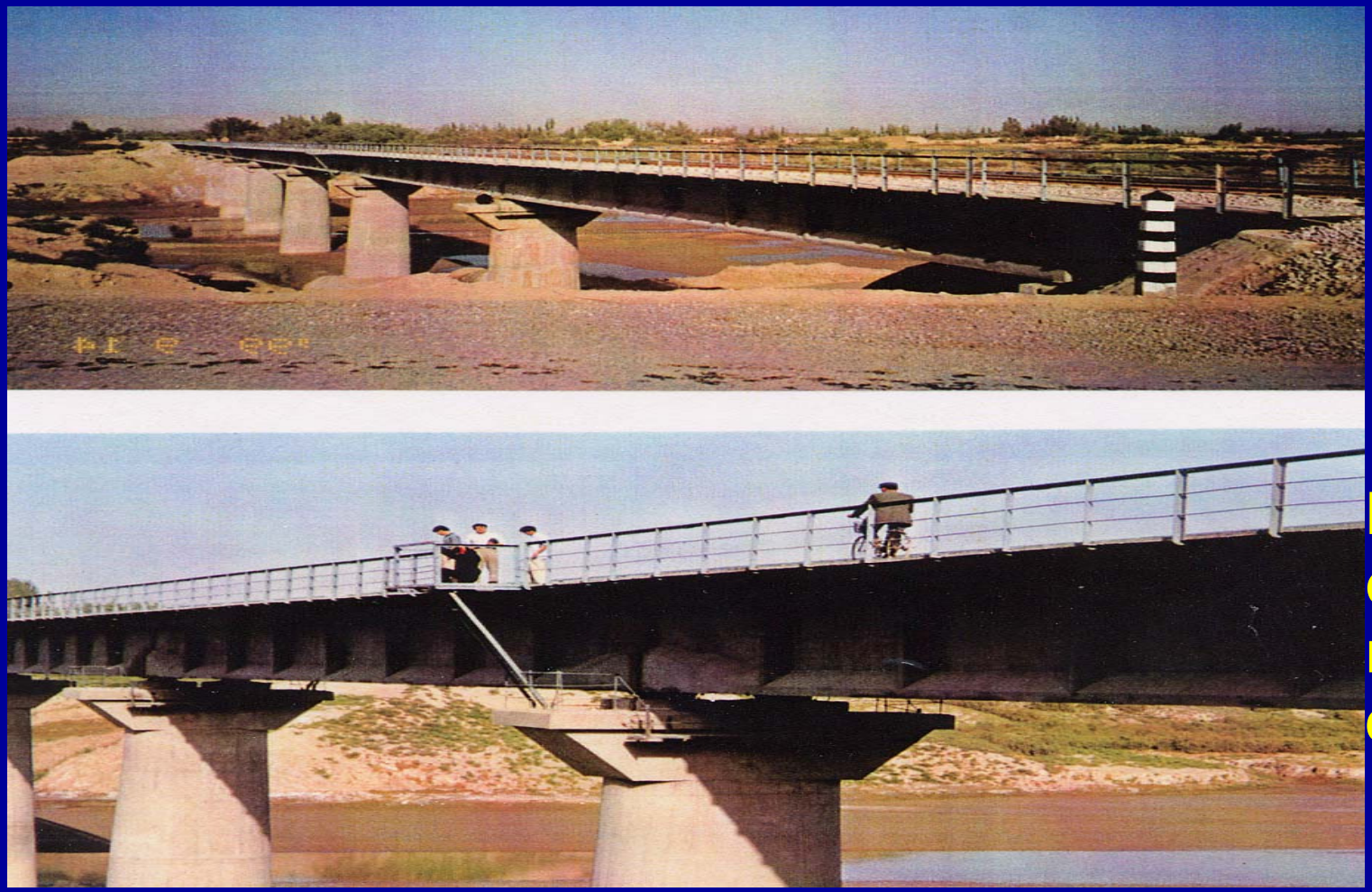
Seismic Isolation-Application in Bridges

Bridges were damaged by Earthquake

Seismic Isolation-Application in Bridges (2)

Bridges were damaged by Earthquake

Isolation Railway bridge in Xinjian (2000)



2003.2.24
Xinjian
E.Q

M 6.2
L= 50KM

No any damage in neal fault earthquake

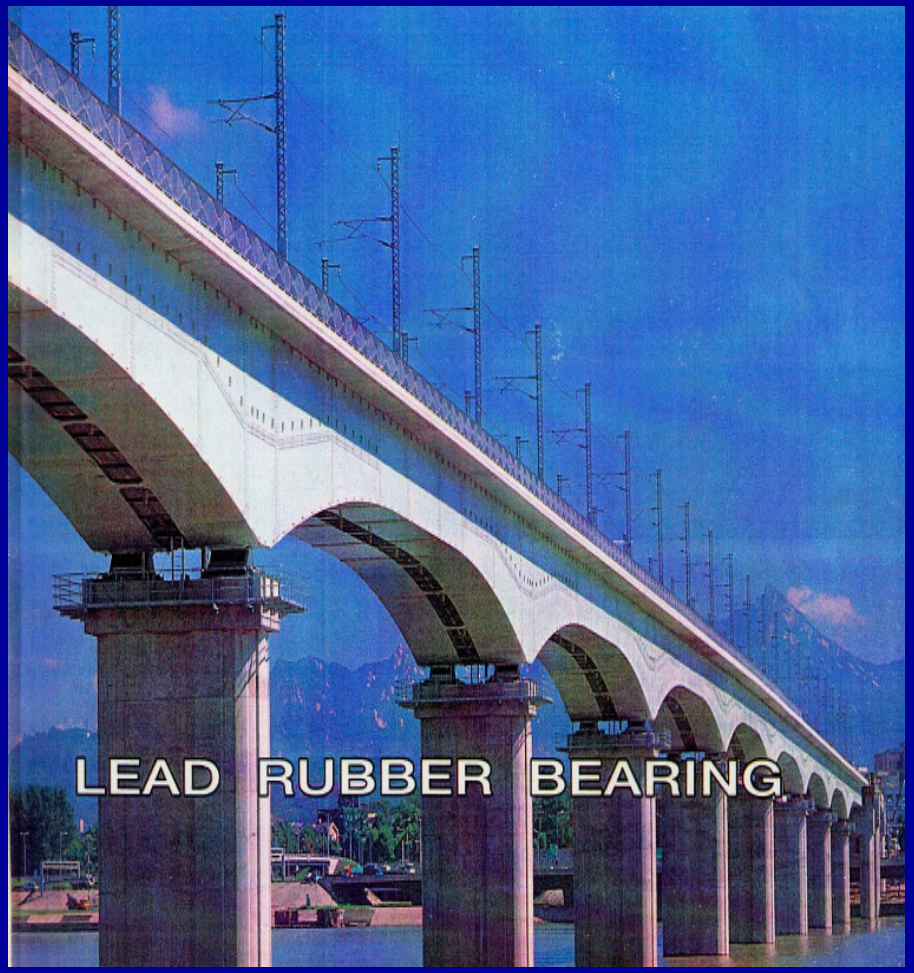
9 spans , 32M /each span

Isolation highway bridge in Fujian (2006)

Isolation highway bridge in Fujian (2006)

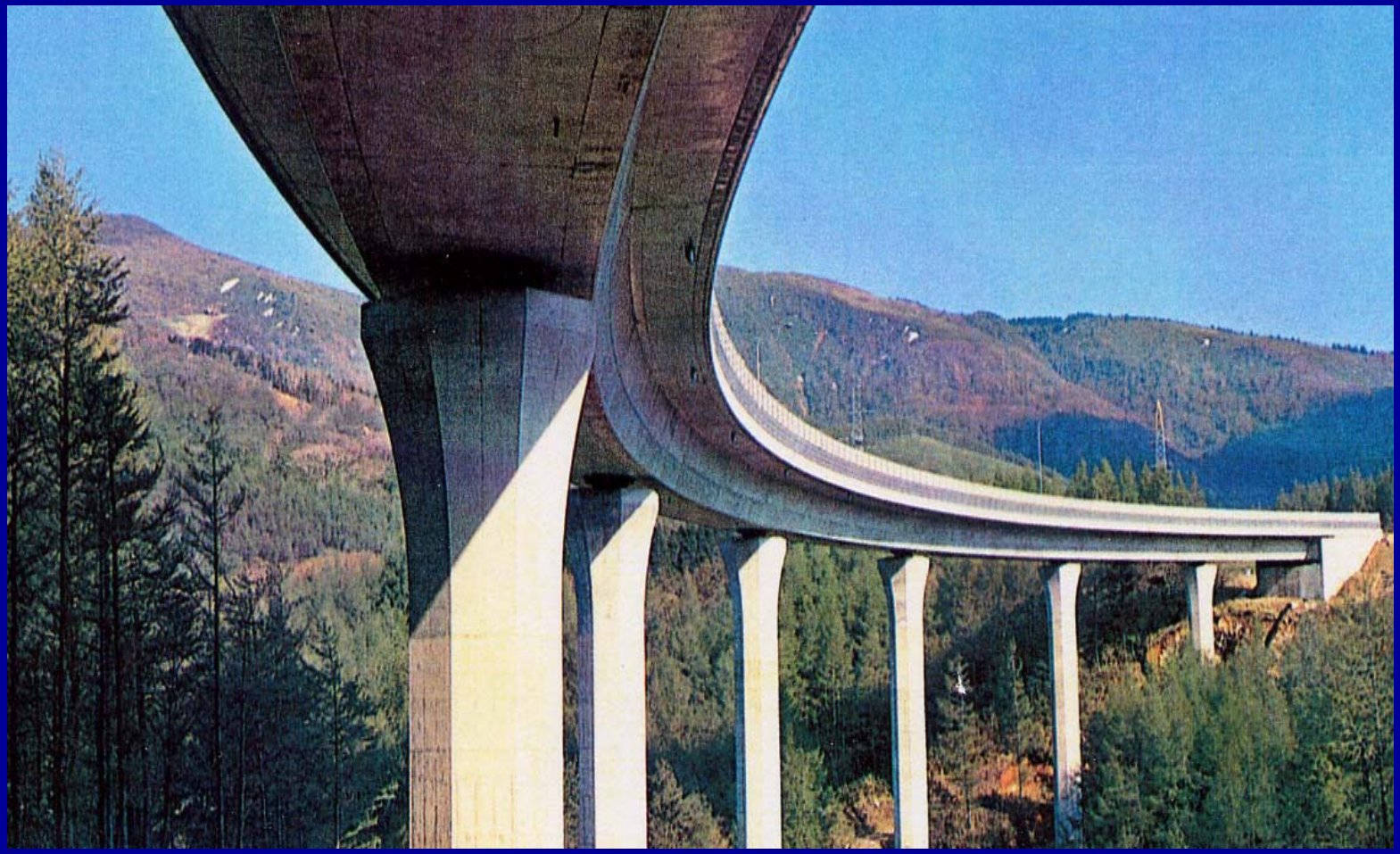
Isolation highway beidges

城市高速公路桥梁隔震

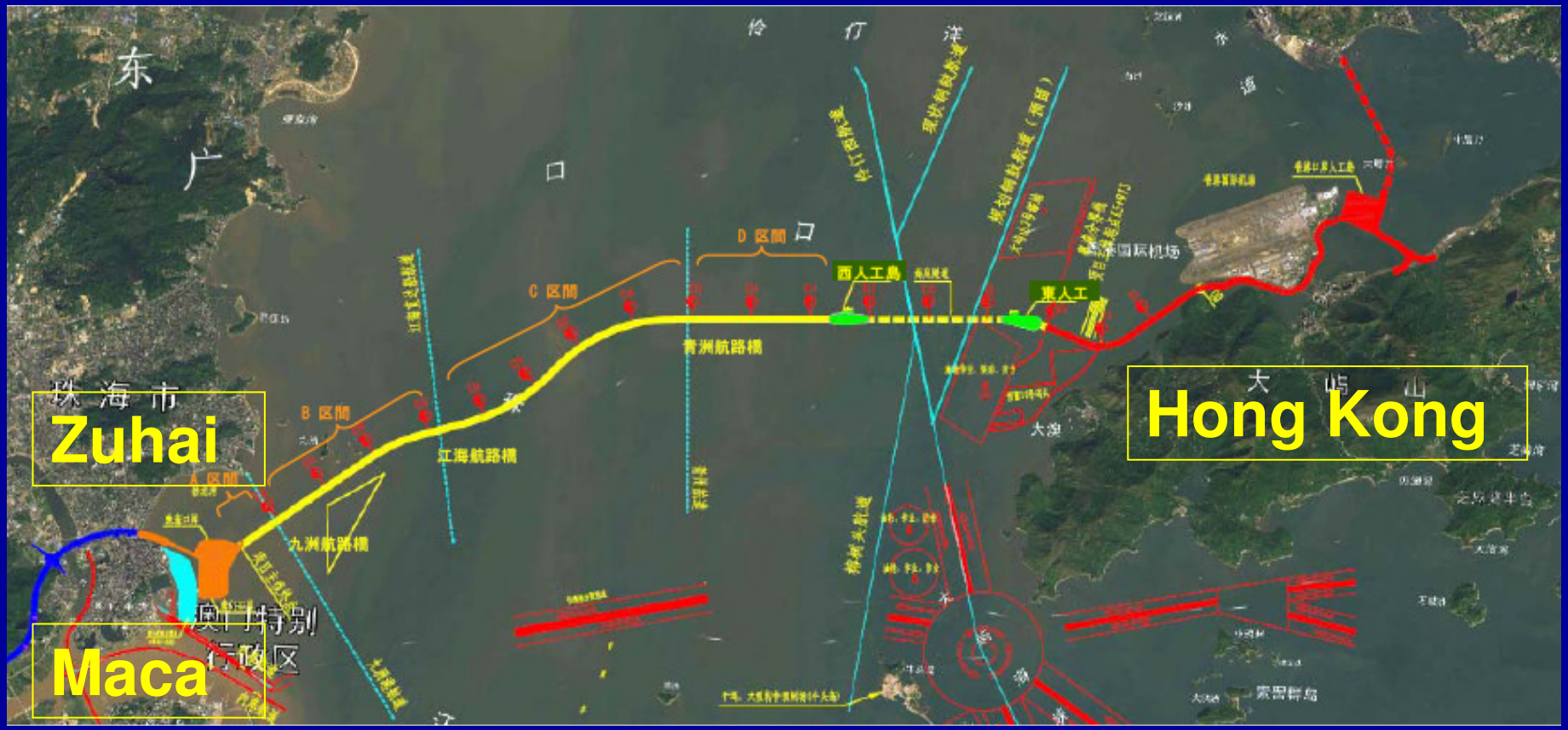


Isolation highway curve bridges

高速公路桥梁 隔震

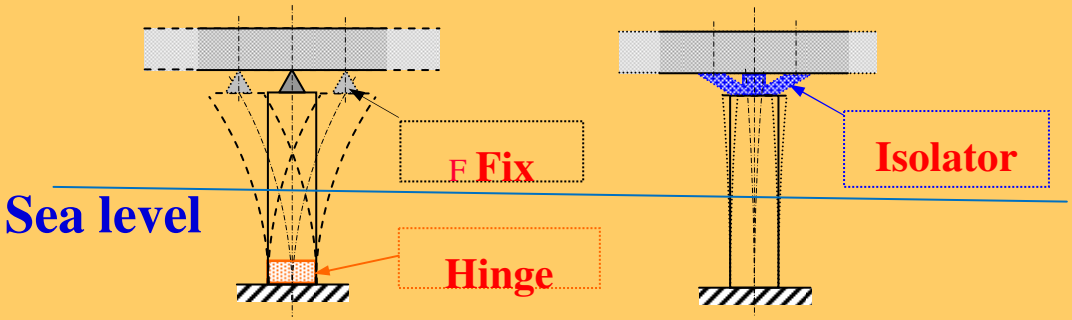


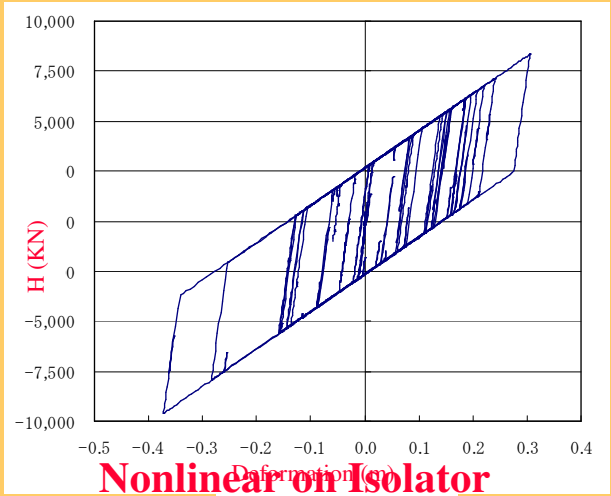
长大桥梁　港株澳大桥 26 KM
Seismic Isolation Bridge Crossing the sea



