

Strong Ground Motion

- Date and time: 14:28, 5.12, 2008
- Location: Wenchuan, Sichuan, Province
- Magnitude: 8.0 (Ms)
- Depth: 14km (depth)
- Duration: 120s, very long
- Acceleration: $A_{EW}=0.96g$, $A_{UD}=0.95g$
large Vertical Component
- Death: 69,000+ 18,000= near 90,000
- Injury: 370,000
- Loss: 100s billion RMB

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A beautiful county before EQ

512地震前 美丽汶川县城



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The county Become a ruin after EQ

512地震 超烈度 汶川县城成一片废墟



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Whole county become a dead city

no people, no any sound, keep in silence



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Still have some animal in ruin city: cat, duck..

北川县城 死城中已无活人, 但仍有动物



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One best middle school in Wenchuan

RC Frame collapse

漩口中学——汶川县的最好中学之一
框架教学楼倒塌



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**The child play happily in school
just before EQ**



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Before EQ

北川县中学 (极震区)

After EQ

most of children are buried



**Mother is finding her son in school
妈妈找孩子, 地震超烈度, 学校一片废墟**



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People asked to be rescued

512地震后 汶川县城 百姓呼救



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**Japanese rescue group works hard on site
Make memorial meeting 5月17日 7:25 青川县, 日本救援队**



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**Classification of Buildings Damage
in Wenchuan EQ**

1. Whole building collapse 房屋整体倒塌
2. A part of building collapse 房屋局部倒塌
3. Serious damage, very difficult to restore
房屋损坏, 外表似完好, 但难完全修复
4. Structure no damage, but inside all failure
房屋完好, 内部设备仪器摔倒, 功能中断
5. Rural buildings all damage or collapse
农民自建房屋严重破坏或倒塌
6. Isolation buildings, perfect 隔震房屋, 完好无损

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1. Whole building collapse 房屋整体倒塌
512地震超烈度, 汶川县城 残垣断壁



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The 1st story of house collapse



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Wenchuan EQ 2008: much Over Predictive INTENSITY, 1st story of house collapse



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School buildings whole collapse
地震超烈度
现浇楼板 及预制楼板 整体垮塌



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**Wenchuan EQ
weak story in middle height collapsed**



Wenchuan EQ 2008: much Over Predictive INTENSITY, weak story in middle height collapsed



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2. A part of building collapse

房屋局部倒塌 (框架住宅, 近年建造, 破坏严重, 局部倒塌)



都江堰
商住楼

The weak first story is serious damaged

底框架房屋 柔性底层 导致破坏甚至倒塌



底层柱头破坏

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The weak first story is serious damaged

底框结构, 柔性底层 接近倒塌



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3. Serious damage, very difficult to restore

房屋损坏, 外表似完好, 但难完全修复



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高层框架结构 但装修严重破坏, 修复难



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Some buildings look well form outside

主体结构破坏轻微, 但装修严重破坏, 修复难



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**But damaged very serious inside,
very difficulty to restore**
框架住宅, 近年建造, 装修惨重破坏, 很难修复



4. Structure no damage, but inside all failure
The communication facilities are failure
even the building is only slight damaged
通信大楼破坏, 通信中断



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**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

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Bridges failure 桥梁 落桥



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**The electric power system damaged
输电线路**



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5. Rural buildings all damage or collapse

农民自建房屋严重破坏或倒塌

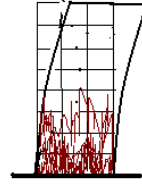


The weak first story destroy failure

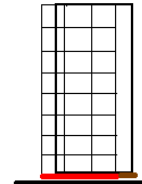


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Fixed Base → Isolated base Base Isolation is a good design concept



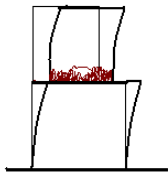
底部固定
结构弯剪摆动
结构底部破坏



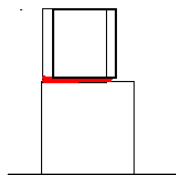
底部柔软层隔离
结构平动
结构完好

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Weak story → Isolated in middle stories story Isolation is a good design concept



