Seismic Isolation Buildings in Japan

May 2017

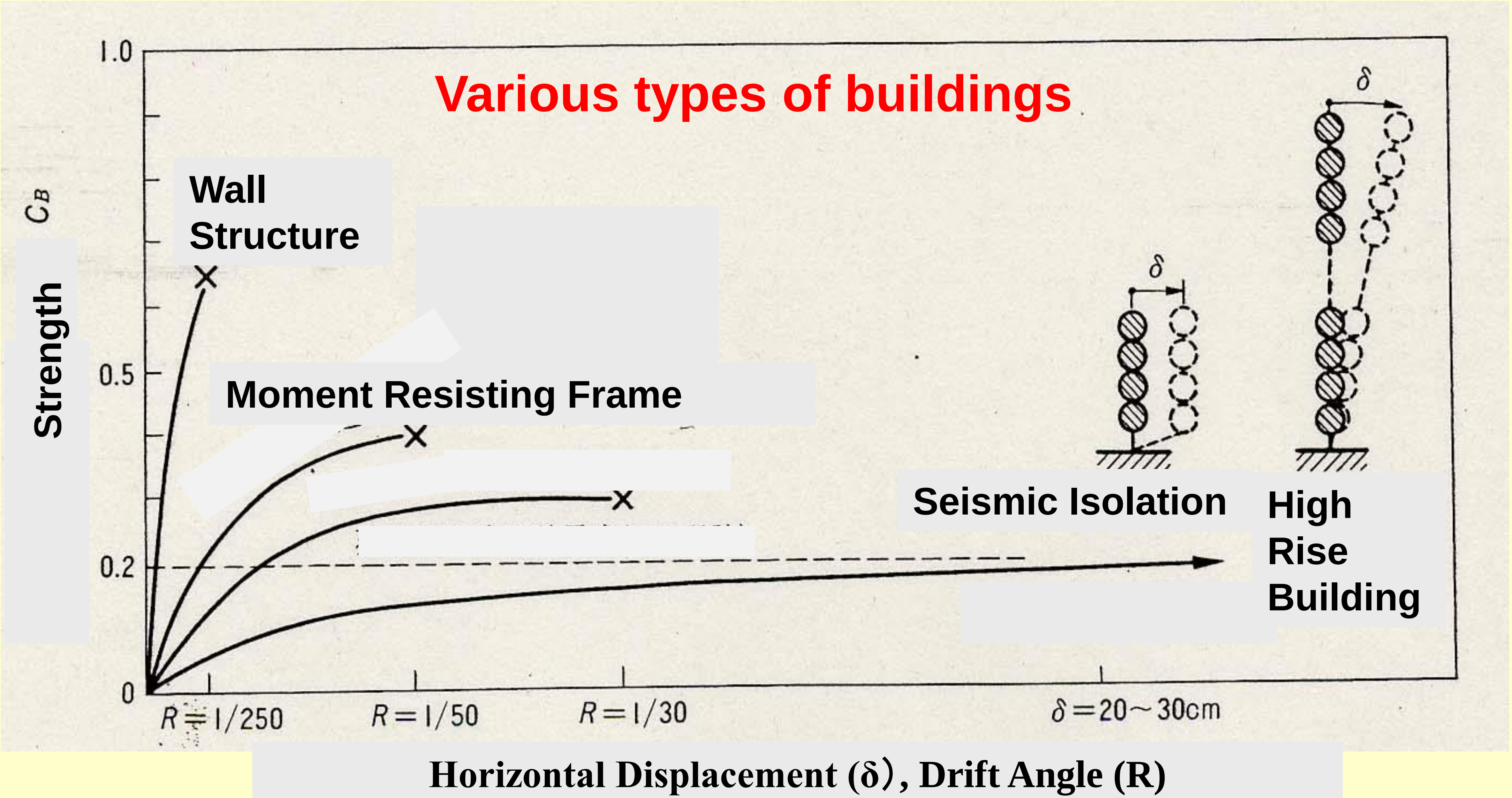
Building Research Institute, Japan

Matsutaro SEKI

Seismic Isolation Buildings, Japan

Contents

Principle of Seismic Isolation



Strength vs. Horizontal Displacement

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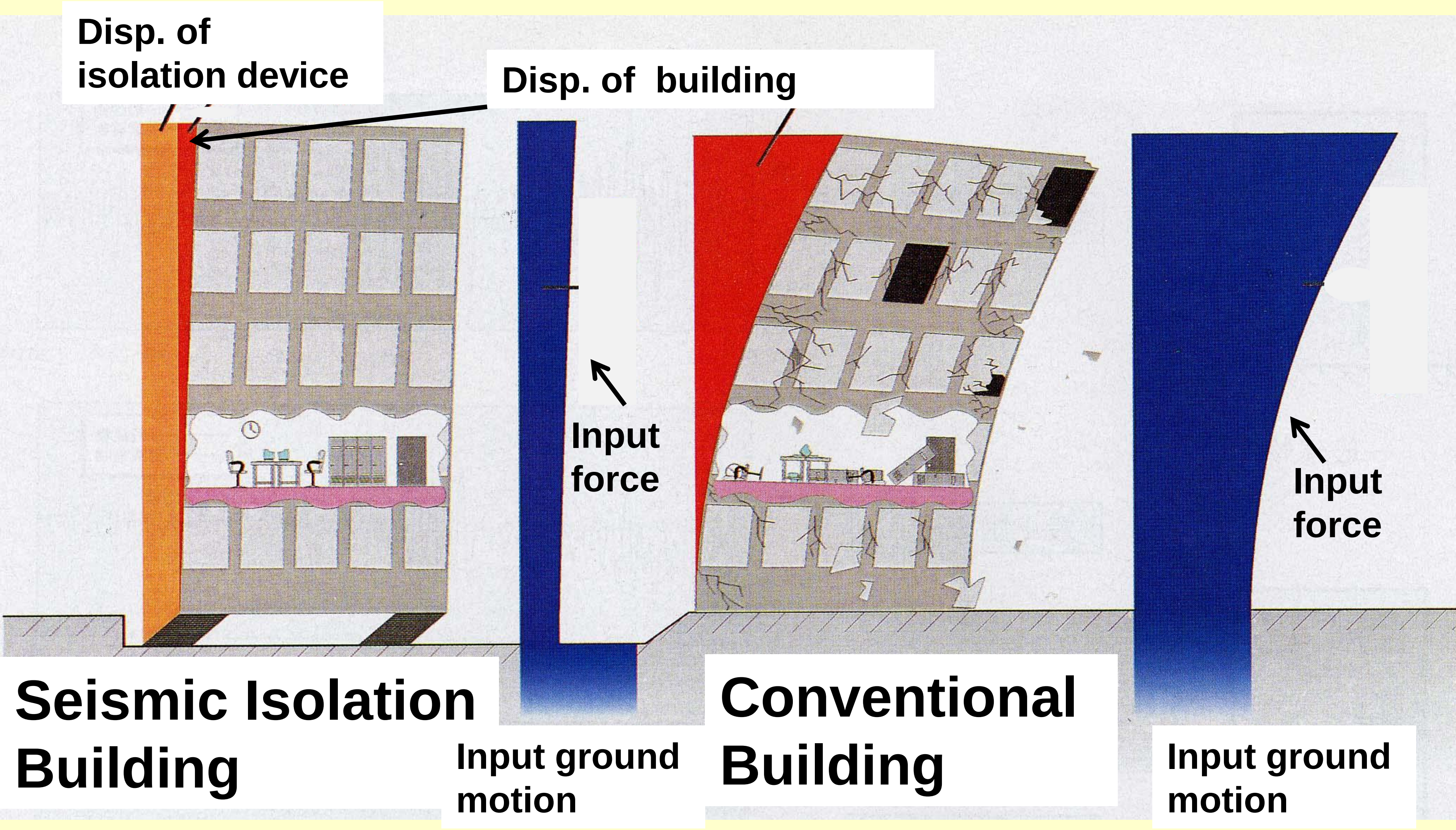
Principle of seismic isolation



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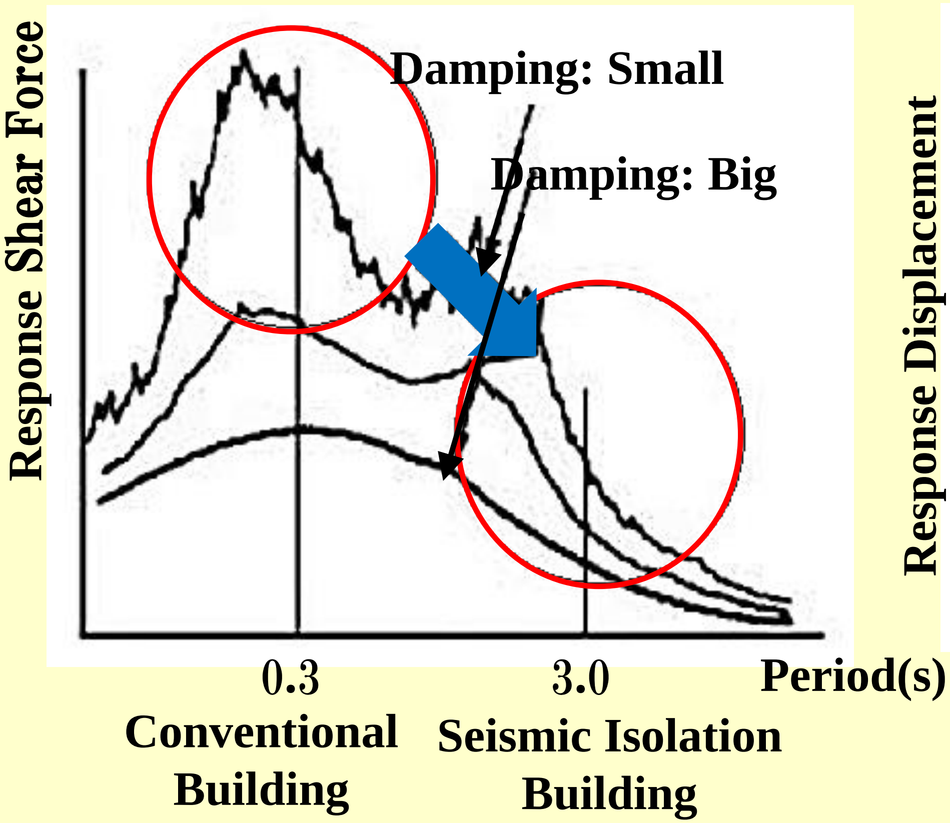
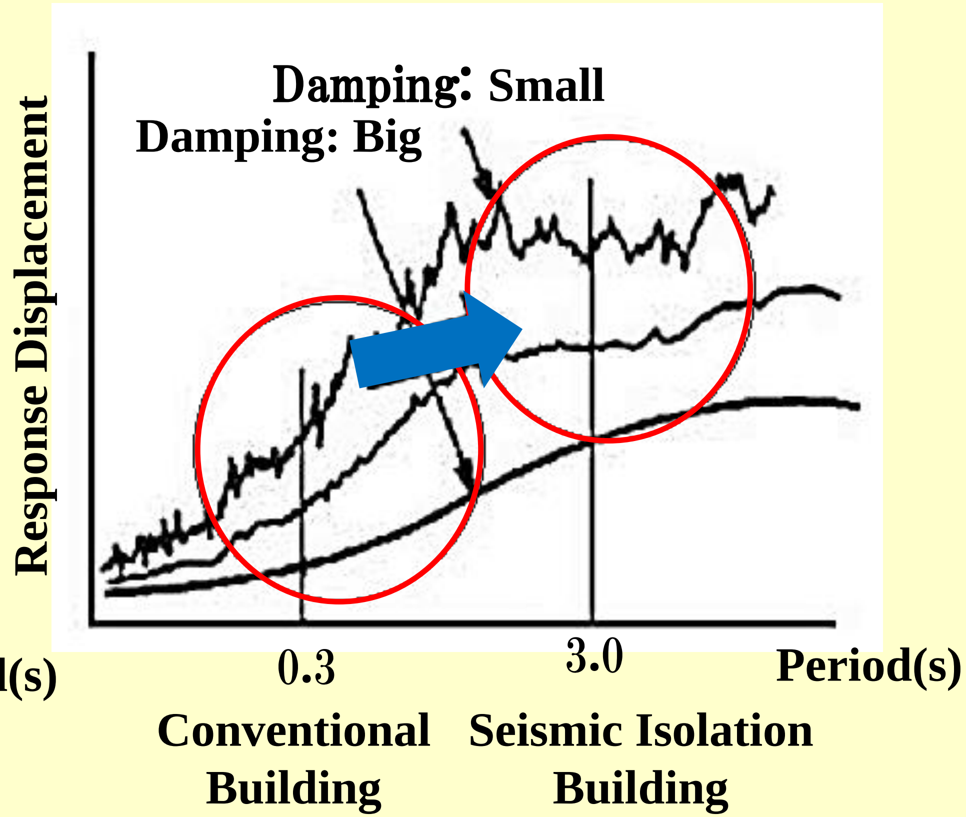
Principle of Seismic Isolation

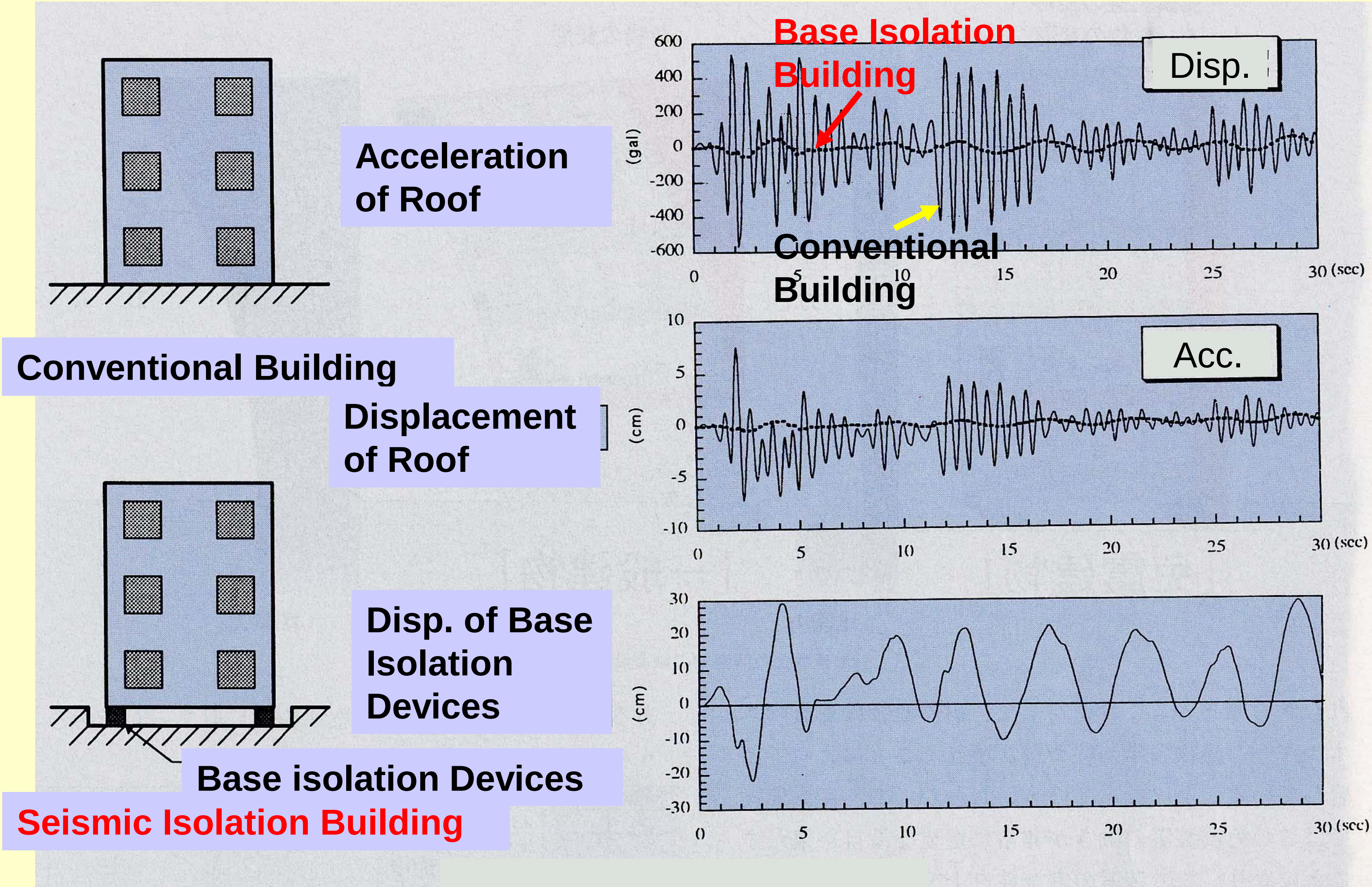
Response Spectrum





The Japan Architectural Education and Information Center

Principle of Seismic Isolation



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Comparison of seismic isolation structure and conventional structure

E-Defense full size seismic isolation building test

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Comparison of seismic isolation and non-isolation 1

（Slide presented by Ichijou Koumuten. Corp.）

この実験は、㈱一条工務店の2階建て戸建免震住宅と非免震住宅の実物を、兵庫県三木市にあるE-ディフェンスで比較実験したものです。

Non-isolation

Isolation

Comparison of seismic isolation and non-isolation 2

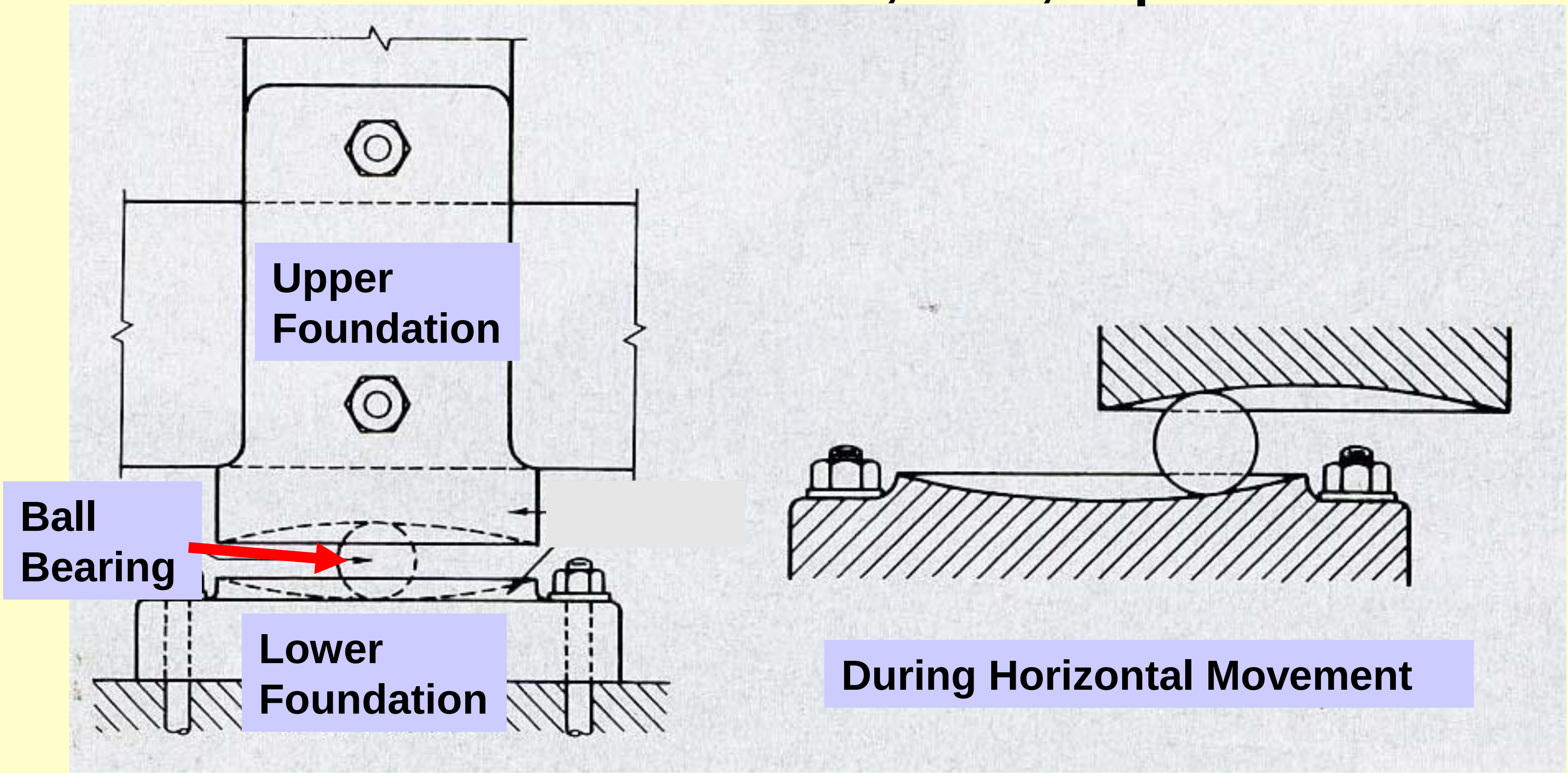
（Slide presented by Ichijou Koumuten. Corp.）

この実験は、㈱一条工務店の2階建て戸建免震住宅と非免震住宅の実物を、兵庫県三木市にあるE−ディフェンスで比較実験したものです。

Non-isolation　　Isolation

History of Seismic Isolation

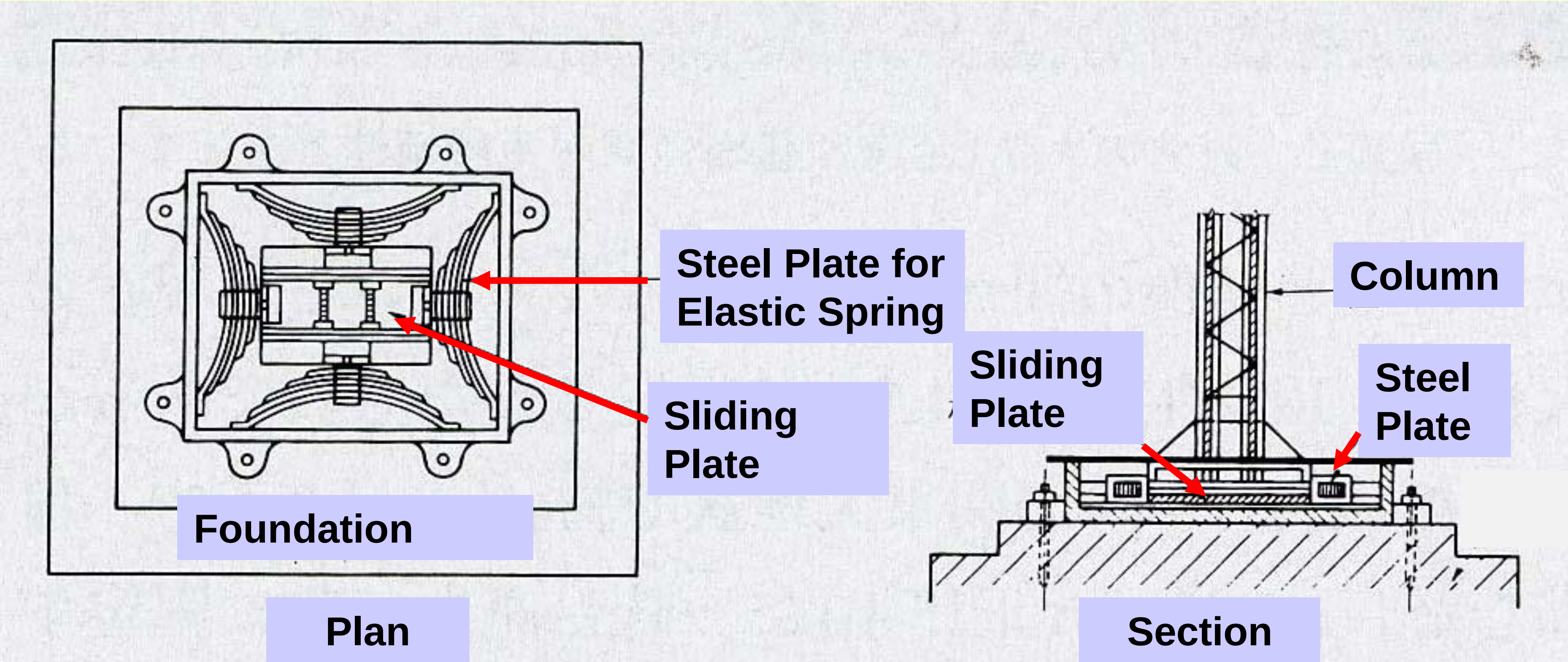
Kenzaburo Kito, 1924, Japan



Seismic Isolation with Ball Bearings

History of Seismic Isolation

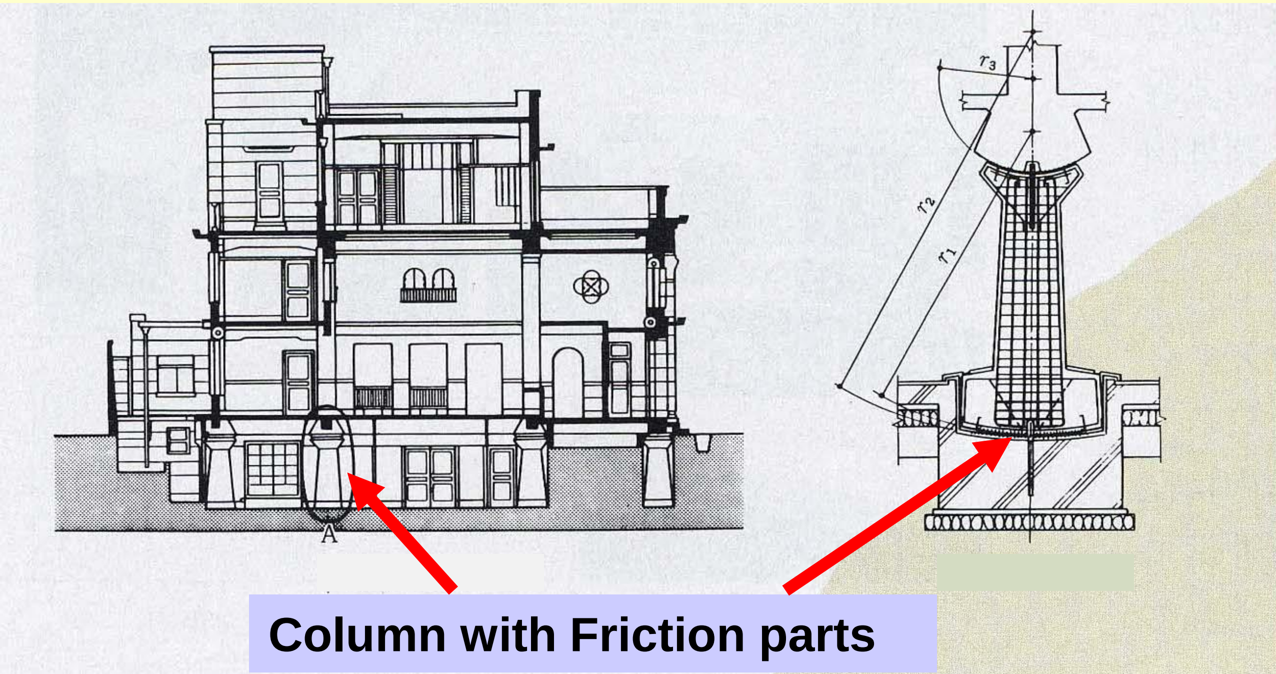
Koya Yamashita, 1927, Japan

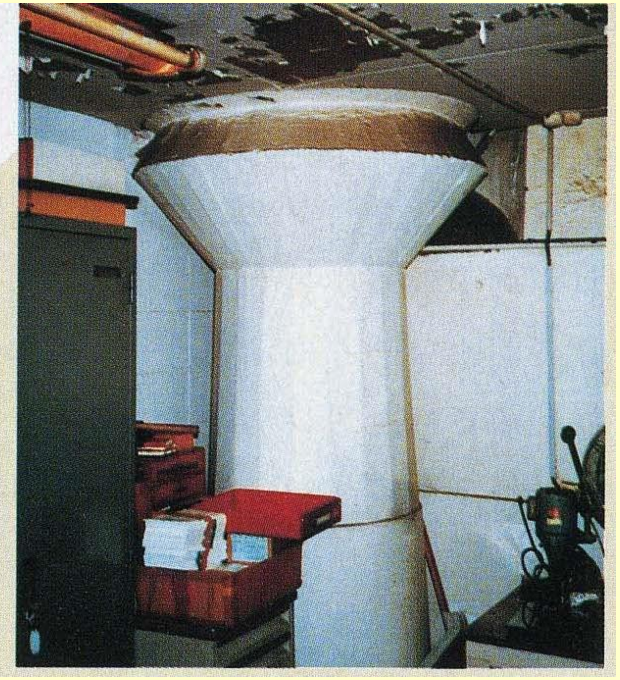


Base Isolation with Sliding Plate and Steel Plate

History of Seismic Isolation

Ryuichi Oka, 1934, Japan

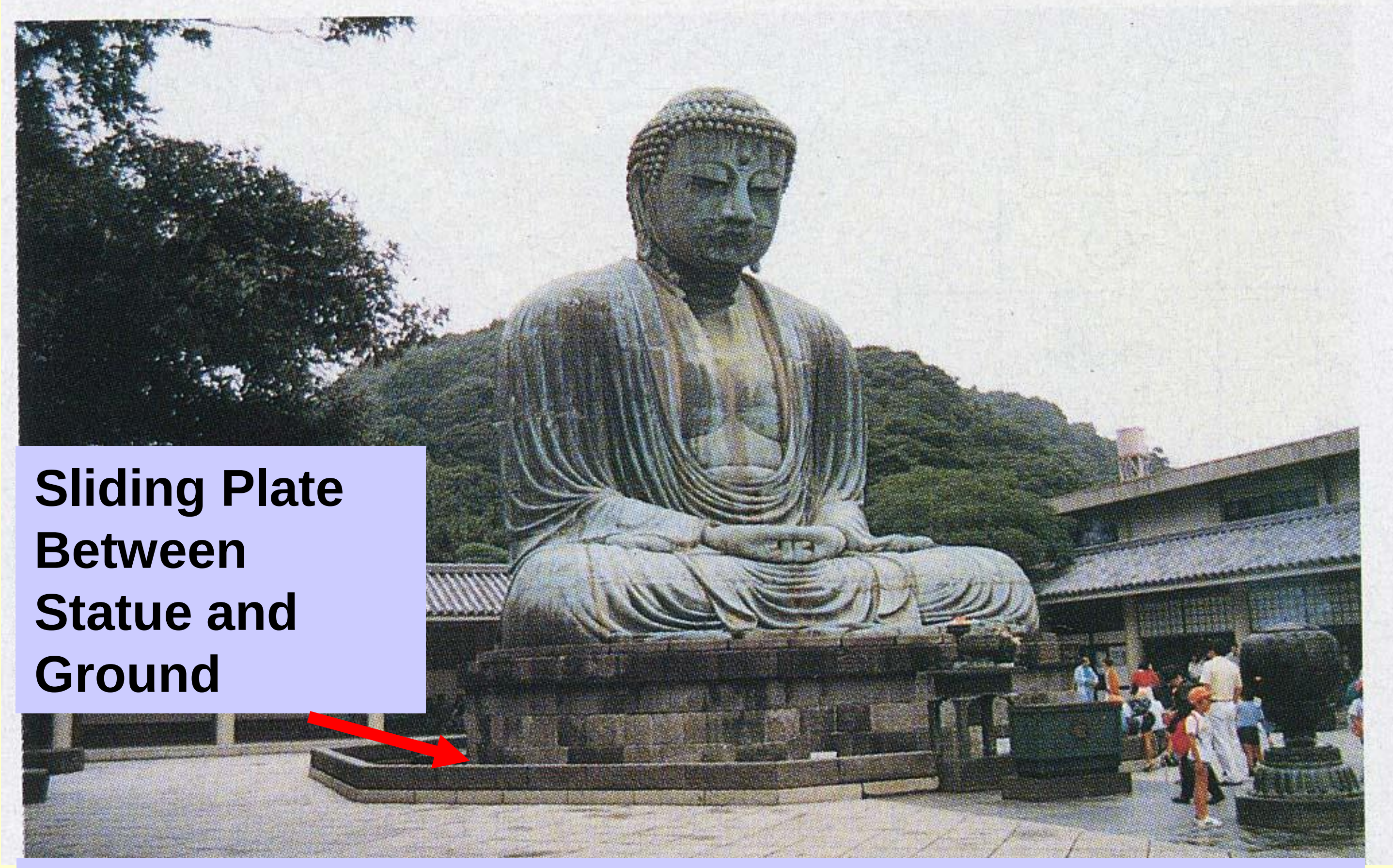




Friction mechanism at the top and bottom of the column

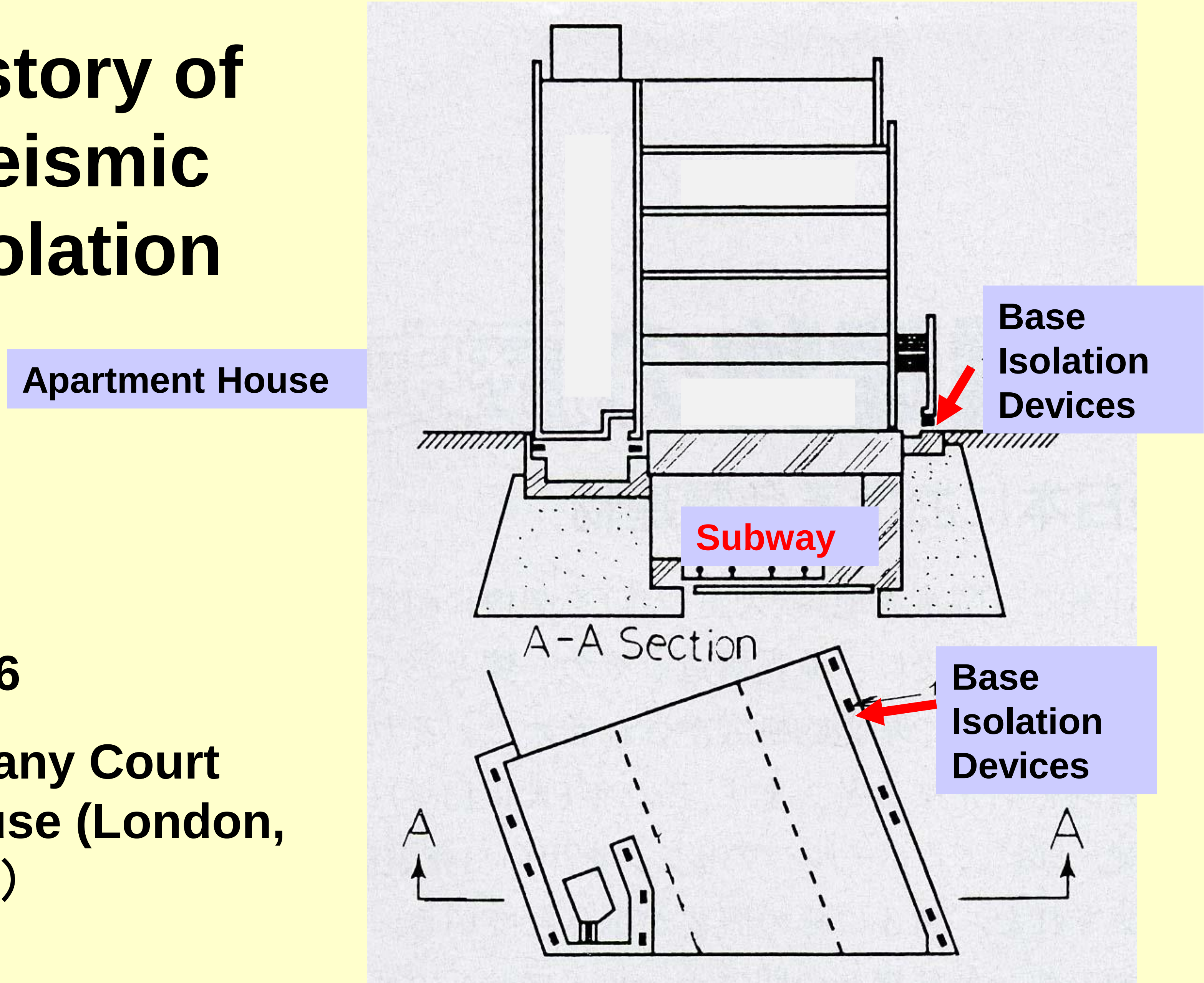
History of Seismic Isolation

1252:Constructed, 1923:Damaged due to Kanto Earth., 1926:Repaired, 1960:Restrengthed by Base Isolation



Statue of Buddha at Kamakura, Japan

History of Seismic Isolation



1966

Albany Court House (London, UK)）

History of Seismic Isolation

1969

School Building,
Skopije City, Makedonija.