固定支座　　隔震支座　　record・H-δloop

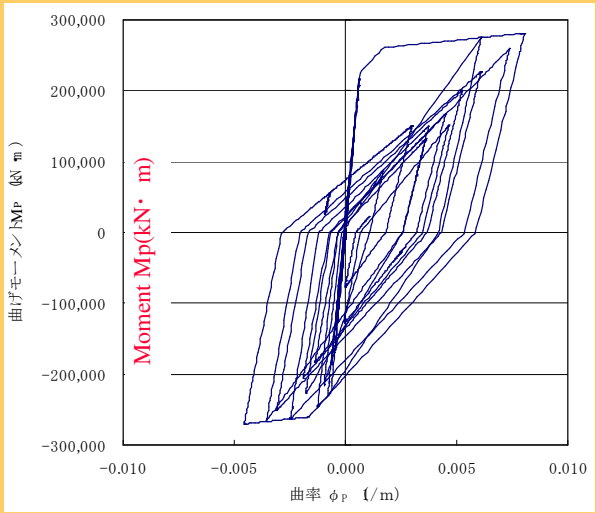
Fix bearing　　Isolation bearing





Nonlinear on Isolator

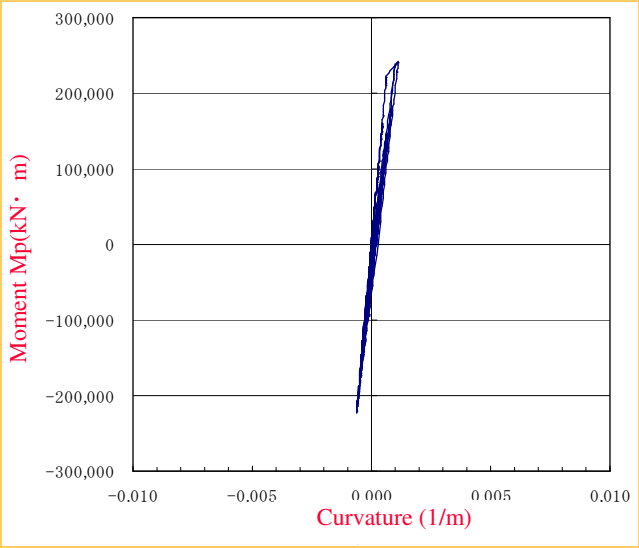
H-δ Loop of Isolation bearing



Curvature (1/m)