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

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6. Isolation buildings, perfect 防震房屋, 完好无损 (Dr. Y.F.DU) In northern Sichuan, southern Gansu, Wudu 3 building with isolation

6 stories brick A=0.17g, 陇南武都县

1. Only feel slowly vibration T=2.6s 振动缓慢
2. No any facilities fall down 屋中家具、花瓶等完好
3. No any crack on brick wall in EQ 墙体无裂缝



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In northern Sichuan, southern Gansu, Wudu Many brick buildings A=0.17g, 陇南武都县 一般6层砖石房屋

1. People feeling shake very serious 振动激烈
2. Most facilities fall down 屋中家具、花瓶、电器等 倾倒
3. Cracks in brick wall after EQ 墙体开裂



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Wenchuan EQ. and Seismic Control of Structures in China

- ◆ Most of strong EQ are over prediction in China
1976.07.28 Tanshan EQ 0.05g → 0.85g, 15 times
- ◆ 2008.05.12 Wenchuan EQ 0.10g → 0.95g, 10 times
- ◆ Most people dead caused by buildings collapse
nearly 90 thousands people died in Wenchuan. EQ
people ask to live in the house that are still safe
when over prediction strong EQ happen
- ◆ EQ Cause severe damages of both structures and inside
facilities
people ask to use the technique that are effect to protect
both structures and inside facilities, for lifeline eng.
- ◆ So, a strong tendency of applying on seismic isolation &
control for structures after Wenchuan EQ in China

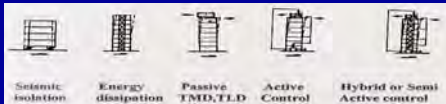
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Seismic Control of Structures in China

Application of Control technique in China

- Seismic Isolation : 690 buildings, 32 bridges
- Energy Dissipation : 85 buildings
- TMD or other Passive : 16 buildings or towers
- Semi- Active & hybrid control: 8 bridges & 5 Towers

Many projects are designing and constructing.



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2. Base or Middle Stories isolation system for buildings

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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 in China
- (5) Rubber block for rural buildings

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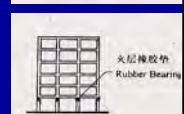
2. Stories isolation system for buildings

Different locations of isolation layer

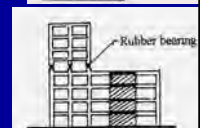
- (1) Base isolation
Basement isolation
(building with basement)



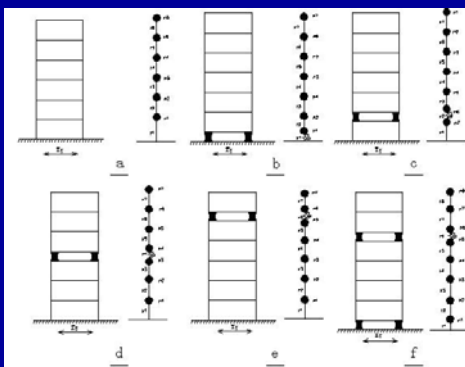
- (2) Middle Storyied isolation
First story isolation
(building without basement)



Stories in Middle high of structure
(on the stories which irregularly changing structural shape, mass or stiffness)



Models for Stories isolation systems



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Shaking table tests for Isolation structures

Base Isolation

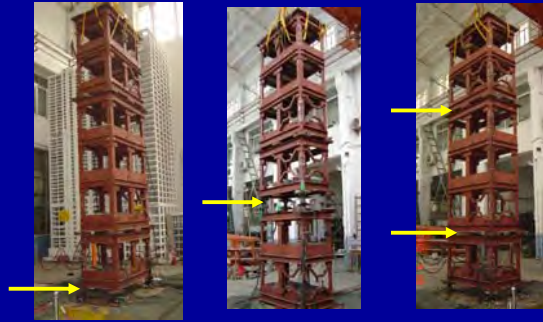


Stories Isolation



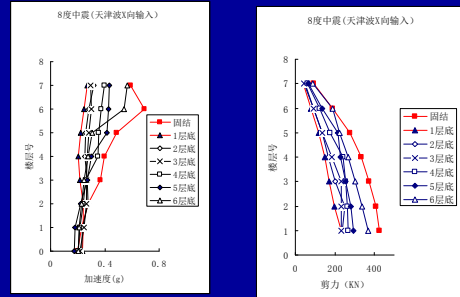
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Shaking table tests for Stories isolation systems
(Guangzhou University 广州大学 振动台试验) 2005