（Donated by Pesttalozzi Foundation, Switzerland)

History of Seismic Isolation

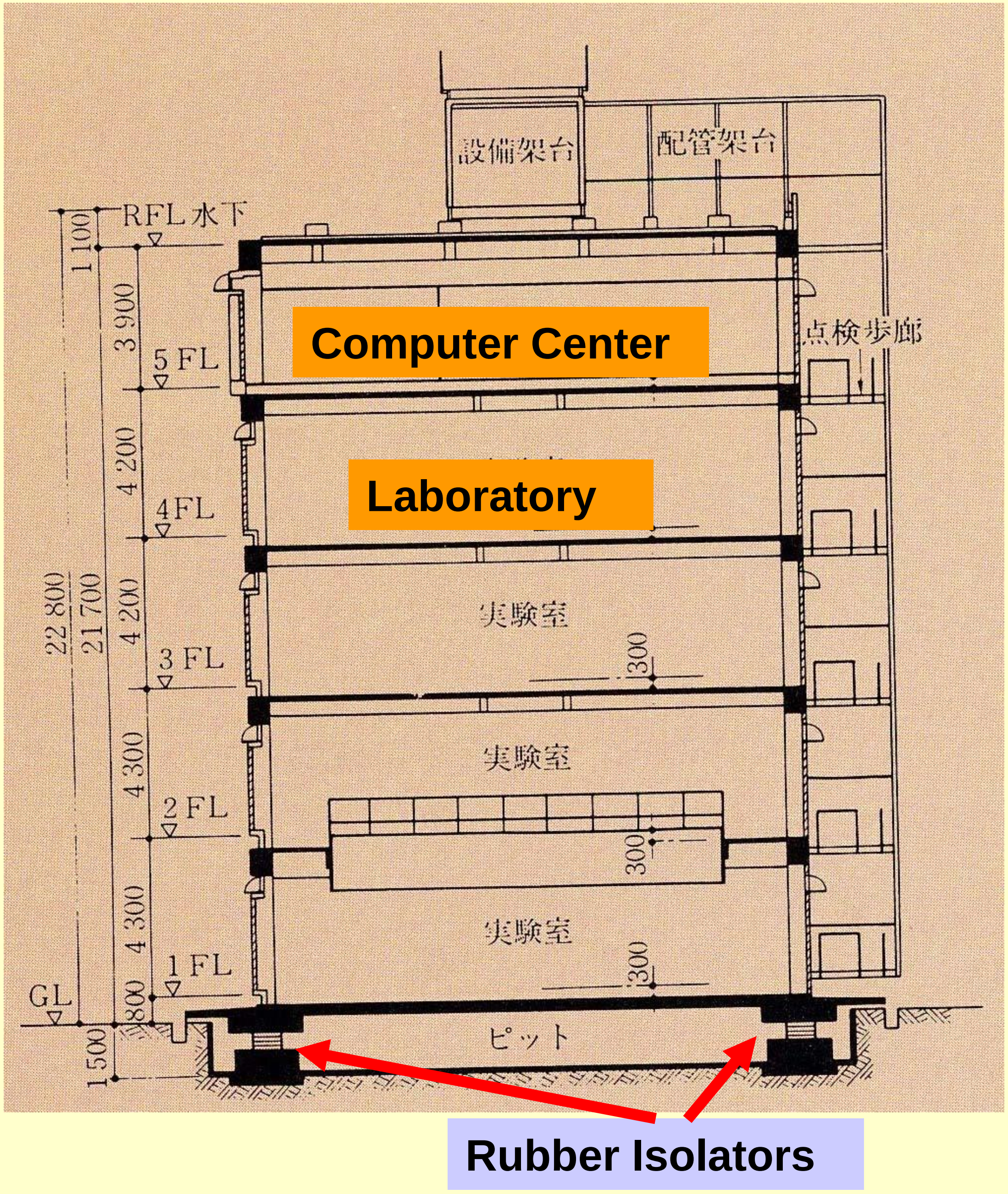
1986

Obayashi Tech. Res. Institute, Japan

High Technology R＆D Center

Section of Building

5 stories RC buildings



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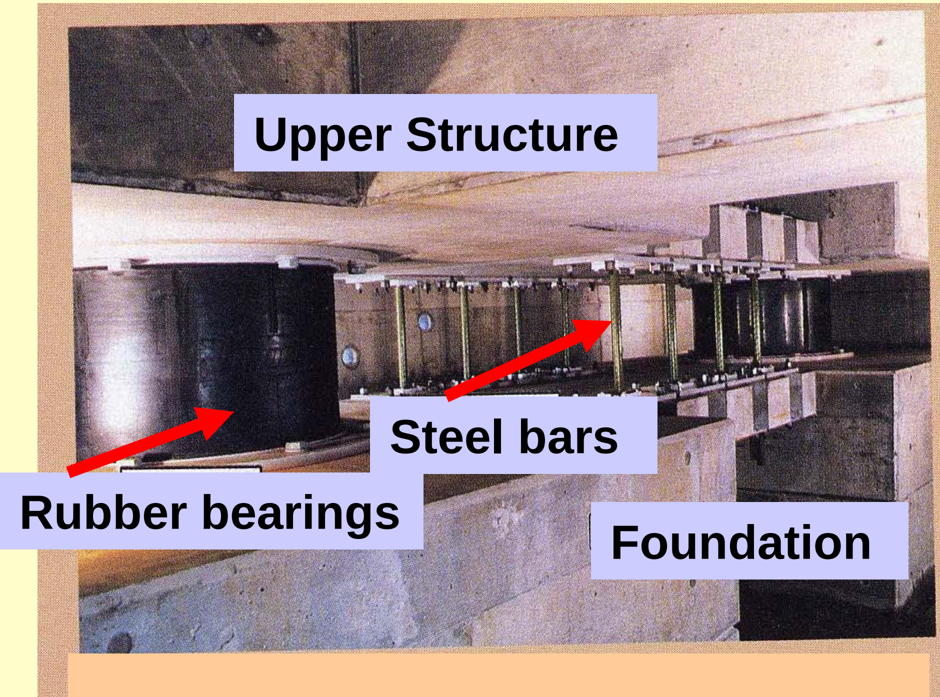
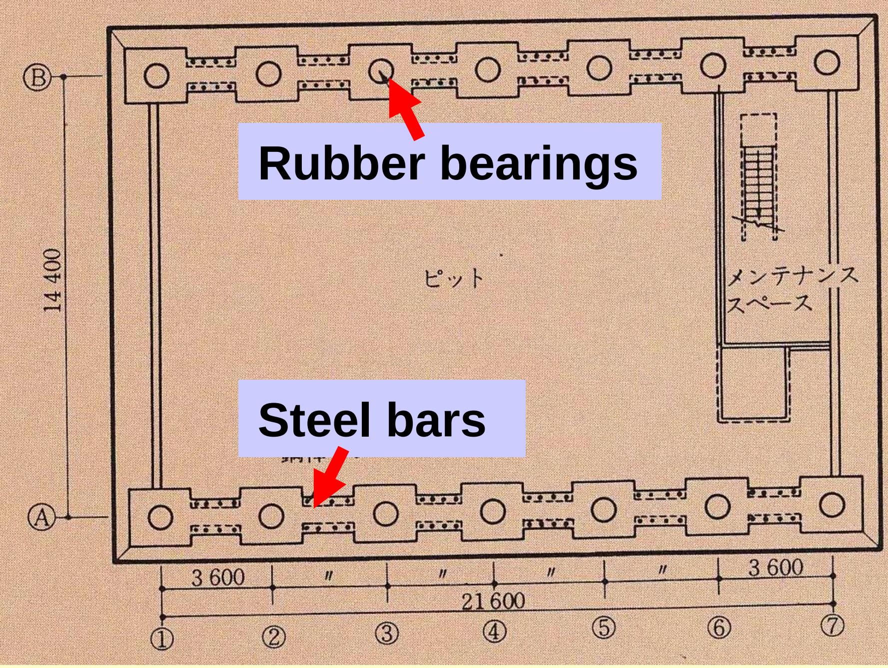
Seismic Isolation Devices



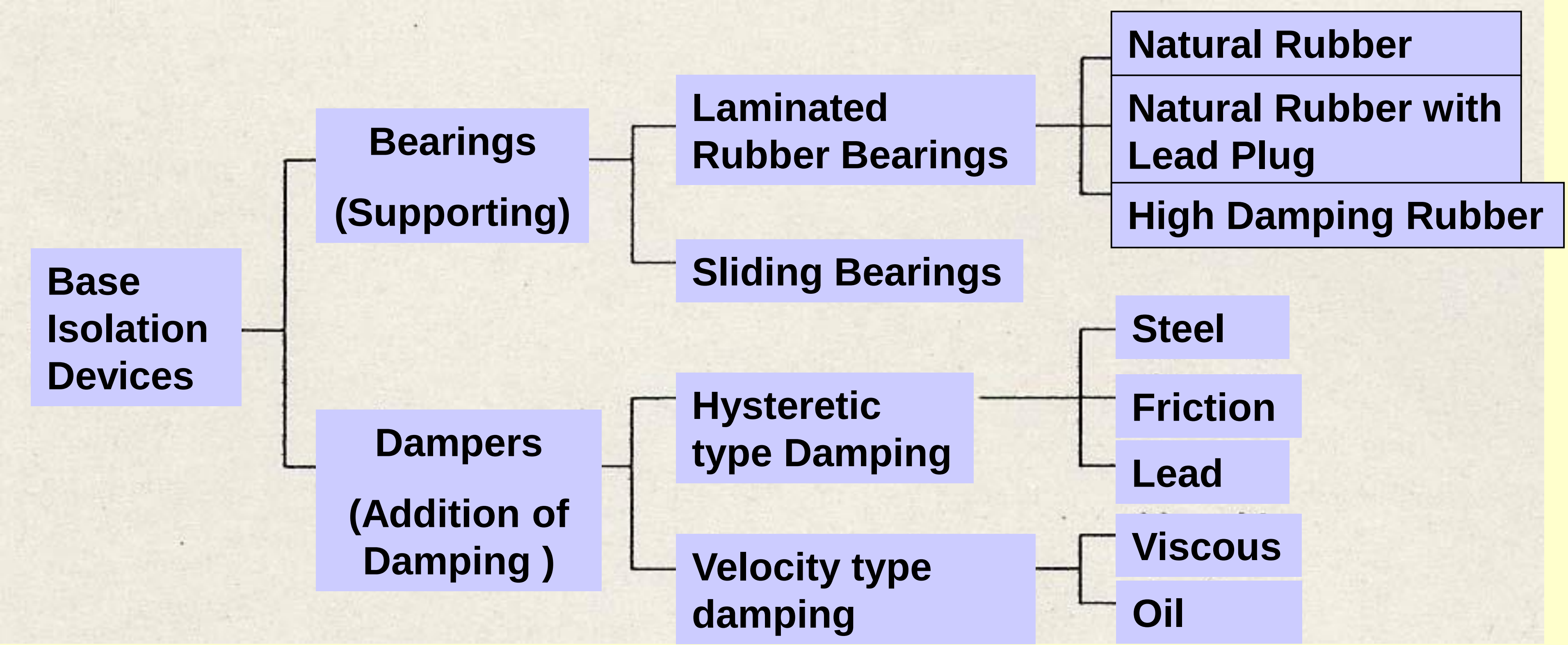
Base Isolation Devices

(Laminated Natural Rubber Bearings + Steel Bars damper)



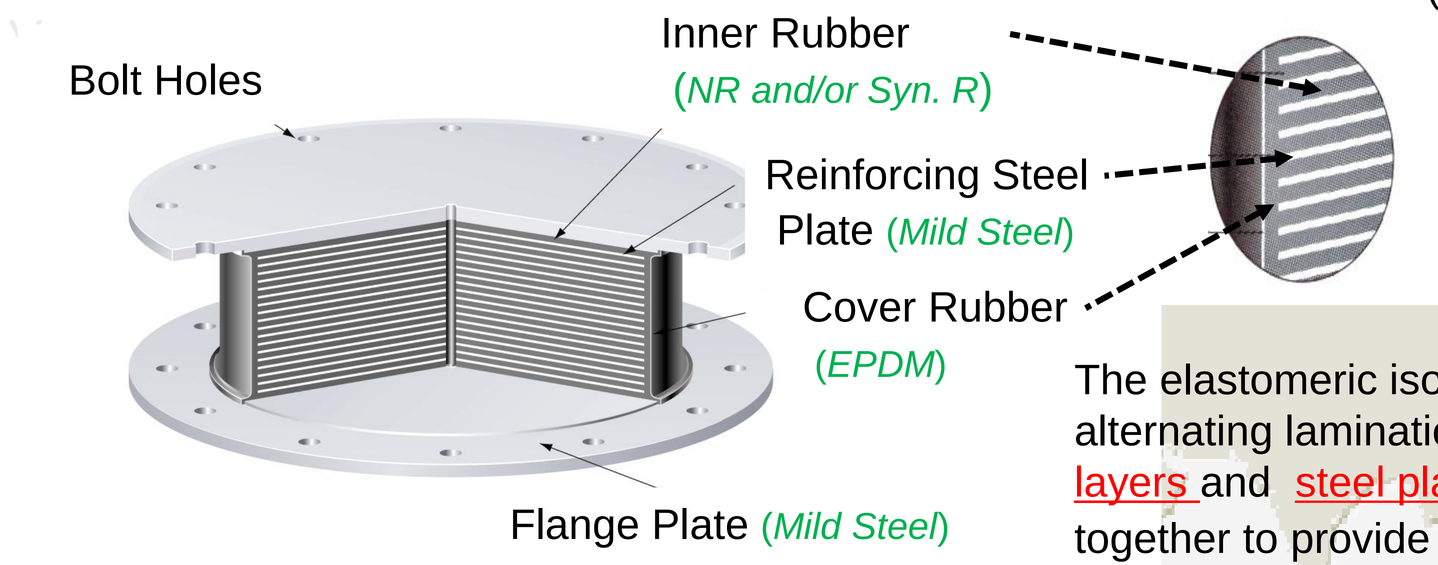
Plan of Building

Seisimic Isolation Devices

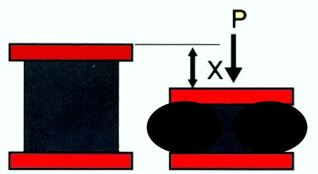
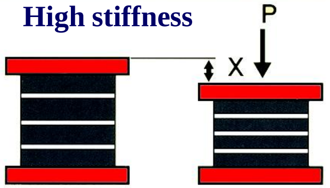
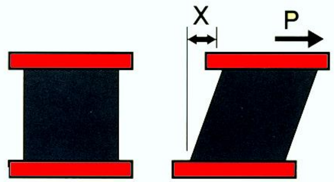
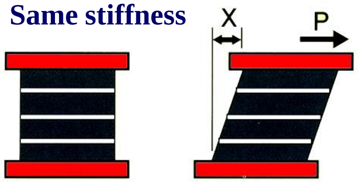


Elastomeric Seismic-Protection Isolators

(After Nishi T.)



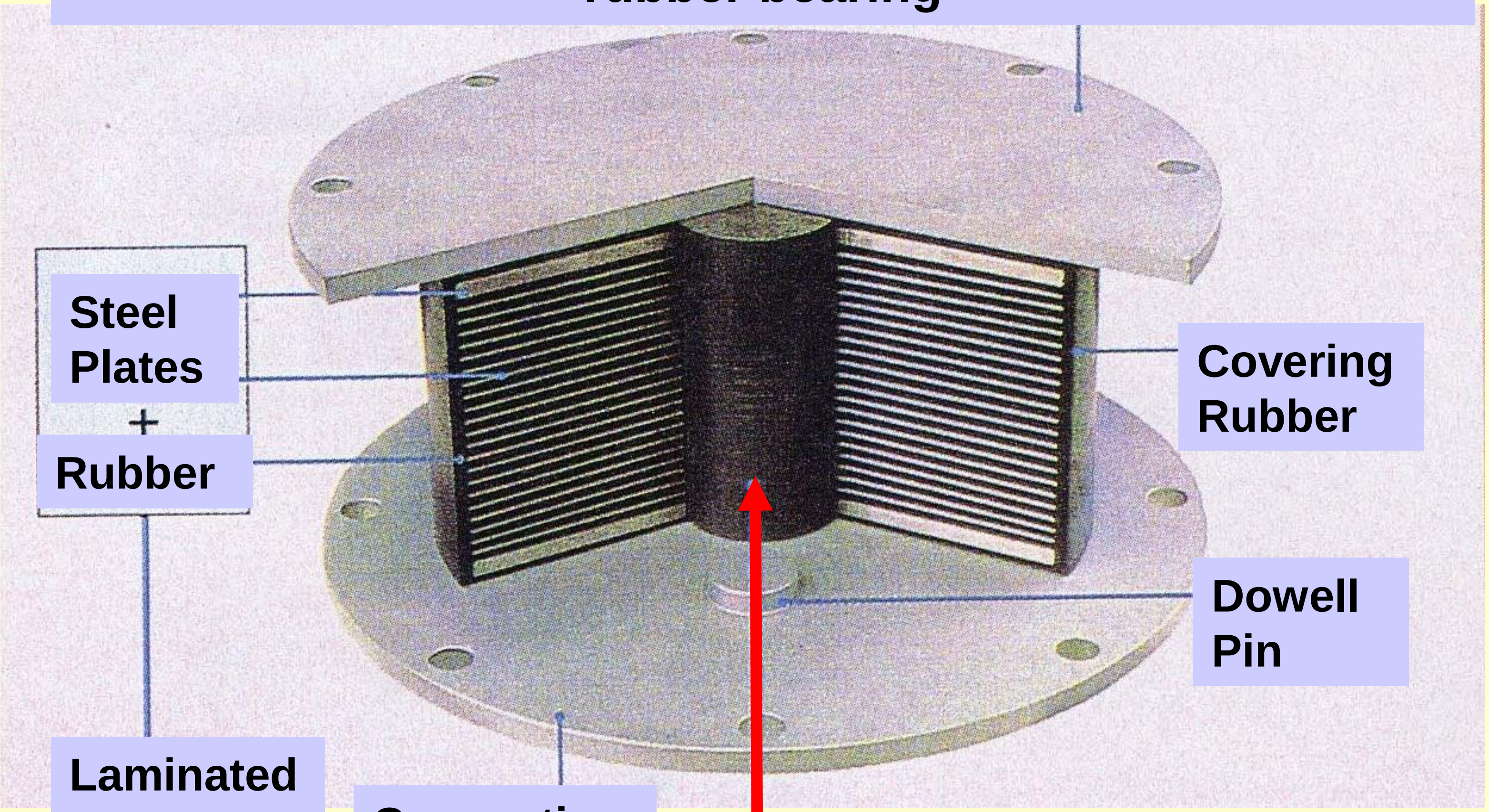
The elastomeric isolators consists of alternating laminations of thin rubber layers and steel plates bonded together to provide ;

	Rubber Block	Laminated Rubber Bearing	
Vertical		High stiffness 	support self weight of superstructure
Horizontal		Same stiffness 	allow large deformation during earthquake

Seismic Isolation Devices

Lead plug Rubber Bearing

Lead plug is inserted at the center of Laminated natural rubber bearing



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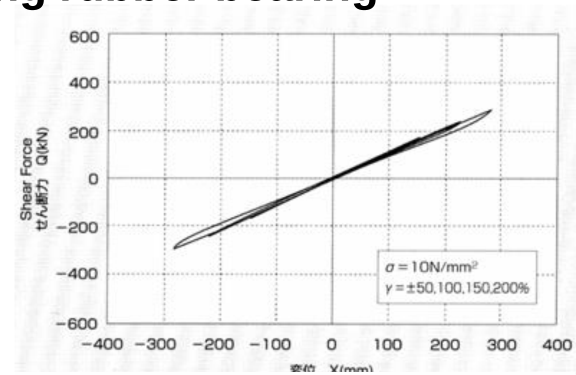
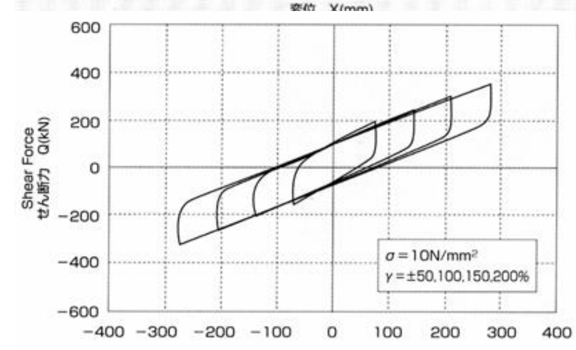
Types of seismic isolators

(After Nishi T.)

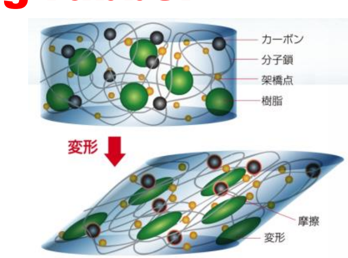
Natural Rubber Bearing(NRB) : Low-damping rubber bearing

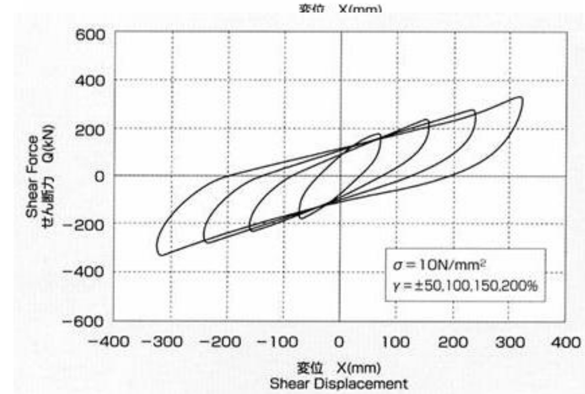


Lead Rubber Bearing (LRB)

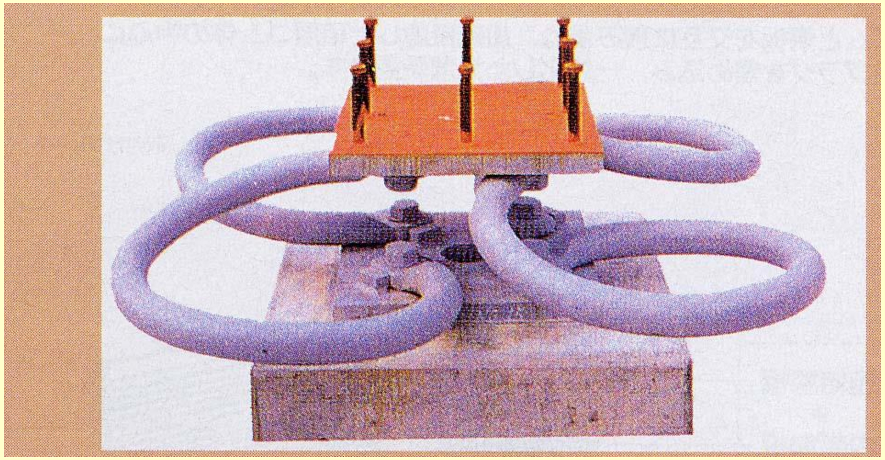


High-damping Rubber Bearings

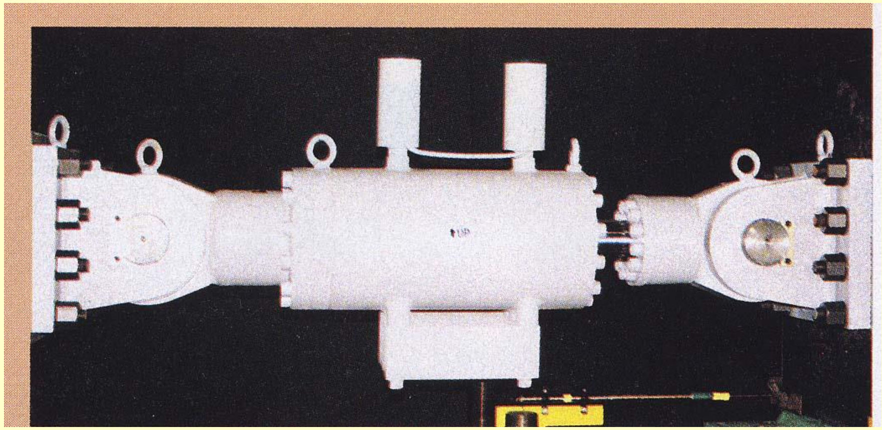




Seismic Isolation Devices



Steel Damper (Shin Nihon Steel Co.)

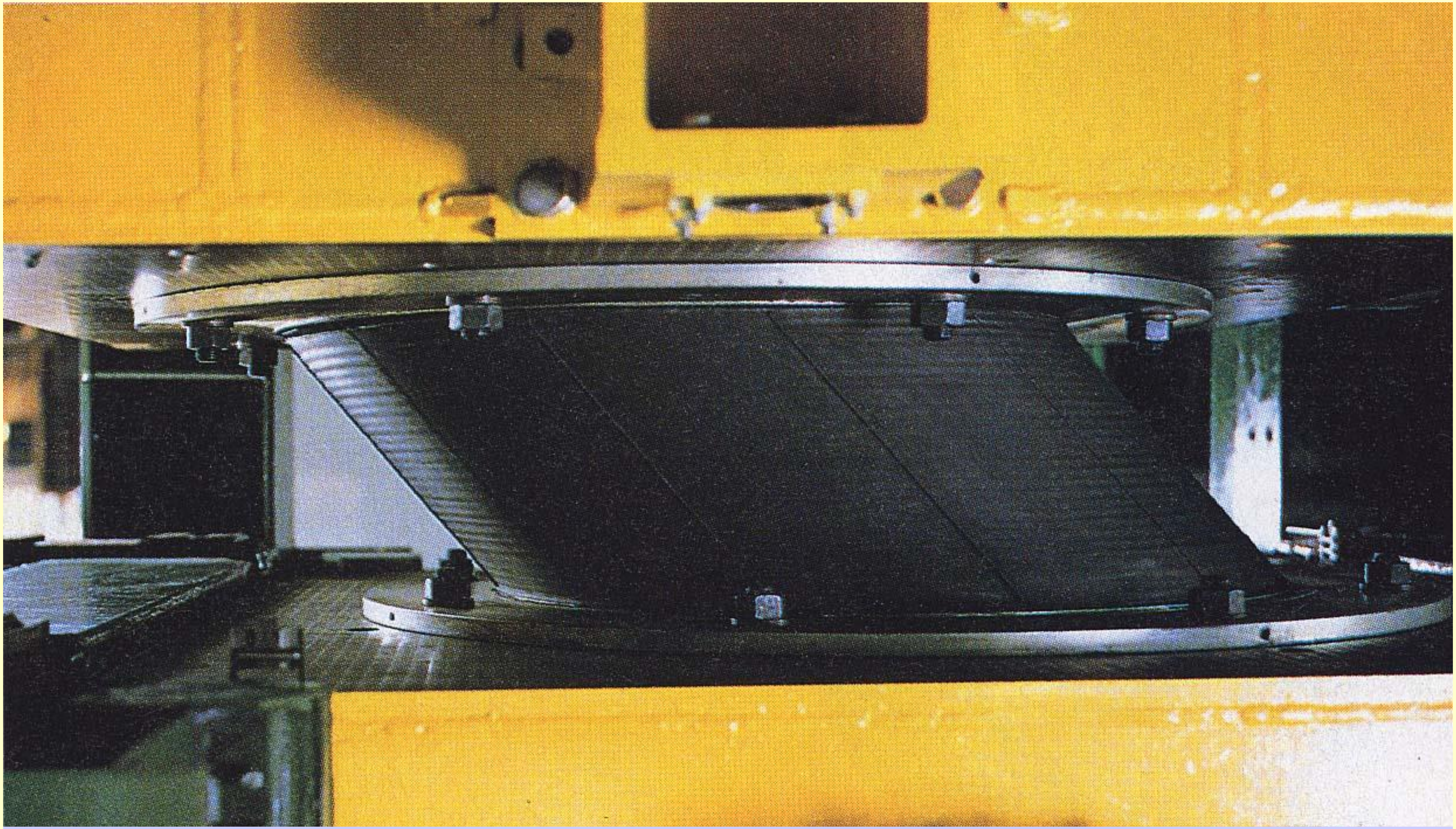


Oil Damper

Lead Damper

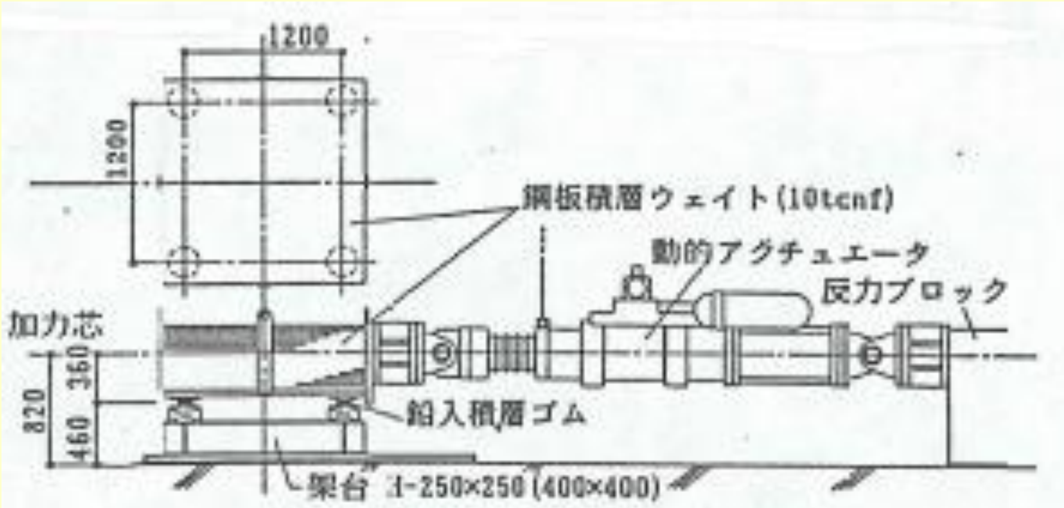
(Mitsubishi Material Co.)