Nonlinear on pier

M-φ Loop of pier with fix bearing

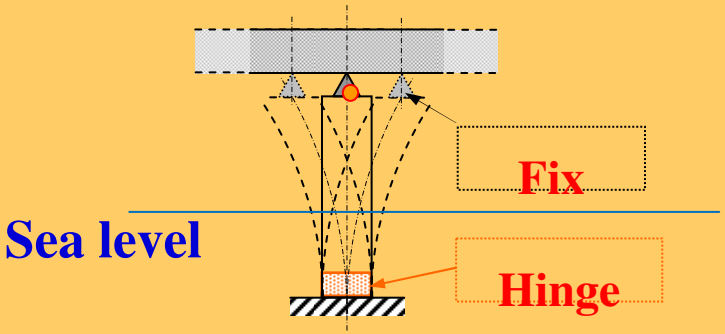


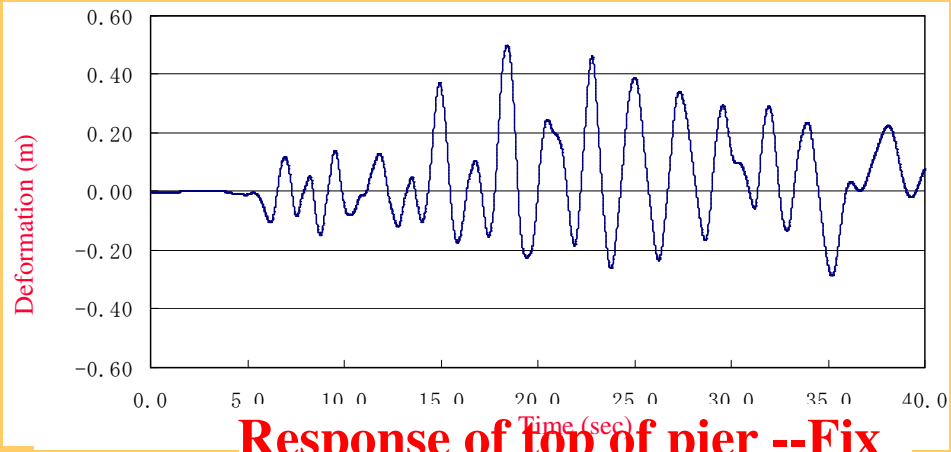
M-φ Loop of pier with isolation bearing

linear on pier

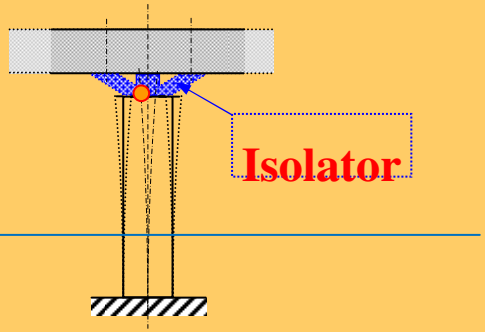
场地地震波·桥墩顶部变形响应

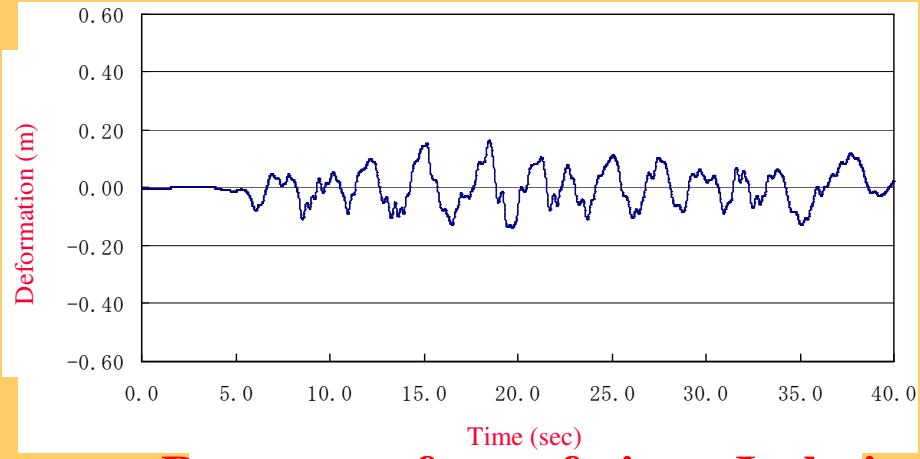
Deformation response of top of pier





Response of top of pier --Fix

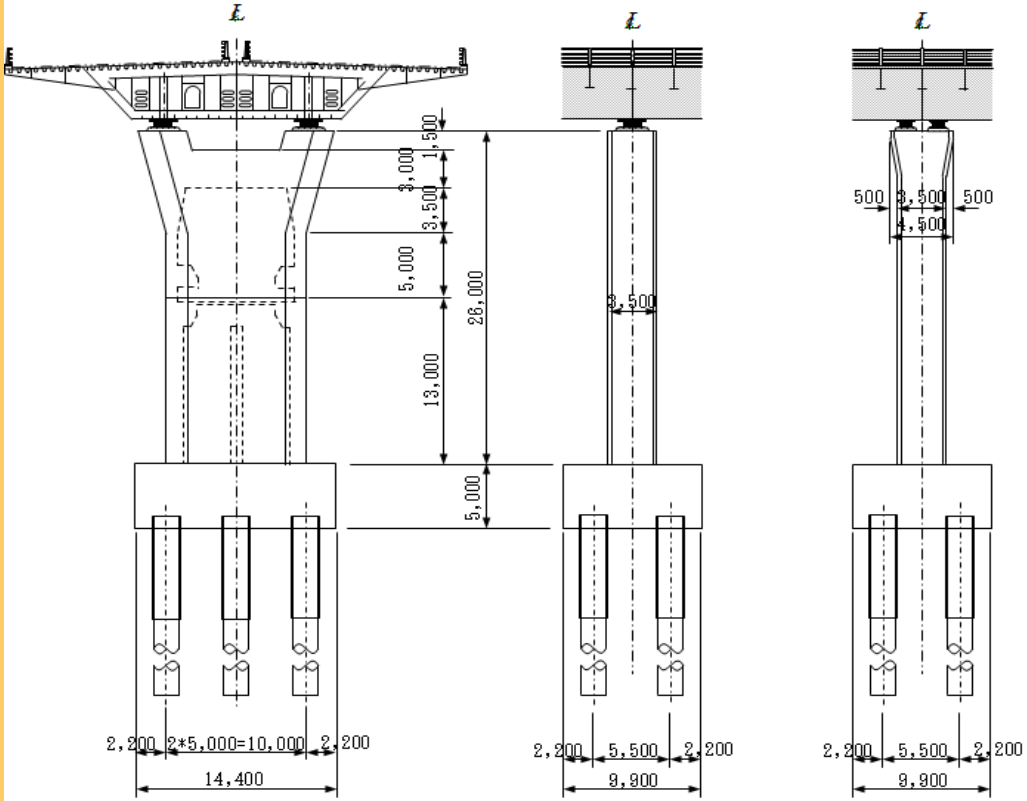




Response of top of pier—Isolation

桥梁隔震设计 Seismic Isolation Design of Bridge

26m桥墩 26m-height pier of H-Z-M



桥墩正面图

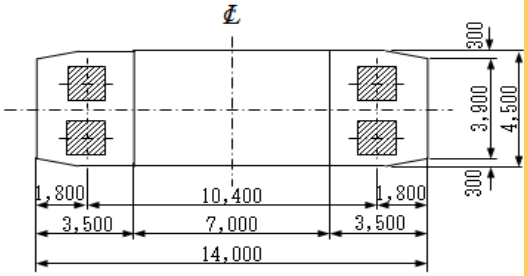
Front view of the pier

中间桥墩侧面图

Side view of mid-pier

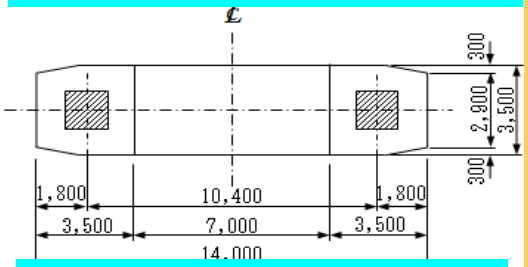
端部桥墩侧面图

Side view of begin and end pier



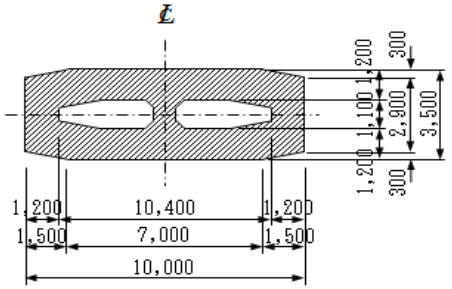
端部桥墩平面图

Ground plan of begin and end pier



中间桥墩平面图

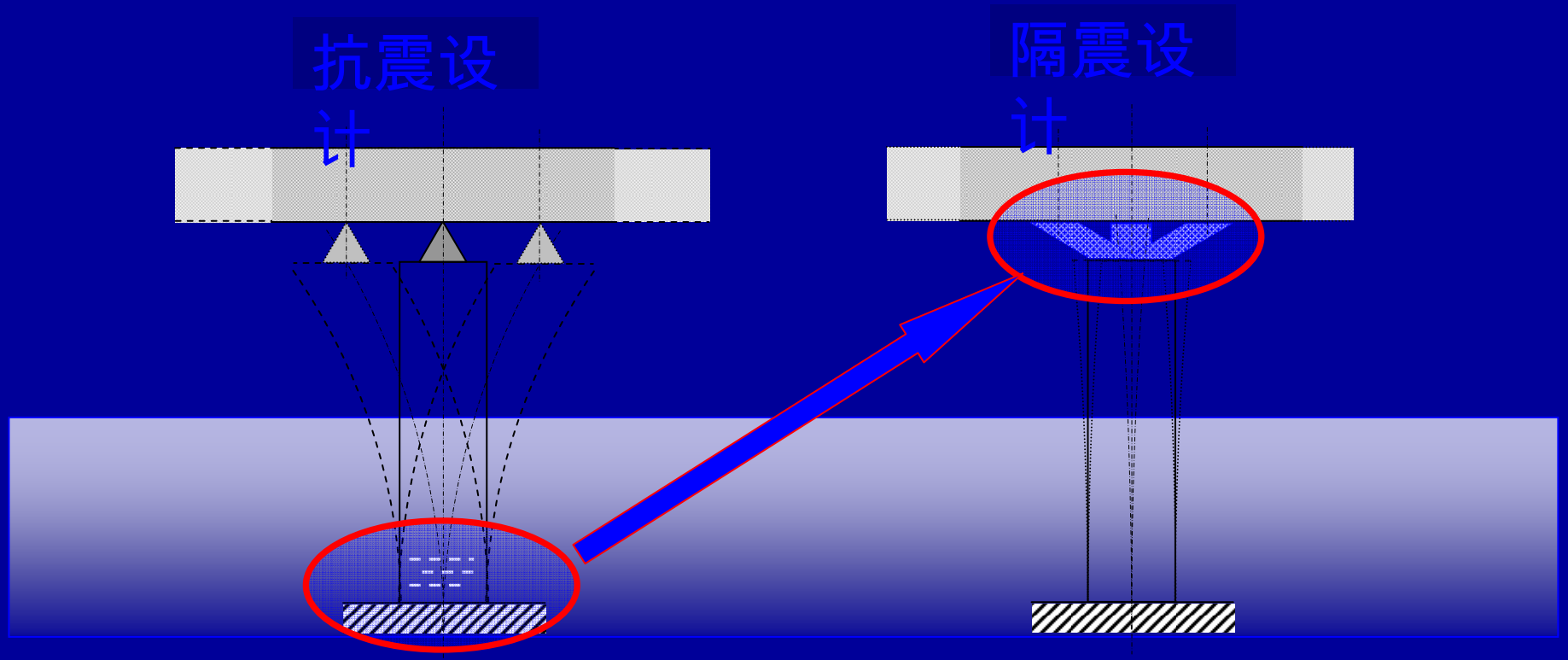
Ground plan of mid-pier



中间桥墩截面平面图

Cross section of mid-pier

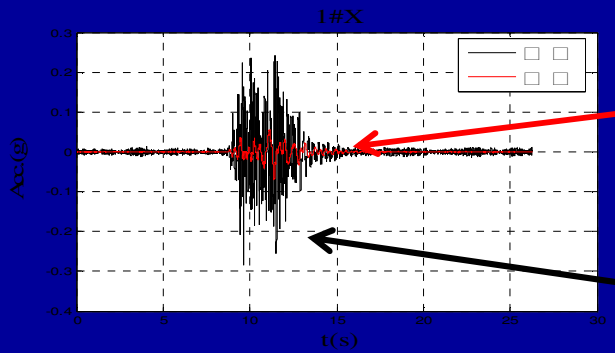
遭遇大震后的 桥墩



港珠澳大桥 隔震等高(平桥)不等高(斜桥) 振动台试验

桥墩 等高(平桥) 模型

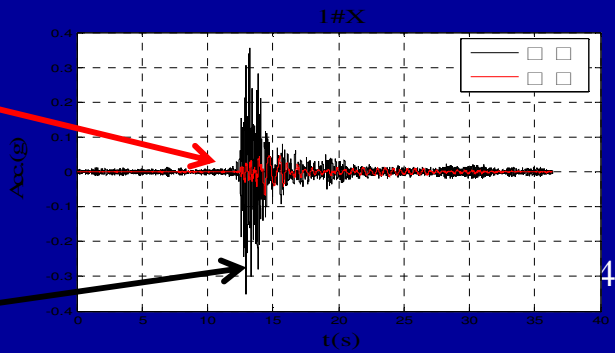
桥墩 不等高(斜桥) 模型



隔震

1/4

不隔震



5.4 Historical or cultural relic

(M) Xian, China, History (1200 years) status isolation protection

中国西安 历史文物 隔震保护 地震试验

Isolation devices

Isolation protection for history statue and stone tablet

(1200 years history) 中国西安 碑林文物 隔震保护

Buddha Temple (Southern China) High 108 M

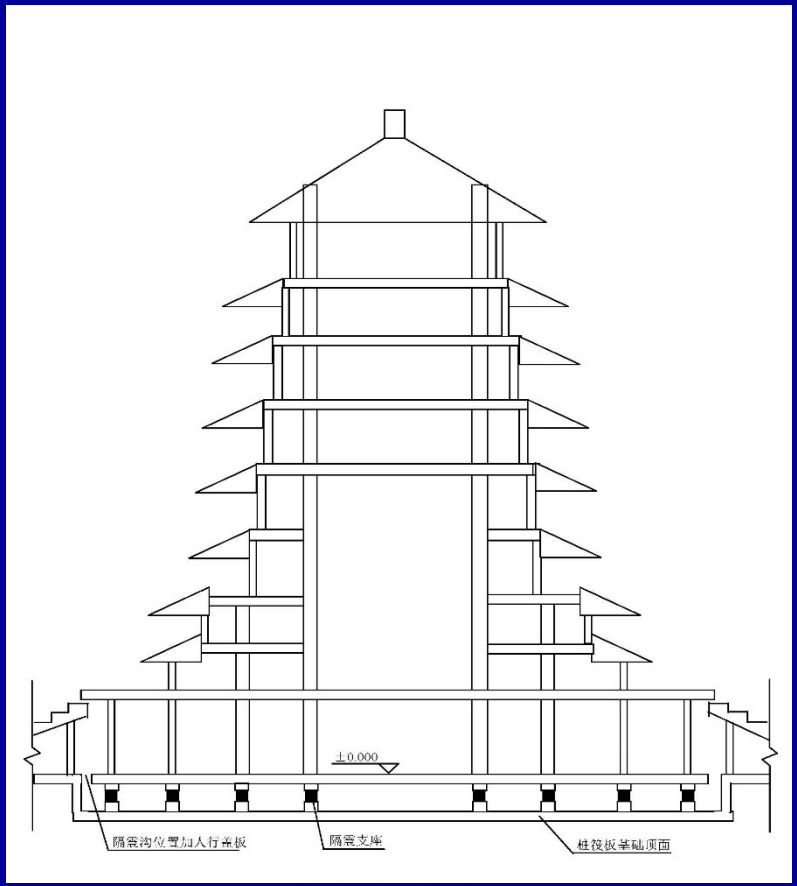
The highest buddha temple in China 广东揭阳 南岩佛寺 高108M

Ask to protect:

1. Structure
2. Statuary inside
3. Pictures on column & wall

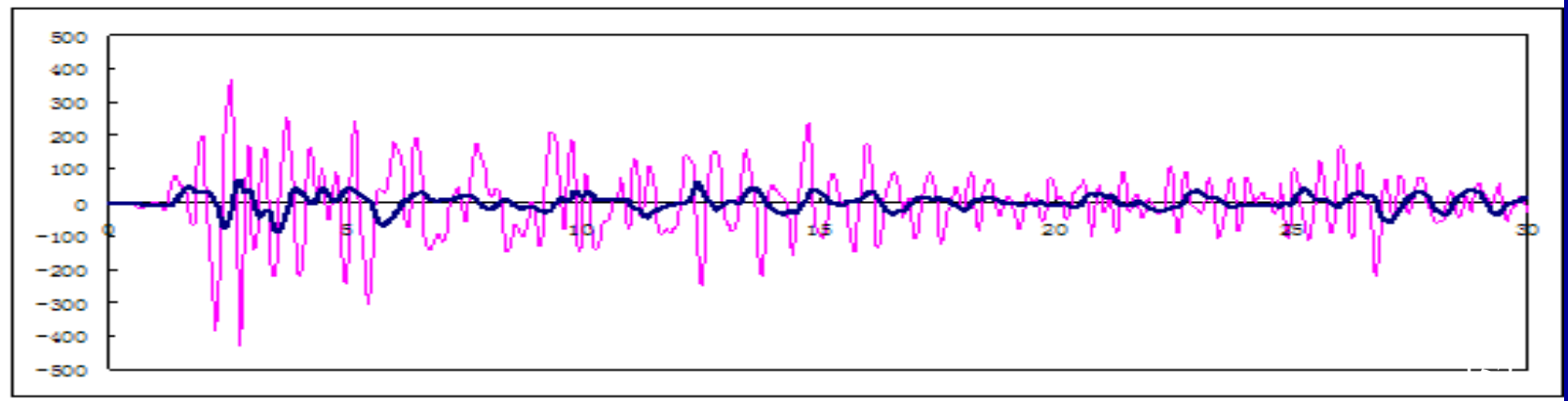
So, need to use isolation

Isolation Analysis result



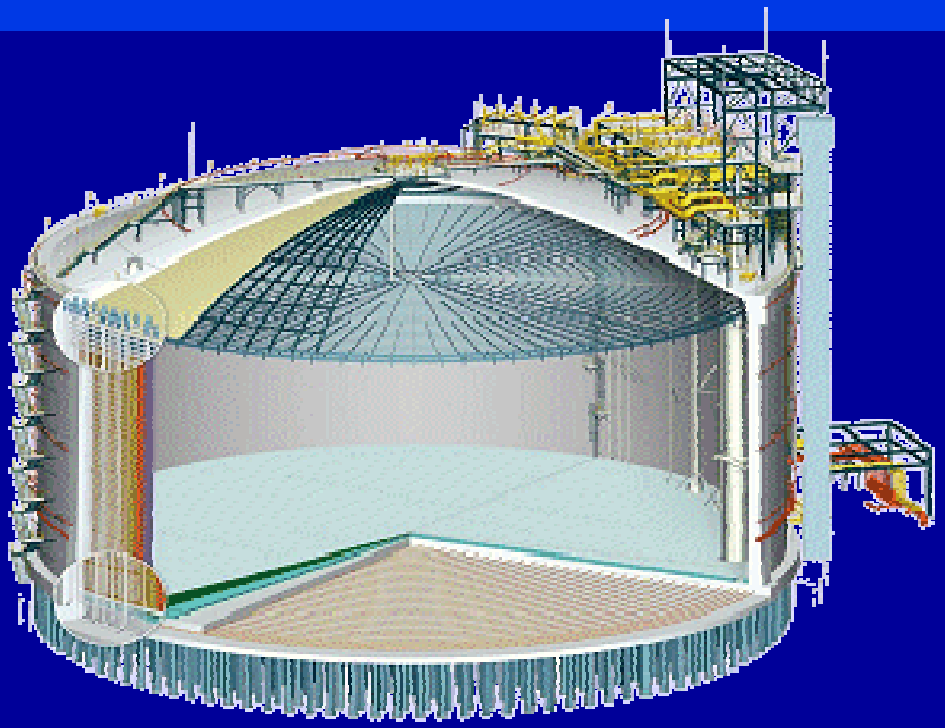
Acce(iso.) / Acce (no iso.)