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Acceleration and Shear Force 加速度和剪力变化
Results: Shear F & A will be smaller with Hi is Lower
Effectively to reduce the response



Acceleration

Shear Force

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Seismic Isolation Houses buildings in southern China

Stories Isolation--Top of first story



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Seismic Isolation Museum in southern China

Stories Isolation--Top of first story



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Guangzhou City E.Q. Observing Center in southern China
with isolation layer at the top of 1st story
首层隔震 广州市地震监测指挥中心 2000年



Isolators 首层隔震

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Isolated buildings group--- Stories Isolation
-- The largest area of isolation in the world in 2003



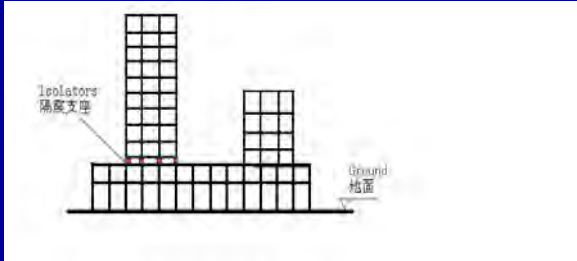
Isolation House Buildings group on Subway Hub in Beijing

- ◆ Large platforms (2 storie RC frame) with 1500m wide × 2000m long cover a railway area in Beijing City
- ◆ 30 isolation house buildings (7~9 stories RC frame) built on the top floor of the platforms
- ◆ floor area of all isolation buildings is approximately 200,000 M²

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New system of Isolated buildings structures

- ◆ **Stories-isolation** -- The rubber bearings layer is located on the top floor of the platform
- Guangzhou University Prof. Ping TAN, X. Y. HUANG,



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Isolated buildings -- the largest area in the world

One part of view



Another part of view



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Shaking table tests-- 1/25 model of isolation system



Stories-isolation

Isolation 隔震
no any damage

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

Isolation
Structural Acc.
结构 $A_s = 0.11 \sim 0.16 g$



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No isolation, severe damage, collapse

不隔震—严重破坏

不隔震
No- Isolation (Fixed)
El Centro (N-S)
(Transverse)
Ground Motion
地震 $A_g = 0.366 g$

Structural Acc.
结构 $A_s = 0.834 g$
Damage, Collapse

Comparison:
Isola./ Fixed = 1/4



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Shaking table tests – Compare testing



Isolation
Input 300 gal
Response 140 gal
Input 600 gal
no any damage

no-isolation
Input 300 gal
Response 720 gal
input 400 gal
Damage, nearly collapse

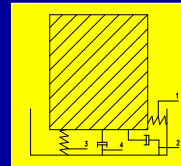
Significant benefits of using Stories Isolation in Beijing Project

1. Seismic safety increases to 4 times.
2. Construction cost save 7 %.
3. Environmental problems: railway vibration could be solved. Ask to use 3D isolation

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3. Three directions (3D) isolation for reducing vertical Vibration

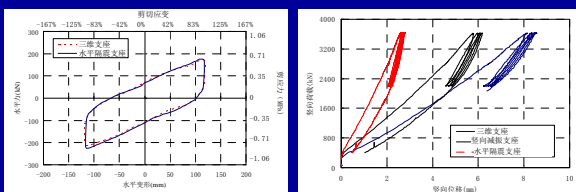
- General isolation, Horizontal Seismic only
- Vertical vibrations always occur by highway, railway, machines or others 地铁、铁路，环境 make people not comfortable 生活舒适度
- mathematics model for 3D isolation 计算模型



- 1:horizontal Isol. device
- 2:horizontal damping
- 3:Vertical isol. device
- 4:Vertical damping

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Mechanics Test for 3D Rubber bearings (Guangzhou University, China)