Seismic Isolation Devices



Testing of Horizontal Direction for Laminated Rubber Bearing

Seismic Isolation Devices

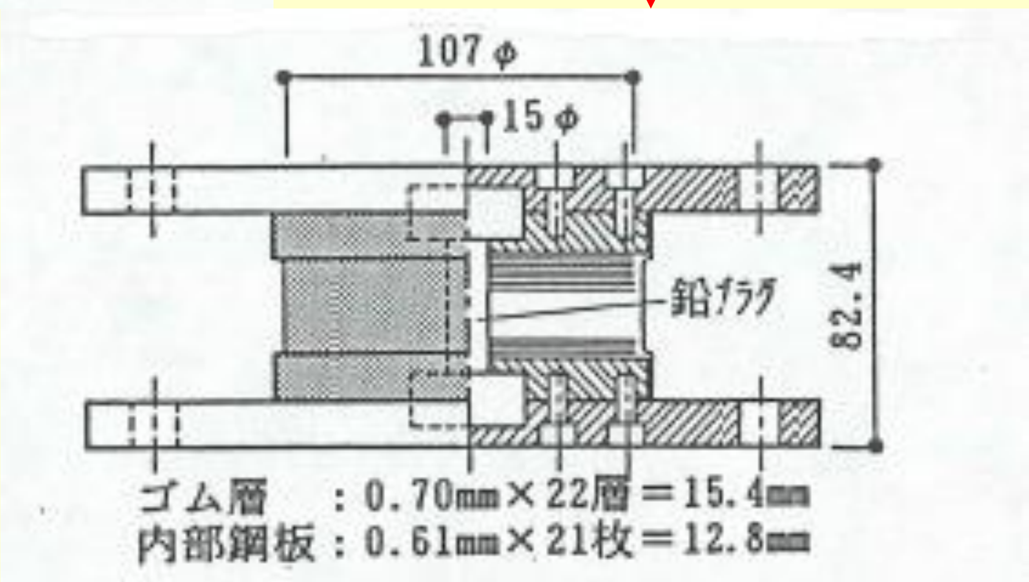


Horizontal Static Test

Horizontal Breaking test

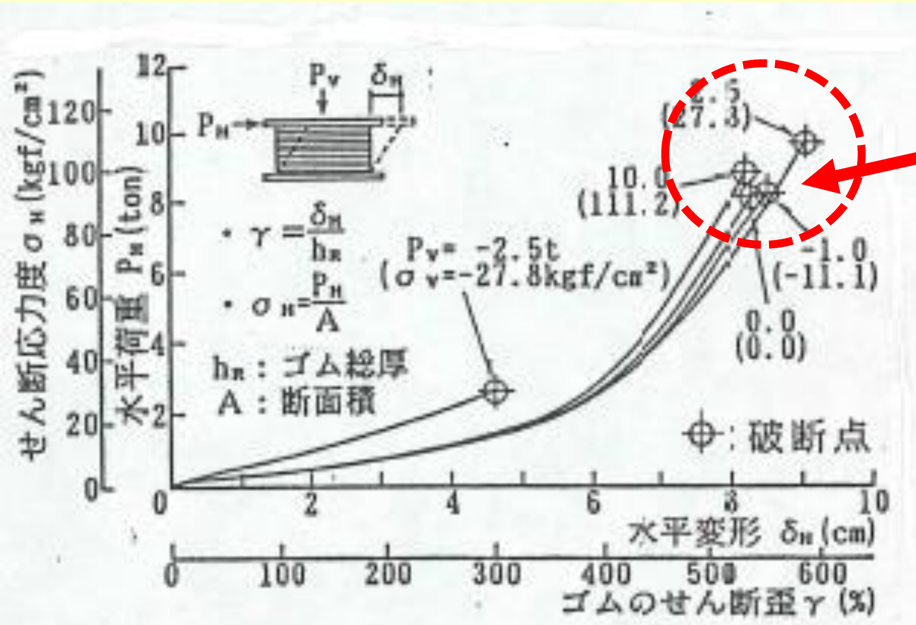
1991, Seki

Lead Plug Rubber Isolator



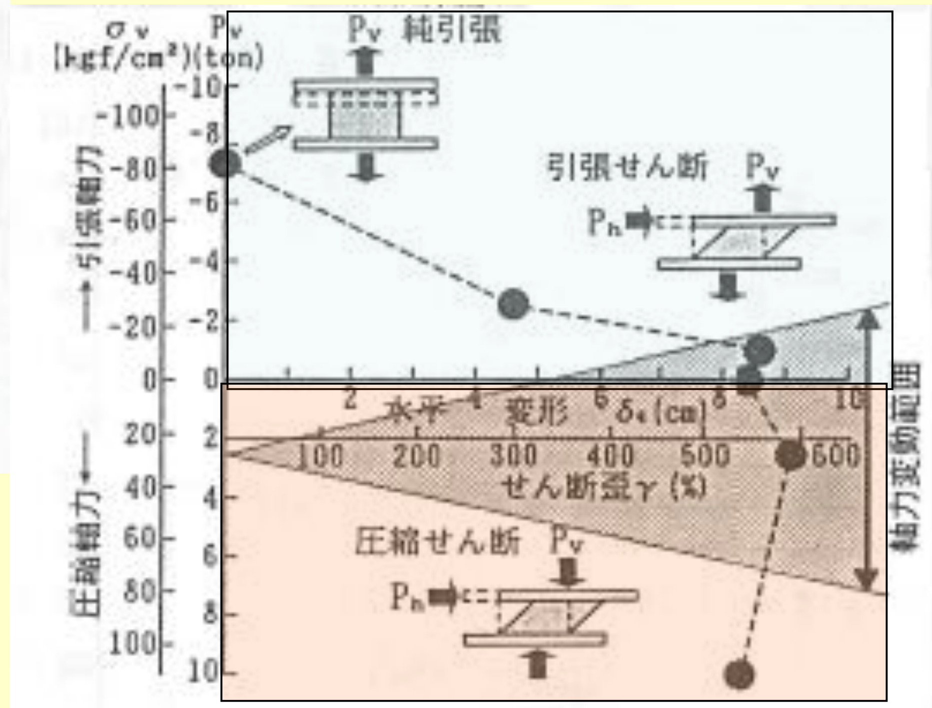
Small Scaled Test Specimen

Seismic Isolation Devices



Breaking Points

Load vs. Horizontal Displacement



Interaction Curve of Ultimate State

Test Results

1991 Seki

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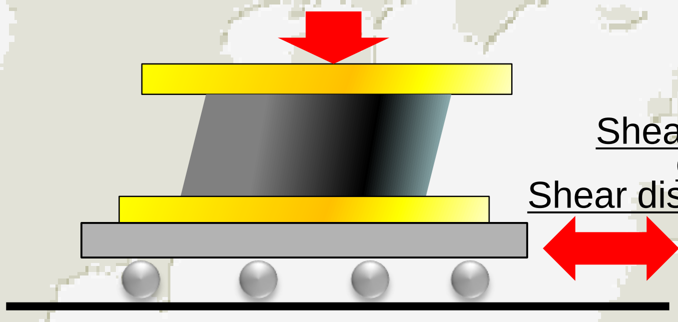
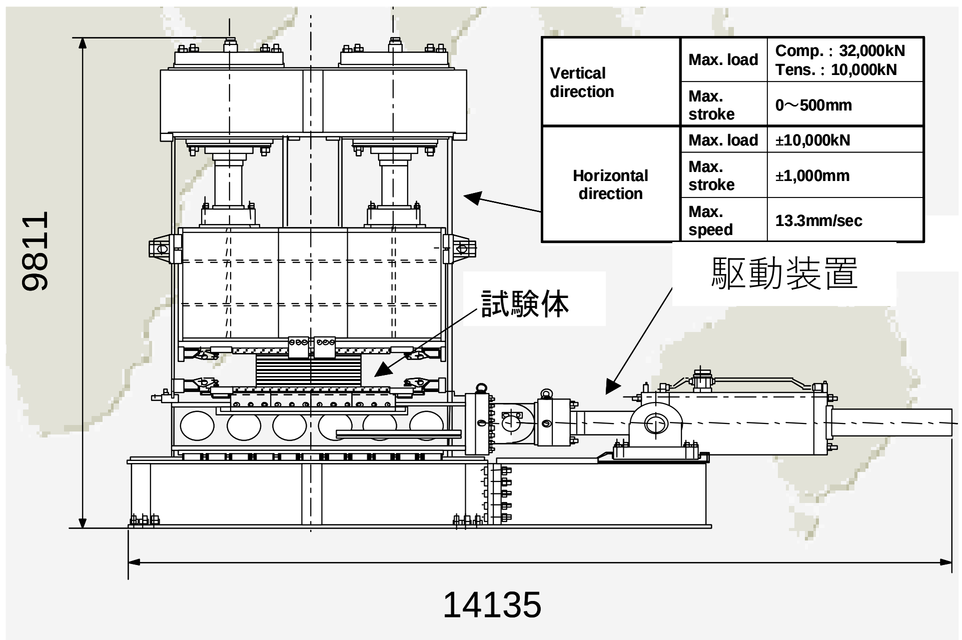
Compression & Shear Testing Machine

(After Nishi T.)



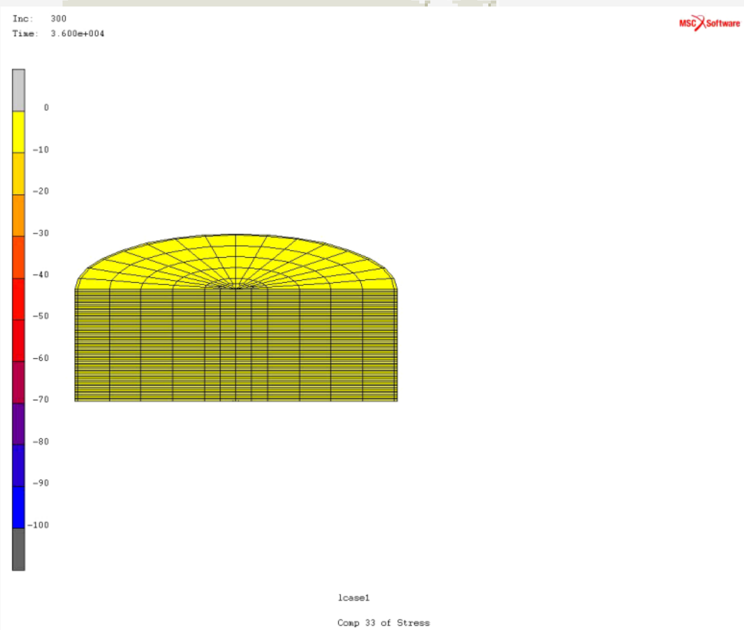


Vertical direction	Max. load	Comp. : 32,000kN Tens. : 10,000kN
	Max. stroke	0～500mm
Horizontal direction	Max. load	±10,000kN
	Max. stroke	±1,000mm
	Max. speed	13.3mm/sec

Presented by: BRIDGESTONE

Dinamic compression & Shear Test

(After Nishi T.)



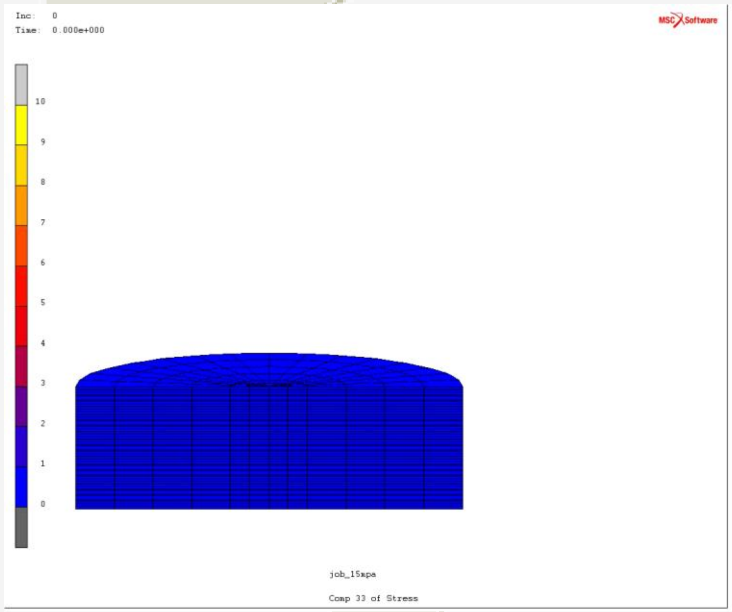
FEM analysis

Full scale model test

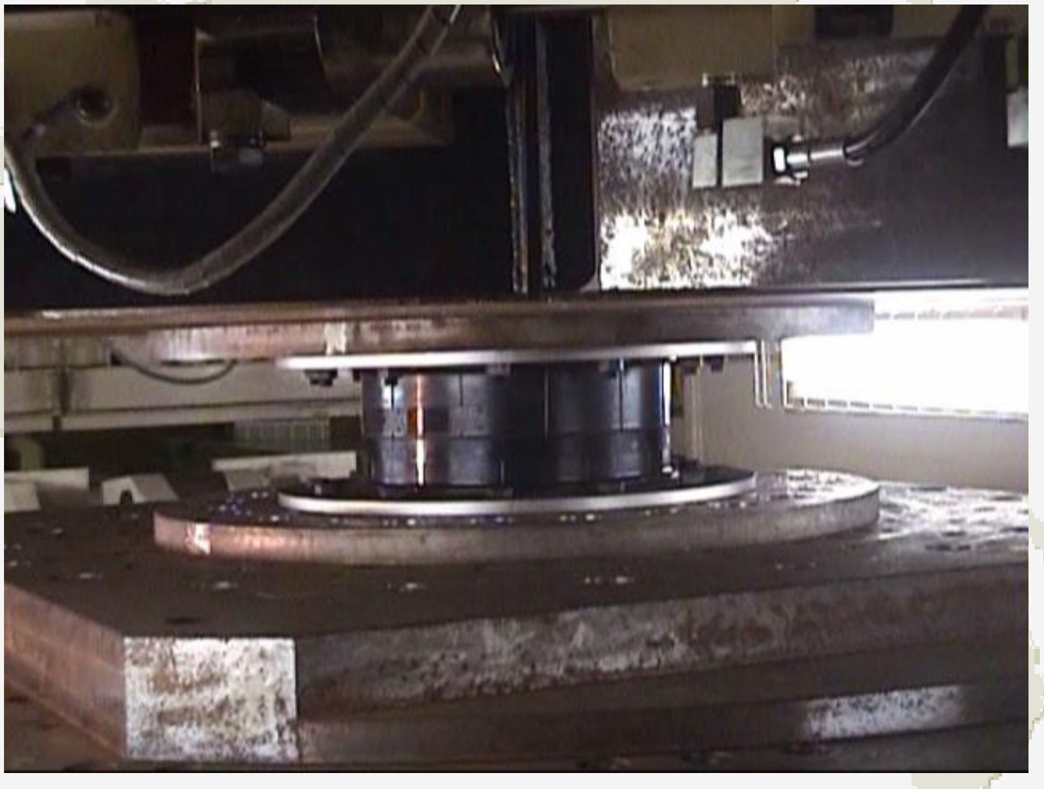
- Diameter: **1000 mm**
- Vertical load: **11,775 kN**
- Shear deformation: **±600 mm**(Shear strain **300%**)

Shear & Tensile breaking Test

(After Nishi T.)

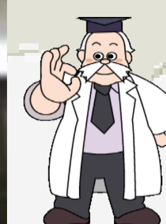


FEM analysis



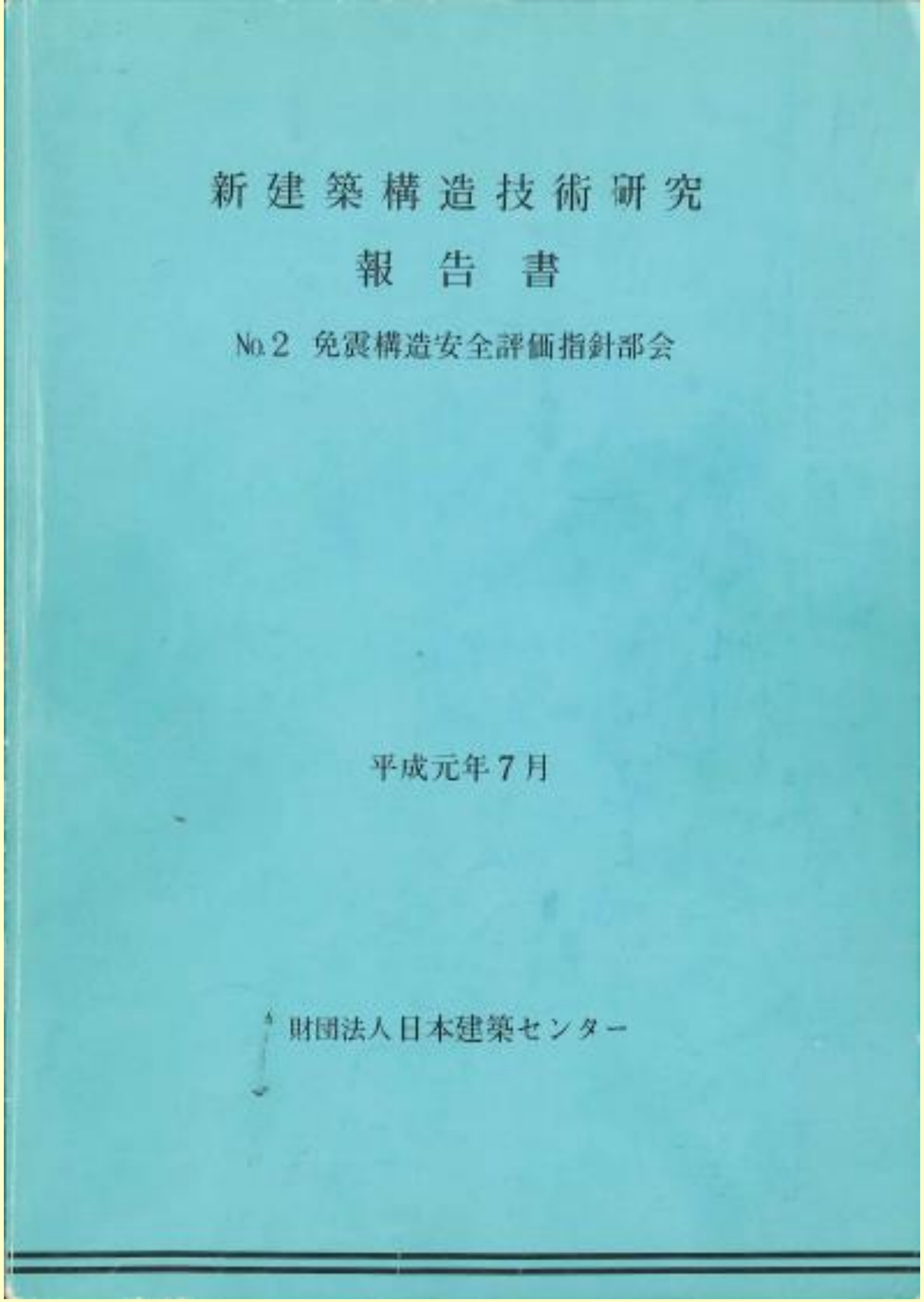
Compression & Shear breaking Test

(After Nishi T.)

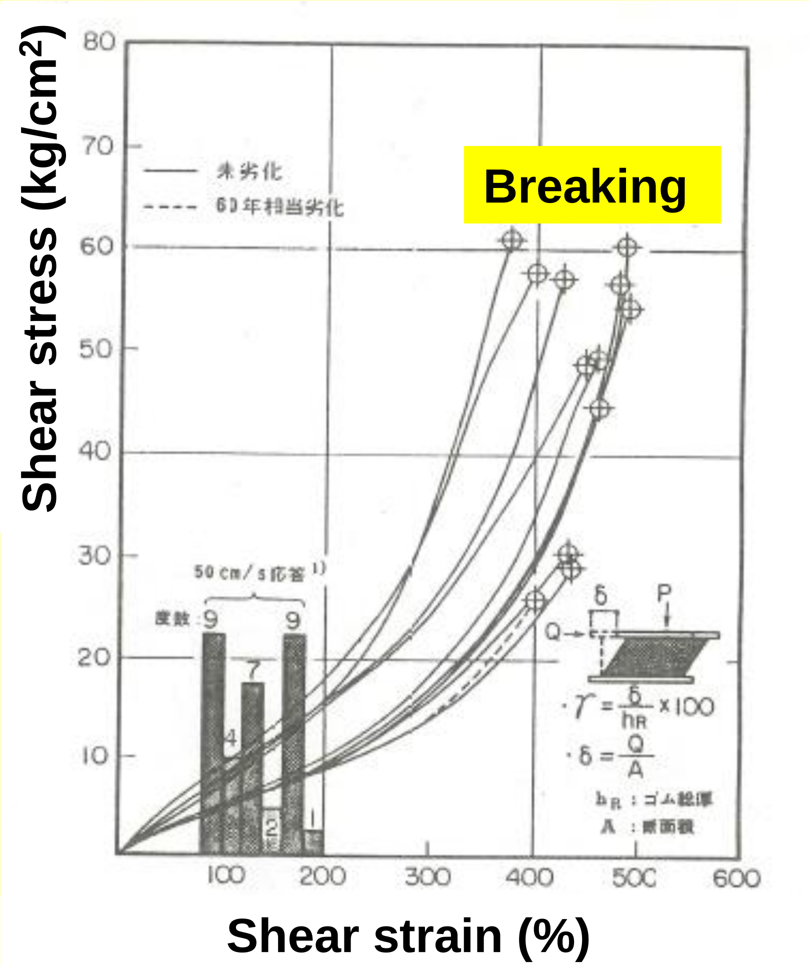


Seismic Isolation Devices

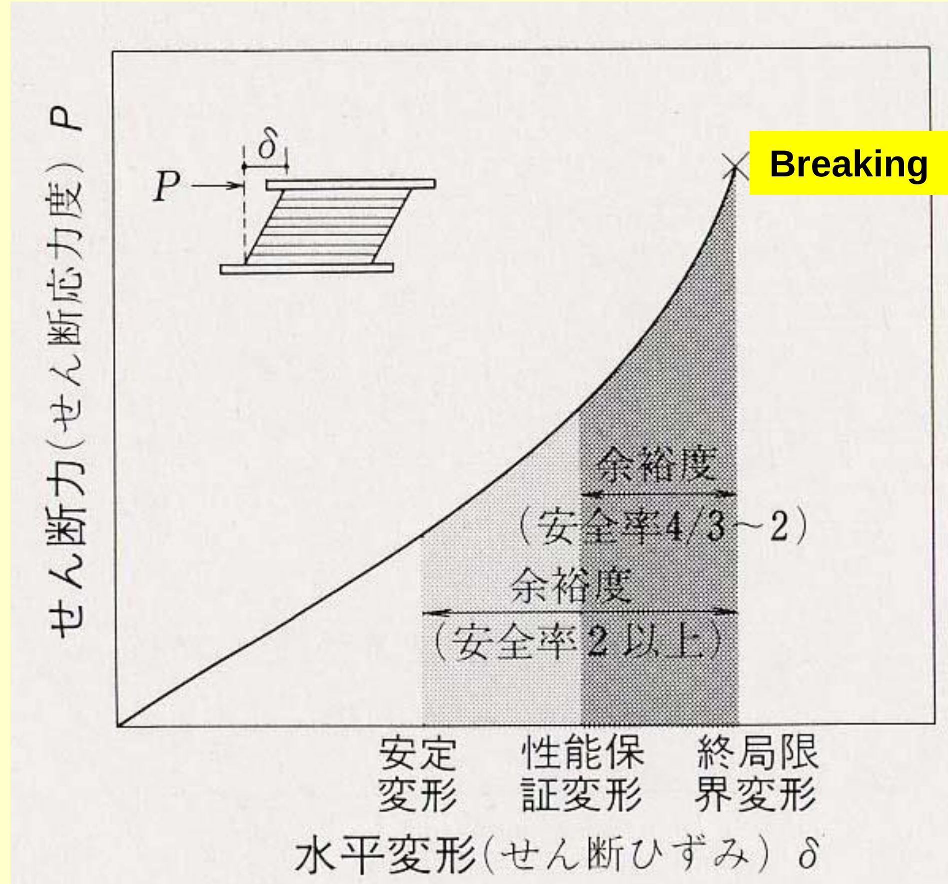
Guideline for Structural Safety Evaluation of Seismic Isolation, Building Center of Japan July 1989



Seismic Isolation Devices



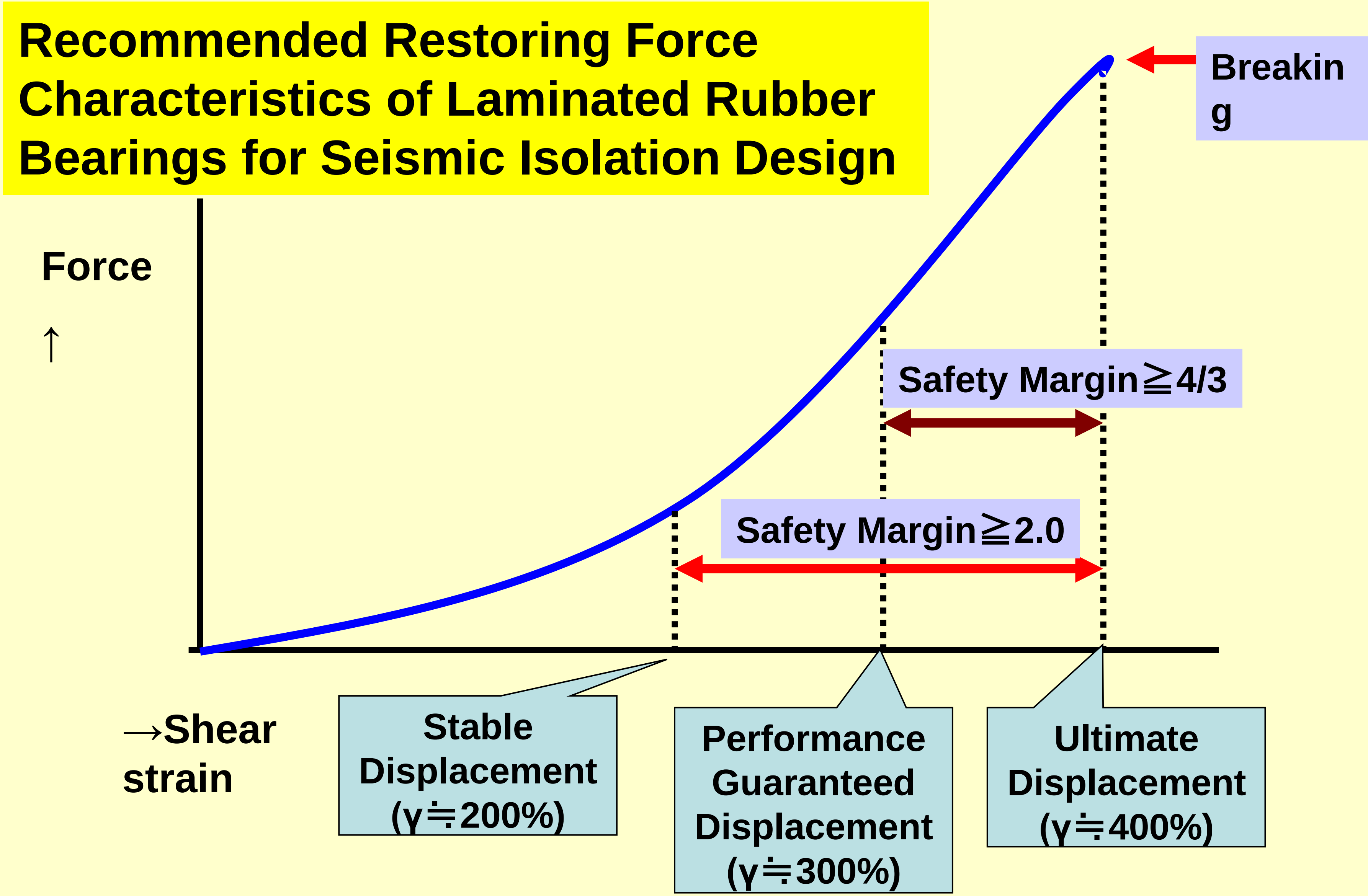
Test results



Recommended Values for Structural Design

Restoring Force Characteristics

Seismic Isolation Devices



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Design of Seismic Isolation Buildings

After Takeda et al.,1988

Input Ground Motions	Select the Ground motions
Assume Period, Damping ratio	Assume Initial Values
Brief Response Analysis	One Degree of Freedom System
Detail Design of Base Isolation Devices and Structural members	Decide the detail items
Time history Response Analysis	Response Analysis for level and 2 ground motions
Response Criteria is Satisfied ?	Super structure, Base Isolation Devices
END	

Flow Diagram of Seismic Isolation Design

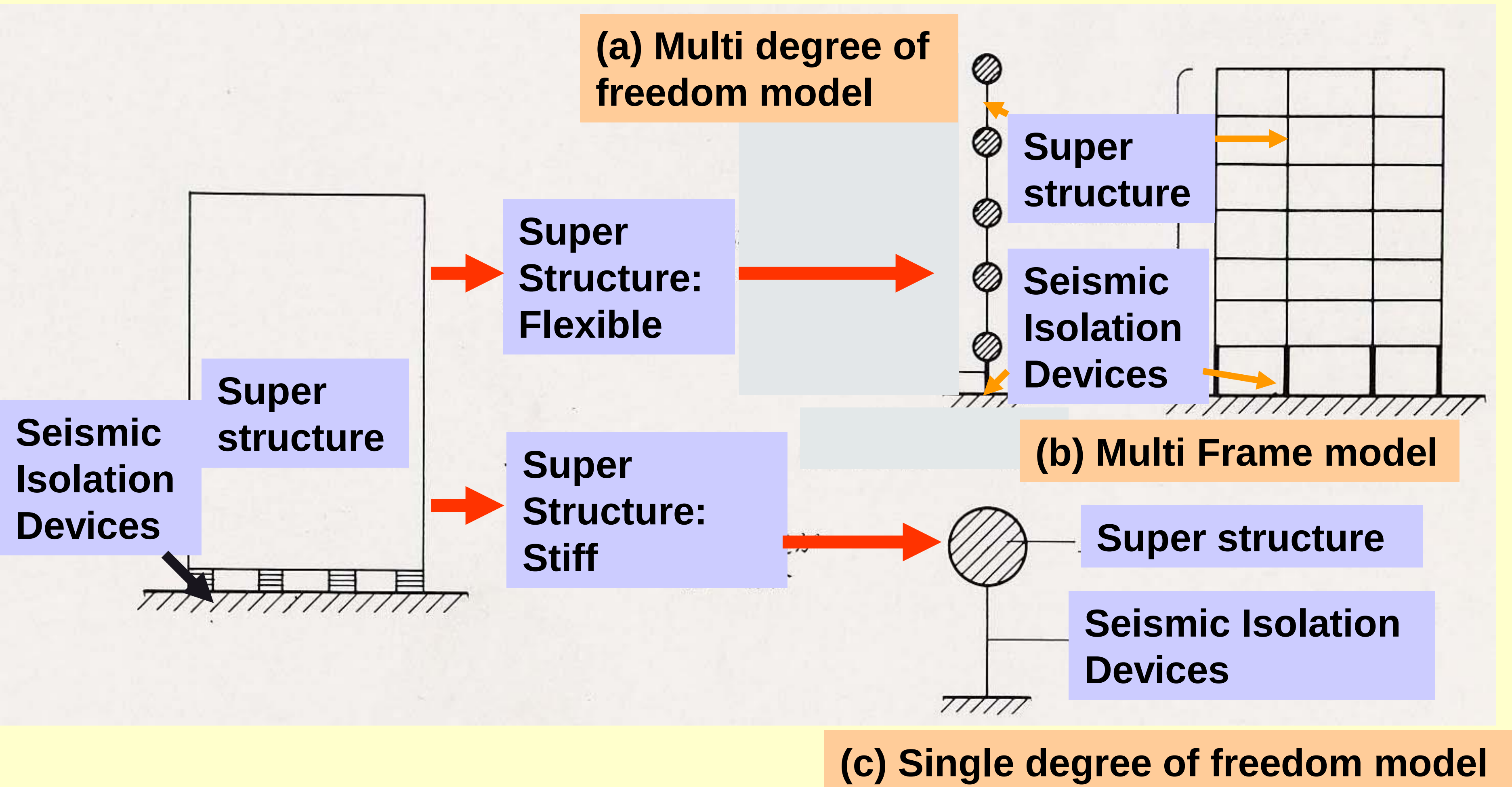
Design of Seismic Isolation Buildings

Ground motion Types and Input Levels for Response Analysis

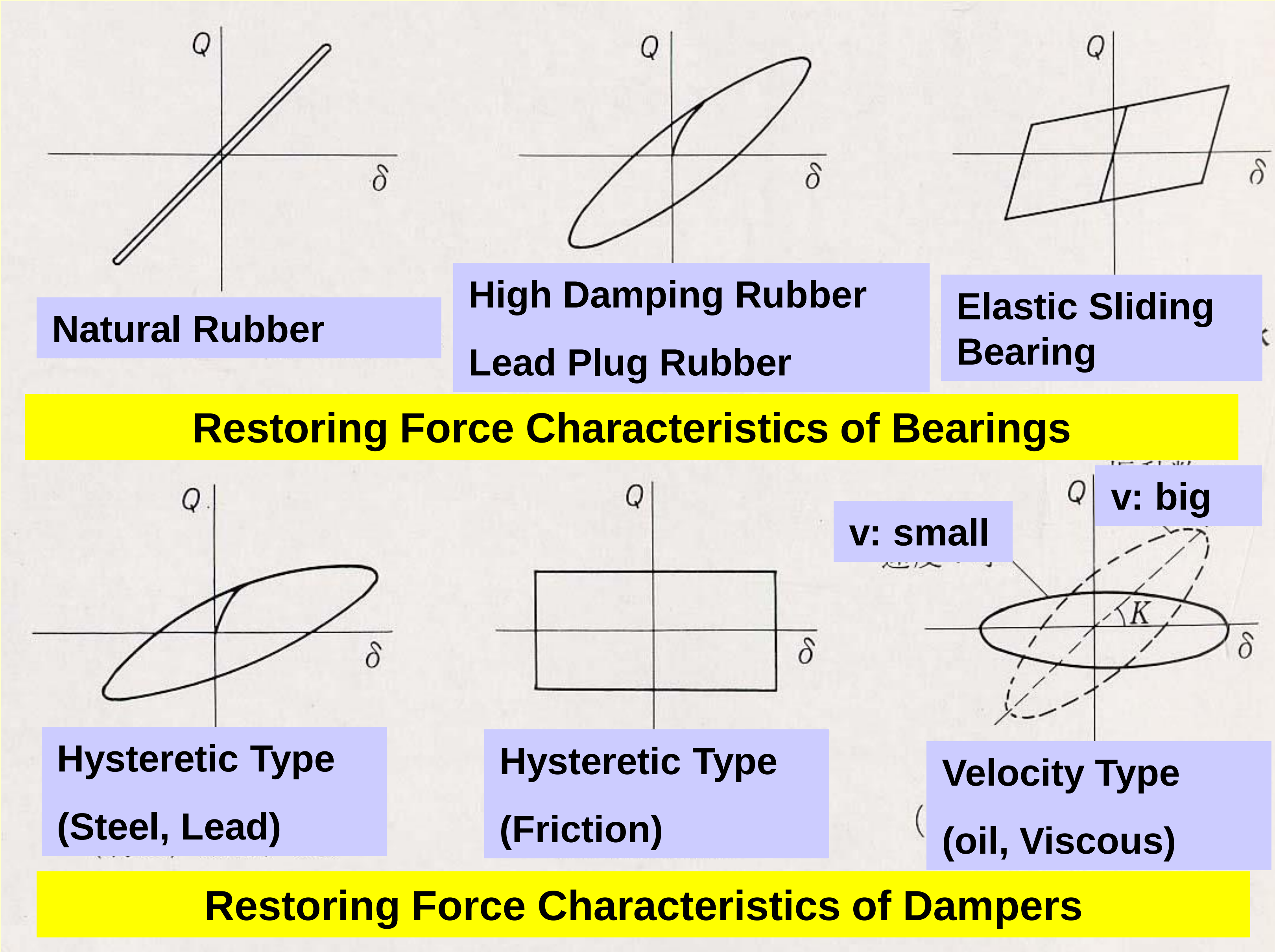
Input Ground Motions		Maximum Acceleration (gal) Level 1 (≒ 25 cm/s)	Maximum Acceleration (gal) Level 2 (≒ 50 cm/s)
Site Recorded Motions	El Centro NS 1940	255	510
	Taft EW 1952	248	496
Long Period Motions	Hachinohe NS 1968	165	330
	Hachinohe EW 1968	128	256

Design of Seismic Isolation Buildings

Structure Modeling for Response Analysis



Design of Seismic Isolation Buildings



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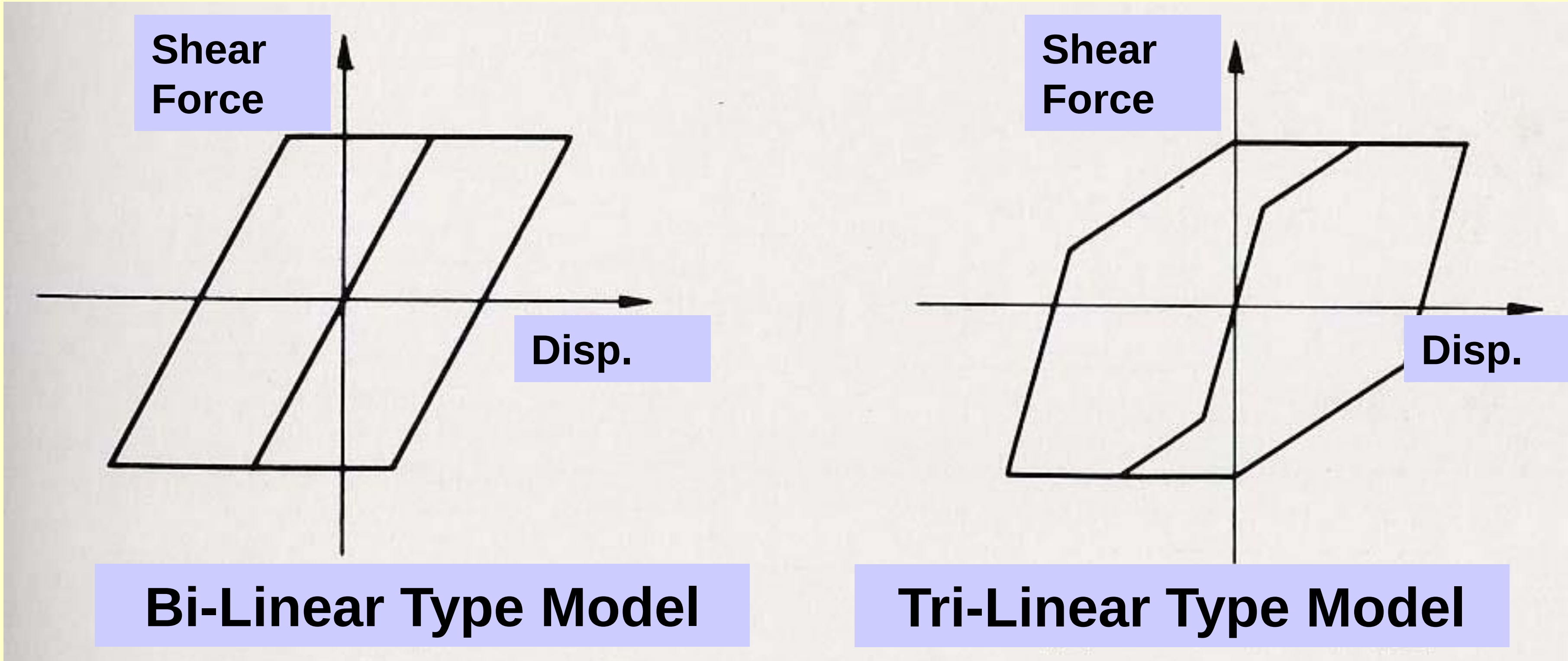
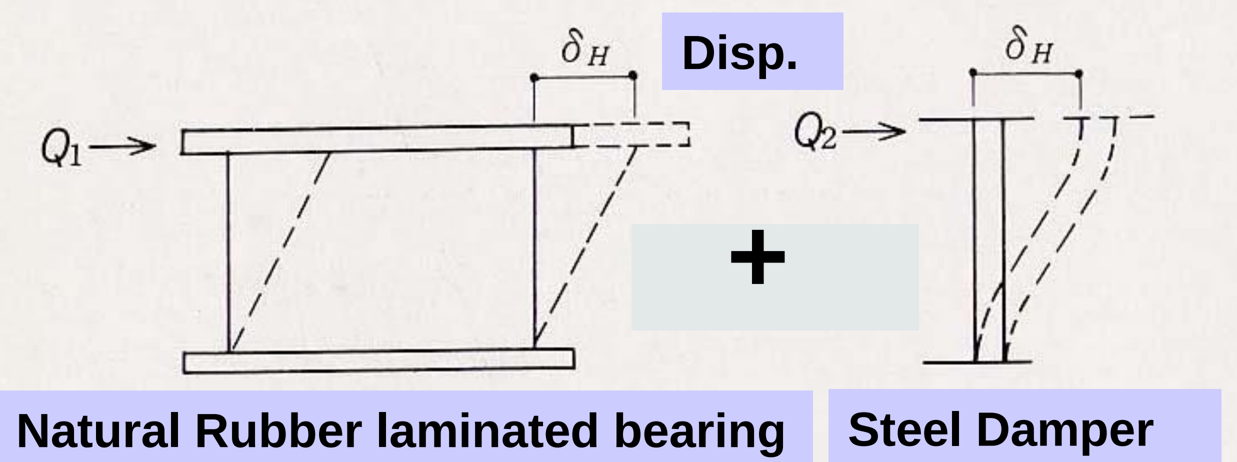
Design of Seismic Isolation Buildings