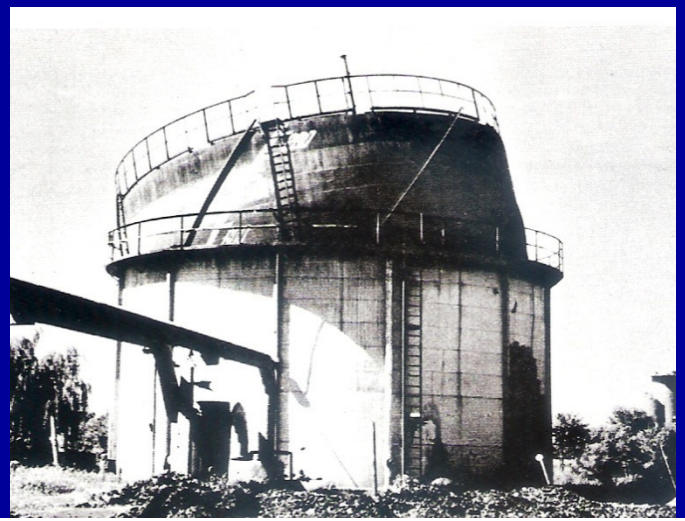
1 / 5



5.5 Industries facilities, oil tanks

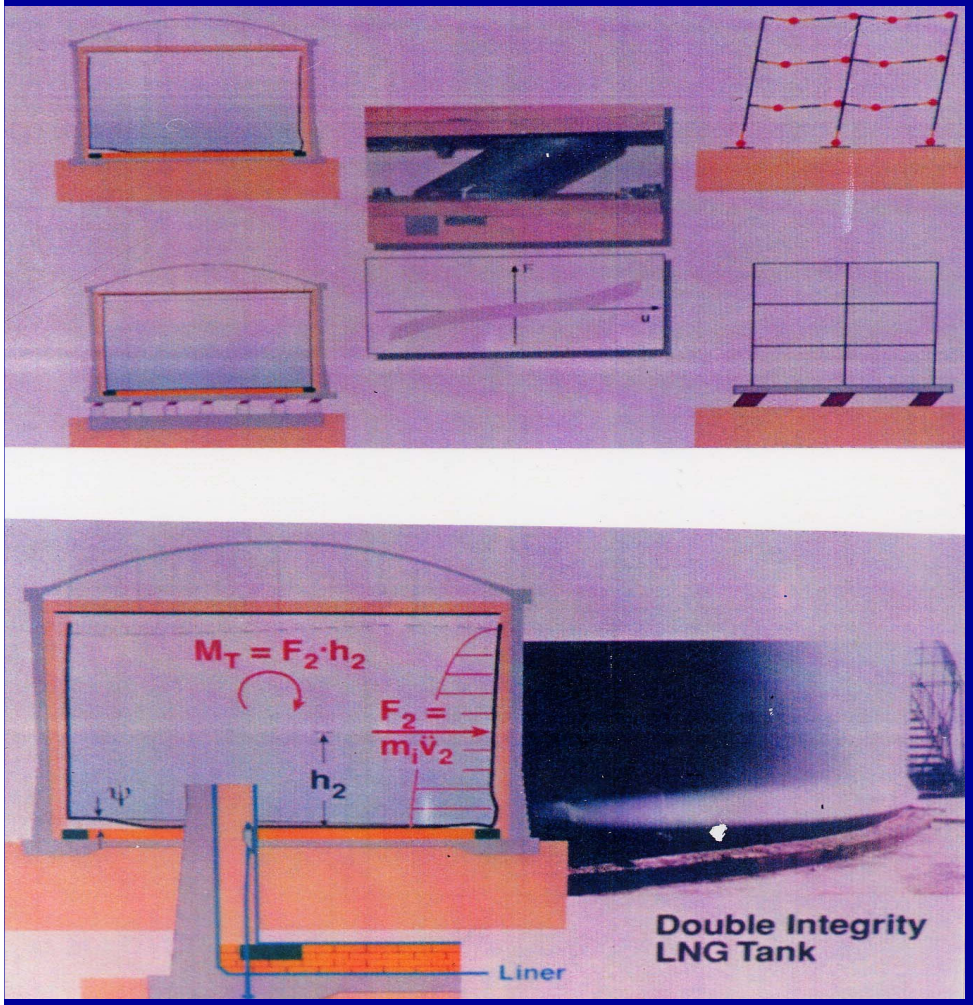
LNG Tank in Tanshan EQ in China

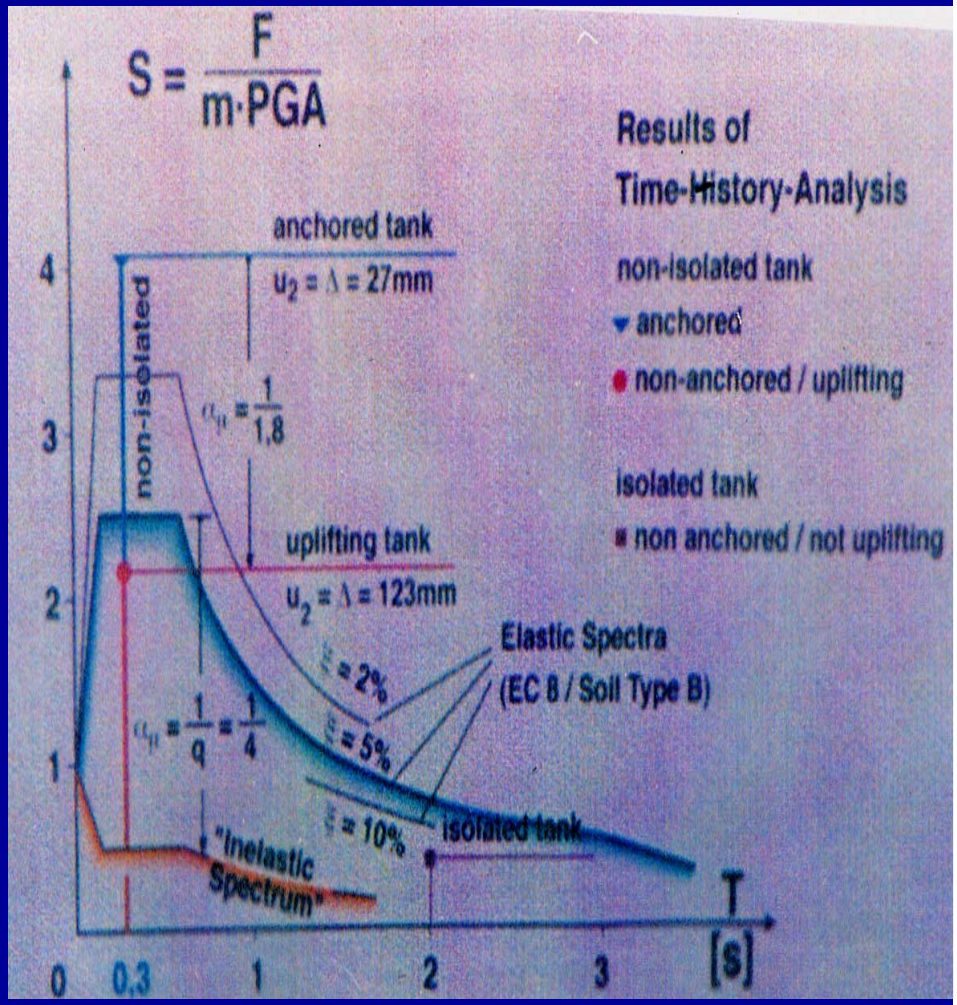




Seismic Isolation-Application in Oil Tank (3)

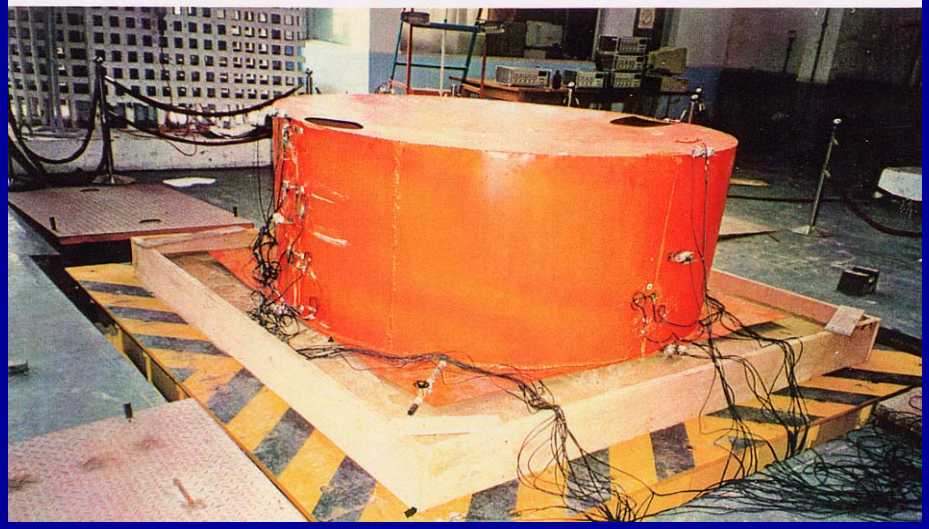
Concept of reducing response for using isolation