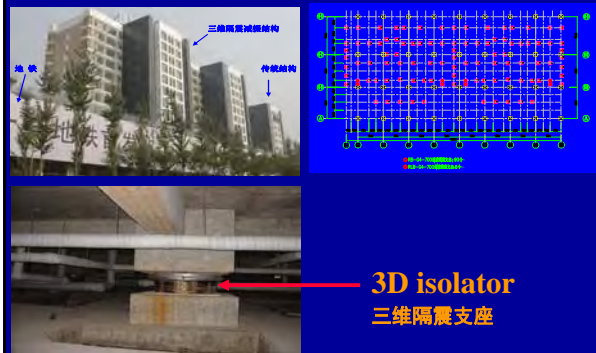


竖向刚度试验结果

竖向减振支座 K_{1v} (kN/mm)	水平隔震支座 K_{1h} (kN/mm)	三维支座 K_3 (kN/mm)
1131	2525	774

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Application of 3D Isolation in China (Beijing and Guangzhou)

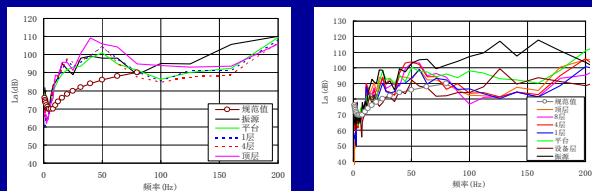


3D isolator
三维隔震支座

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Observer records in Sit for 3D Isolation

北京地铁 地面枢纽平台上 隔震住宅楼



No isolation system
传统无隔震结构

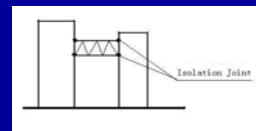
3D isolation system
三维减振结构

- Records: ● If no-isolation, Vibra. be amplified
传统结构对地铁振动放大，人感明显
- 3D reduce 50% of Verti. Vibra.

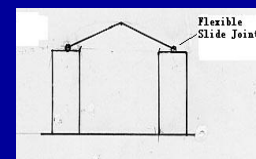
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4. Isolation for long span & space structures

Over bridge isolation between two buildings using isolation joint decouple the different model shapes of two buildings



long span space Isolation structures



Shaking table test: Traditional Rigid joint
 连廊 传统 固定支座 (广州大学, 广州市规划院)

固定节点
节点破坏

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Guangzhou Zhen Jia Plaza
 广州正佳广场 志诚商场连廊 2005
 (广州市设计院, 广州大学)

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Isolation for long span space structures
 Shanghai F1 Racing stadium (Tonji Univer. Prof. LU Xi Lin)

隔震支座

Long span 160 M
 To solve the Temperature deformation and E.Q problem

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Guangzhou Sport Stadium (Span 300M)
 Flexible Slide Isolation Joint 广州体育馆

Slide isolators
柔性滑动支座

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Guangzhou Sport stadium
 大跨空间结构——广州体育馆
 (广州市设计院)

Slide isolators
隔震支座

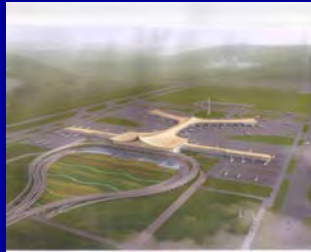
A large sport stadium structure with isolation and energy dissipation (Prof. W.Q.Liu 刘伟庆)

Floor Area 23,000 M²
 Response:
 isolation / no isolation
 1 / 4.2

20 9 16

Kun Min Isolation new Airport 2008-2010
(Design by Beijing Architectural Design Institute)

Floor Area 建筑面积:
360,000 M²
Rubber Bearings 支座:
1700 个
(ϕ 800~ ϕ 1000)
Oil Dampers 油阻尼器:
140 个
(行程 D= \pm 600mm,
阻尼力 F=150T)



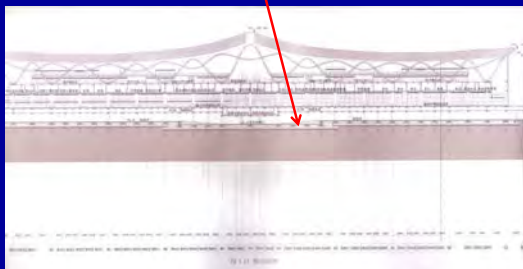
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Kun Min Isolation Airport