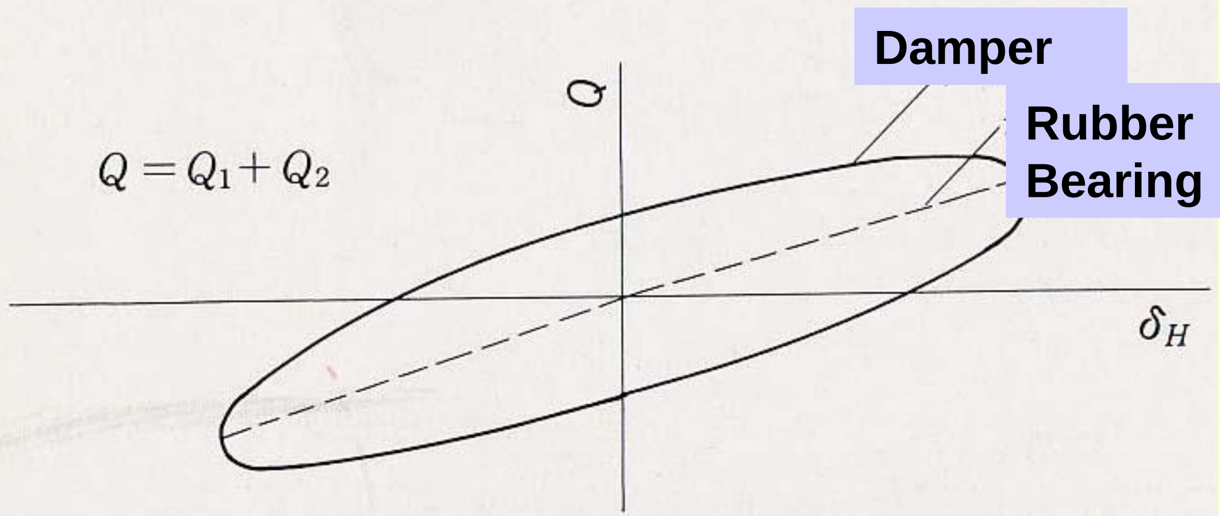


Restoring Force Characteristics of Super Structure

Design of Seismic Isolation Buildings



Component of Base Isolation Device (an example)



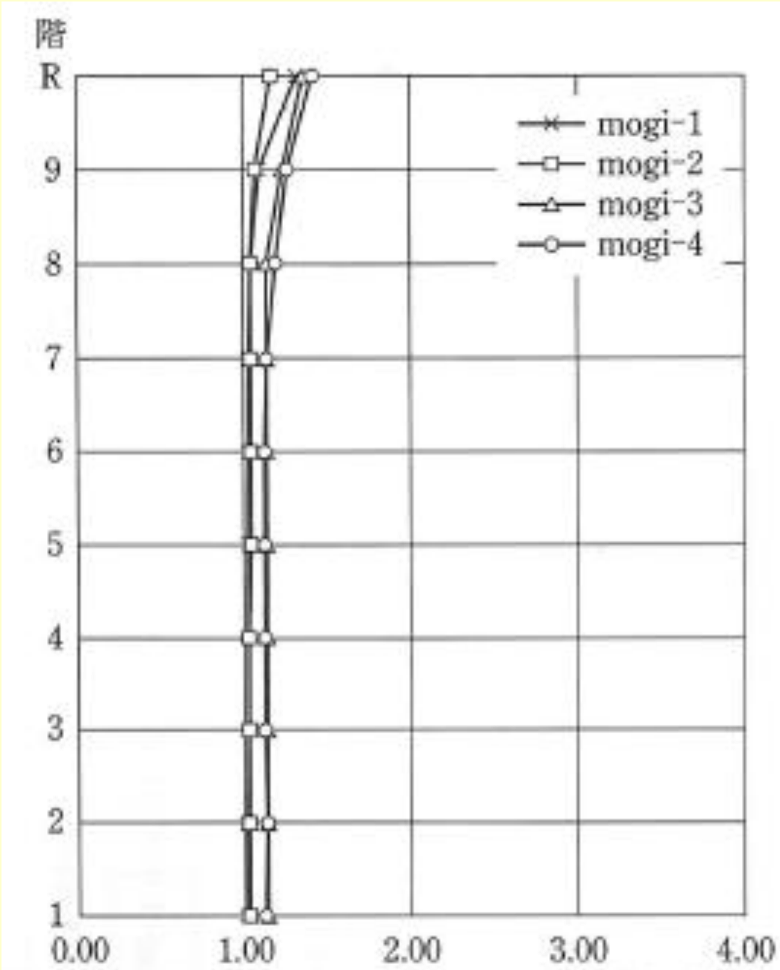
Restoring Force Characteristics of Base Isolation Device (an example)

Design of Seismic Isolation Buildings

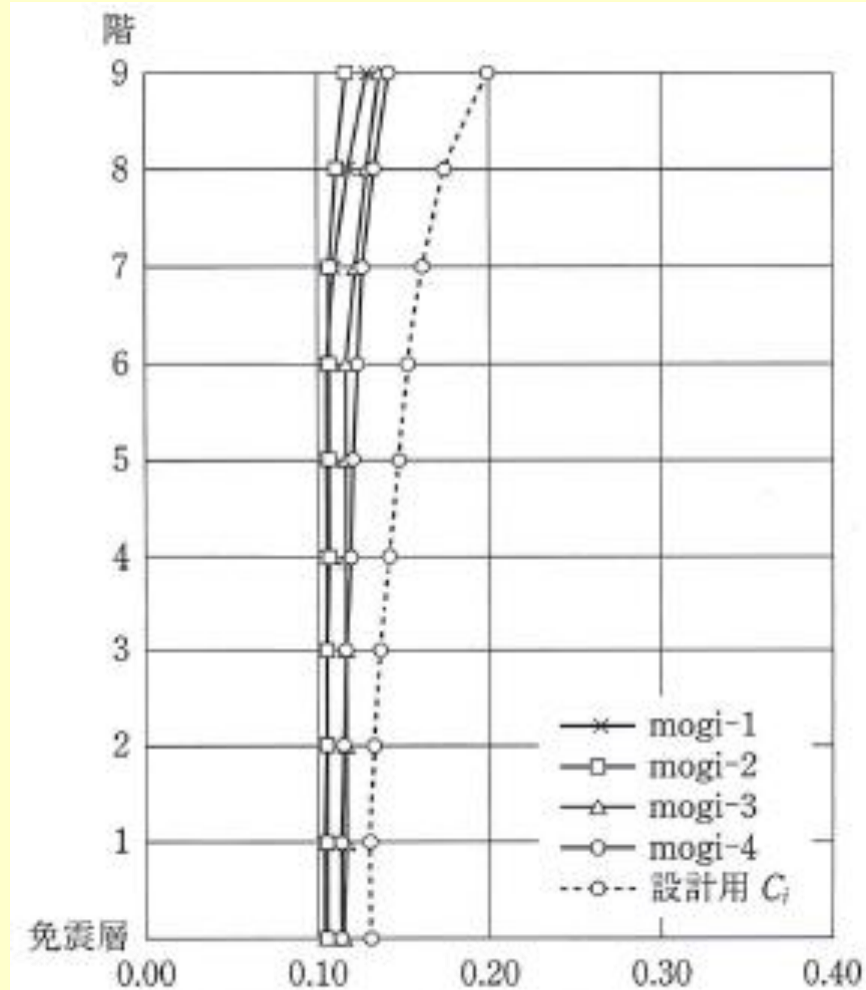
Performance Criteria for Response Analysis (an example)

Maximum Velocity	Seismic Performance	
	Super Structure	Max. Disp. of Seismic Isolation Device
25 cm/s	Elastic Behavior	≦ Stable Disp.
50 cm/s	≦Yielding Strength	≦ Performance Guaranteed Disp.

Design of Seismic Isolation Buildings



Response Accelerations (m/s²)



Response Shear Coefficients

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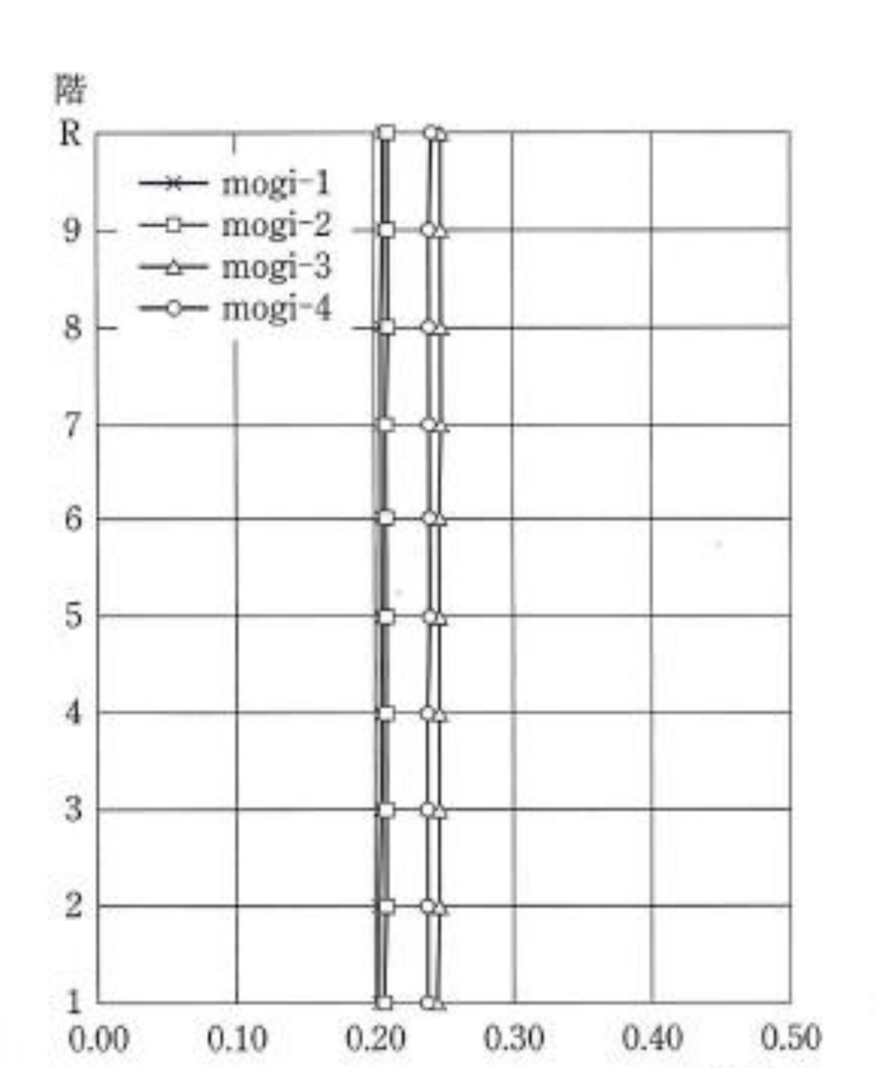
Design of Seismic Isolation Buildings



Response Horizontal Displacement (m)

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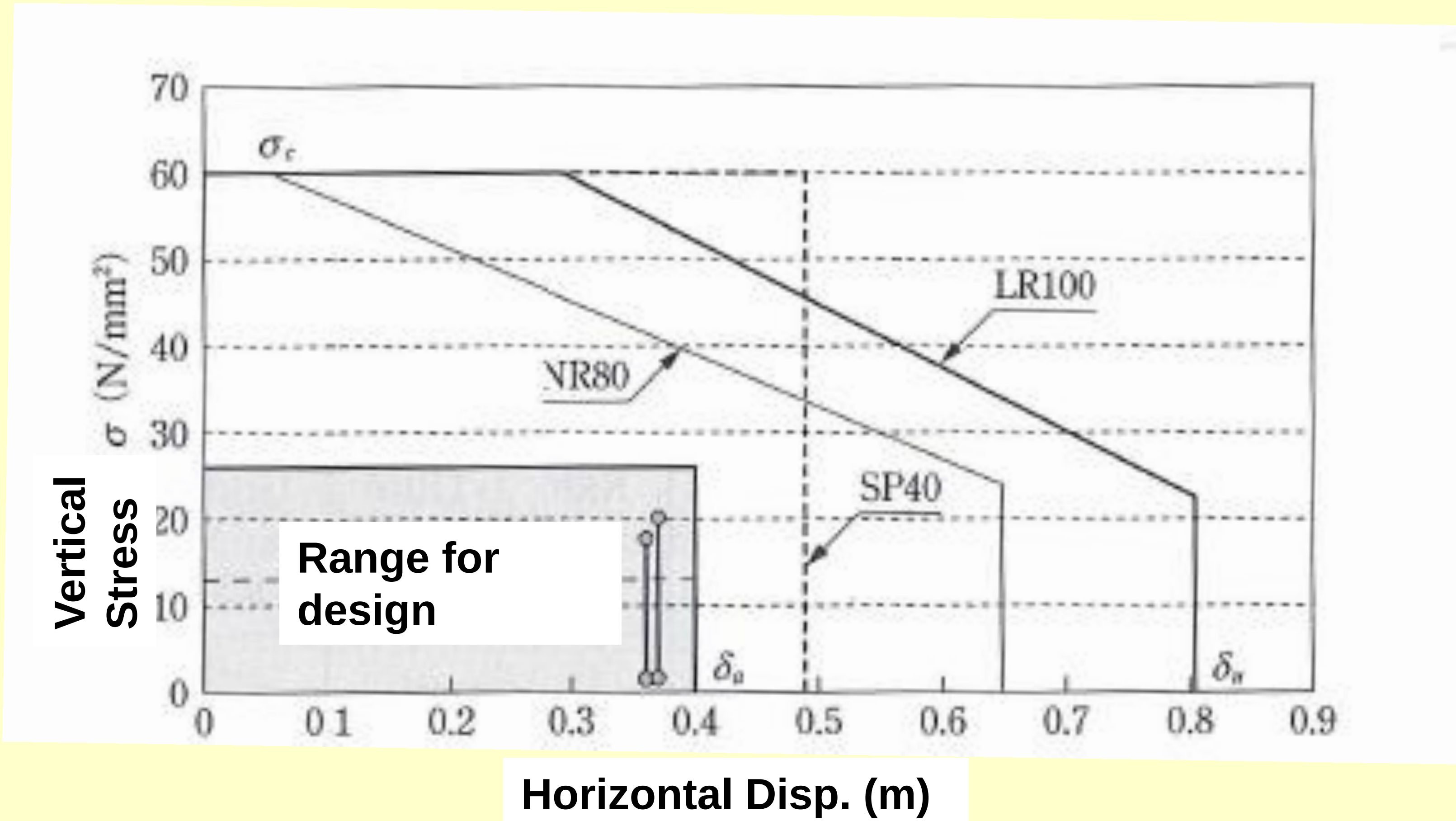
Design of Seismic Isolation Buildings



Vertical Stress vs. Maximum Horizontal Displacement of Seismic Isolation Devices (an example)

Collision Test at E-Defense shaking table , Japan

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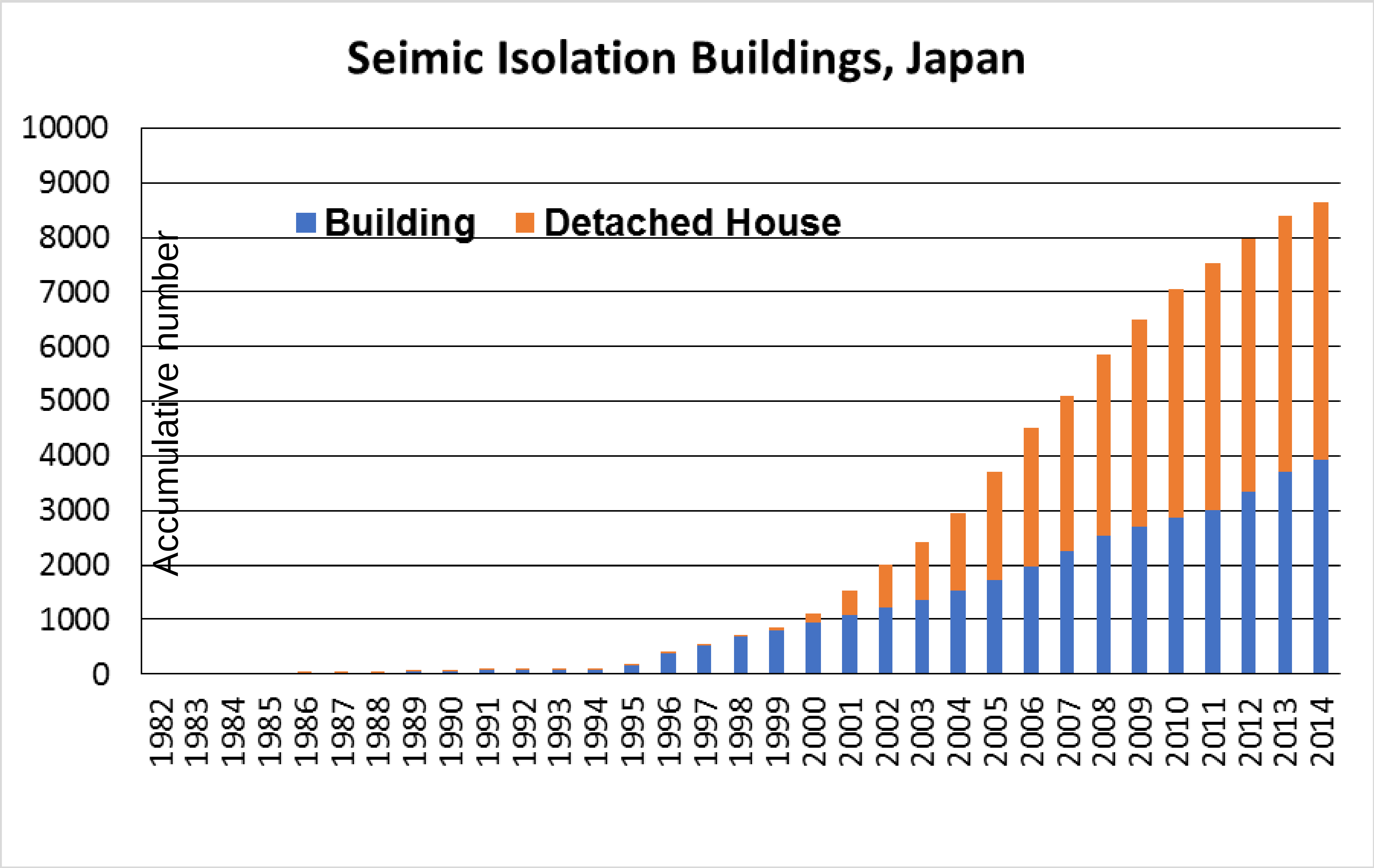
Seismic Isolation Buildings、Japan



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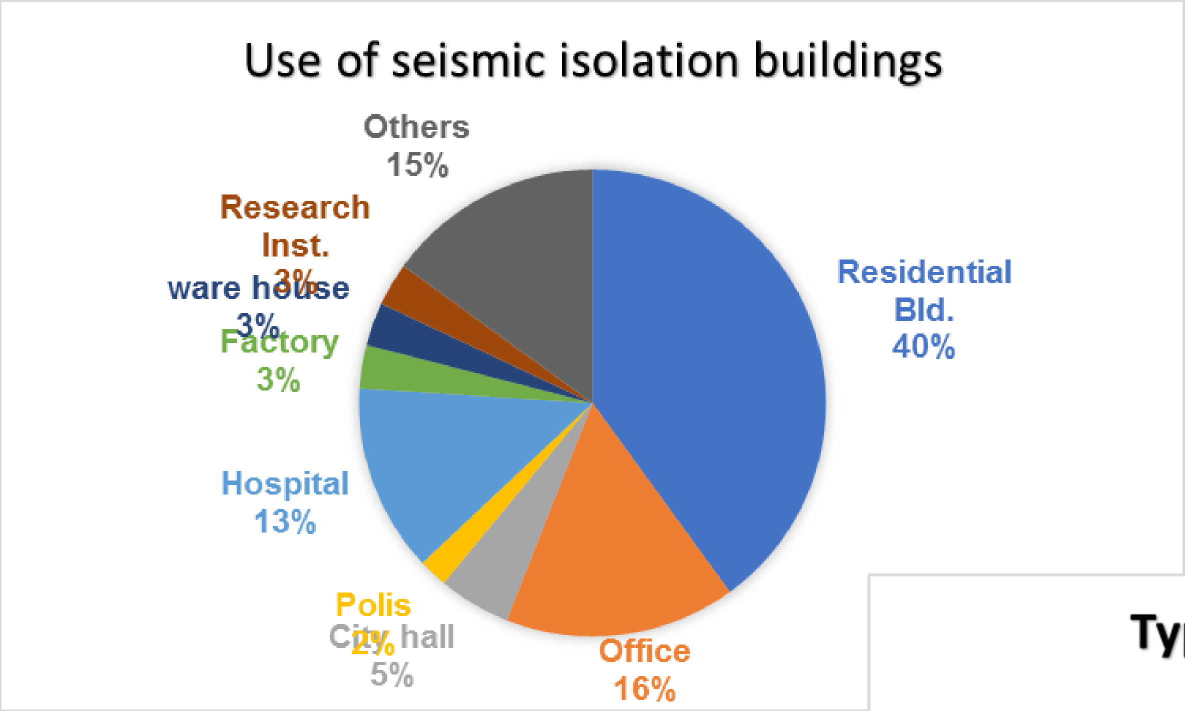
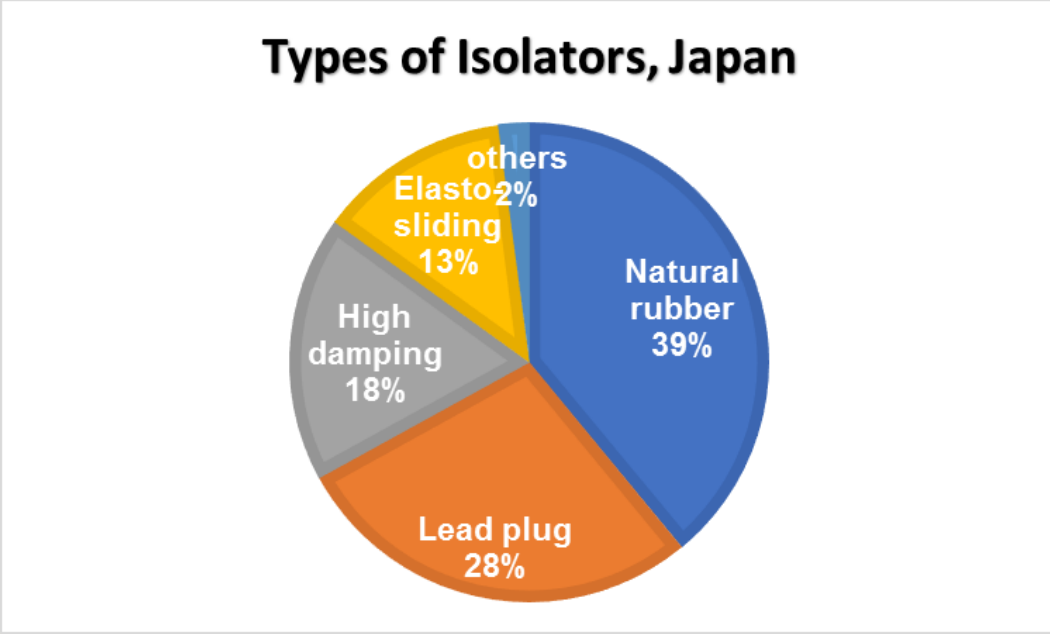
Seismic Isolation Buildings、Japan





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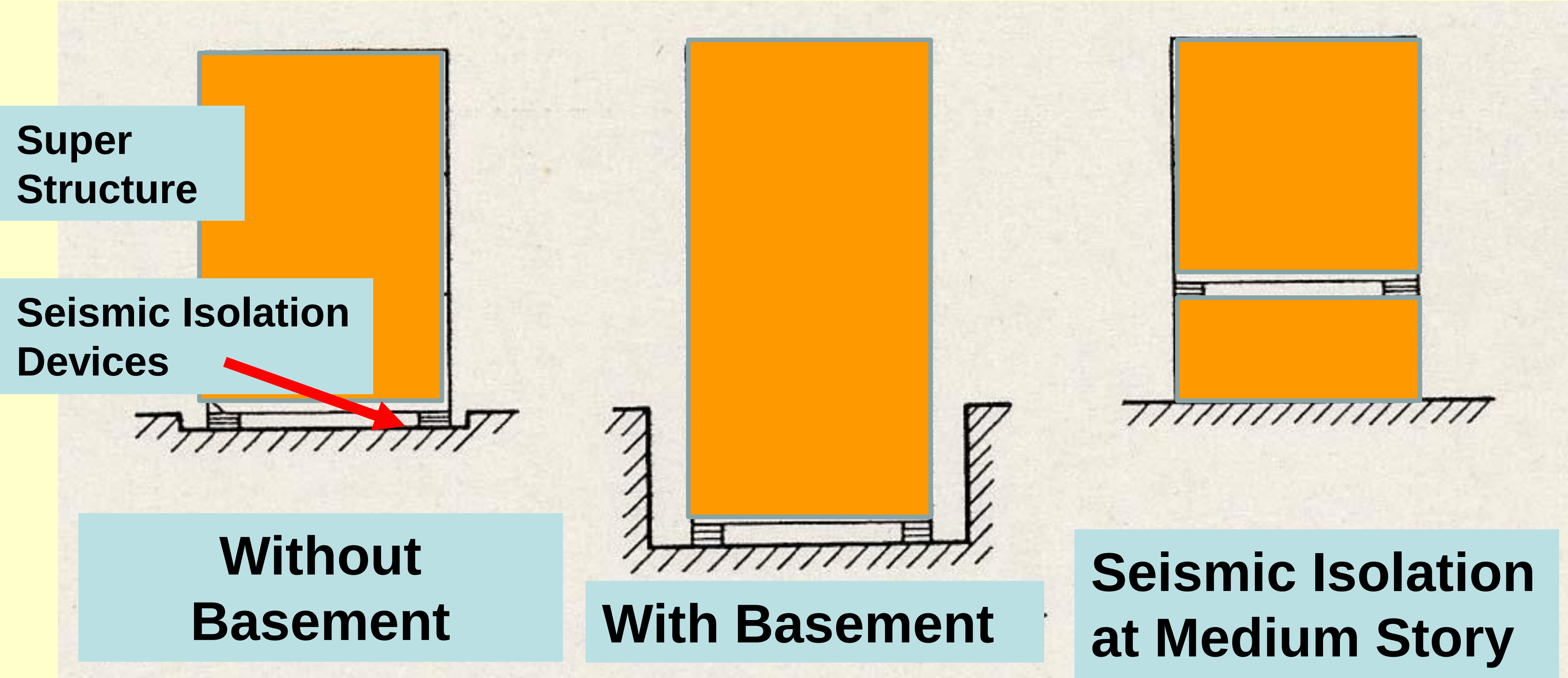
Examples of Seismic Isolation Buildings



Location of seismic isolation devices

Seismic Isolation Building, Japan

A Boutique Building in Tokyo

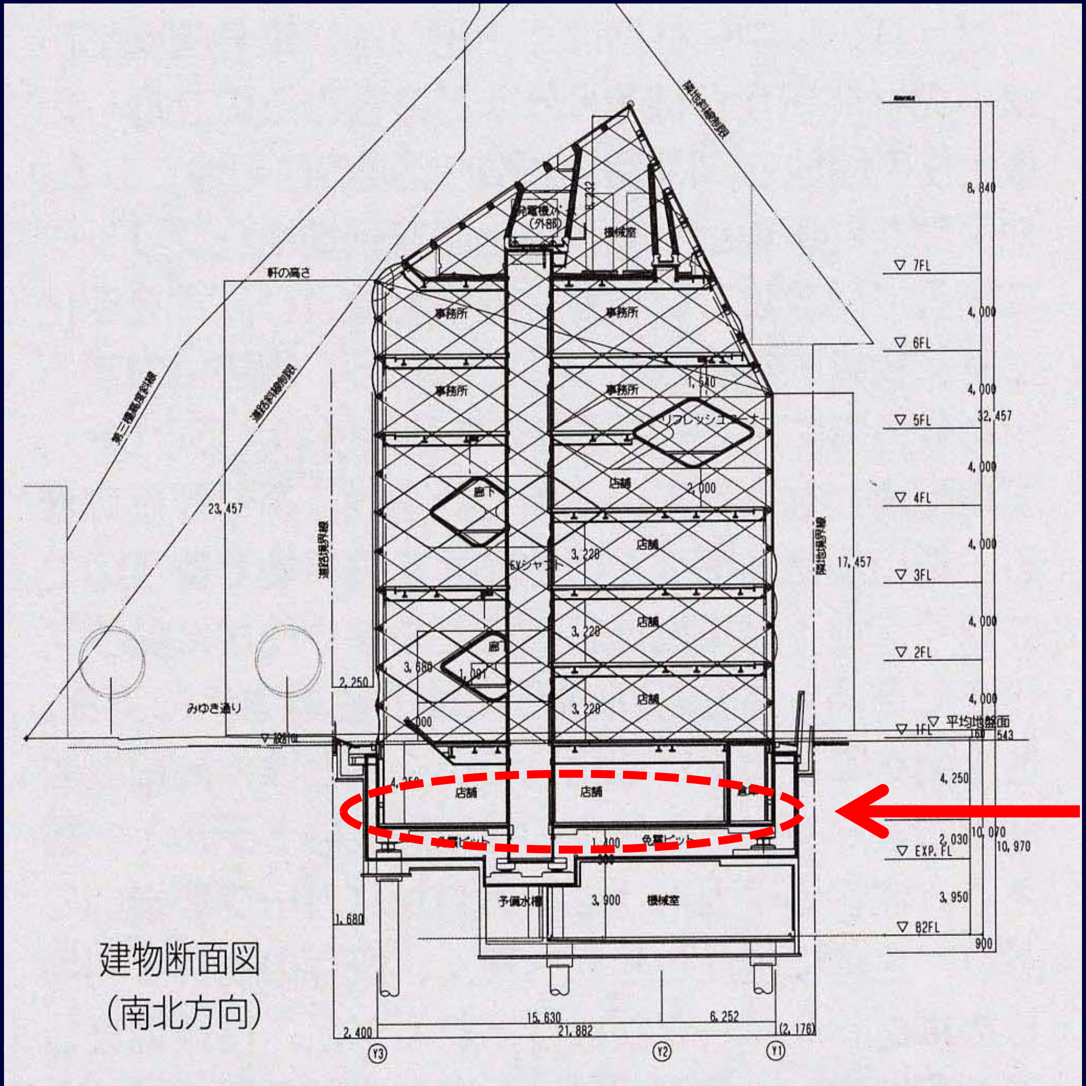
5th JSSI Award, 2004

MENSHIN,NO.5,2004.8

http://www.sawadalab.se.shibaura-it.ac.jp/kenken/kenken2005

Seismic Isolation Building, Japan

A Boutique Building in Tokyo



Seismic Isolator

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Seismic Isolation Building, Japan