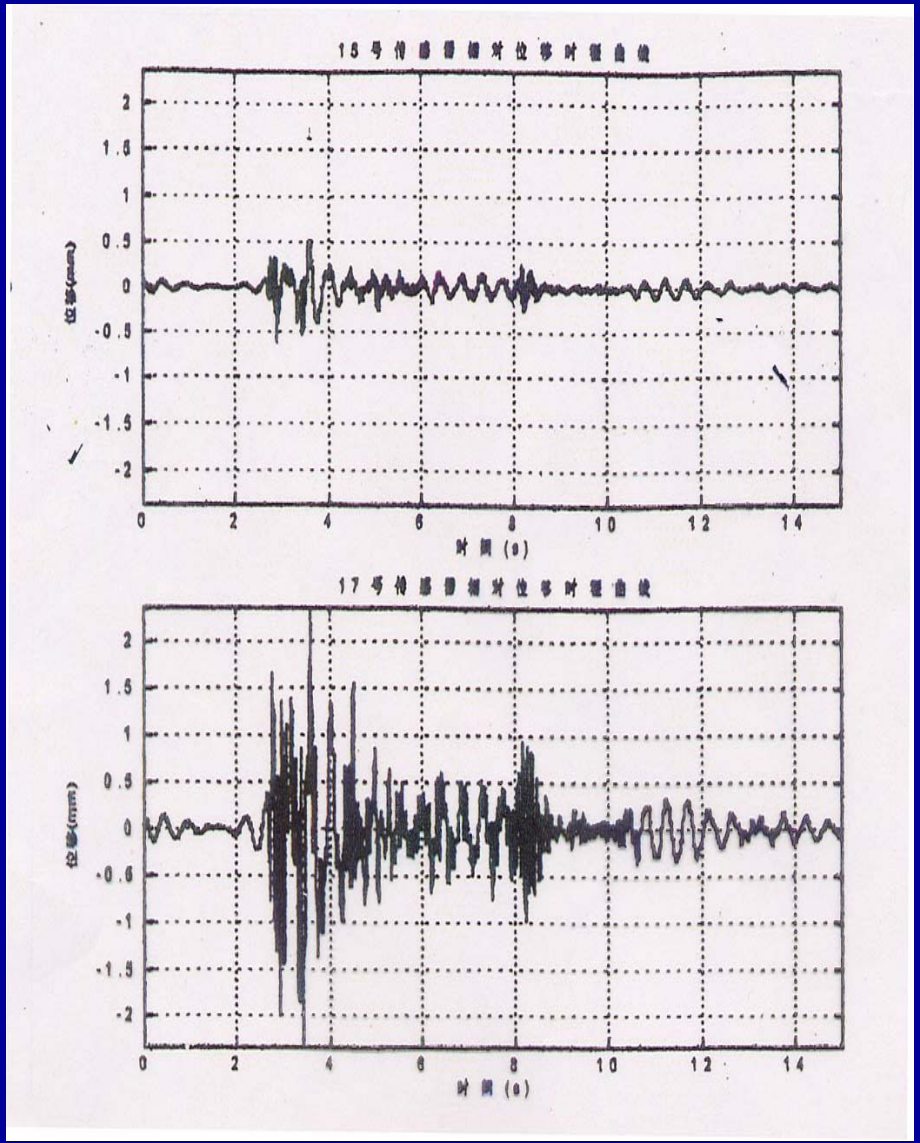




Shaking table tests for Isolation LNG tank in China

Guangzhou University 储油罐试验 广州大学 1998

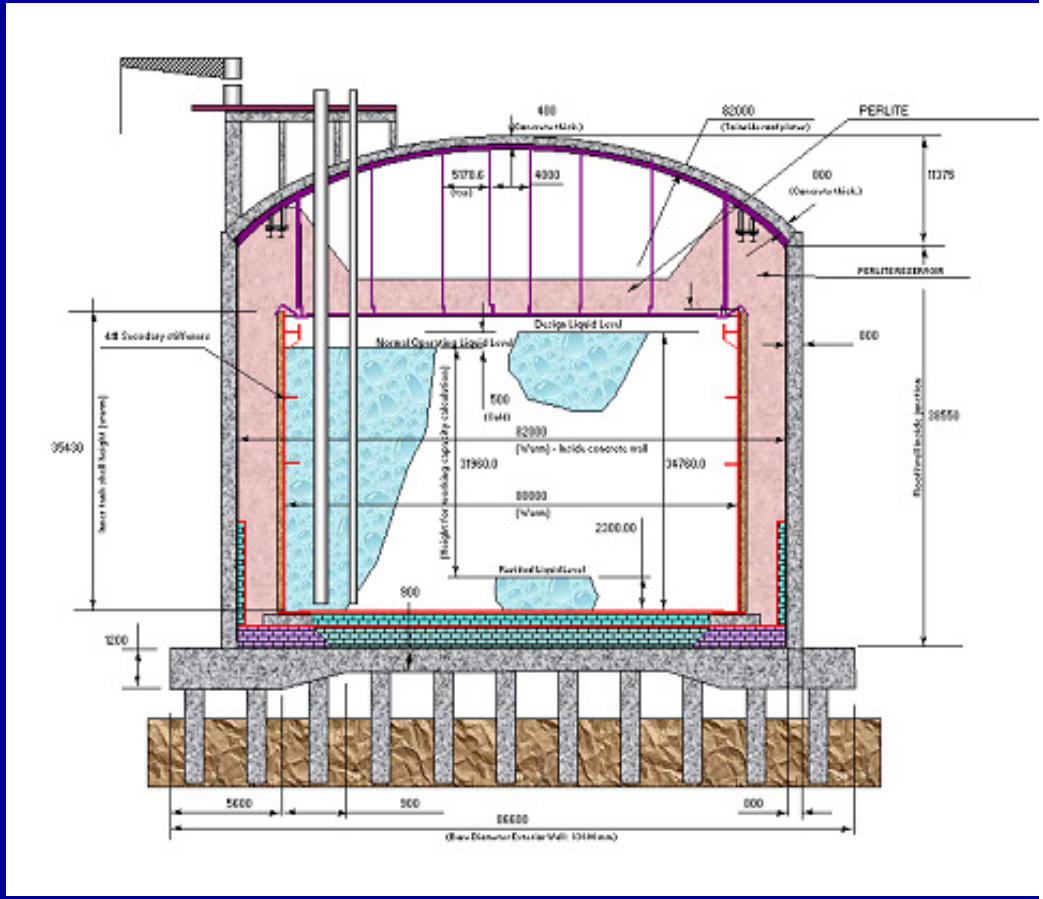




LNG Tank uses Isolation

Guandong, China
中国,广东省
D: 84m
H: 40m
Capacity: 160.000m^3
No of piles: 360 1.2m

Seismic zone: 0.37g

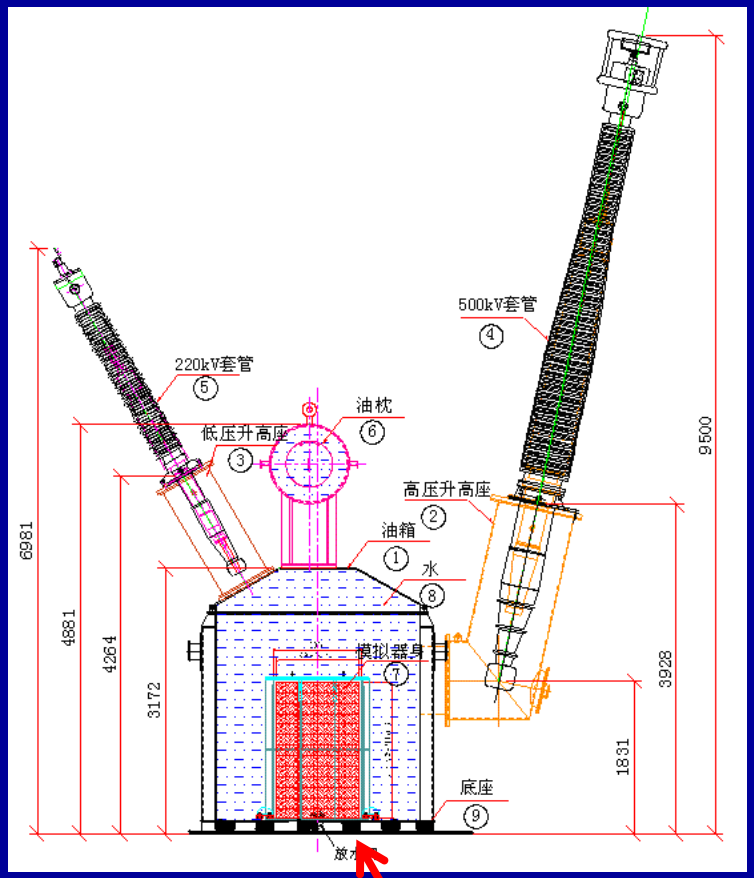


Bearings under the LNG tank

Using Isolation in Oil Tank 儲油罐 隔震

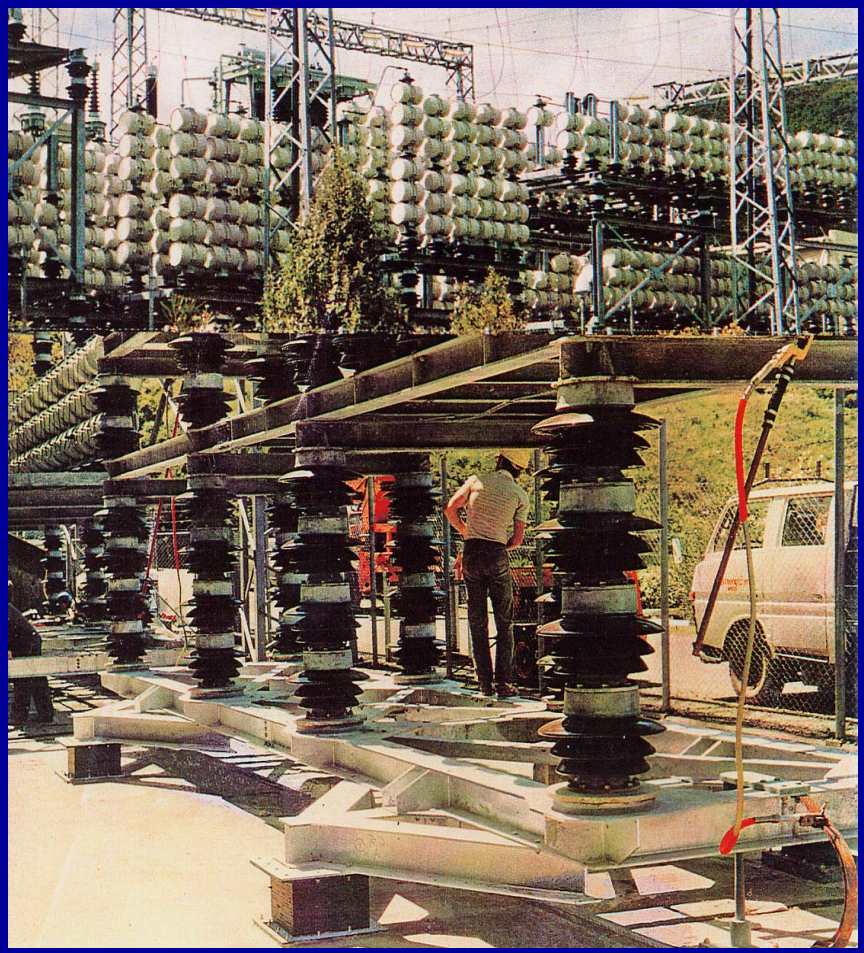
Rubber bearings
Isolators

Isolation for 500KV Transformer



Rubber bearings

Seismic Isolation for industry facilities

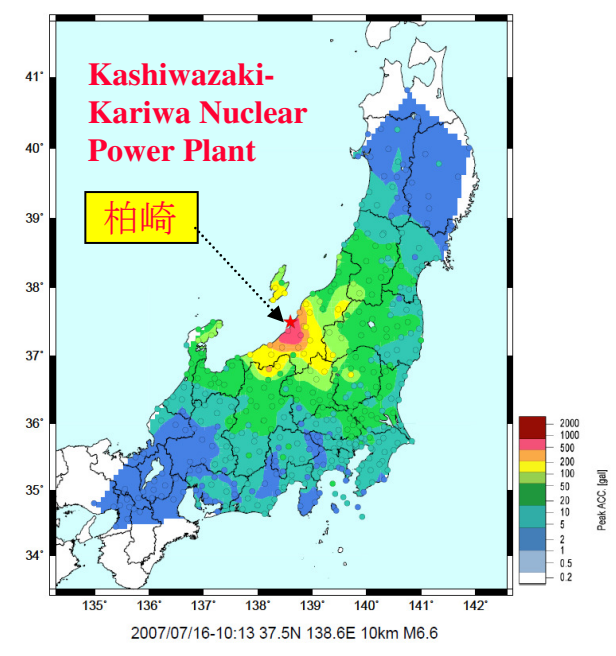


5.6 Isolation for NPP
Nuclear power plant

Applied to The Nuclear Power Plant

Advanced Institute for Materials Research

Niigataken Chuetsu-Oki Earthquake:July.16.2007



Design acceleration

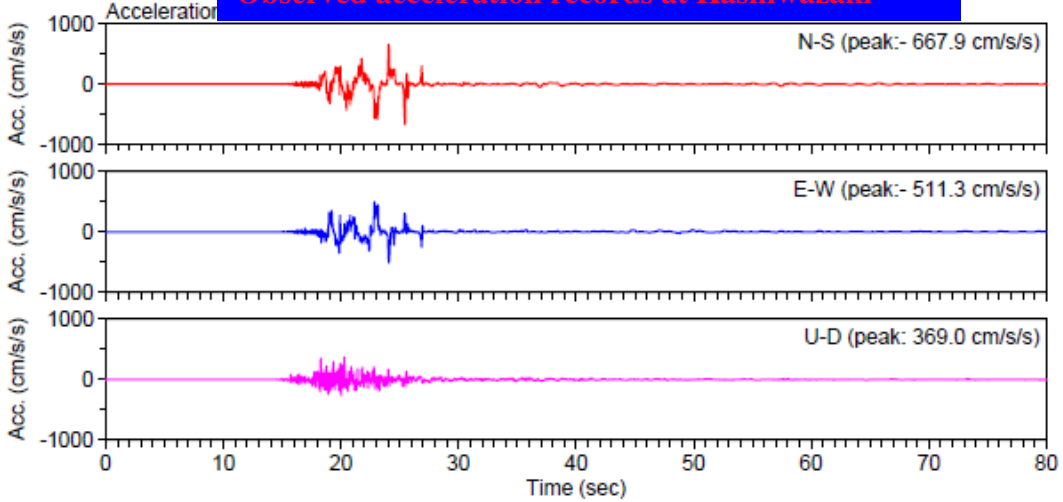
273 gal

Observed acceleration

668 gal

About 2.5 times acceleration at DESIGN

Observed acceleration records at Kashiwazaki



Damage by the Earthquake

The outbreak of the fire

The fall of a drum for waste storages

Applied to The Nuclear Power Plant

Advanced Institute for Materials Research

METI PROJECT for Isolated Nuclear Power Plant

Purpose

Safety improvement in the nuclear power plant

(The standardization of the nuclear plant design)

Project plan

Study period:2008 ~ 2016 years

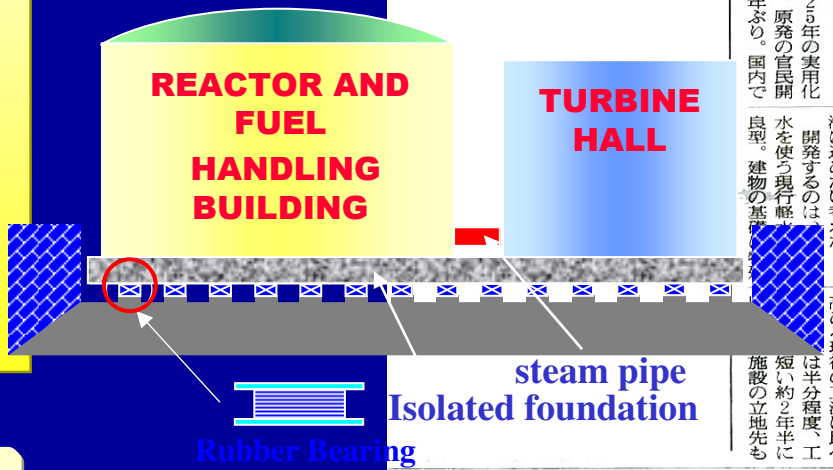
Study budget:60,000 million yen

Reactor maker & Construction company

Device maker

Practical use at 2016 year

The construction of the isolated nuclear power plant at 2016 year



「免震」原子炉開発へ

官民投資、25年実用化目標

経済産業省は、免震技術に基づく「揺れない」次世代原子炉の開発に着手する。来年度から8年間で官民折半により60０億円の研究開発費を投じ、2025年の実用化を目指す。原発の官民開発は約20年ぶり。国内で

は2030年ごろには既存原発が相次いで更新期を迎えるため、同省は早期に免震技術導入にめどをつけ、代替炉建設を円滑に進めたい考えだ。

開発するのは、水を使う現行軽良型。建物の基

ゴムを付けるなどして地震の揺れを吸収する免震技術を導入する。

実用化できれば、大量のコンクリートで強度を高める現行の工法に比べ

は半分程度、工短い約2年半に施設の立地先も

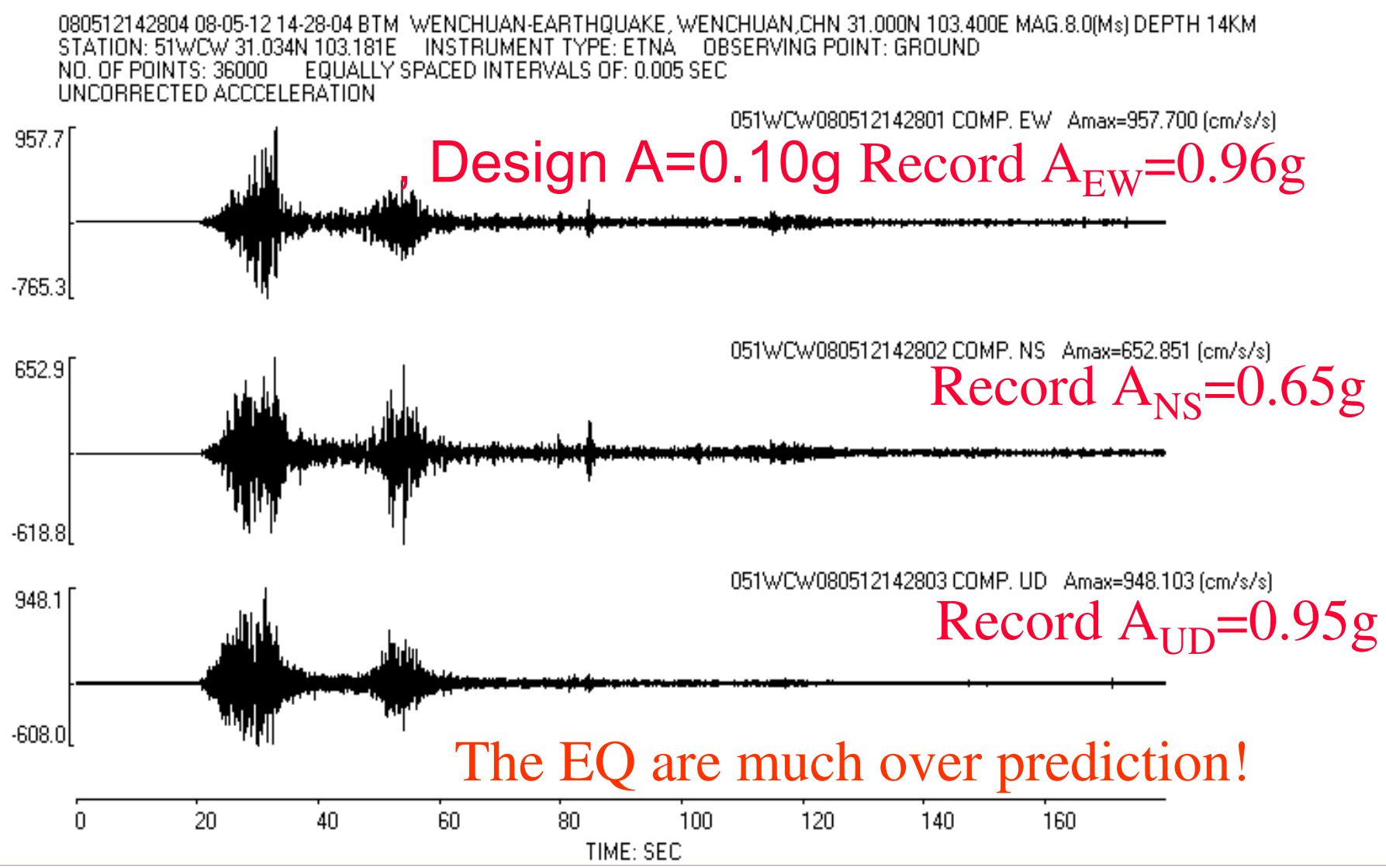
柔軟に選べるようになるという。

開発には、東芝、日立製作所など原子炉メーカーと、東京電力などの電力会社の計10社程度が参加する。各社が研究を分担し、同省は費用を半額補助して支援。来年度予算の概算要求には初年度分として約15億円を盛り込む。新潟県中越沖地震では、東電柏崎刈羽原発が設計時の想定の倍近い揺れに襲われ、トラブルが続出。安全性への不安も広がった。世界では地震多発国を含めて今後130基以上の新設が見込まれており、同省は「免震型を世界標準にしたい」としている。

2011.3.11 Japan E.Q.

Records of Wenchuan EQ 20080512

震中距18KM, 汶川卧龙台



, Design A=0.10g Record A_{EW}=0.96g

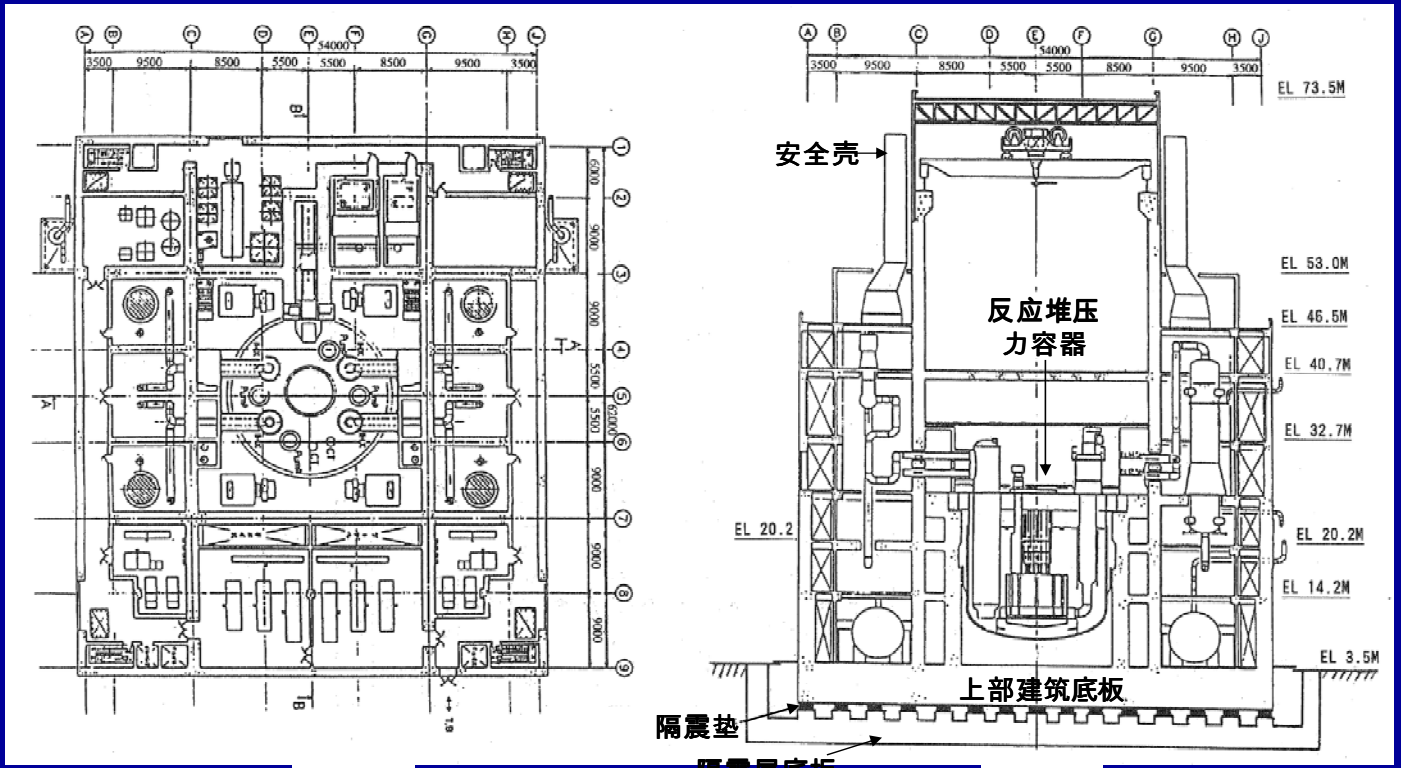
Record A_{NS}=0.65g

Record A_{UD}=0.95g

The EQ are much over prediction!