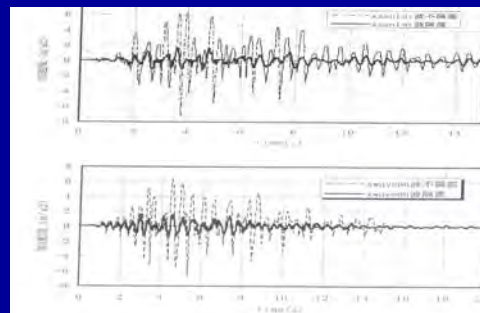
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Kun Min Isolation Airport
Rubber bearings & dampers



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Kun Min Isolation Airport
Time history analysis



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Kun Min Isolation Airport
Keep safety in large Earthquake



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5. Isolation for rural buildings in Contryside
乡镇房屋隔震橡胶块 隔震技术

- (1) Used for 1-4 stories masonry structure.
1-4层民房, 砖、石墙, 或地方材料
- (2) Very simple construction
要求施工简易
- (3) Low cost, about 1/5 rubber bearings
低造价住房
- (4) Do not need any large facilities for const.
交通不便, 免吊车, 免建筑机械, 普通工匠就可建造

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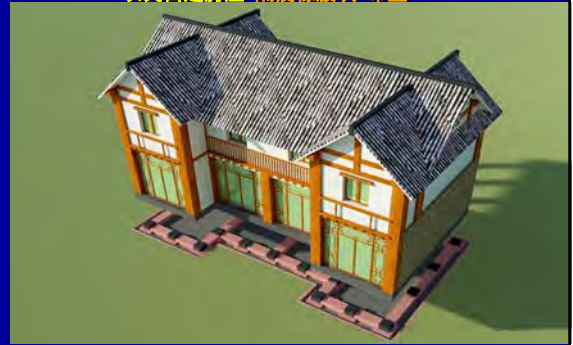
The Typical Rural house

某乡镇农民自建房屋



Rubber block isolators

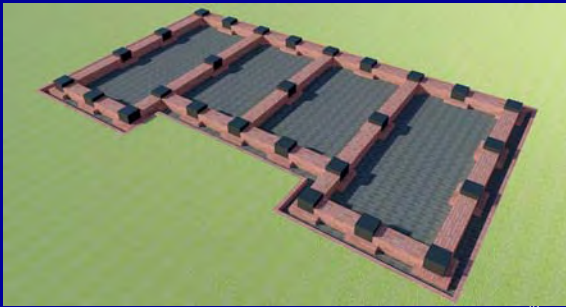
农民自建房屋 隔震橡胶块 布置



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Rubber block isolators

农民自建房屋 隔震橡胶块 布置(1)



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Rubber block 隔震条产品



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Rubber blocks are very light, could move it by hands