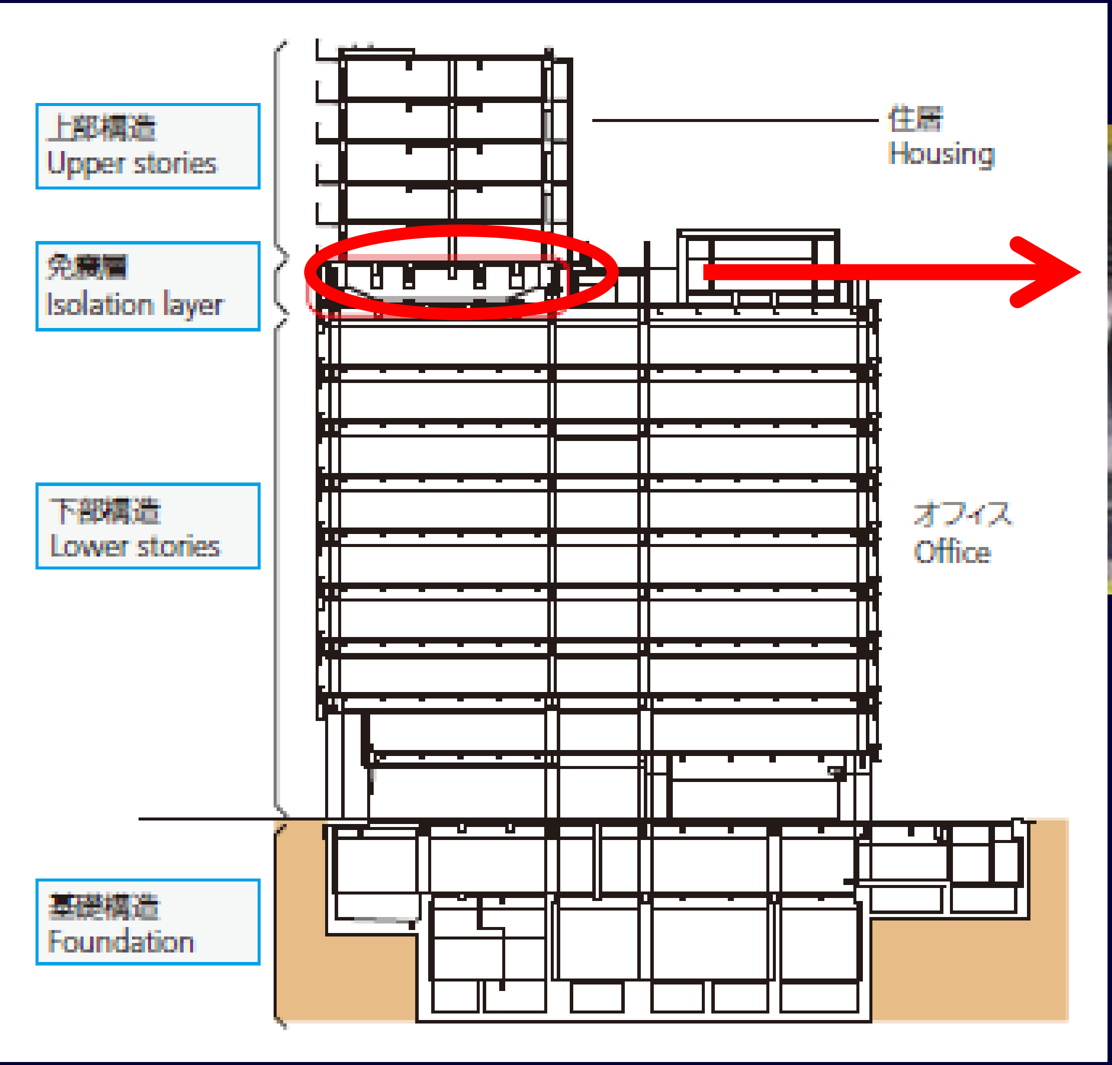
Middle Floor Isolation

14F, B2F, Isolation Story: between 9F and 10F
Office(1-9F, S), Residence (10-14F, RC)

http://www.nikken.co.jp/ja/archives/20013.html

Seismic Isolation Building, Japan

Middle Floor Isolation



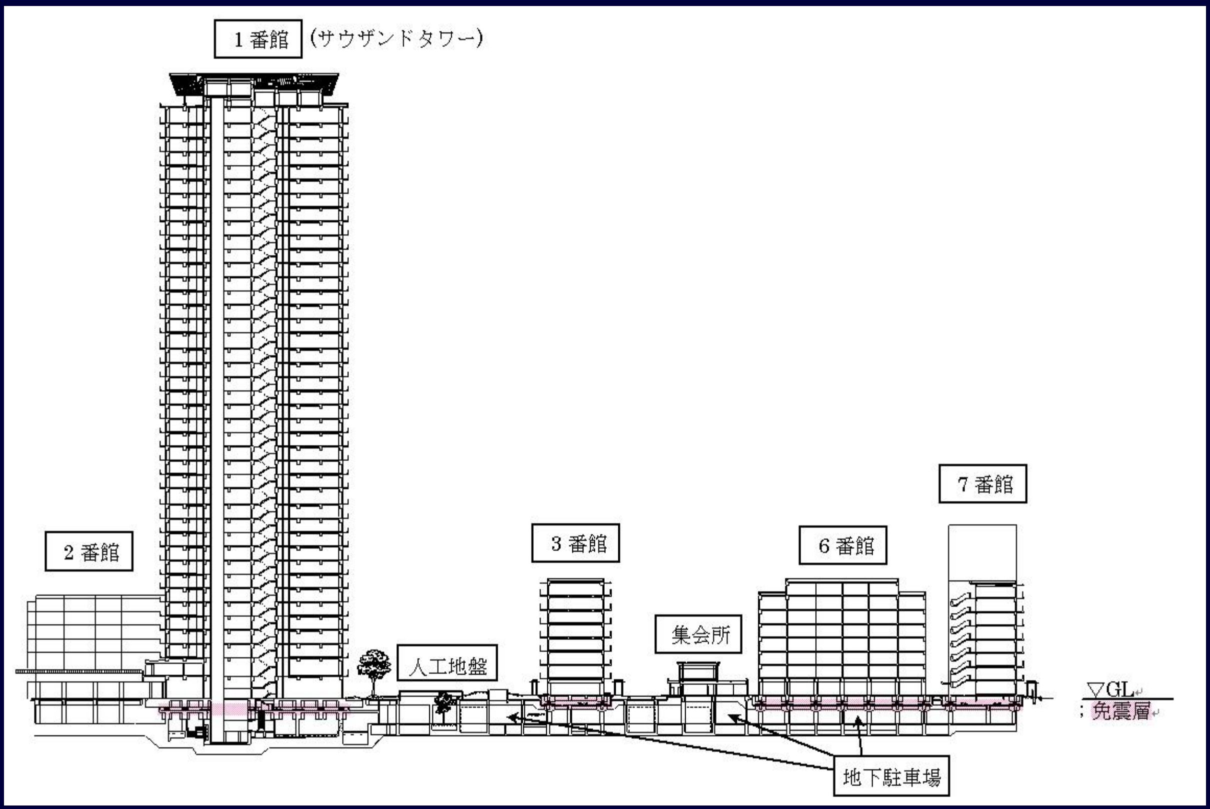
Isolation Story
(Isolator + Lead Damper)

http://www.nikken.co.jp/ja/archives/20013.html

Seismic Isolation Building, Japan

Thousand City, Kawasaki, Japan

A 7 buildings district (with one thousand residential housing units) seismically isolated, Dec. 2002



http://www.taisei-design.jp/de/feature/menshin/gaiku01.html#

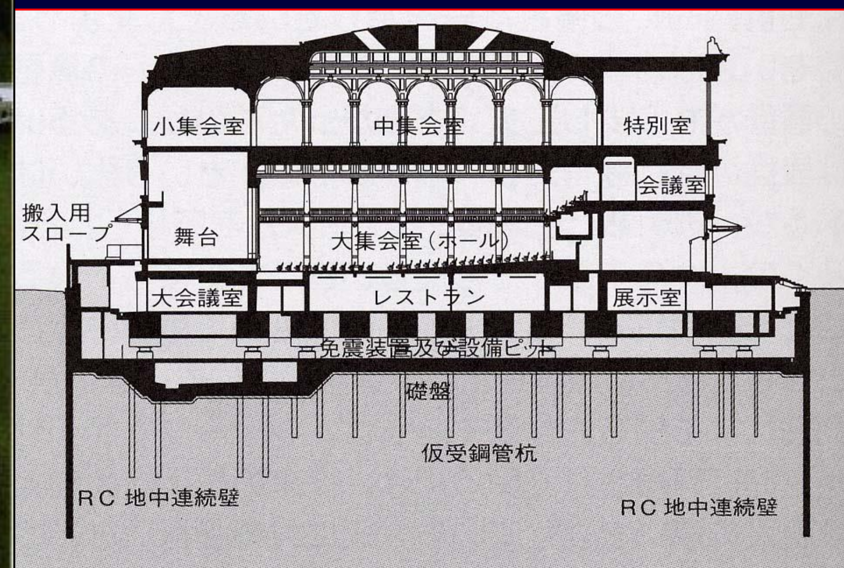
Seismic Isolation Building, Japan

Strengthened by Seismic Isolation

Osaka Central Public Hall (1918)

5th JSSI Award, 2004

MENSHIN,NO.5,2004.8



Seismic Isolation Building, Japan

Strengthened by Seismic Isolation

Tokyo Station **(1914:Original Construction)**

http://image.search.yahoo.co.jp/search?rkf=2&ei=UTF-

Seismic Isolation Building, Japan

High rise Residential Building

Location: Kobe City, Japan

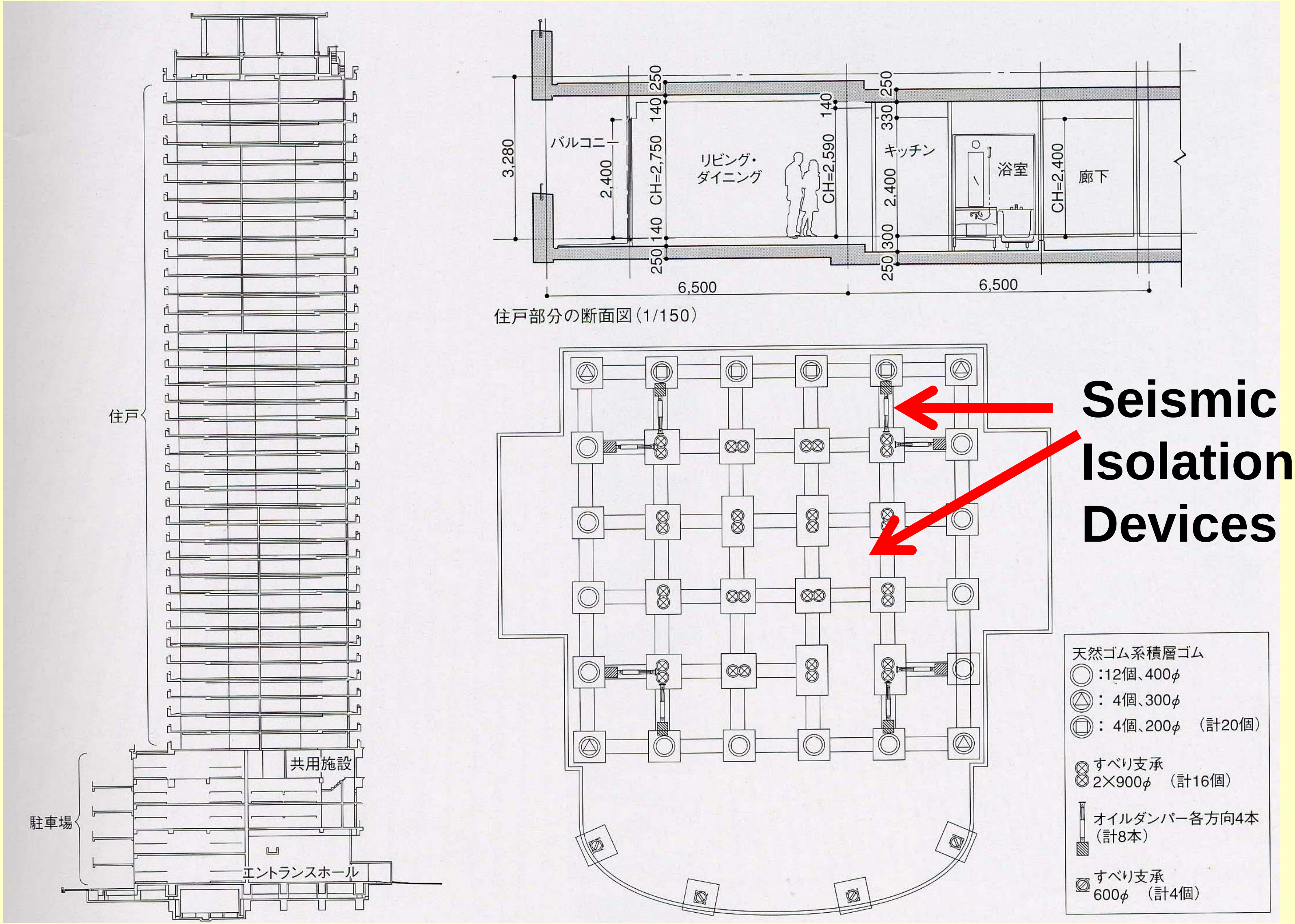
Story :43 Stories

Height : 152 m

Super structure: Reinforced Concrete

Nikkei Architecture 2004 9-26

Seismic Isolation Building, Japan



Section **Plan**

Seki M., UTCB Lecture note, May 2017, BRI, Japan

Seismic Isolation Building, Japan

5th JSSI Award, 2004

MENSHIN,NO.5,2004.8

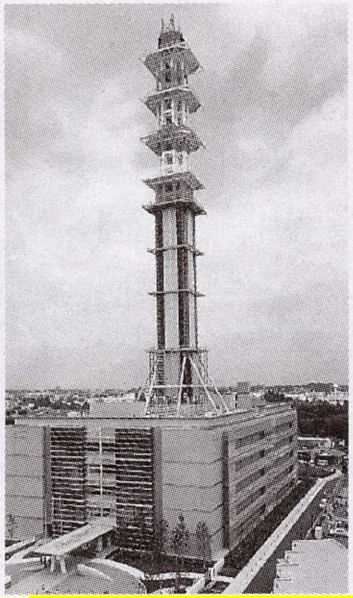
Building with Big Tower

（NTT Facilities）

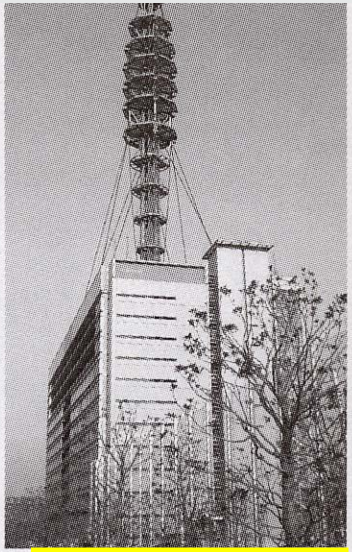
Kobe City

TMD

Visco-Elastic Damper



Tama City



Osaka City

Seismic Isolation Building, Japan

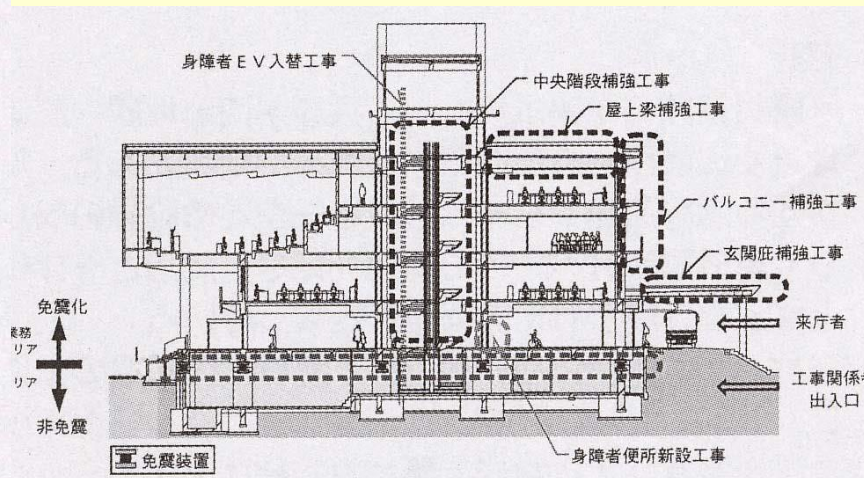
Murakami City Office, Niigata Pre.

Kajima Corporation

5th JSSI Award, 2004

MENSHIN,NO.5,2004.8

Exterior View after Strengthened by Seismic Isolation



Section

Seismic Isolation Building, Japan

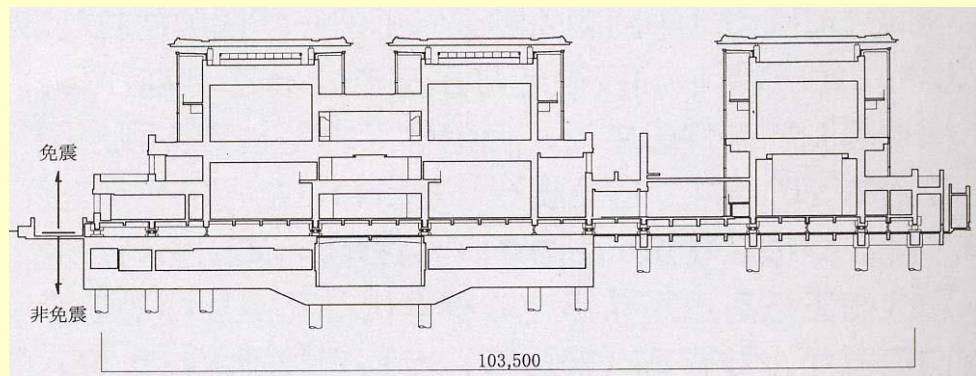
5th JSSI Award, 2004

MENSHIN,NO.5,2004.8

Hyogo Pref. Museum

（Tadao Ando、Obayashi Corporation)

Exterior View



Section

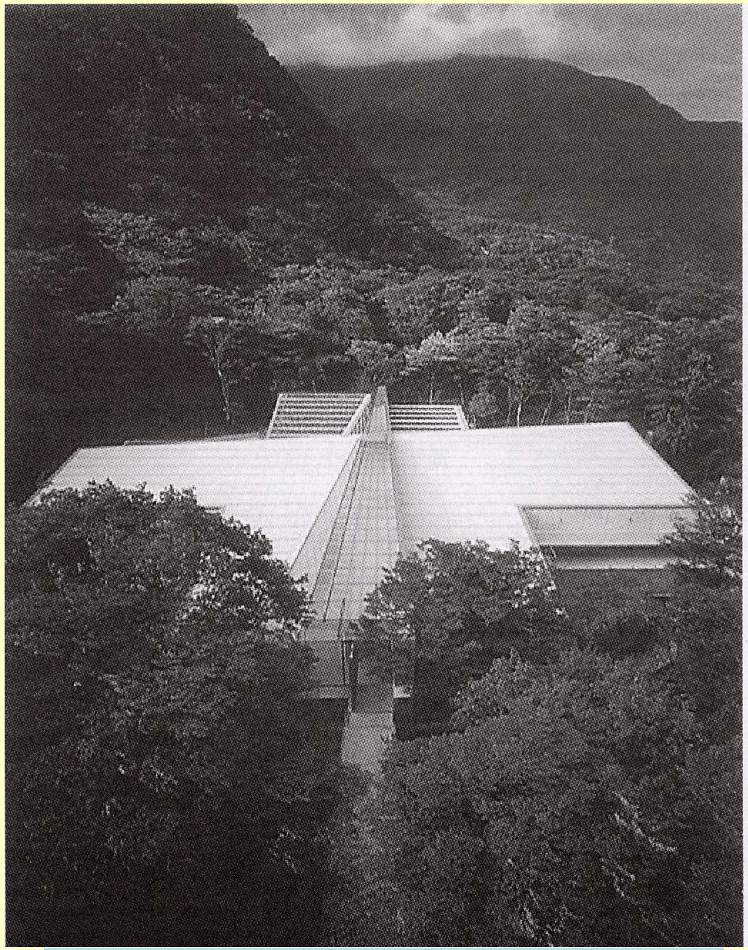
Seismic Isolation Building, Japan

Pola Art Museum

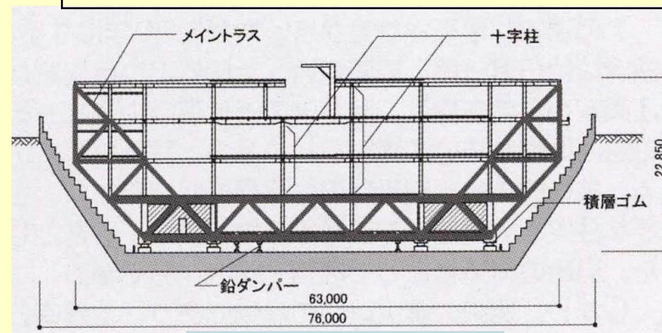
（Nikken Sekkei Co., Tkenaka Corporation）

5th JSSI Award, 2004

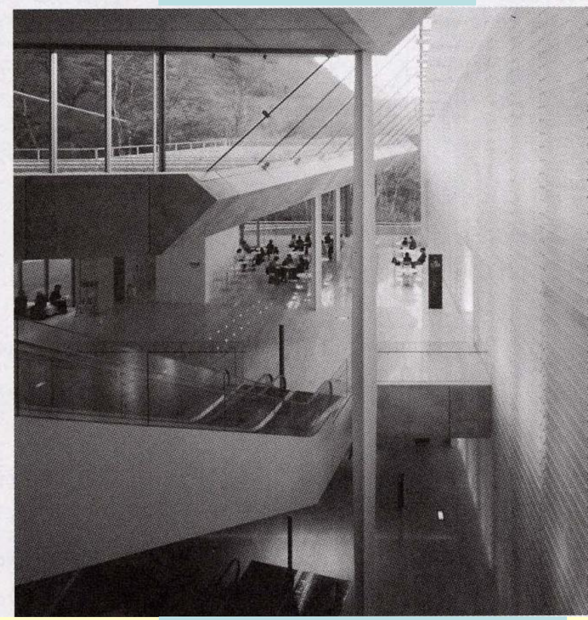
MENSHIN,NO.5,2004.8



Exterior View

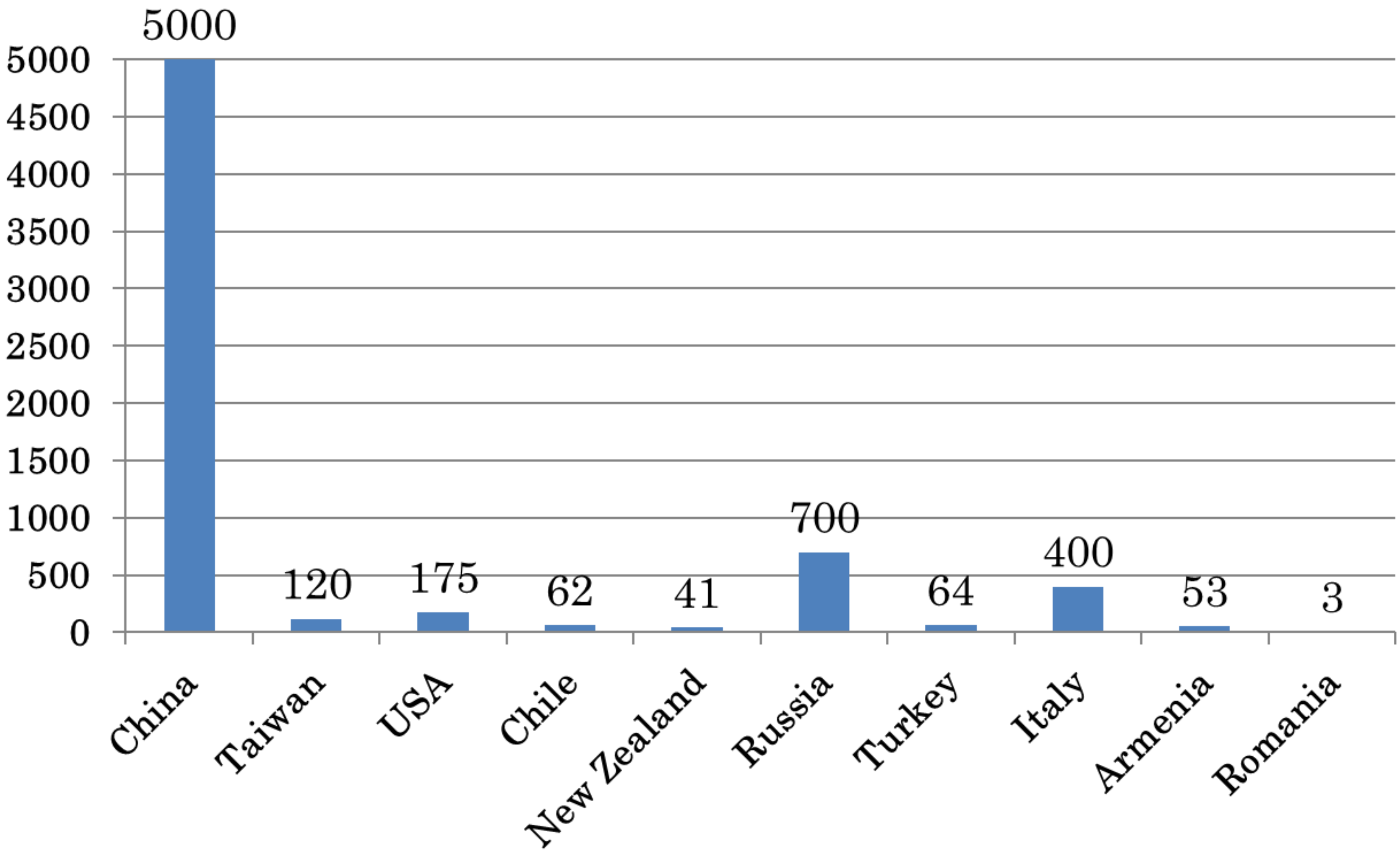


Section



Atrium

Number of seismic isolation buildings (except Japan)



Seki M., UTCB Lecture note, May 2017, BRI, Japan

Kun Ming Chang Shui International Airport (China)

A=560,000m^2 Biggest building in the world, Completed in 2012.4

http://baike.baidu.com/picture/6238016/6329444/

Kun Ming Chang Shui International Airport (China)

(Photo; M.Seki)

Kun Ming Chang Shui International Airport (China)

Natural rubber bearing : 1180
Lead plug rubber bearing : 654
(1000mmΦ)

Oil damper: 108
(600ϕ,1800L)

(Photo; M.Seki)

Unification with plural buildings in Tangshan City (China)

(Photo; M.Seki)

A=240,000m^2,RC, Completed in 2015 , Five buildings; 6F, 12F, 20F, 27F, 30F are on the common B4F

Unification with plural buildings in Tangshan City (China)

A=240,000m^2,RC, Completed in 2015 , Five buildings; 6F, 12F, 20F, 27F, 30F on the common B4F

Unification with plural buildings in Tangshan City (China)

A=240,000m², RC, Completed in 2015 , Five buildings; 6F, 12F, 20F, 27F, 30F on the common B4F

Unification with plural buildings in Tangshan City (China)

(Photo; M.Seki)

Natural rubber bearings:388(900-1000Φ), Oil damper:70 (1500KN)
Isolation devices are installed between B4F and B3F

Bucharest City Hall (Romania)

(Photo; M.Seki)

Brick masonry , 4F,B1,PH1, A=20,000m^2, Original 1910, Retrofitted in 2015.

Bucharest City Hall (Romania)

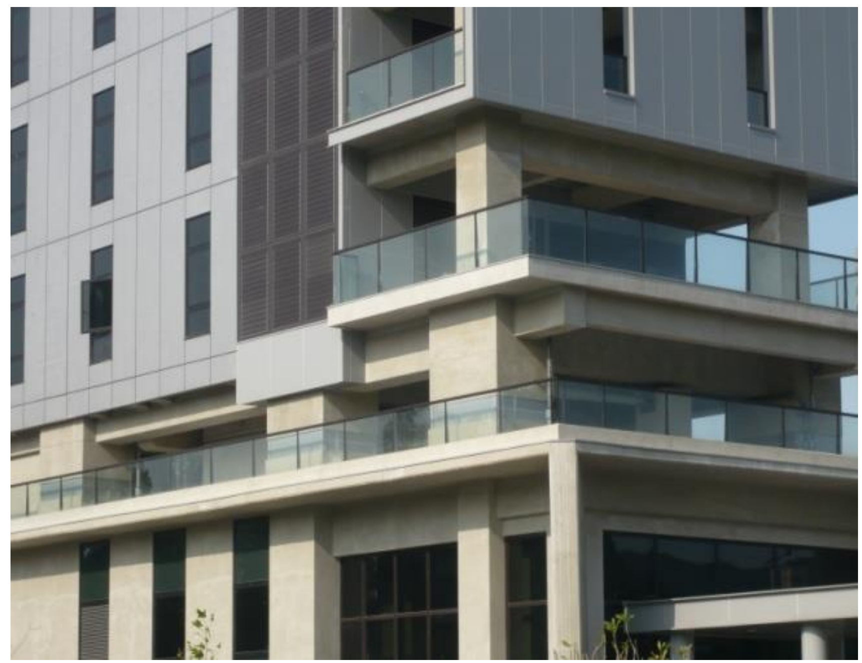
Natural rubber bearings:262(1000mmΦ)

Oil dampers:36 (1750KN, ±700mm)

(Photo;
M.Seki)

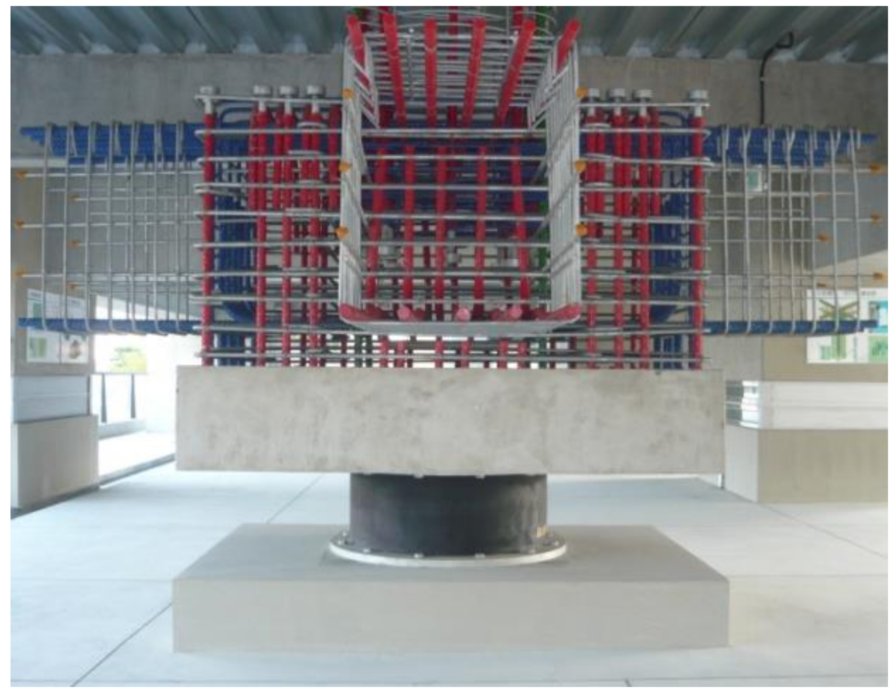
The Civil Engineering Research Center of The National Taiwan University (Taiwan)

PC, 9F,B1F,PH2F, Isolated at top of 1st floor column



(Photo; S.J.Wang)

The Civil Engineering Research Center of The National Taiwan University (Taiwan)

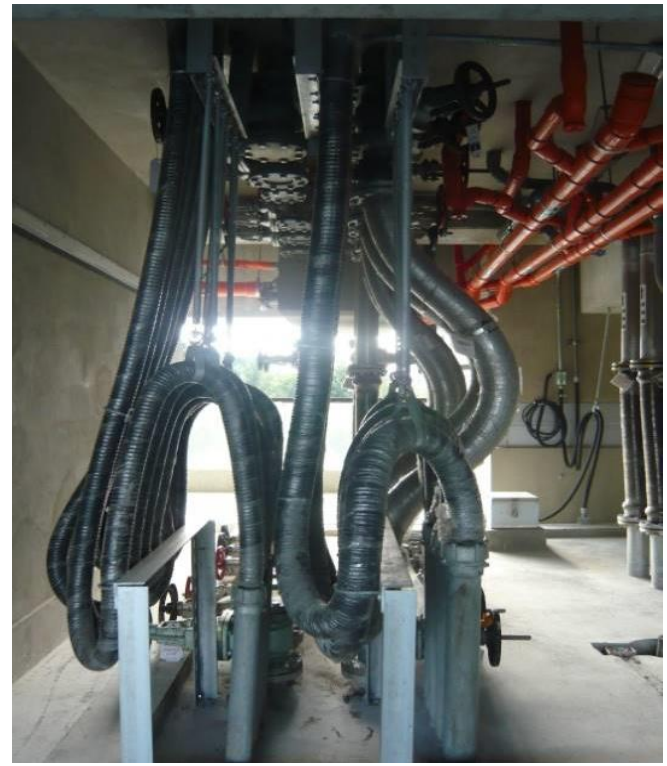



(Photo; S.J.Wang)

Lead plug rubber bearing: 19 (900mmΦ）

The Civil Engineering Research Center of The National Taiwan University (Taiwan)

Viscous damper: 6 (1000KN)



Flexible joints

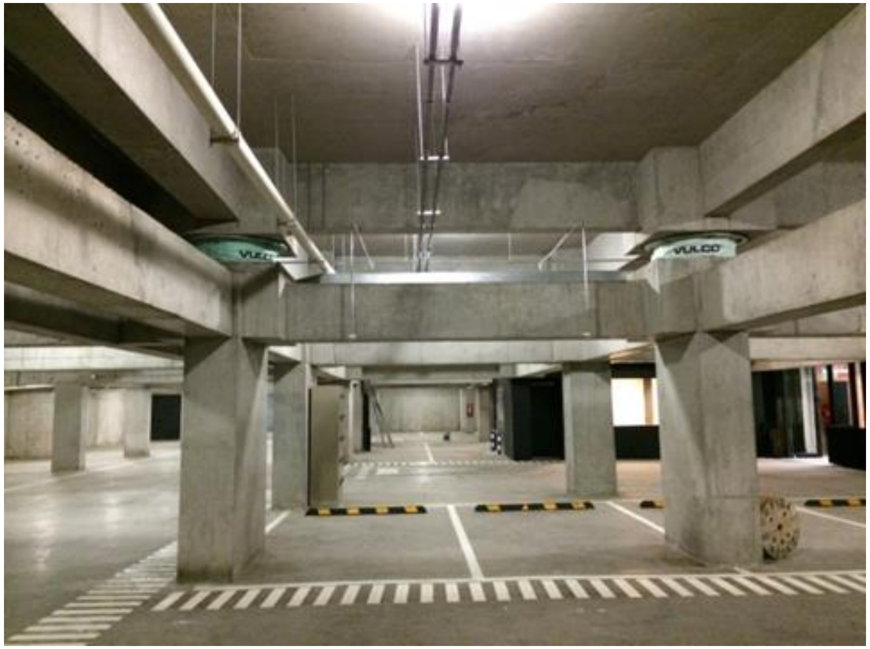
(Photo; S.J.Wang)

Anacleto Angelini Center for Innovation and Technology (Santiago, Chile)

RC, 11F,B3F, A=20,000m^2, The biggest bld. in South America, The design Museum Award (London), Completed in 2013

(Photo; SIRVE S.A. Co.)

Anacleto Angelini Center for Innovation and Technology (Santiago, Chile)



Inner core frame is supported at B3F.

HDRB:43 (12 of them: Lead plug)(750-850mmΦ), Friction bearing:12, Supported at the top of column of B1F

(Photo; SIRVE S.A. Co.)

Residential complex called "Dawn" (Russia)

Lead plug rubber bearing:160
(Plug: 800mmΦ)

(Photo; V. Smirnov)

24F,B3F, H=105m, Completed in 2015.9, 3 storeyed car parking is a common bed floor

Sabiha Gökçen International Airport (SIGA) Terminal Building (Istanbul, Turkey)

S, 4F,B1F BxD=160mx272m, H-32.5m,Completed in 2209, ECCS Award

(Photo; Prota Inc.)

Sabiha Gökçen International Airport (SIGA) Terminal Building (Istanbul, Turkey)

Inside Steel Frame

(Photo; Prota Inc.)

Sabiha Gökçen International Airport (SIGA) Terminal Building (Istanbul, Turkey)

Under construction of steel frame

Isolator: 296 pieces between ground floor and basement

(Photo; Prota Inc.)