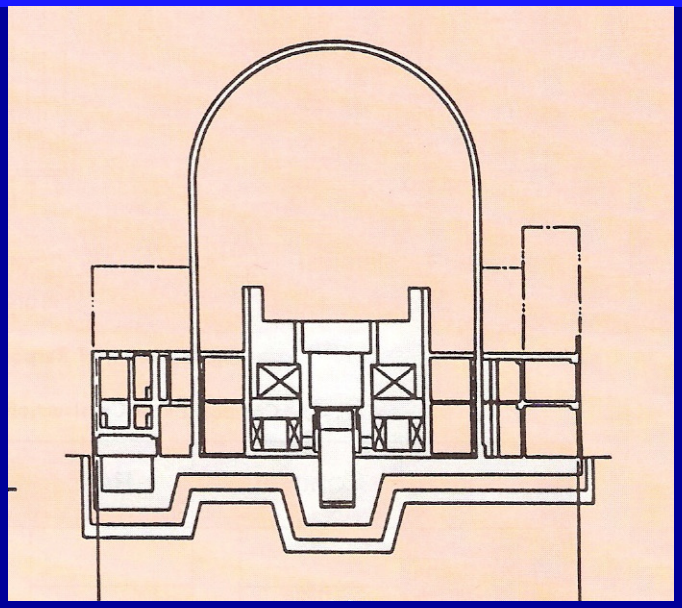
Seismic Safety for Nuclear Plant in China

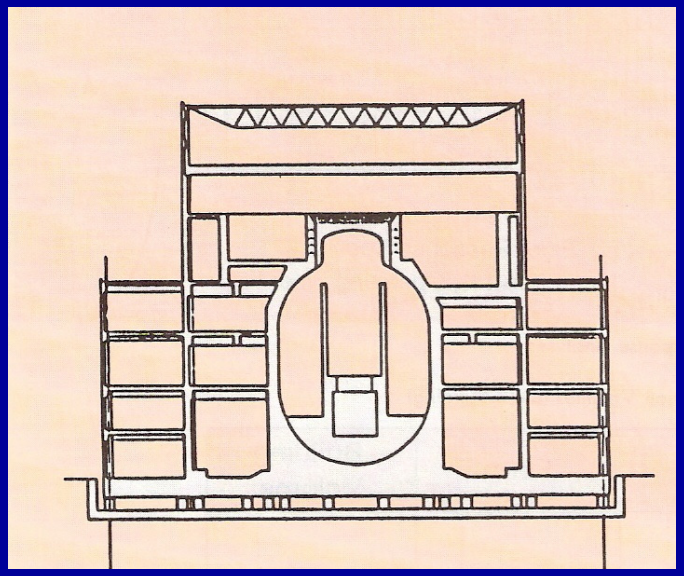
1. China have built 20 Nuclear plants.
   Plan to build 80 N.P in future 20 years
2. Nuclear plants do not allow to be damaged
   on both of Structures and facilities inside in any E.Q.
3. So, using Isolation technique is the best way!



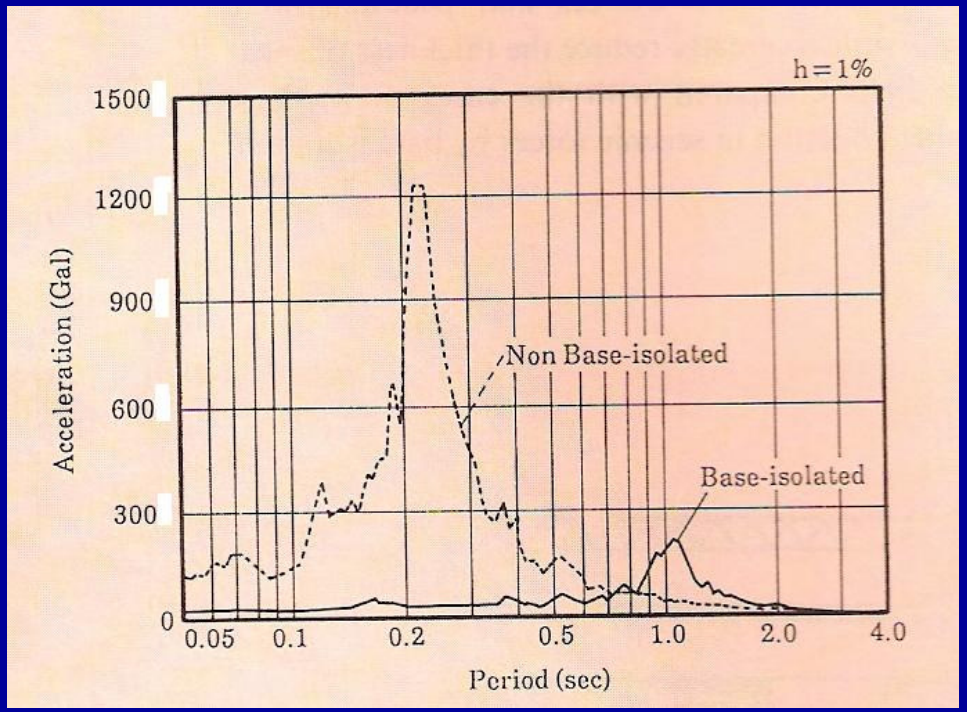
平面图　　剖面图

Seismic Safety for Nuclear Plant in China – Use isolation (After Wenchun E.Q. 2008)





National Plan: 2008-2013 (5 years)



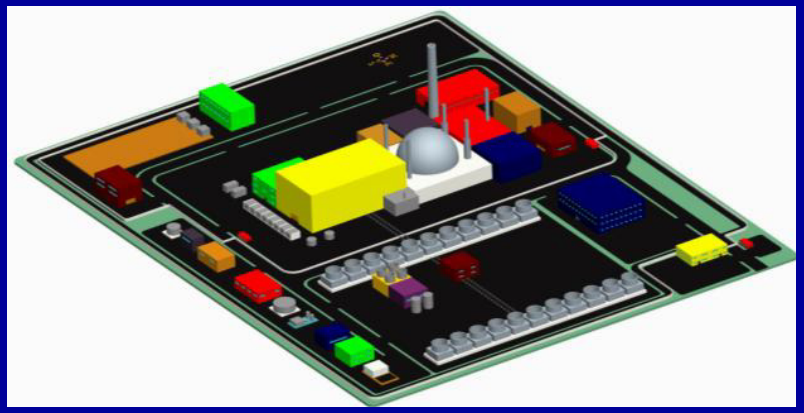
Base isolation Application to Reactors in the world

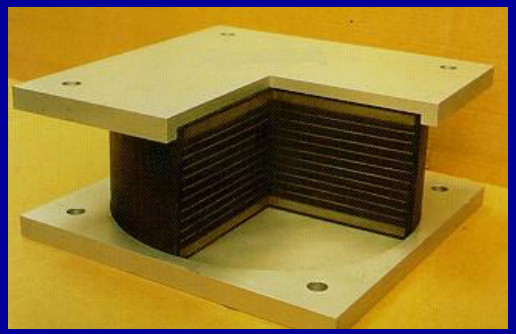
Aim:

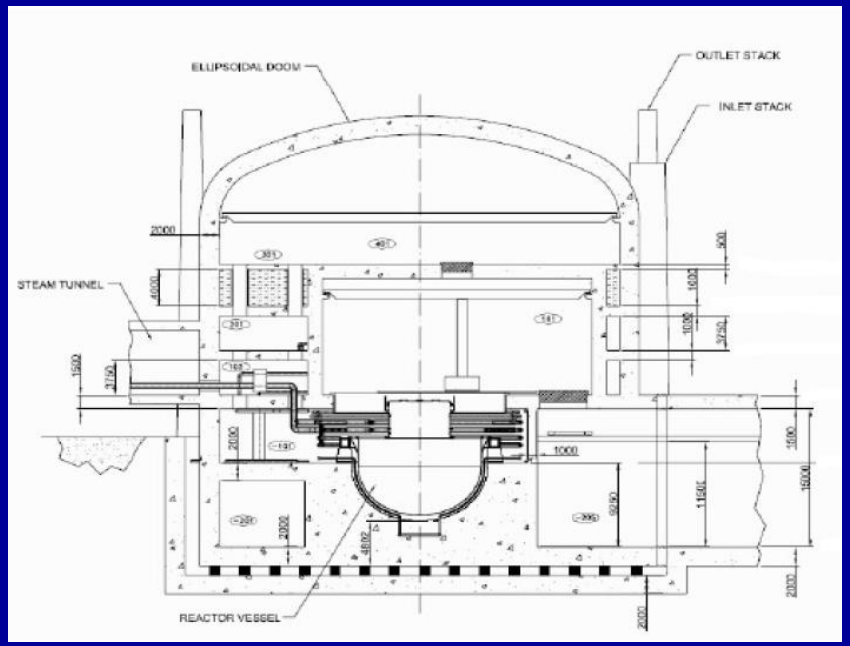
1.Lead to high level design standard SSE 0.3-0.6g

2. *in beyond design* seismic events 0.7-1.0g

3.Protect both on structures/component facilitie <0.2g



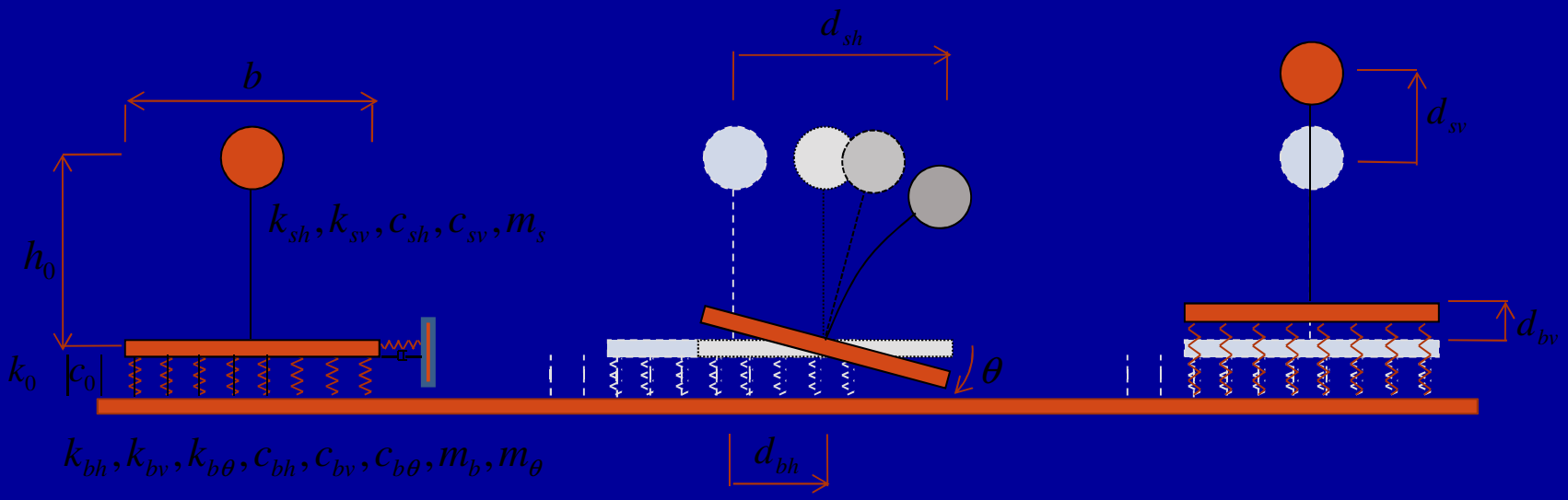


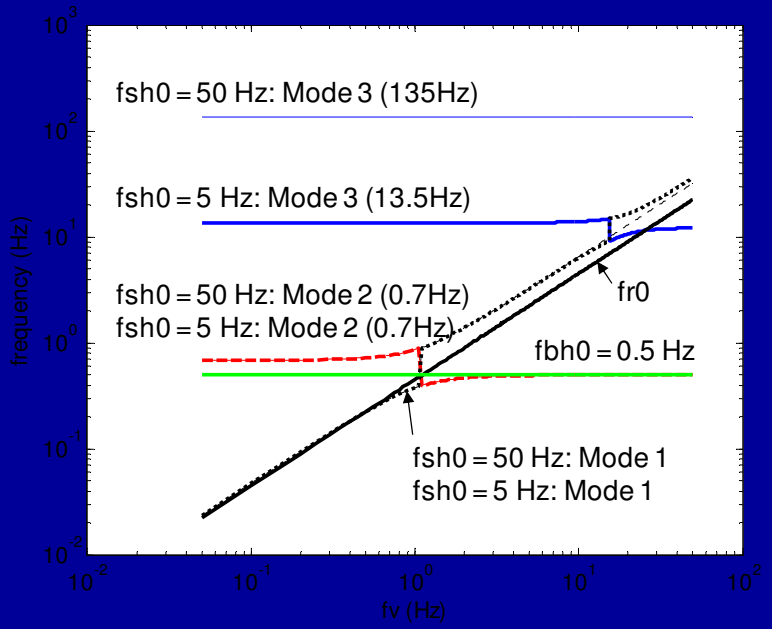


High Damping Rubber Bearing

Lead Rubber Bearing

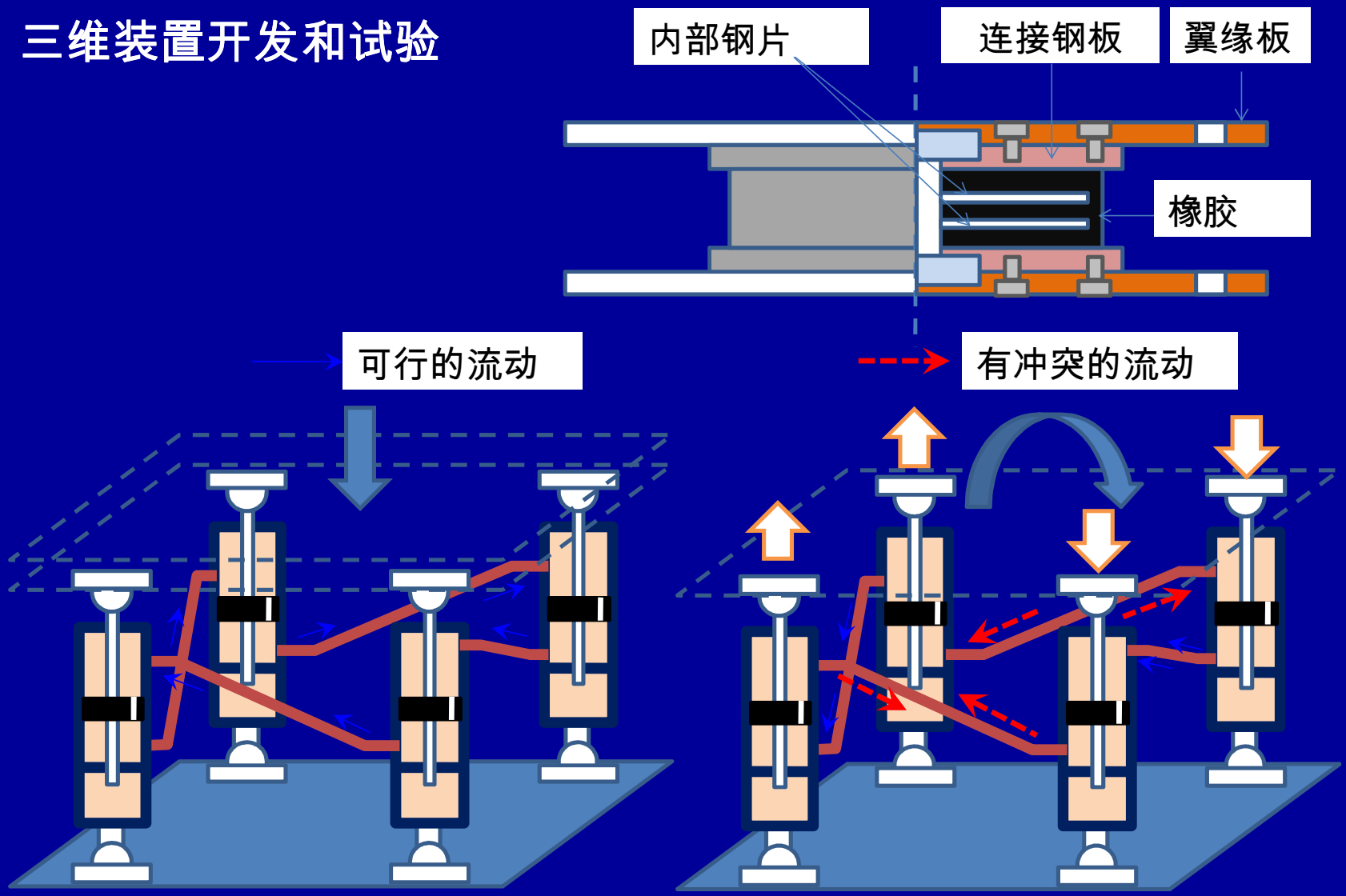
Model for 3D isolation in E.Q.