隔震条 重量轻 手可搬动铺设, 免吊车



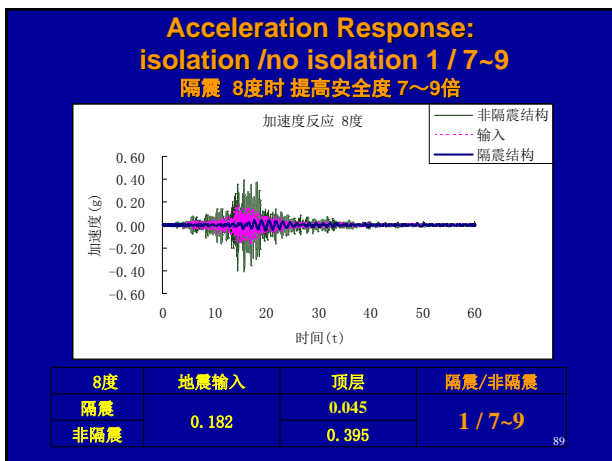
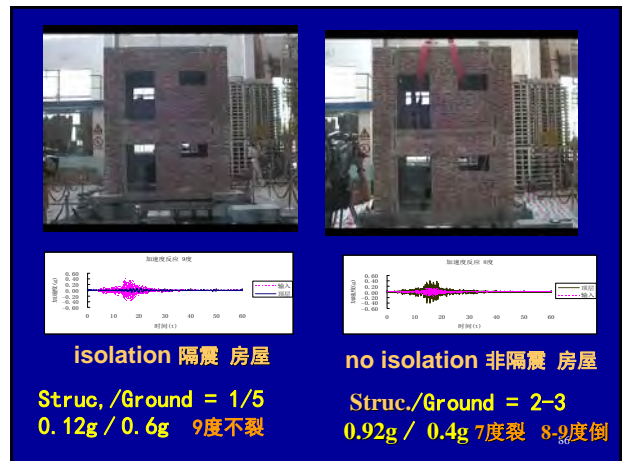
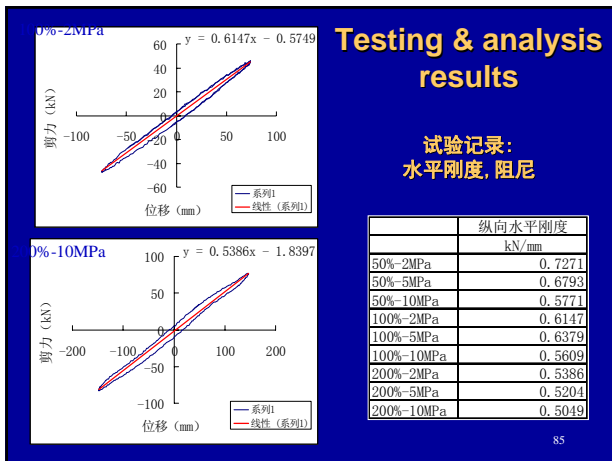
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(M) Rubber block testings

隔震支座压剪性能



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School isolation buildings

四川 绵竹 遵道镇 遵道学校
隔震楼将成为
大地震避难所




隔震展览室



Hospital isolation buildings

四川 绵竹 遵道镇
遵道卫生院 隔震楼
2008. 12. 31 finished 建成启
将成为大地震中
安全的 急救中心





Kindergarten isolation buildings

四川汶川县威州镇第二小学, 第一幼儿园(8栋)
(隔震) 2009年5月7日 封顶建成

广州市对口援建汶川县第二小学工程



Isolation school

四川汶川县第二小学(威州镇)
隔震支座 (橡胶支座+部分滑板支座)



Isolation school, small columns

隔震房屋, 上部结构地震作用 按降1度设计
柱配筋小, 免剪力墙, 造价降 17%



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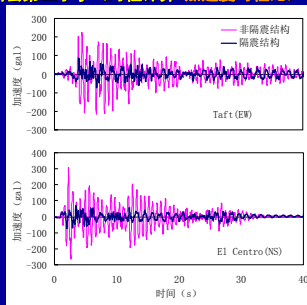
no isolation buildings big columns, thick wall

四川汶川县第一小学(非隔震)
按8度抗震, 9度构造,
柱配筋很大很密, 剪力墙很多很厚,
平面使用受限, 造价提高17-25%



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**Acceleration Response:
isolation / no isolation 1 / 6**
汶川县第二小学 (时程计算: 加速度时程比)



顶层加速度反应 隔震/抗震=1/6

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**Brilliant future of
seismic isolation & control for structure**

Structural isolation & Control system is:

- ▶ More safe, even in over prediction EQ.
- ▶ More protection for both struc. & facilities inside
- ▶ More effective to keep elastic state of super stru.
- ▶ More economical, inexpensive, $\pm 5\%$
- ▶ more Satisfied for irregular architectural design

The coming years:

- ▶ Traditional anti-seismic struc. still is main struc. system
- ▶ seismic isolation & control will being one of main system

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The end

Thank you !

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Announcement

**11 th World Conference on Seismic
Isolation, Energy Dissipation and
Active Vibration Control of Structures**

**Sponsored by
Anti-Seismic Systems International Society
(ASSISi)**

**November 17-21, 2009
Guangzhou, China**

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