Wellington Regional Hospital building (New Zealand)

RC, 10F, BxD=160mx100m, A=60,000m^2, Biggest of all New Zealand seismic isolation buildings

Lead plug rubber bearing:135, Flat slide baering:132

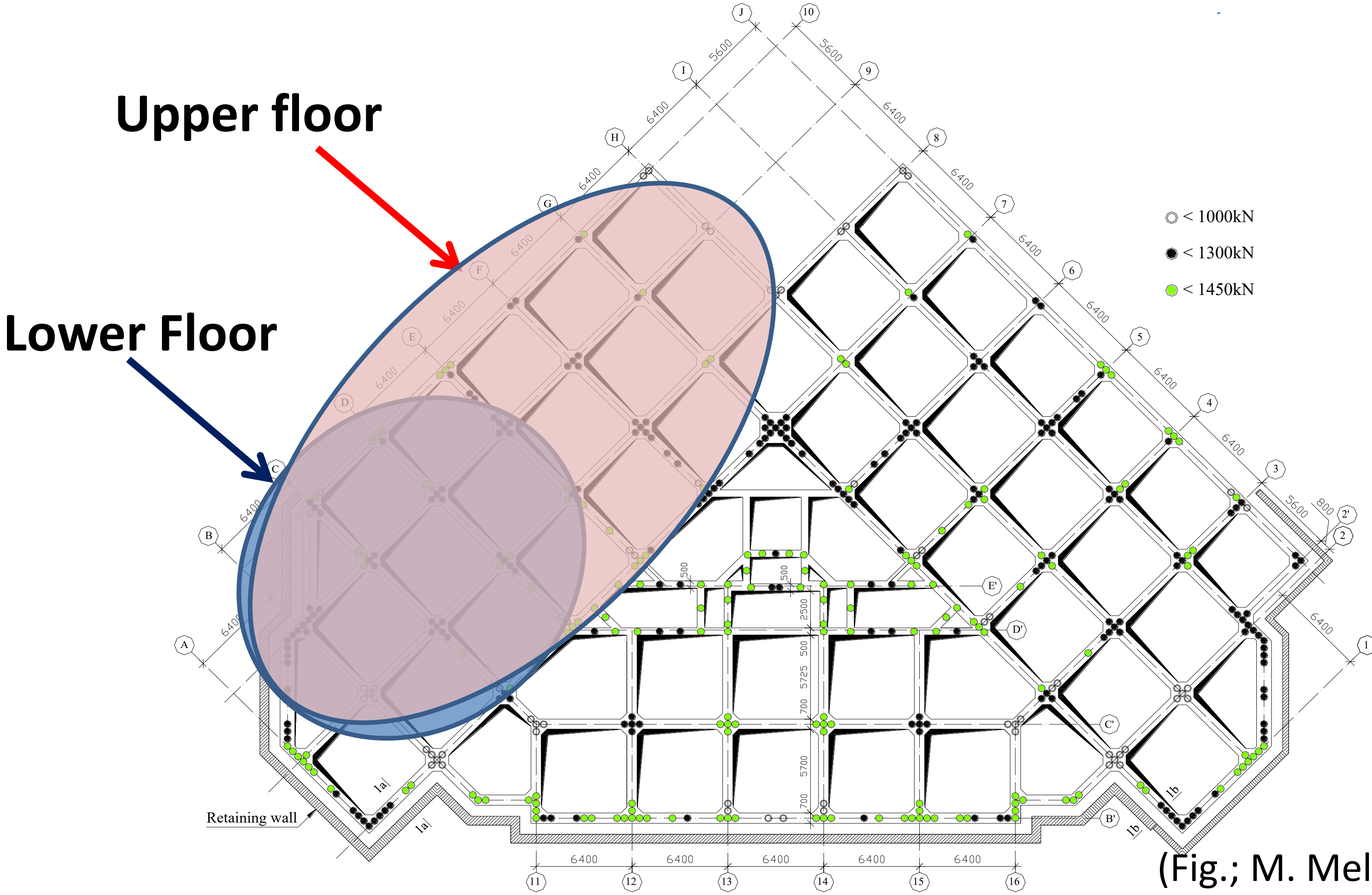
(Photo; D. Whittaker)

Multi-functional Residential Complex of Seismic Isolated Buildings/Twins "Northern Ray" (Yerevan,Armenia)

RC,15F,B3F, Twin Residential buildings, H-53.25m

(Photo; M. Melkumyan)

Multi-functional Residential Complex of Seismic Isolated Buildings/Twins "Northern Ray" (Yerevan,Armenia)



(Fig.; M. Melkumyan)

Multi-functional Residential Complex of Seismic Isolated Buildings/Twins “Northern Ray” (Yerevan,Armenia)

Isolator:904, Group of small size bearings (308mmΦ,H=202mm)

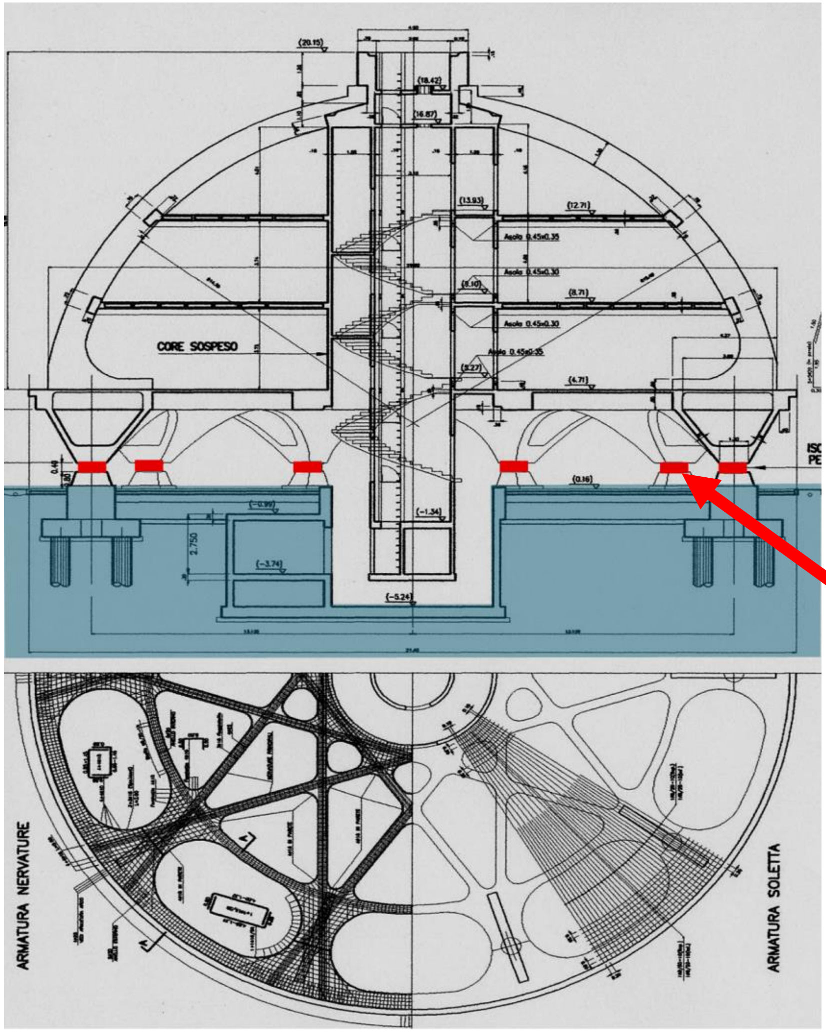
(Photo; M. Melkumyan)

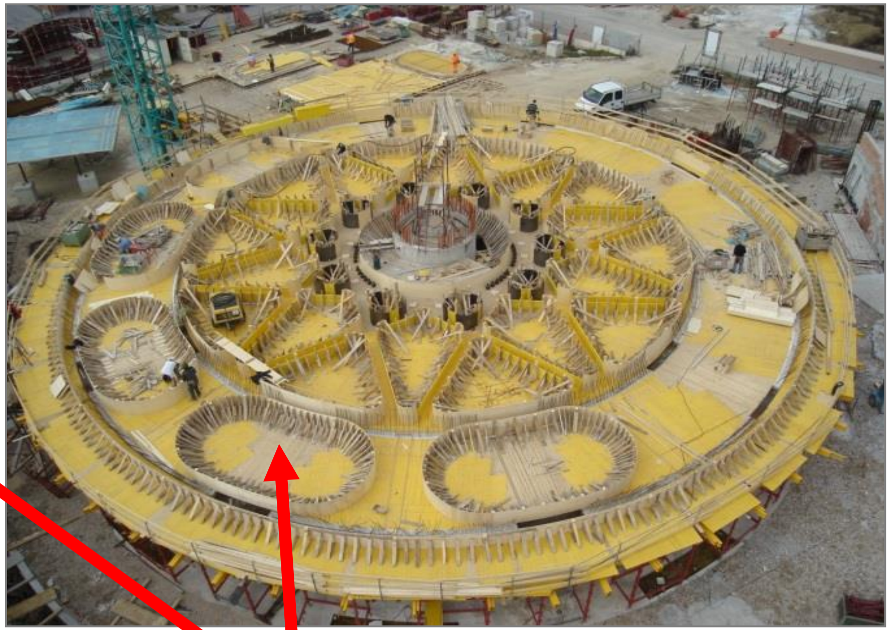
Main building of the New Regional Emergency Management Centre, Foligno (Italy)

RC dome, 32mΦ, 3F, Emergency Management Center,
European Concrete Award(ECSN-2012) & Premio di Eccellenza Award (AICAP-2010)

(Photo; Alberto Parducci)

Main building of the New Regional Emergency Management Centre, Foligno (Italy)





HDRB:10 (1000mmΦ, ±400mm Capacity)

(Photo; Alberto Parducci)

Los Angeles City Hall, Los Angeles, California(USA)

S+BW(External), 26F H=138m,
The highest base isolated building in USA
A=83,000m², W≒1,100,000KN
Original construction:1928
Damaged in 1994 Northridge Earthquake
Retrofitted: 1999-2001

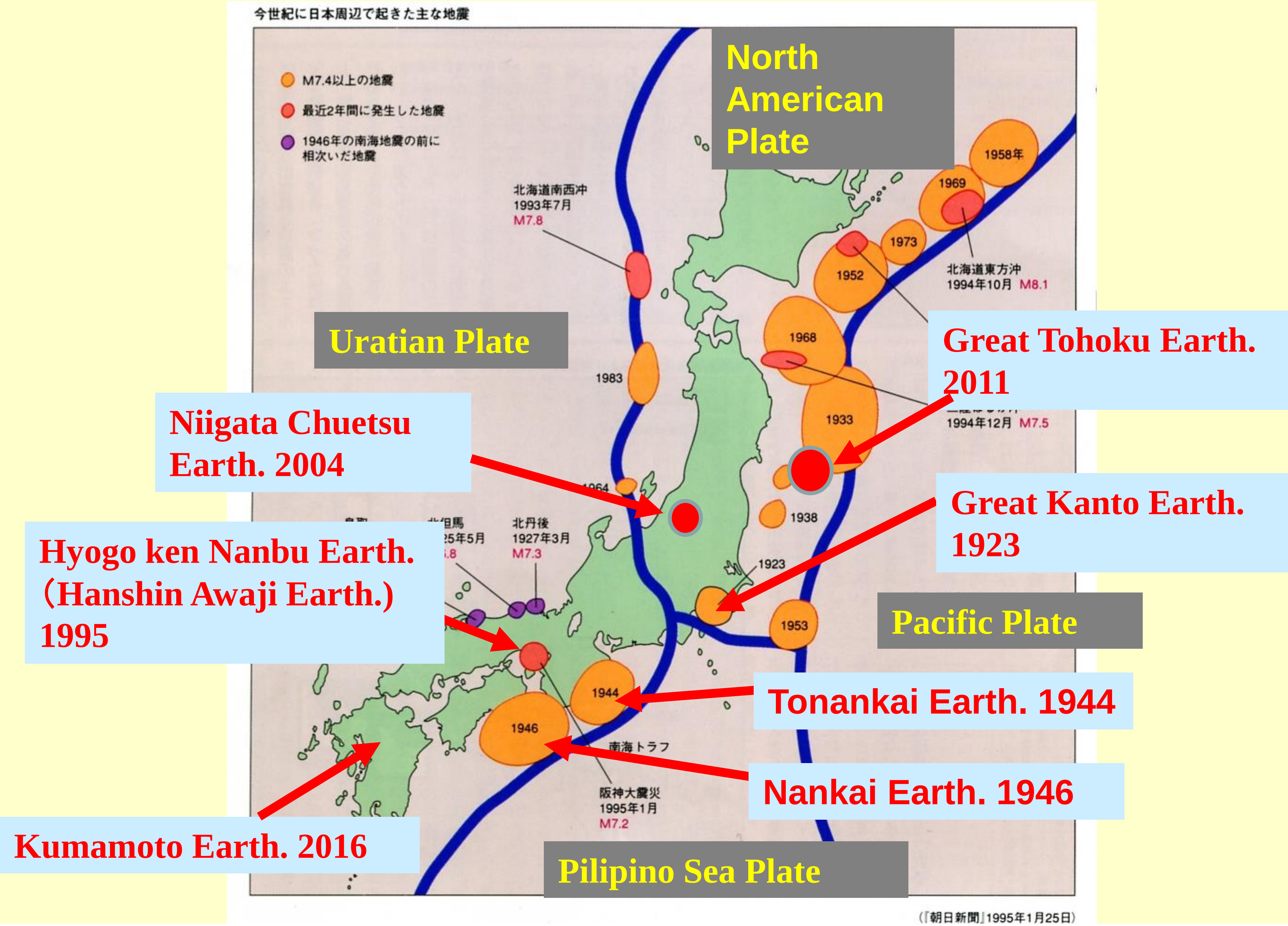
(Photo; SIE, Inc.)

Los Angeles City Hall, Los Angeles, California(USA)

HDRB:416 Friction bearing:90(900-1300mmΦ,
Viscous damper:52(±580mm capacity)
RC shear walls are newly installed in upper storeys.
12 Viscous dampers at 24F-26F tower.

(Photo; SIE Inc.)

Earthquake Around Japan Island（1900-2017）

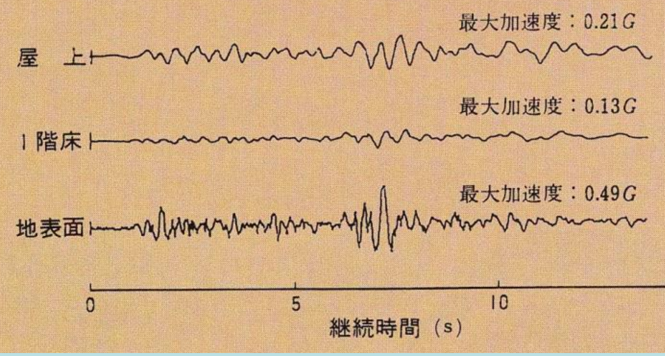


Seki M., UTCB Lecture note, May 2017, BRI, Japan

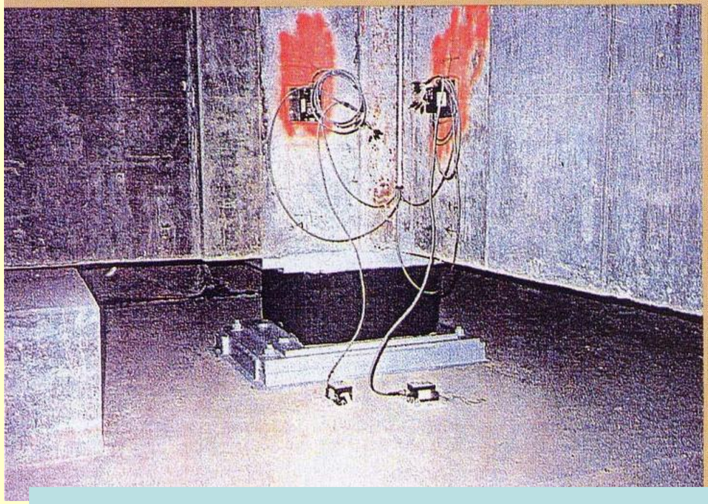
Verification of Seismic Isolation Effect

Northelege Earthquake（1994.1.17)

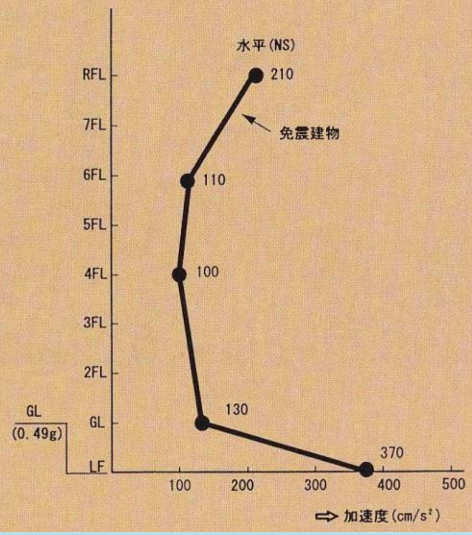
Hospital, South California Univ.



Observed Accelerations (NS)



Seismic isolation Devices

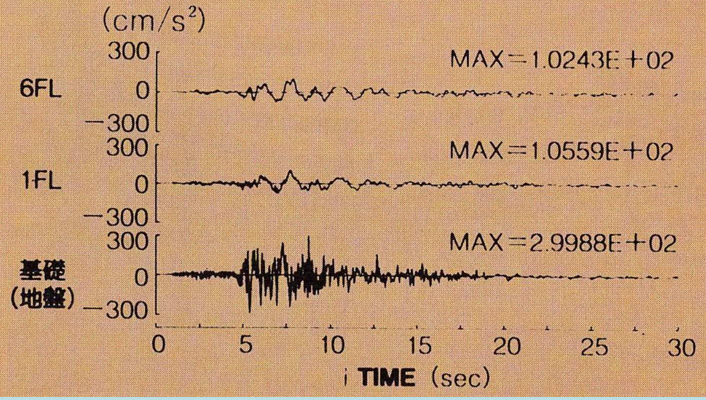


Base Isolation Effect

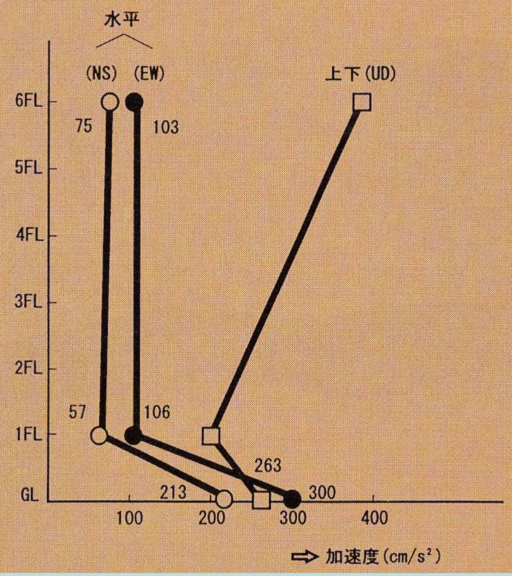
Verification of Seismic Isolation Effect

Hyogo Ken Nanbu Earthquake（1995.1.17）

West Building, Sanda City,
Close to Kobe City ,30km



Observed Acceleration (EW)



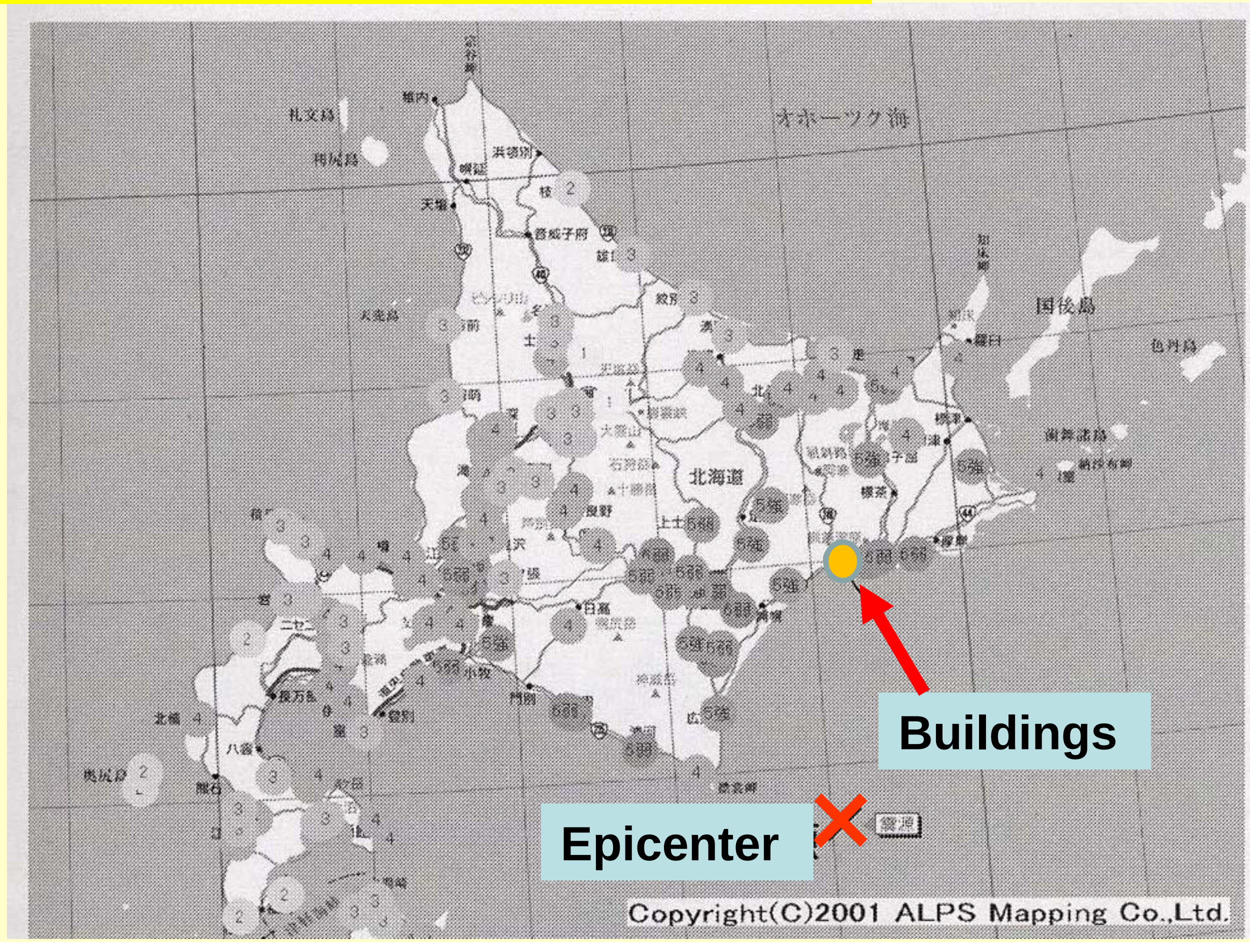
Seismic Isolation Effect

Verification of Seismic Isolation Effect

Tokachi - Oki Earthquake, 2003

September 26th, 2003

Magnitude: 7.0



Hokkaido Island, Japan

Verification of Seismic Isolation Effect

■Kushiro City, Hokkaido

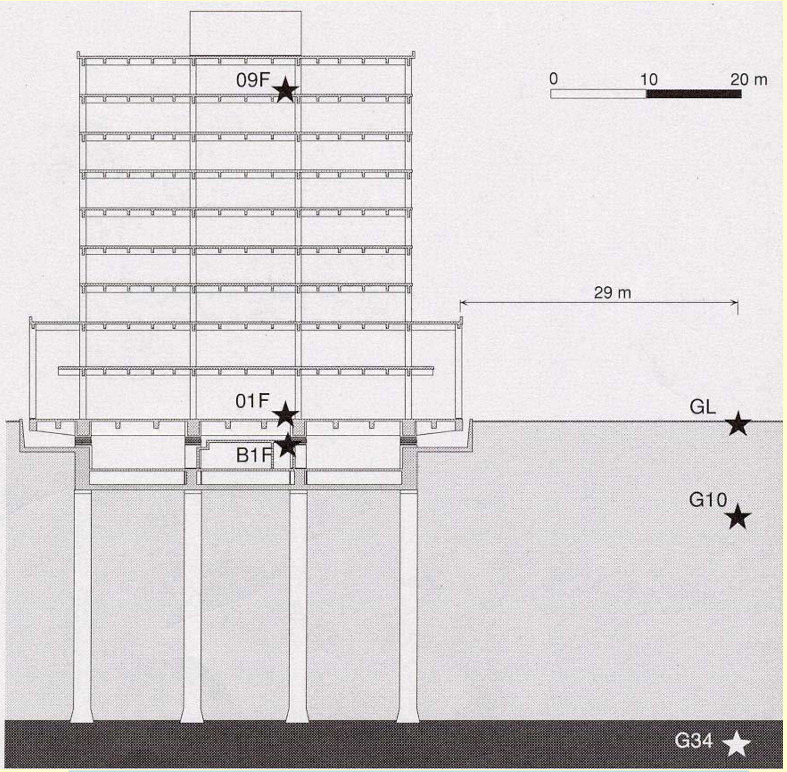
■Office Building（Local Government ）

■Basement: One story, Nine Stories, PH: One story

■SRC, RC Piles (-31.5m)

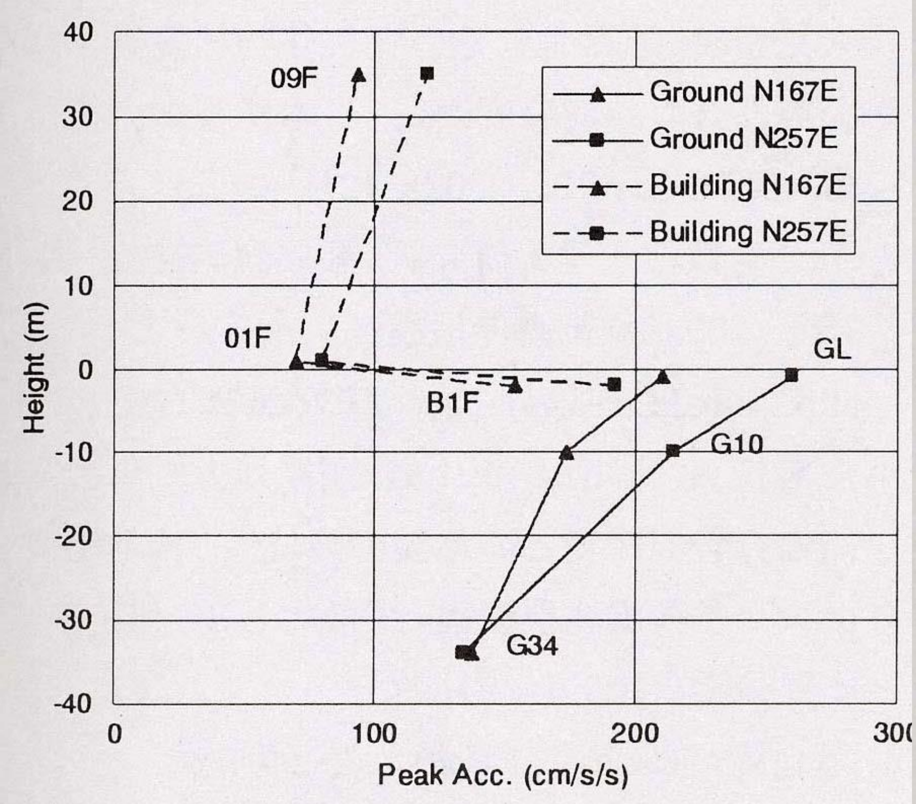
(Kashima et al.：MENSHIN,NO.43,2004.2)

Exterior View of Building

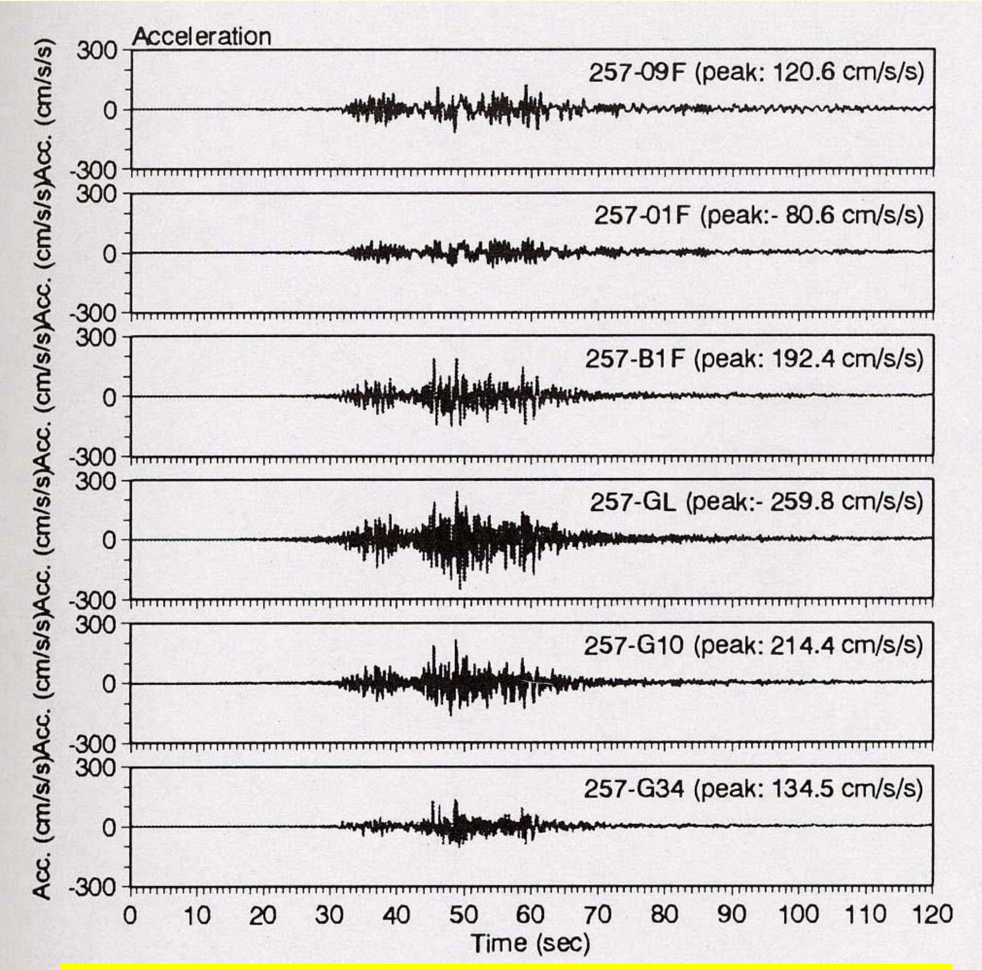


Location of Accelerometers

Verification of Seismic Isolation Effect



Observed Maximum Accelerations



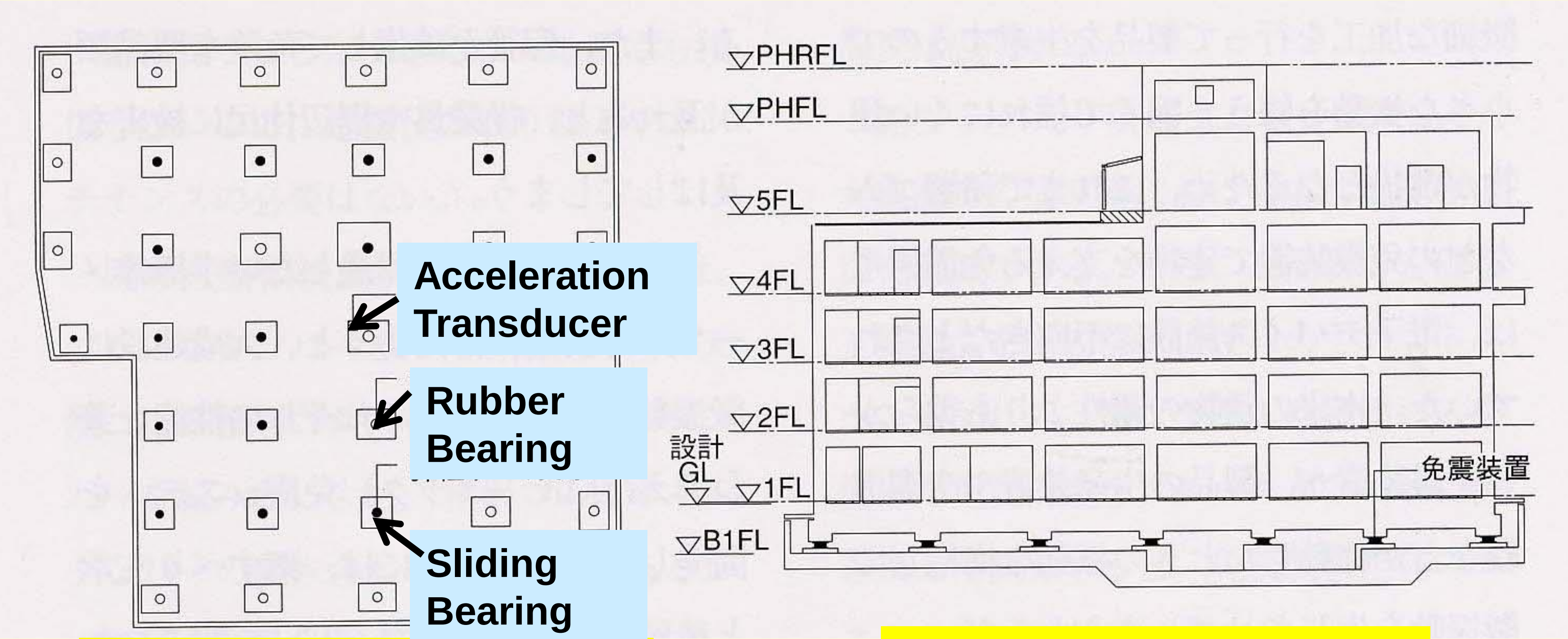
Observed Time History of Accelerations

Verification of Seismic Isolation Effect

Niigata Cyuetsu Earthquake (October, 2004)

Verification of Seismic Isolation Effect

Niigata Cyuetsu Earthquake (October, 2004)