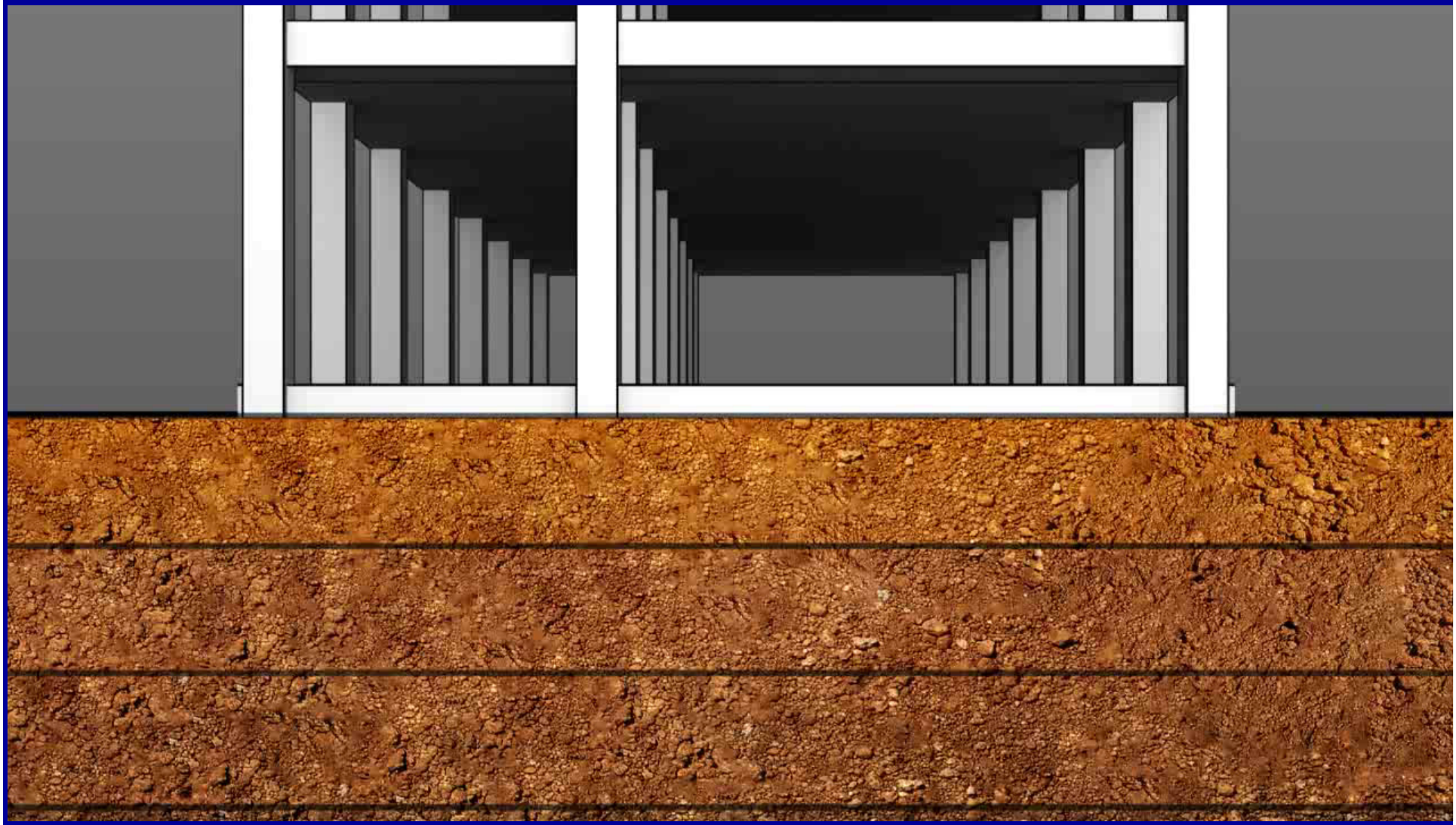
3D Isolator for Nuclear plant

三维装置开发和试验



5.7 Seismic Retrofit (about 100)

Retrofit for existed buildings with Isolation



Seismic isolation retrofit for school Buildings

1.Million of School buildings need to retrofit for E.Q.
2 Use Isolation to retrofit school buildings
3.Government held a National Meeting to extend it e

Isolation layer on different location (赖忠毅)