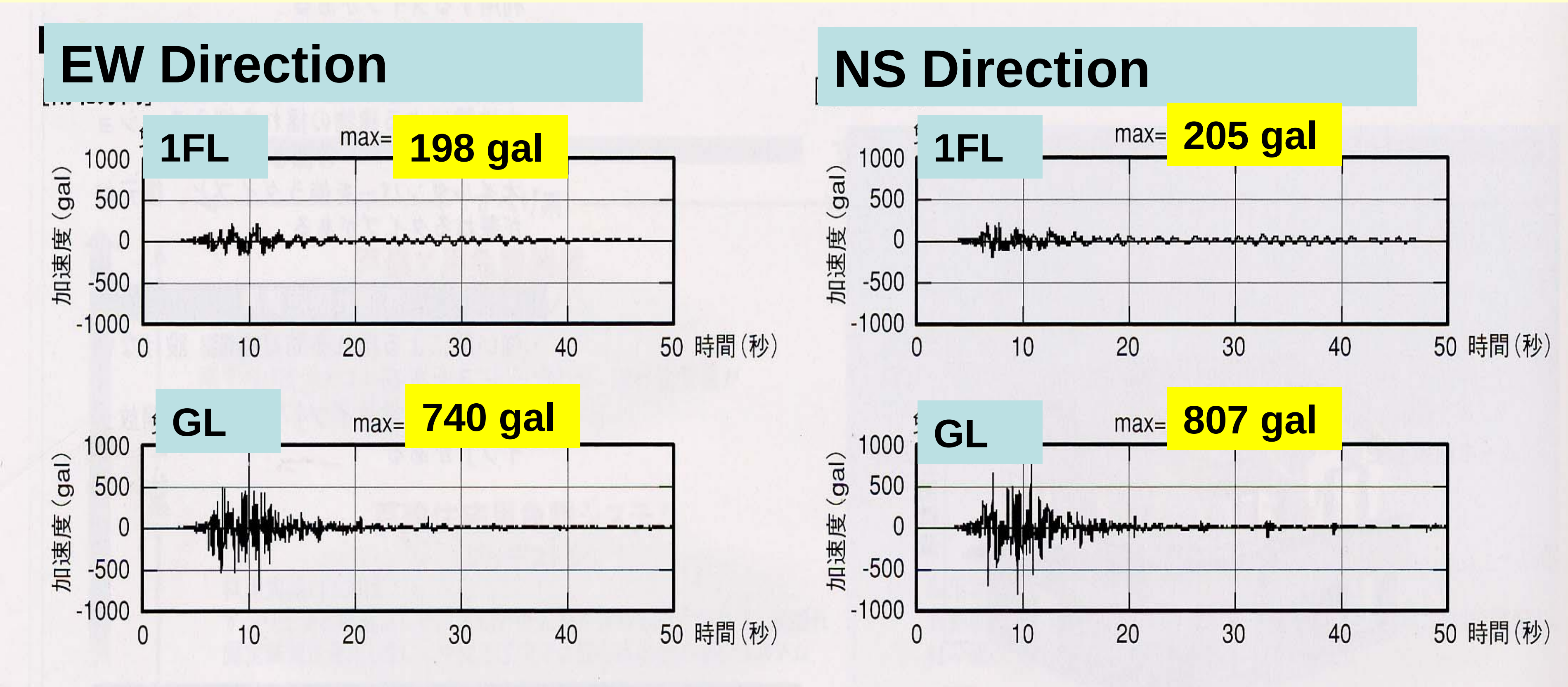


Location of Seismic Isolation Devices

Section of Building

Verification of Seismic Isolation Effect

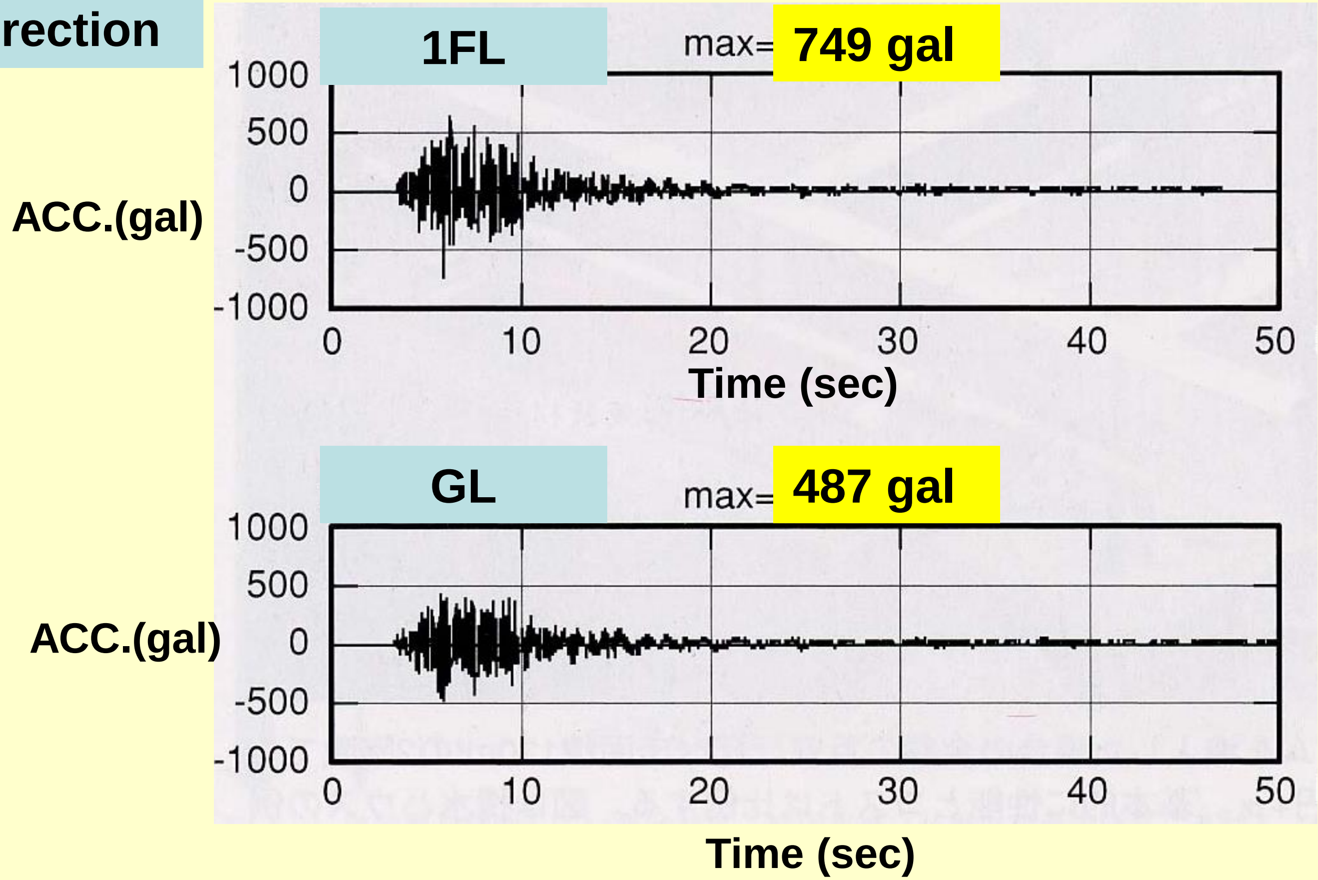
Niigata Cyuetsu Earthquake (October, 2004)



Verification of Seismic Isolation Effect

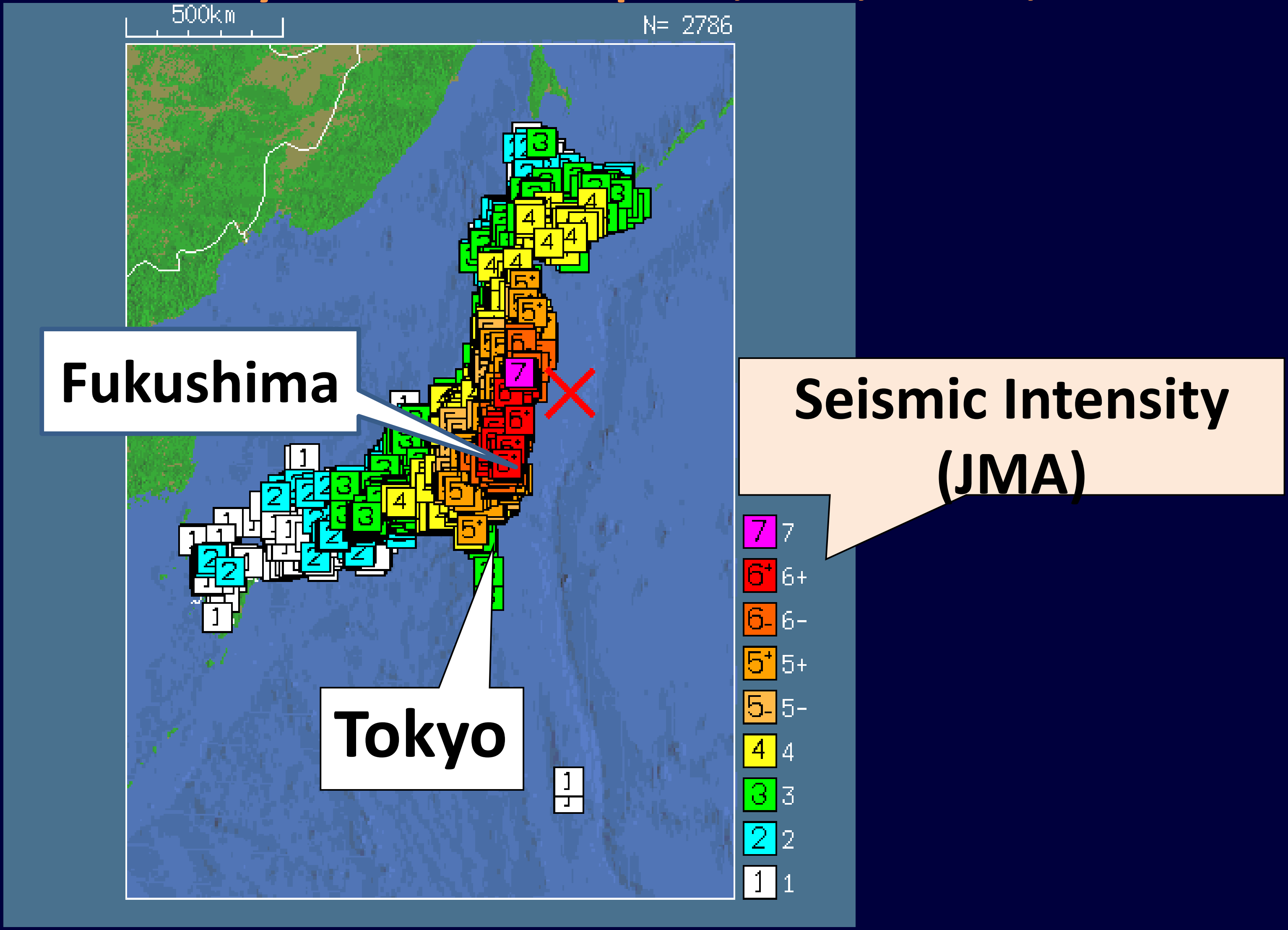
Niigata Cyuetsu Earthquake (October, 2004)

UD direction



Verification of Seismic Isolation Effect

Seismic Intensity: Tohoku Earthquake, 11th, March, 2011



Verification of Seismic Isolation Effect

Fukushima 1st Nuclear Power Plants

Seismic Isolation Important Building

July 2010 (Completed)

http://image.search.yahoo.co.jp/search?rkf=2&ei=UTF-

Verification of Seismic Isolation Effect

Fukushima 1st Nuclear Power Plants

Damage of Main Building

Seismic Isolation Building Used as Rescue Center

http://arinkurin.cocolog-nifty.com/blog/2013/06/http.html

Verification of Seismic Isolation Effect

Fukushima 1st Nuclear Power Plants

福島第一原発（gal）

F1	NS	EW	UD
BASE	582	756	446
1FL	176	213	516
2FL	155	185	621

Acceleration Records at Seismic Isolation Building

http://image.search.yahoo.co.jp/search?rkf=2&ei=UTF-8&p

Verification of Seismic Isolation Effect

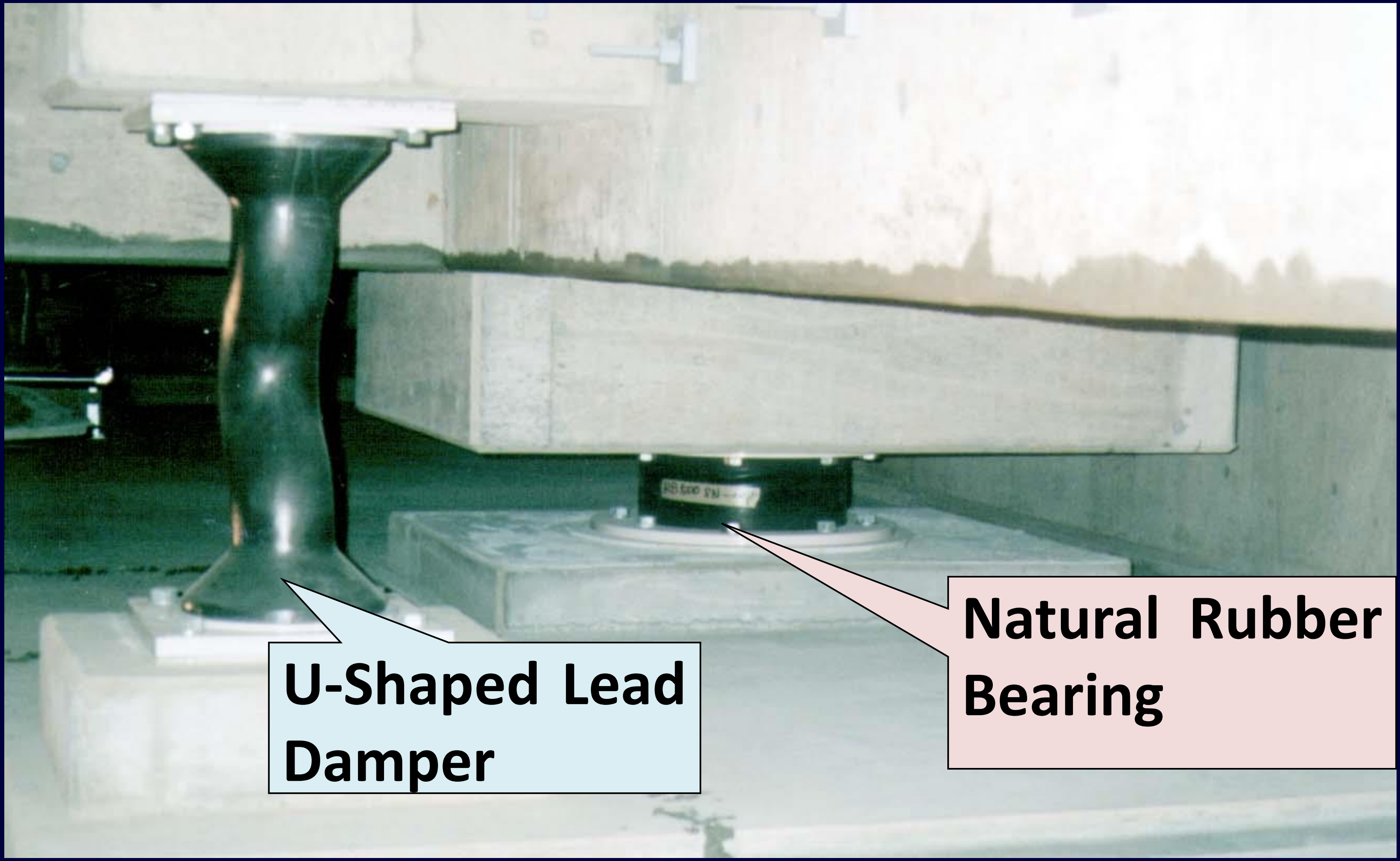
Rikkyo Unv. Chapel Building, Tokyo

1918 completed, masonry Building,
Rehabilitated by Seismic Isolation

Outside view

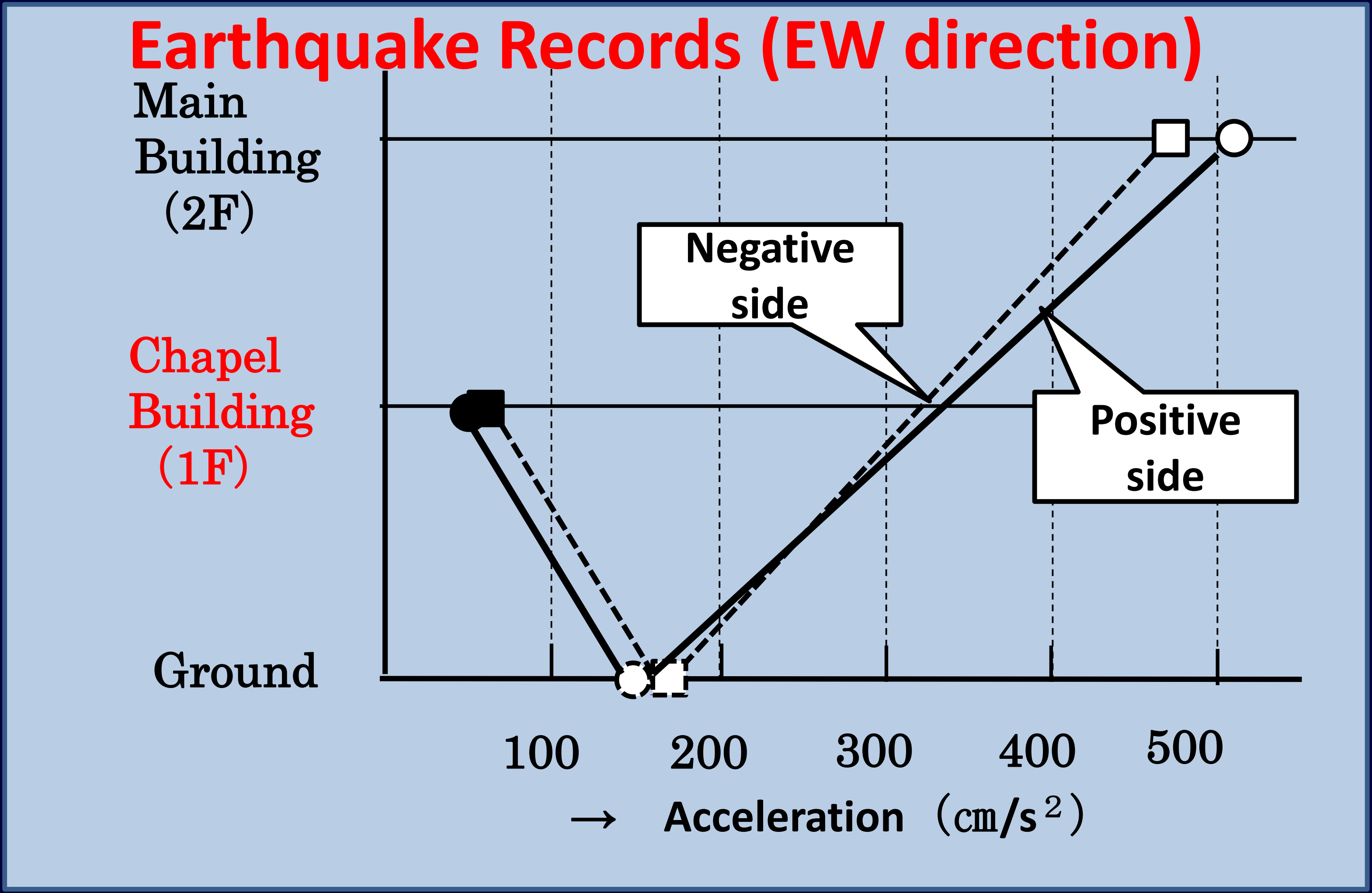
Inside view

Rikkyo Unv. Chapel Building



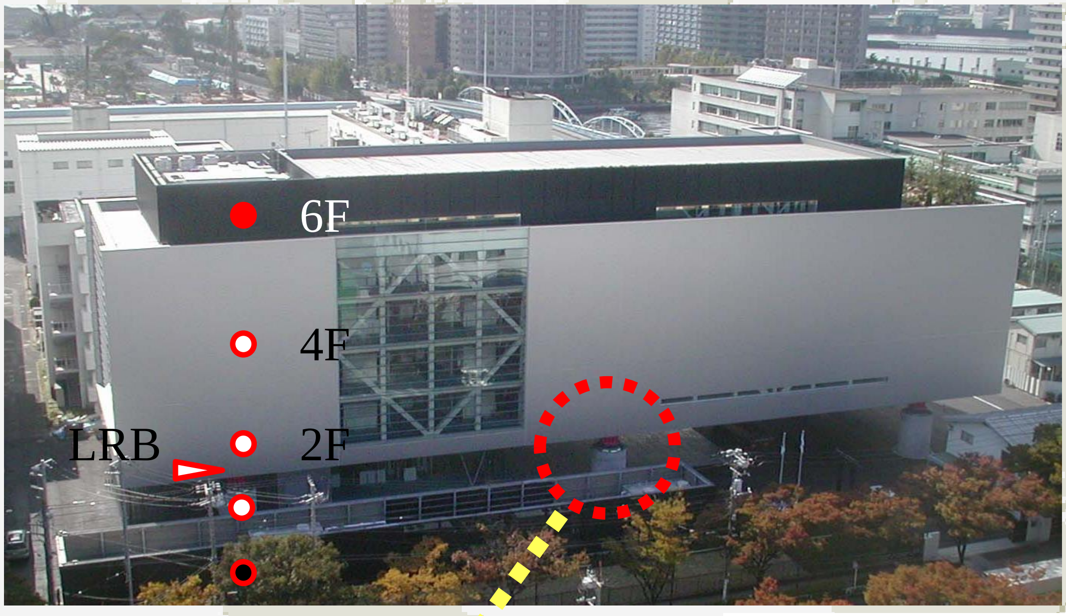
Verification of Seismic Isolation Effect

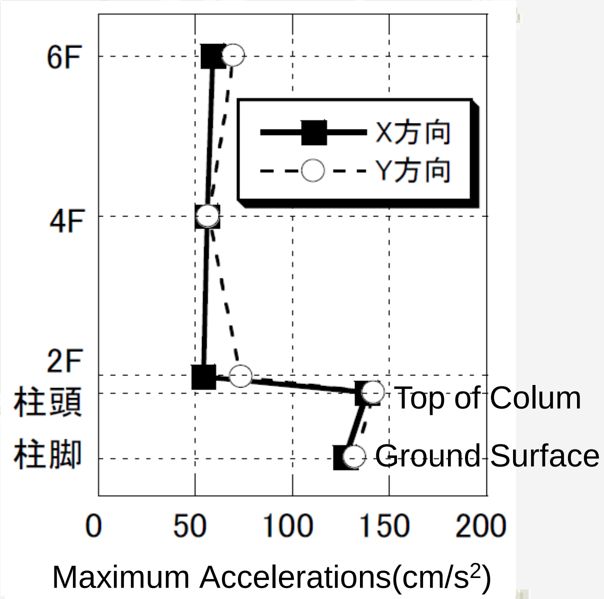
Rikkyo Unv. Chapel Building

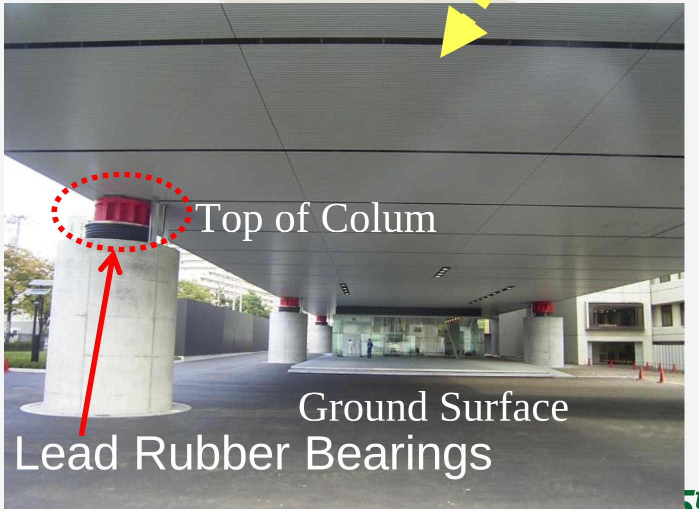


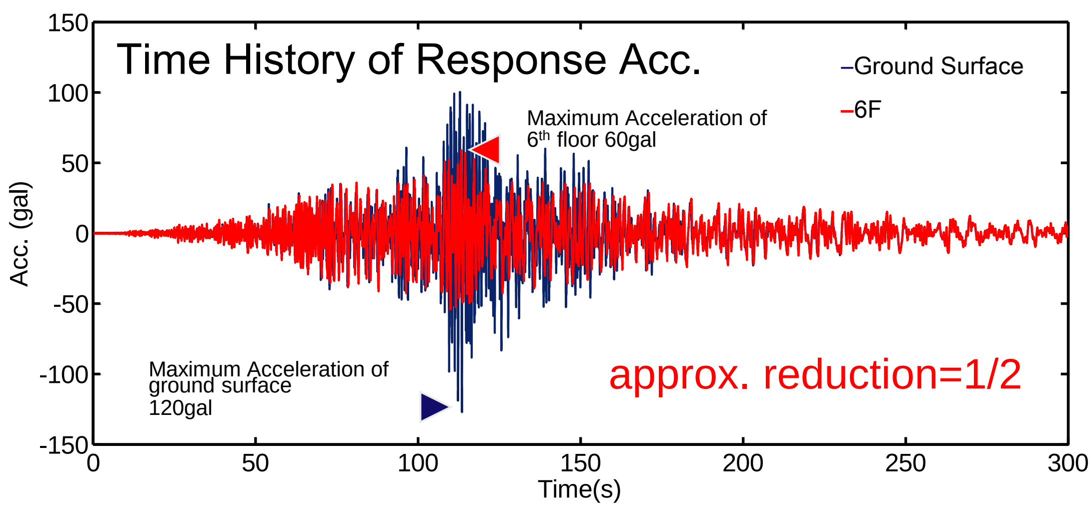
Performance of Seismically Isolated Buildings in Tokyo Area

（Slide presented by Shimz Corp.）

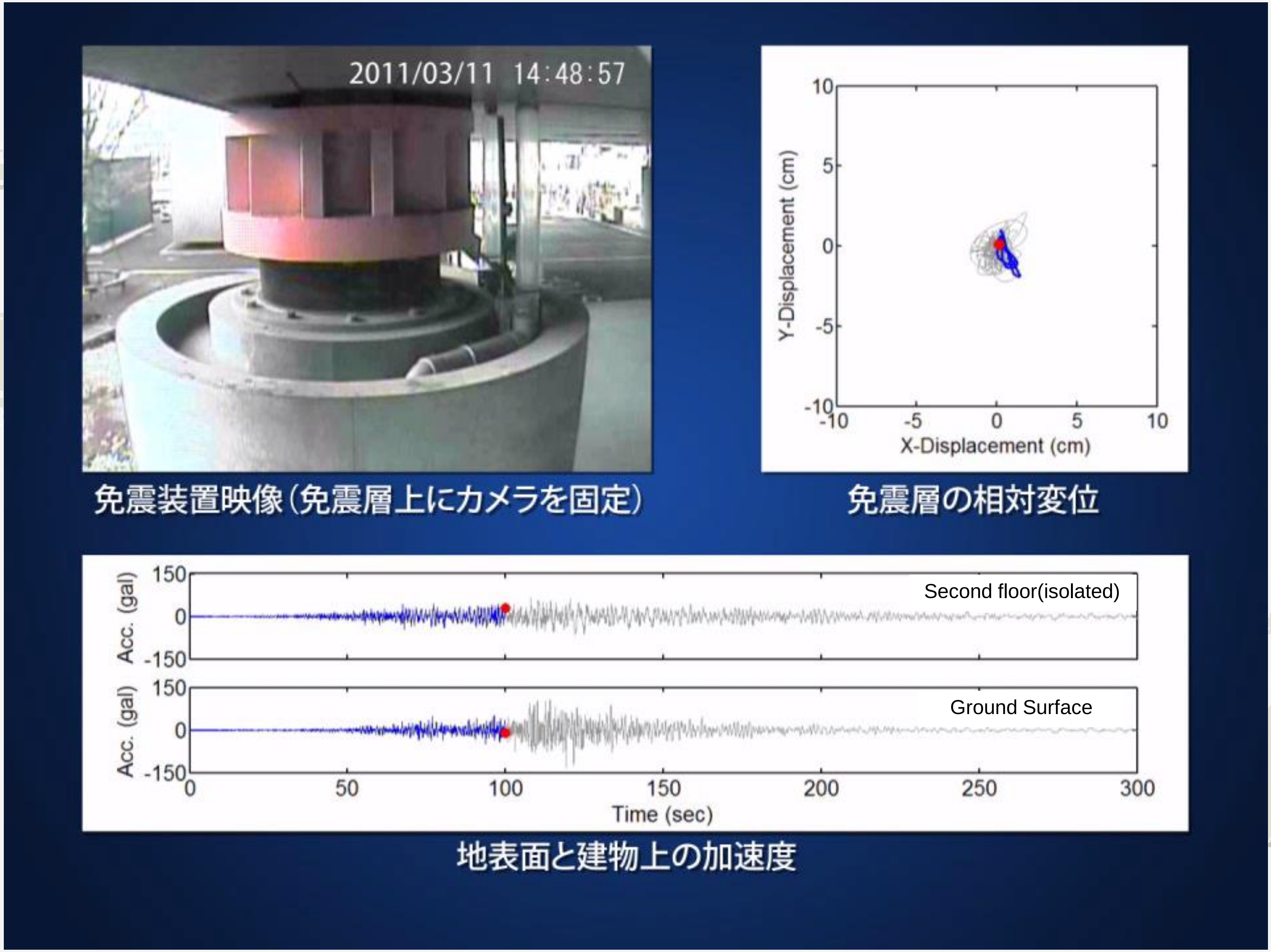






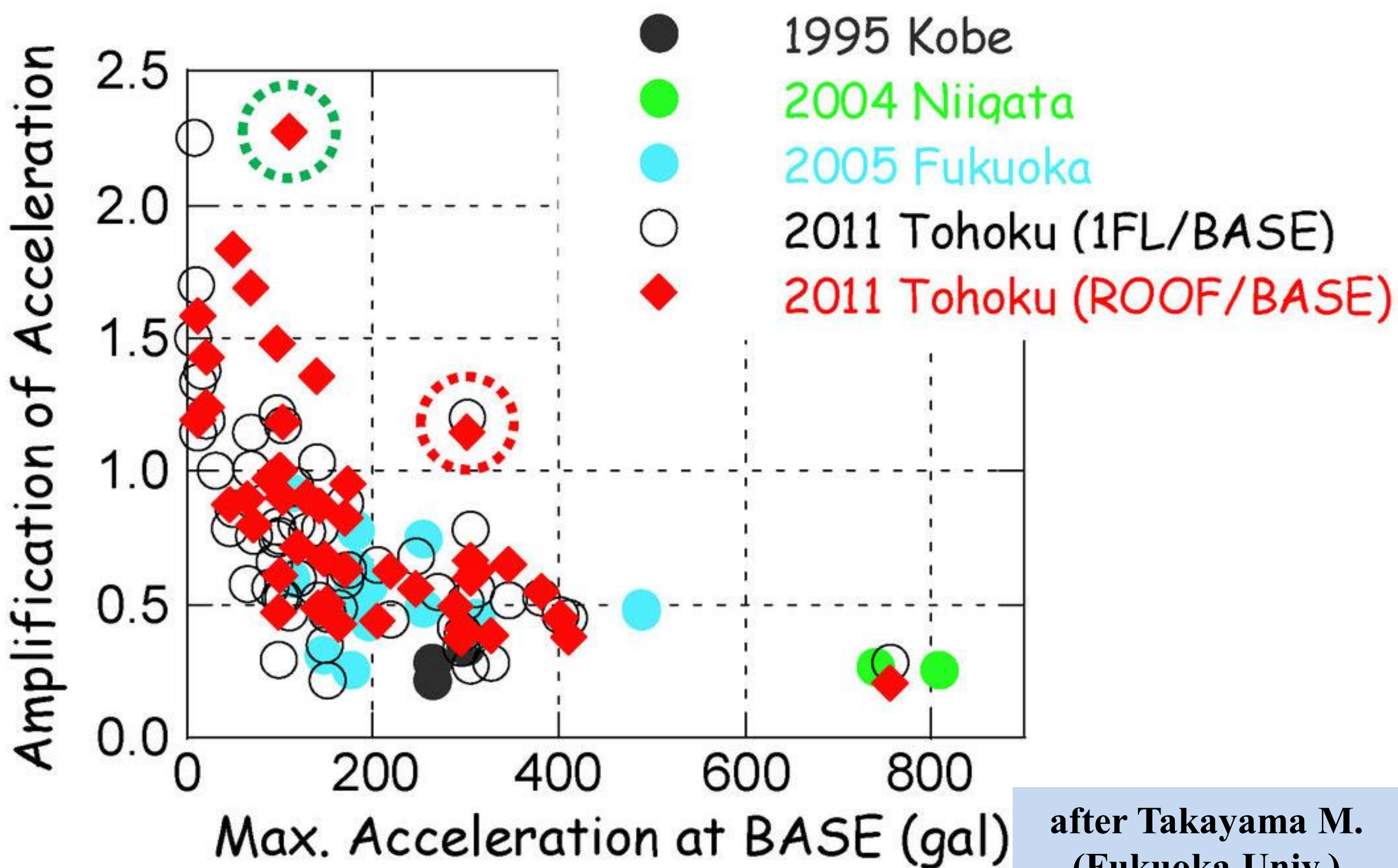


Seki M., UTCB Lecture note, May 2017, BRI, Japan


2011/03/11 14:48:57
免震装置映像（免震層上にカメラを固定）
Y-Displacement (cm)
X-Displacement (cm)
免震層の相対変位
Second floor(isolated)
Ground Surface
Acc. (gal)
Time (sec)
地表面と建物上の加速度

Verification of Seismic Isolation Effect

Isolation effectiveness in Strong Earthquakes



after Takayama M.
(Fukuoka Univ.)