On ground

In basement

On the first story

Seismic isolation retrofit for school Buildings

山西省忻州市

For the 1st step
finished 24 schools buildings
Retrofit with isolation

Seismic isolation retrofit for school Buildings

山西省忻州市

For the 1st step
finished 24 schools buildings
Retrofit with isolation

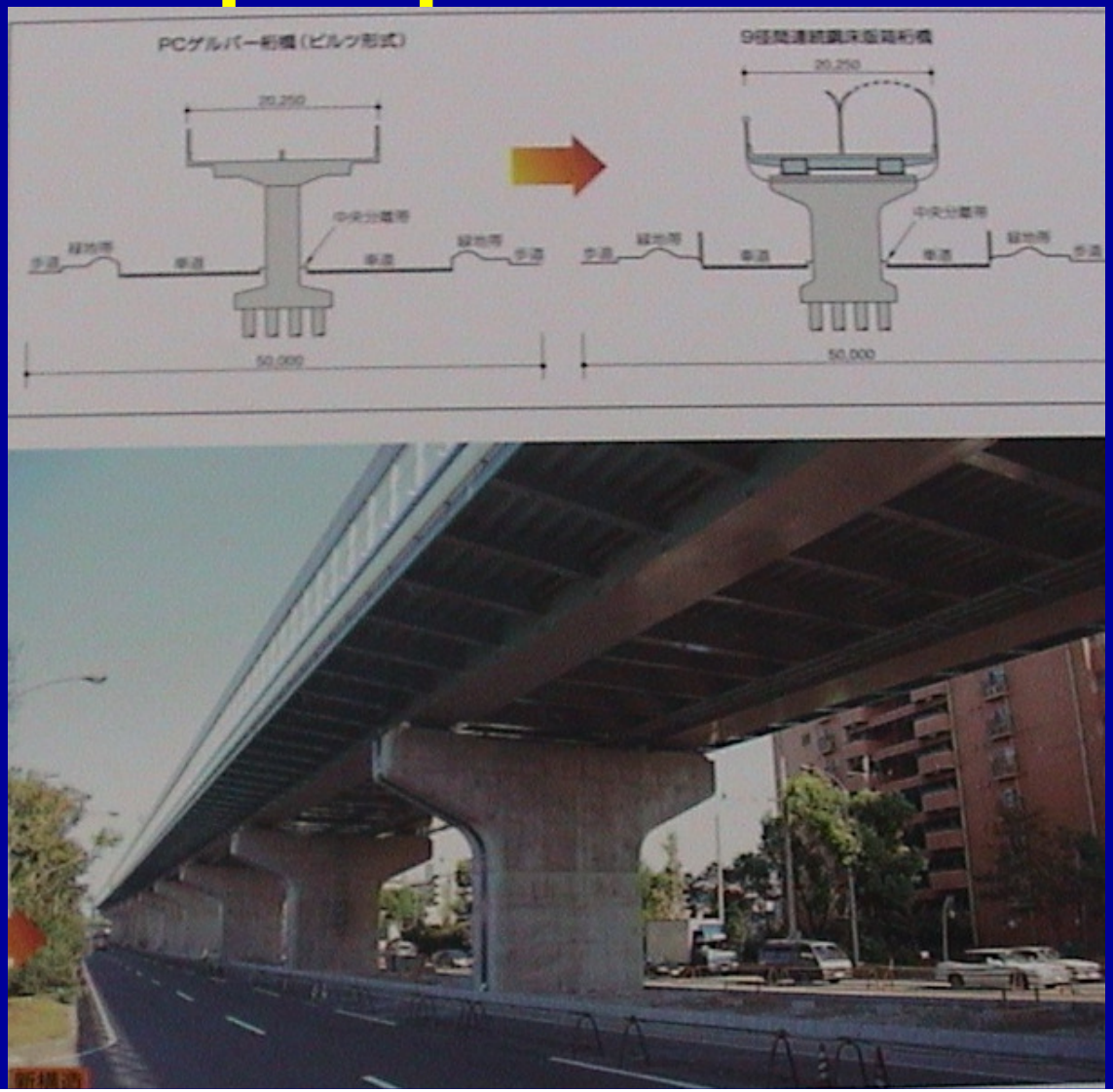

为学生健康发展导航奠基
唯
实
求
进
取
创


责任 行动 细节
建高质量校舍 育高素质人才
忻州田家炳中学

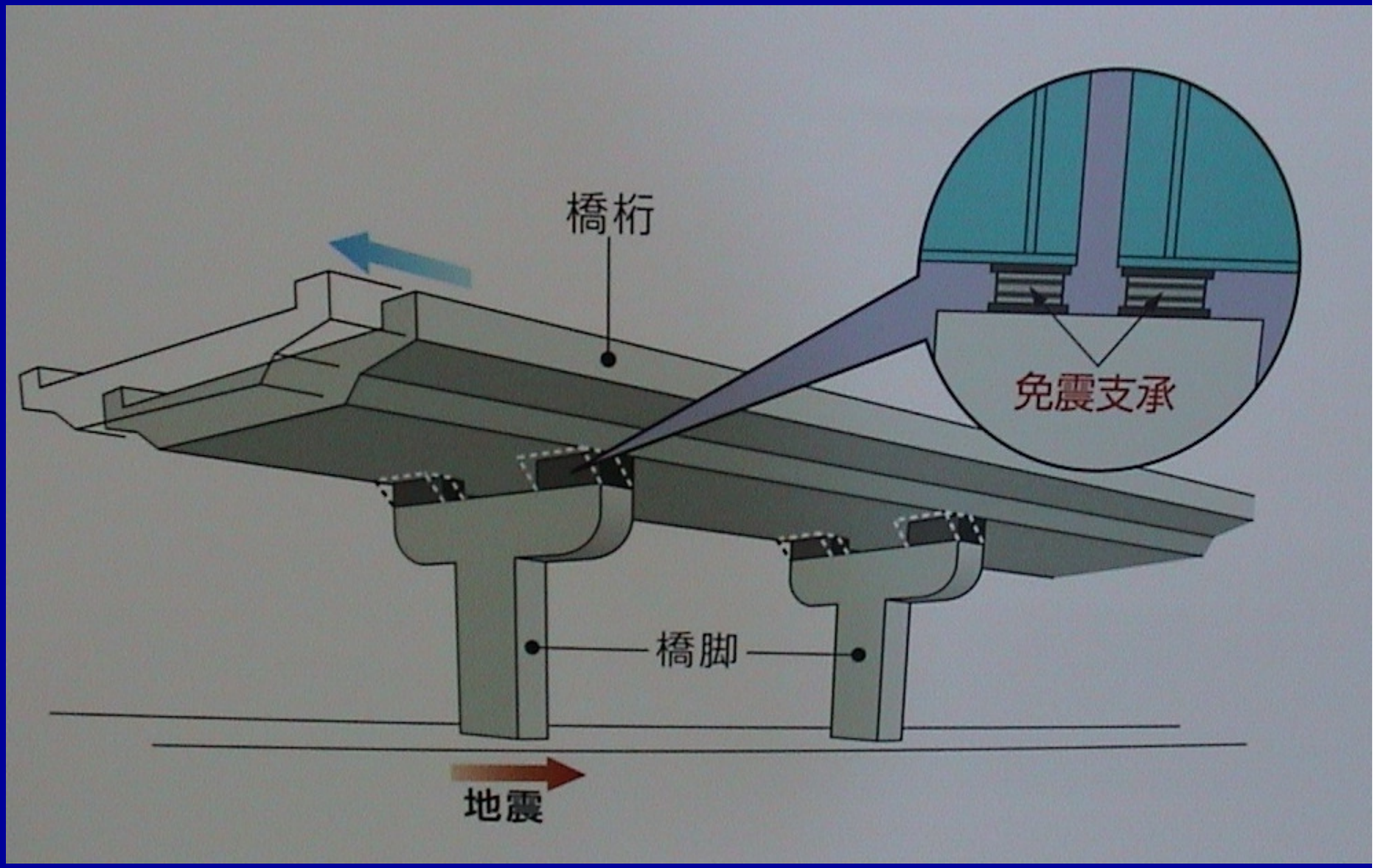
Seismic isolation Retrofit for bridges

桥梁震后 隔震加固

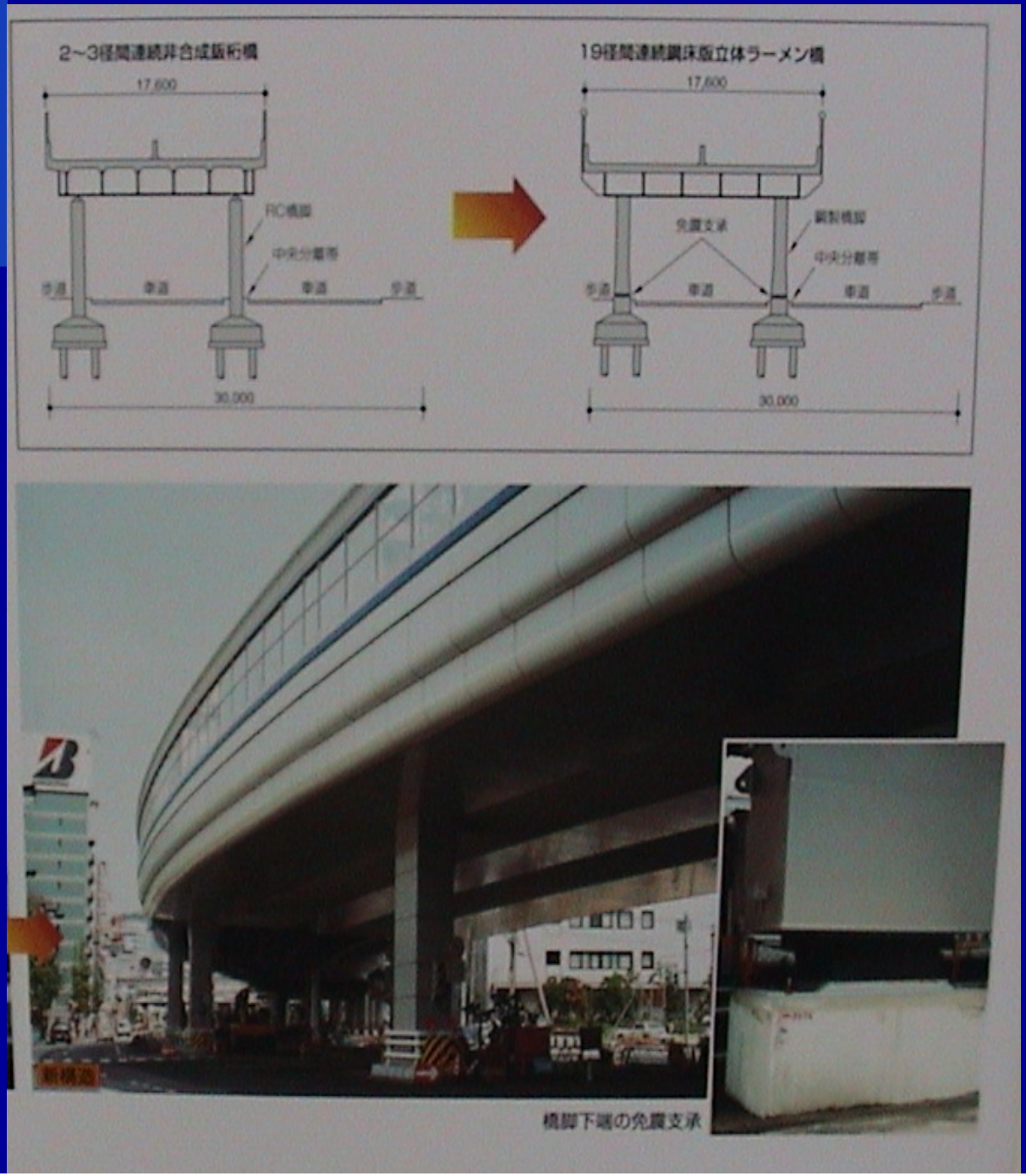
on top of pier 桥墩 顶部



on top of pier 桥墩 顶部



at bottom of pier
桥墩 底部



at bottom of pier 桥墩 底部

6. Isolation for low cost rural buildings

One of the Typical Rural house

Isolation for low cost rural buildings

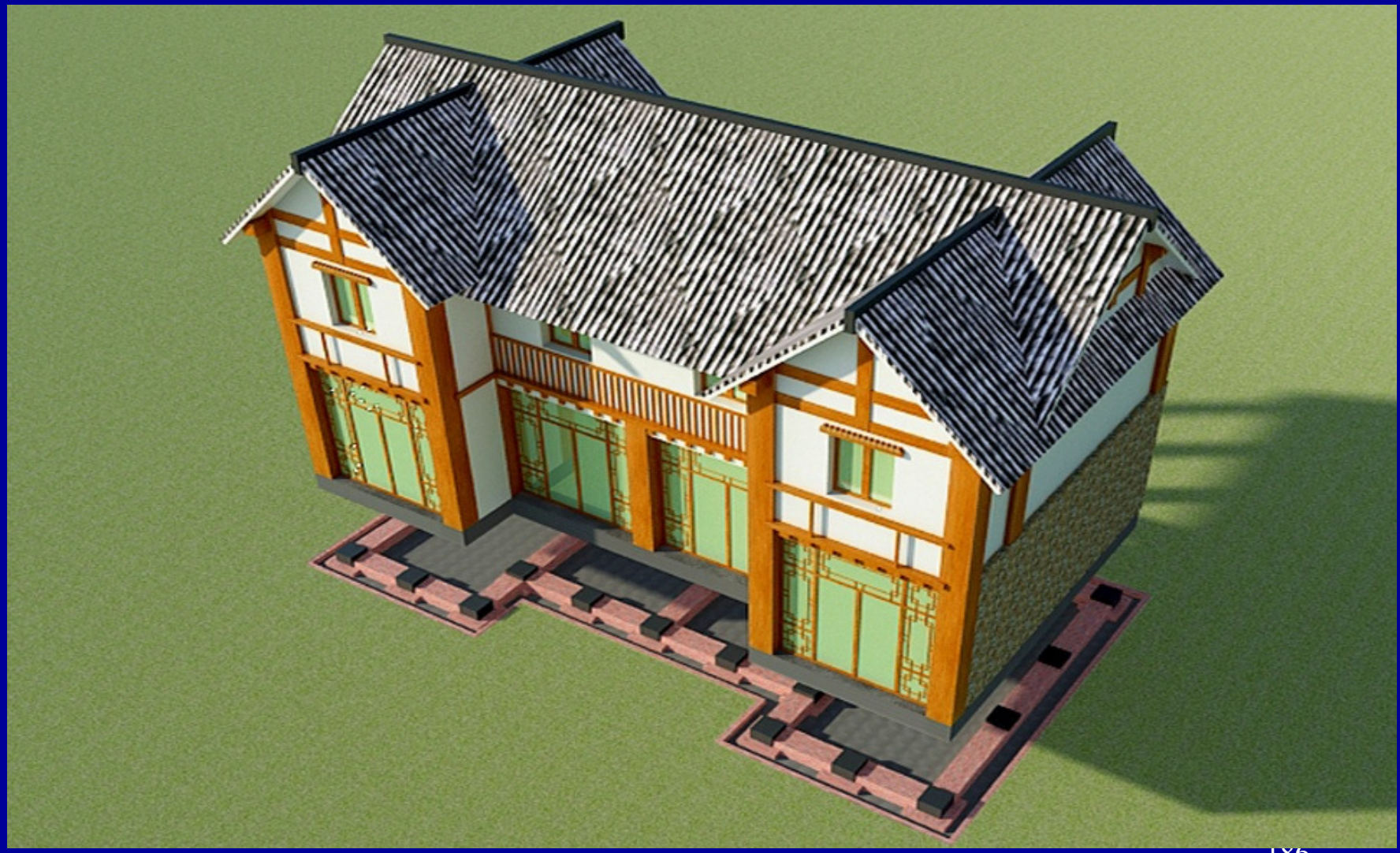
(1) Used for 1-4 stories masonry structure.

(2) Very simple construction

(3) Low cost, about 1/5 rubber bearings

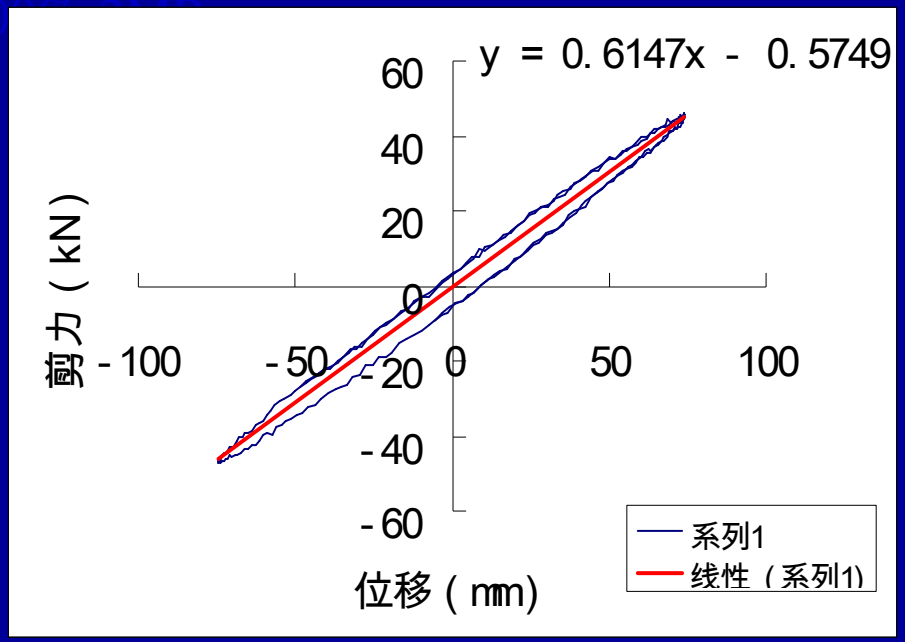
(4) Do not need any large facilities for const.

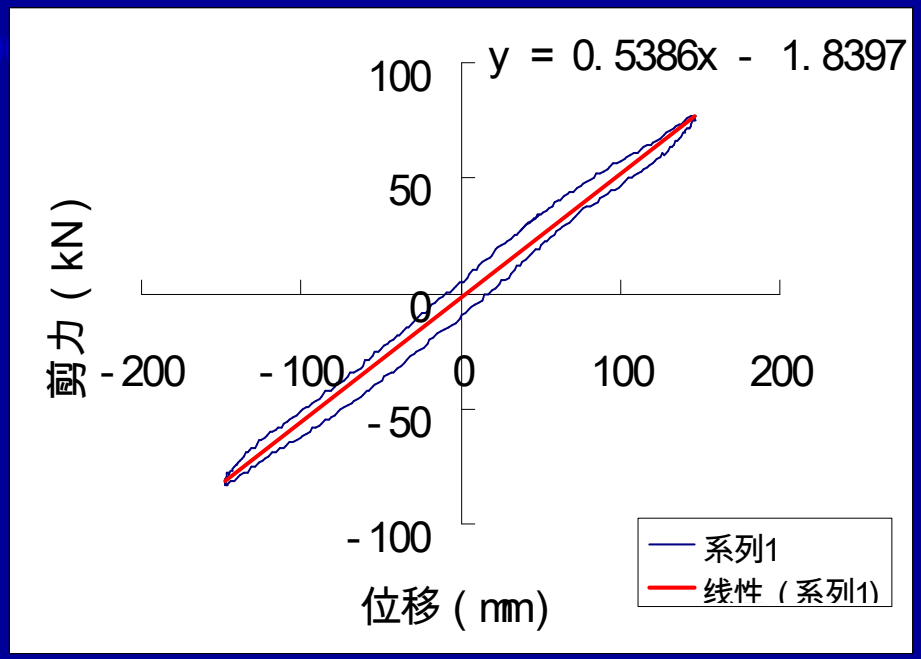
Rubber block isolators



Rubber blocks are very light, could move it by hands

Testing & Results

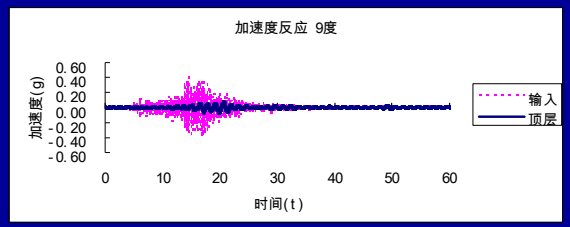


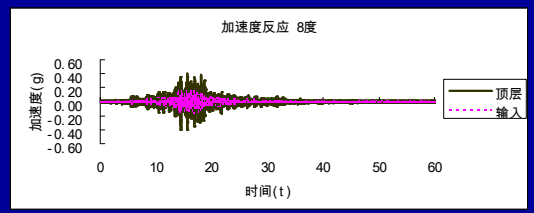


Stiffness
Damping
Displacement
Stability

Shaking Table Test for Rural house

Flower vase





Isolation
Ground = 0.40g
Struc. = 0.12g

No isolation
Ground = 0.4
Struc. =0.92g

Isolation / no Isolation = 1/8

7. Technical maturity of isolation technique

ISO for isolater 隔震支座 (2006)

Isolation Rubber Bearing 橡胶隔震支座

ISO 22762-1 Testing method
ISO 22762-2 Isolators for bridges
ISO 22762-3 Isolators for buildings

编制：中国,日本，美国…..主编（2001-2006)

Chinese National Standards for isolator

1. Seismic Isolation Rubber bearings
   (JG118- 2000)

2. Rubber Bearing (GB/T 20668-2007)
   Part.1 Seismic-Protection isolators Test methods
   Part.2 Seismic-Protection isolators for bridges
   Part.3 Seismic-Protection isolators for buildings

3. Dampers (2011)

Chinese National Design Code for isolation

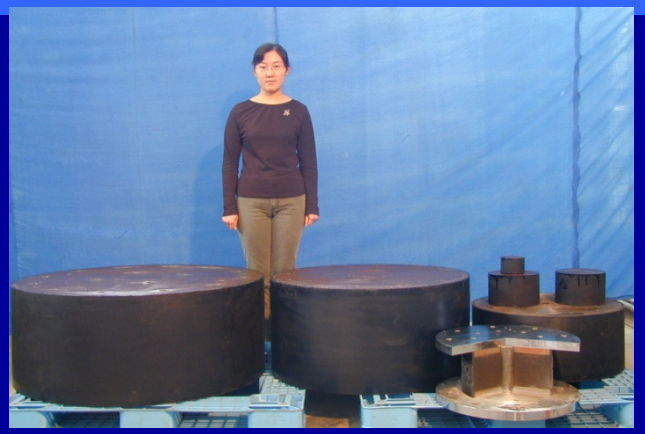
1. Seismic Design Code for Buildings
   (GB 50011--2010)
   Chapter 12 (Isolation and Energy Dissipation)

2. Technical Rule for Seismic Isolation
   with Laminated Rubber Bearing (CSCE :2001)

3. Technical Rule for energy dissipation (2011)

Chinese product
Large diameter RB isolators

(1) Rubber Bearing
Diameter ϕ300 ~ 1600 mm



(2) Ask products with
high quality also low price

(3) China has perfect testing
facilities for control quality

(4) Provide the needs for
China and other countries.

8. Future development tendency of isolation

Brilliant future of Seismic for structure

Structural isolation system is:

- More safe, even in over prediction EQ. iso/no iso=1/4-1/8.
- More effective protection for both struc. & facilities inside
- More effective to keep elastic state of stru.
- More economical, inexpensive, ±5 ~ 10%
- more Satisfied for irregular architectural design

The coming years:

- Traditional anti-seismic struc. still is main system
- seismic isolation will be one of main systems

The end

Thank you !