April 2016 Kumamoto Earthquake in Japan

Damage of Seismic Isolation Buildings

Building Research Institute, Japan
International Institute of Seismology and Earthquake Engineering (IISEE)

2017.3.30

Matsutaro Seki

平成 28 年熊本地震建築物被害調査報告（速報）

Quick Report of the Field Survey and the Building Damage by the 2016 Kumamoto Earthquake

平成 28 年 9 月

国土交通省　国土技術政策総合研究所

National Institute for Land and Infrastructure Management

Ministry of Land, Infrastructure, Transport and Tourism, Japan

国立研究開発法人　建築研究所

Building Research Institute

National Research and Development Agency, Japan

Hereafter, We call " **BRI, MLIT Report, 2016.9**"

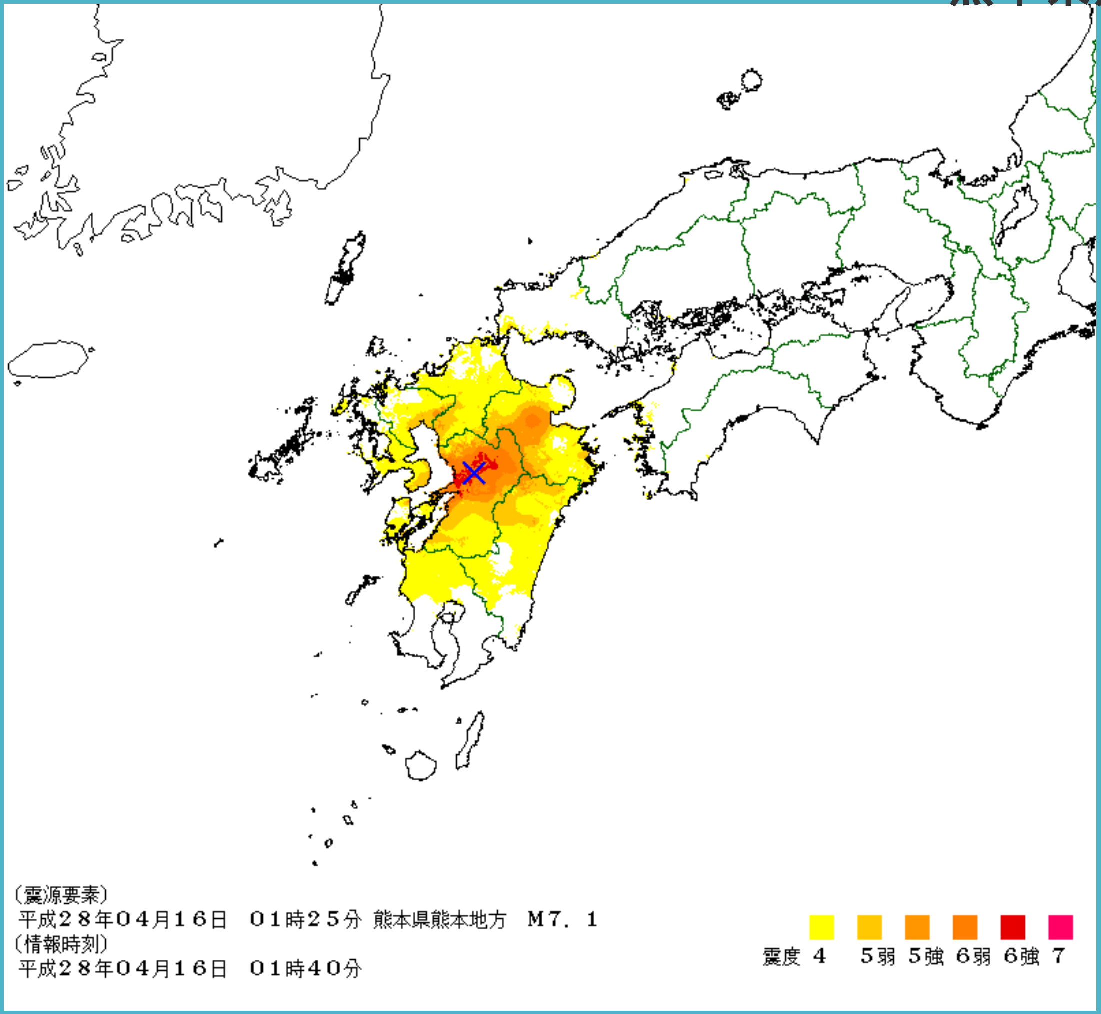
Earthquakes exceeding JMA Seismic Intensity level 6 lower since 14 April 2016 21:26 JST (as of 04 August)

Date and Time	Hypocenter	Magnitude	JMA Seismic Intensity (Max)
14 April 2016 21:26 JST (12:26 UTC)	Kumamoto Chiho of Kumamoto Prefecture	6.5	7
14 April 2016 22:07 JST (13:07 UTC)	Kumamoto Chiho of Kumamoto Prefecture	5.8	6-
15 April 2016 00:03 JST (14 April 2016 15:03 UTC)	Kumamoto Chiho of Kumamoto Prefecture	6.4	6+
16 April 2016 01:25 JST (15 April 2016 16:25 UTC)	Kumamoto Chiho of Kumamoto Prefecture	7.3	7
16 April 2016 01:45 JST (15 April 2016 16:45 UTC)	Kumamoto Chiho of Kumamoto Prefecture	5.9	6-
16 April 2016 03:55 JST (15 April 2016 18:55 UTC)	Aso Chiho of Kumamoto Prefecture	5.8	6+
16 April 2016 09:48 JST (00:48 UTC)	Kumamoto Chiho of Kumamoto Prefecture	5.4	6-

http://www.jma.go.jp/jma/en/2016_Kumamoto_Earthquake/2016_Kumamoto_Earthquake.html

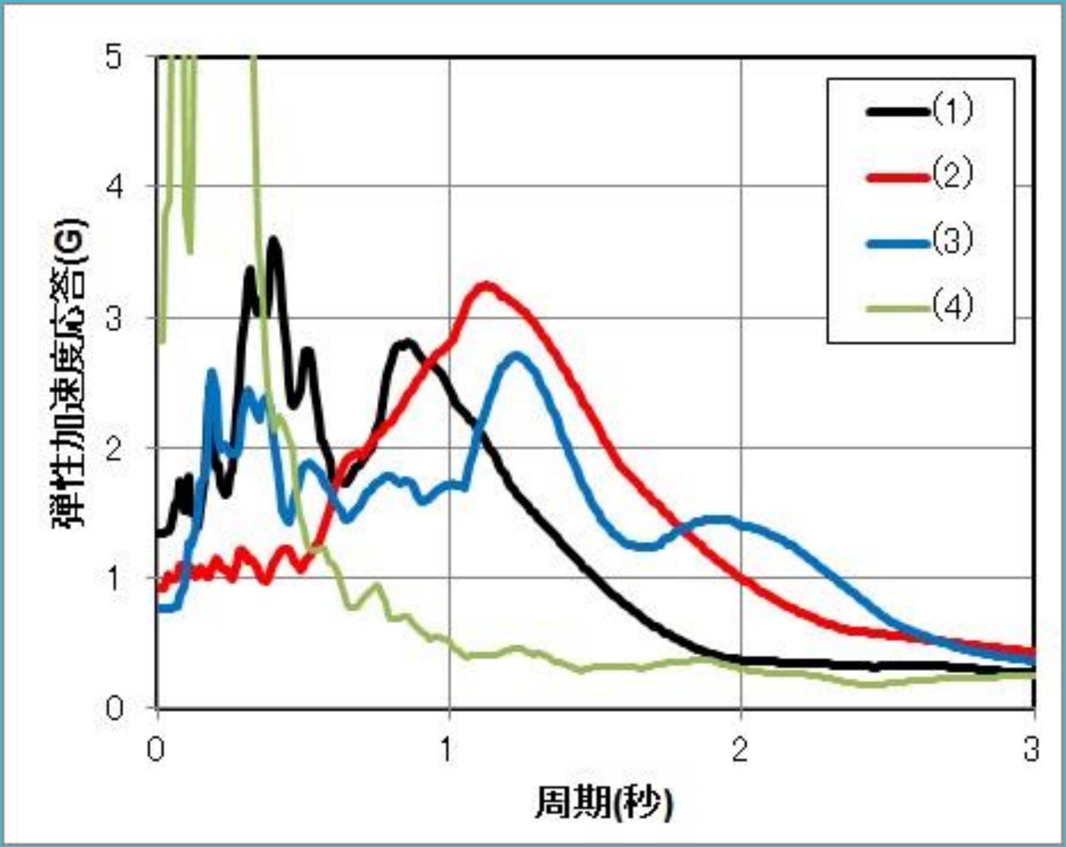
Map of Seismic Intensity (JMA)

2016年04月16日01時25分
熊本県熊本地方　M7.1



http://www.data.jma.go.jp/svd/eew/data/suikei/201604160125_741/201604160125_741_1.html

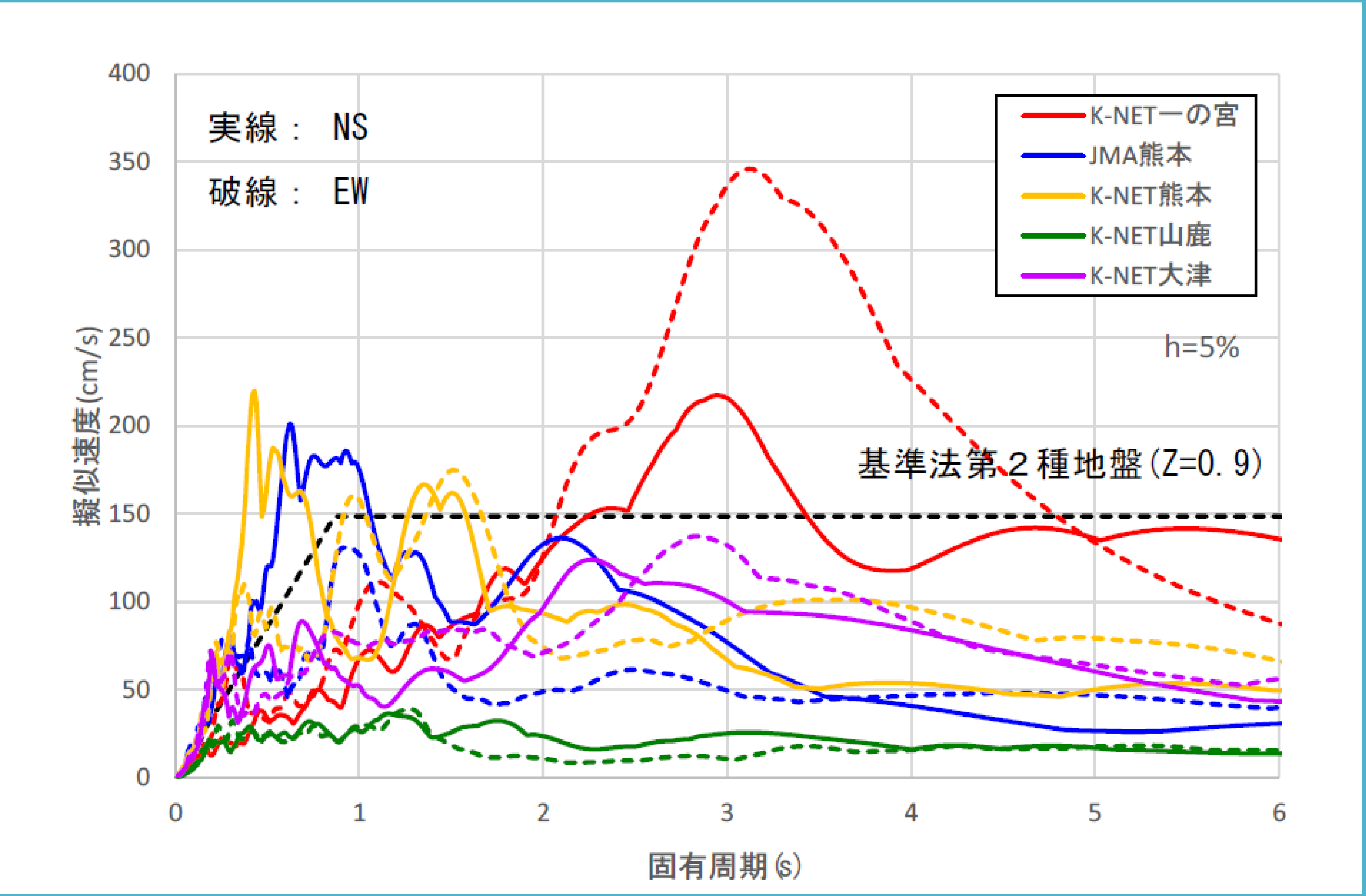
Elastic Acceleration Response Spectrum (h=5%)



(1) Kumamoto Earth. (Mashiki, K-net), 2016.4
(2) Kumamoto Earth. (Mashiki,Miyazono),2016.4
(3) Hyogoken Nanbu Earth. (JR Takatori), 1995.1
(4) Tohokuchiho Taiheiyo Earth. (K-NET, Tsukidate), 2011.3

https://www.kz.tsukuba.ac.jp/~sakai/kmm_hk2_jp.htm

Elastic Velocity Response Spectrum (h=5%)



BRI, MLIT Report, 2016.9

SEKI M., Lecture for IISEE, BRI, March, 2017

Location of Seismic Isolation Buildings

図 3.1 調査建築物（A～J）及び地震観測点（▽）位置（左図は右図の熊本市内を拡大）

背景地図：国土地理院電子地形図（タイル）：×印は震央（下が 4/14 前震、上が 4/16 本震）、• 印は布田川断層帯周辺の地表の亀裂分布

BRI, MLIT Report, 2016.9

Summary of Investigated Buildings

表 3.1 調査建築物一覧（建築物Ａ～Ｊは図 3.1 と対応）

建築物 （＊は告示免震 [a]）	クリアランス [b]	上部構造		免震材料 [d]	評定年 [e] （建設年）	罫書き記録	最寄り [f] の震度（本震）
		形式 [c]	階数				
Ａ医療施設＊	620mm	RC	4	RB， LRB	(2014)	○	6弱
Ｂ事務所＊	650mm	S+SRC	8	RB， SnRB， USD	(2015)	○	6強
Ｃ共同住宅＊	（未確認）	RC	13	RB， USD， LD	2007		6強
Ｄ事務所	600mm	S	5+B1	RB， ESD， USD	2012	○	5弱
Ｅ事務所	（未確認）	S	5+B1	RB， LRB， LSB， OD	2014		6強
Ｆ宿泊施設	450mm	RC	12	HRB， OD	2001		6強
Ｇ共同住宅 Ａ棟	430mm	RC	14	HRB	1996		6強
Ｂ棟	430mm	RC	11	HRB	1996		
Ｈ共同住宅 Ｅ棟	600mm	RC	14	HRB	2000		6強
Ｗ棟	600mm	RC	14	HRB	2000		
Ｉ共同住宅＊	600mm	RC	15	RB， USD， LD	2006		6強
Ｊ倉庫	580mm	S+SRC	2	RB， LRB， ESD	2011	○	6強

a…平成 12 年建設省告示第 2009 号を満たすものとして設計された免震建築物をいう。
b…免震建築物と周囲に設けられた擁壁等との間の距離。免震建築物の地震時の動きを損なわないように設けられる。
c…RC：鉄筋コンクリート造、S：鉄骨造、SRC：鉄骨鉄筋コンクリート造
d…RB：天然ゴム系積層ゴム、HRB：高減衰積層ゴム、LRB：鉛プラグ入り積層ゴム、SnRB：錫プラグ入り積層ゴム、ESD：弾性すべり支承、LSB：直動転がり支承、USD：U形鋼材ダンパー、LD：鉛ダンパー、OD：オイルダンパー
e…時刻歴応答解析を行い、指定性能評価機関等において性能評価を取得した年を指す。
f…図 3.1 に示す観測点（▽印）のうち、それぞれの建築物に最も近い地点。Ａは K-NET 一の宮、Ｄは K-NET 山鹿、Ｇは K-NET 熊本、Ｊは K-NET 大津、その他はすべて JMA 熊本である。

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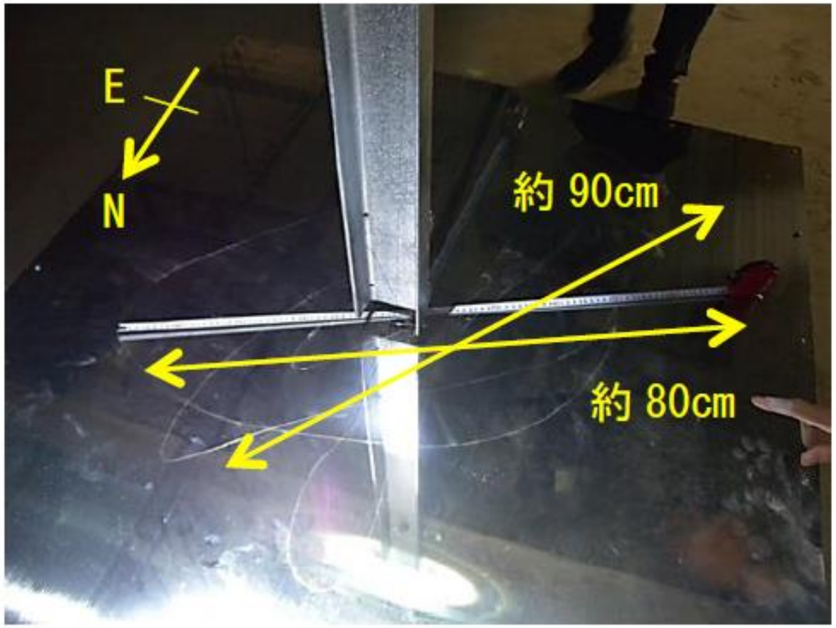
A building: monitoring by scriber, Swelling of covering rubber



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A building: Damage of expansion joint

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A building: Sliding and Overturning of locker

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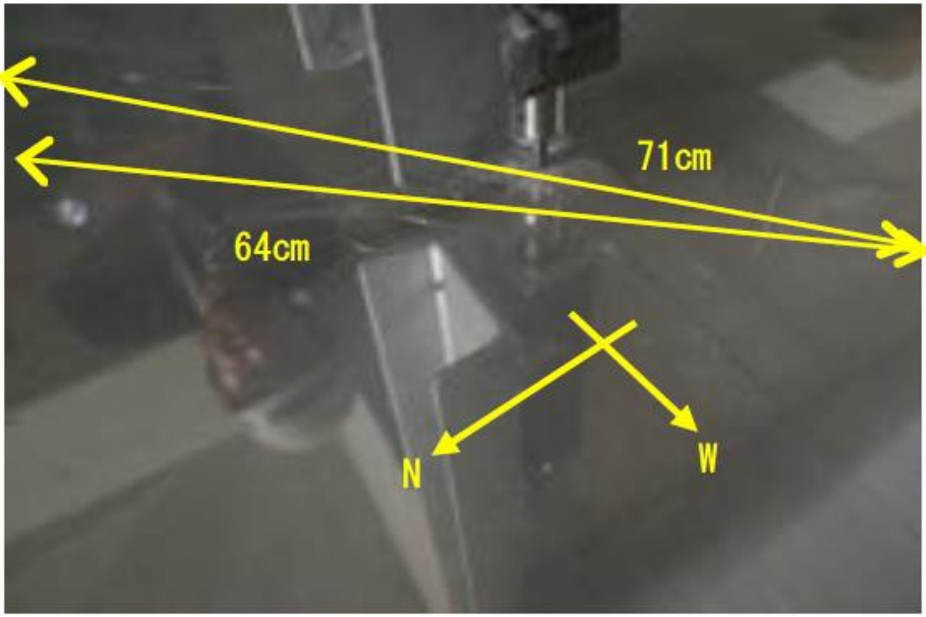
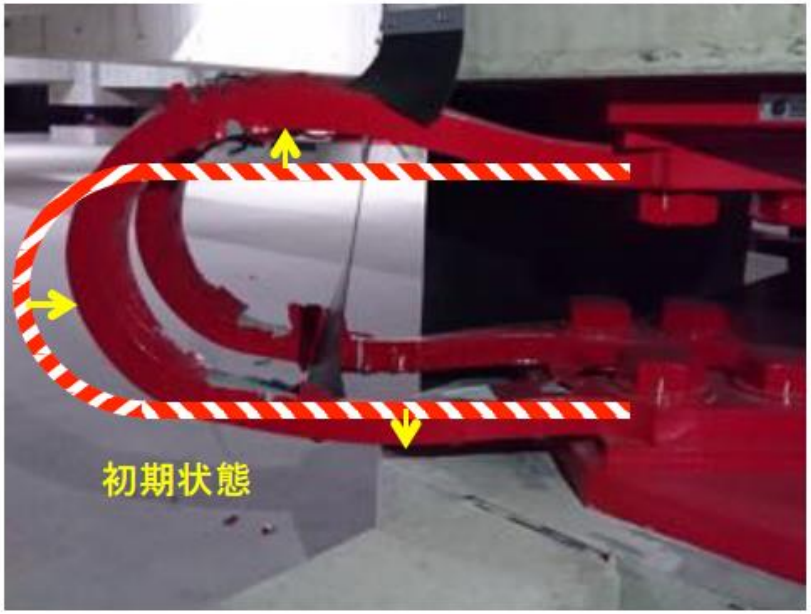
B building: monitoring by scriber, deformed steel damper





BRI, MLIT Report, 2016.9

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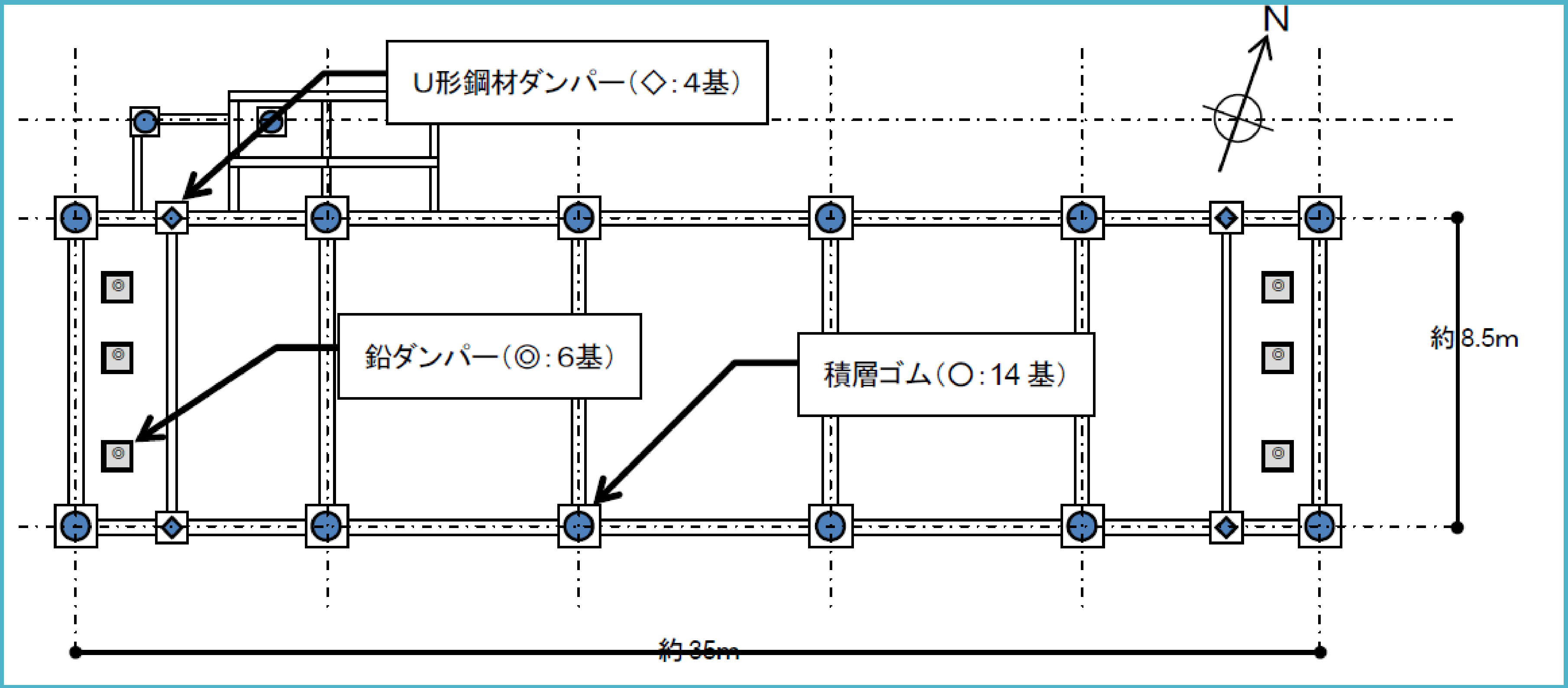
C building: Location of isolators and dampers



BRI, MLIT Report, 2016.9

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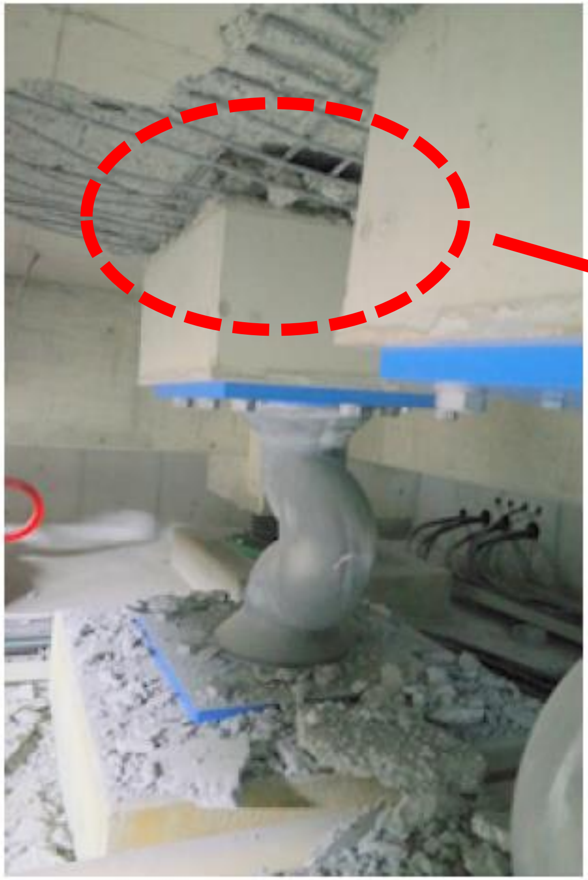
C building: Damage of supporting portion of lead plug damper



BRI, MLIT Report, 2016.9

C building: Deformed steel damper

BRI, MLIT Report, 2016.9

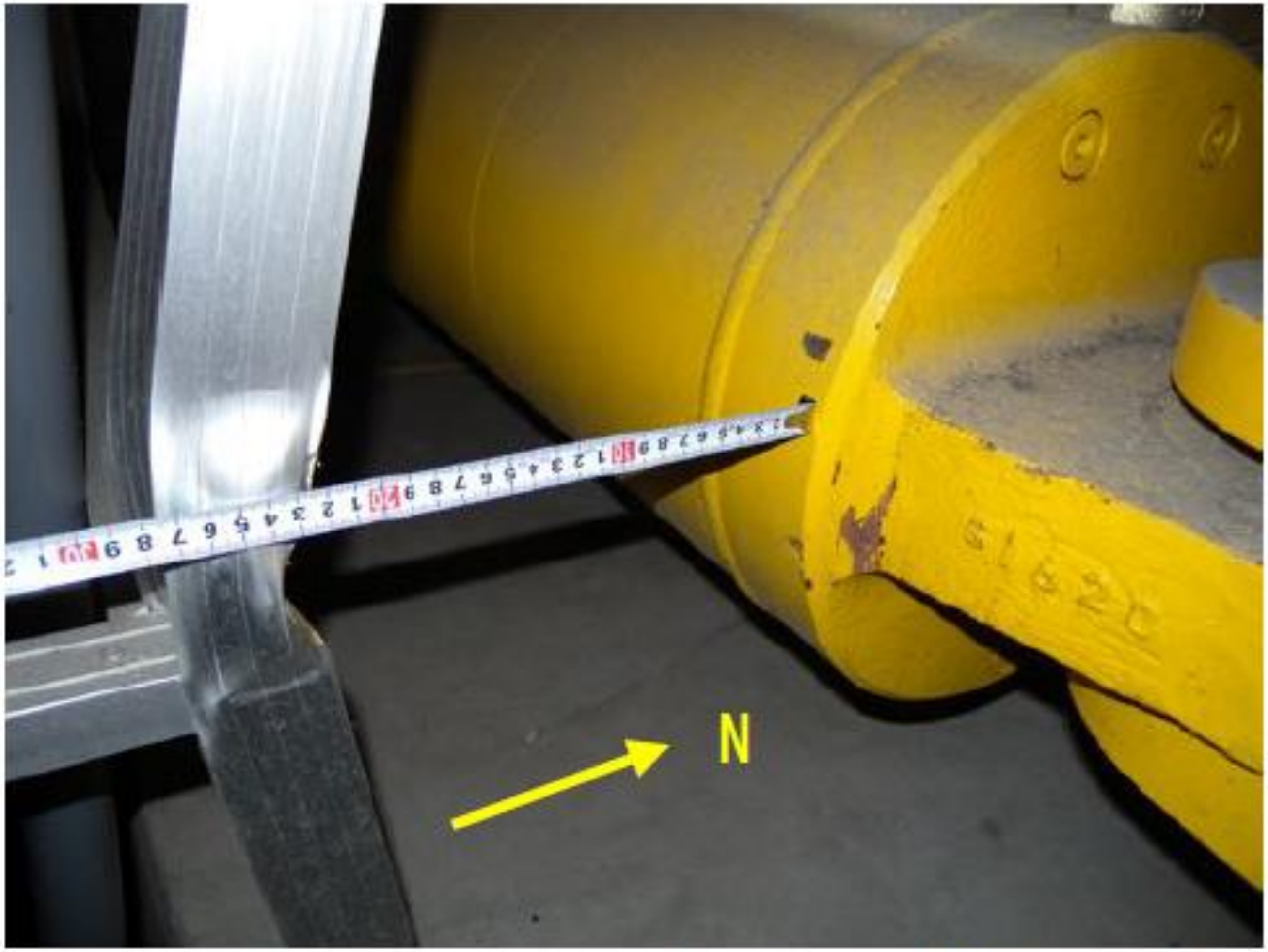
C building: Exfoliation of covering rubber

BRI, MLIT Report, 2016.9

D building: Slippage of sliding plate of elastic friction damper

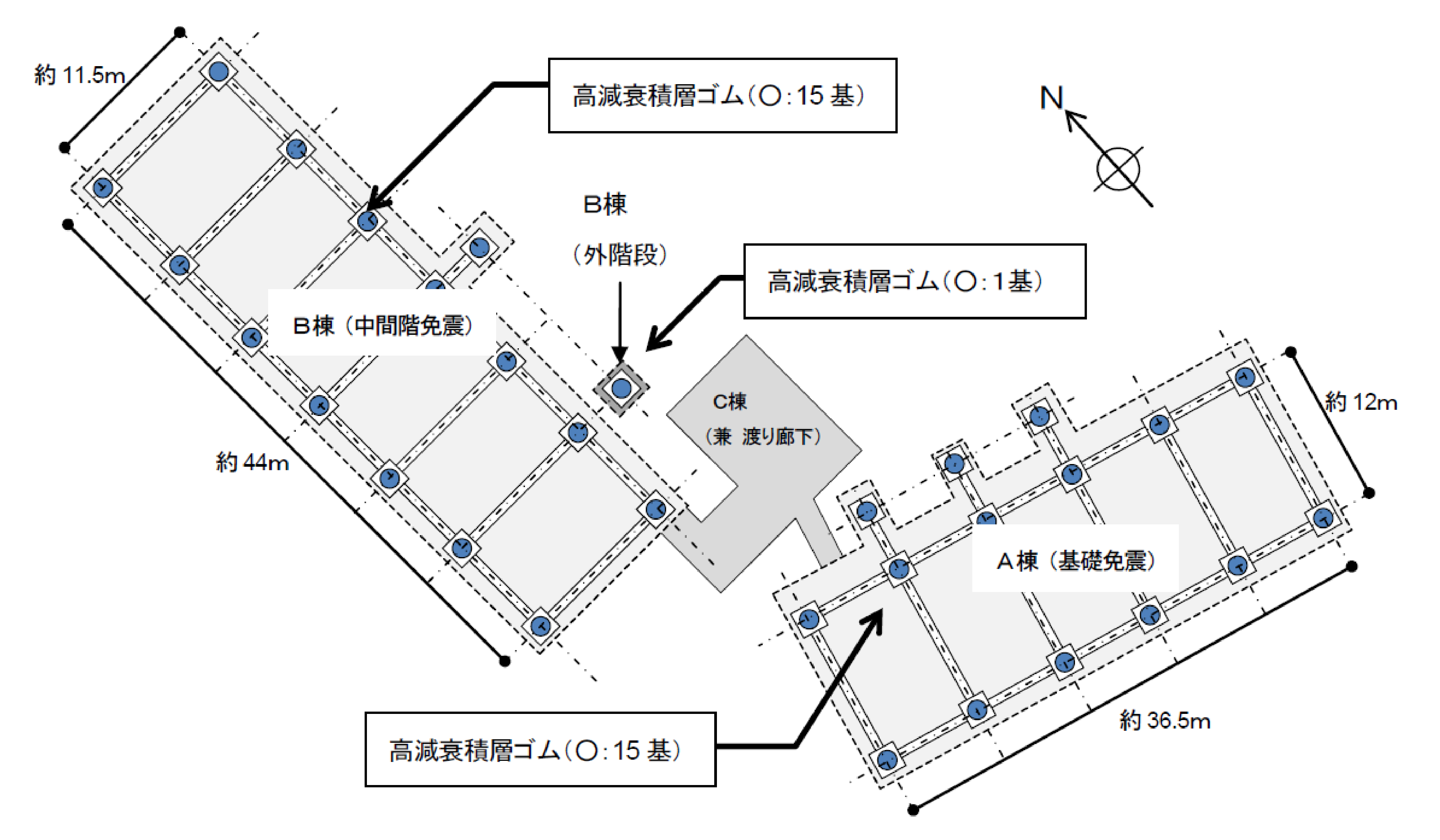
BRI, MLIT Report, 2016.9

F building: Collision of oil damper and deformation of surrounding frame



BRI, MLIT Report, 2016.9

G building: Location of isolators



BRI, MLIT Report, 2016.9

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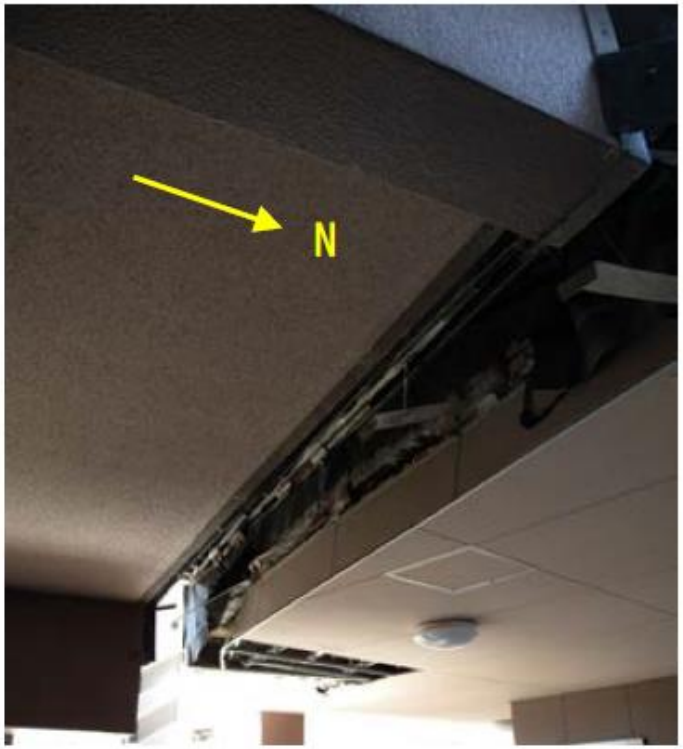
G building: Movement of copy machine, overturning of petition wall

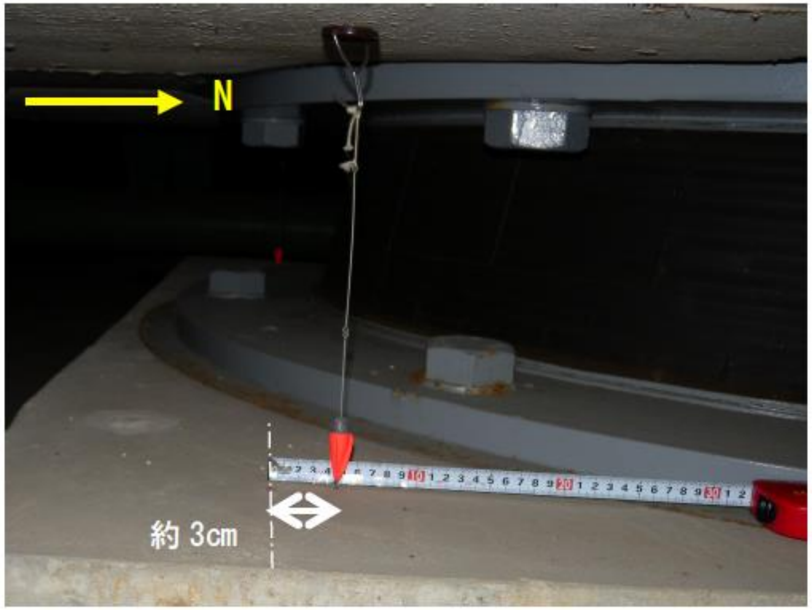
BRI, MLIT Report, 2016.9

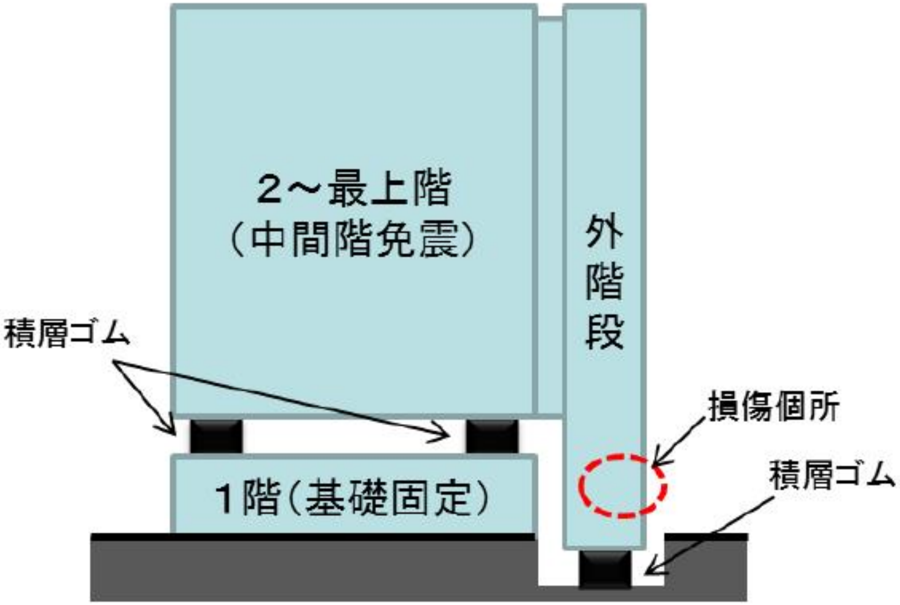
G building: Damage of expansion joint between building and connecting corridor



BRI, MLIT Report, 2016.9

G building: Monitoring by scriber, Section of the building





BRI, MLIT Report, 2016.9

G building: Damage of connecting corridor (1st floor)

写真 5. 7. 2–39 外付け階段の被害状況①（階段南側）

BRI, MLIT Report, 2016.9

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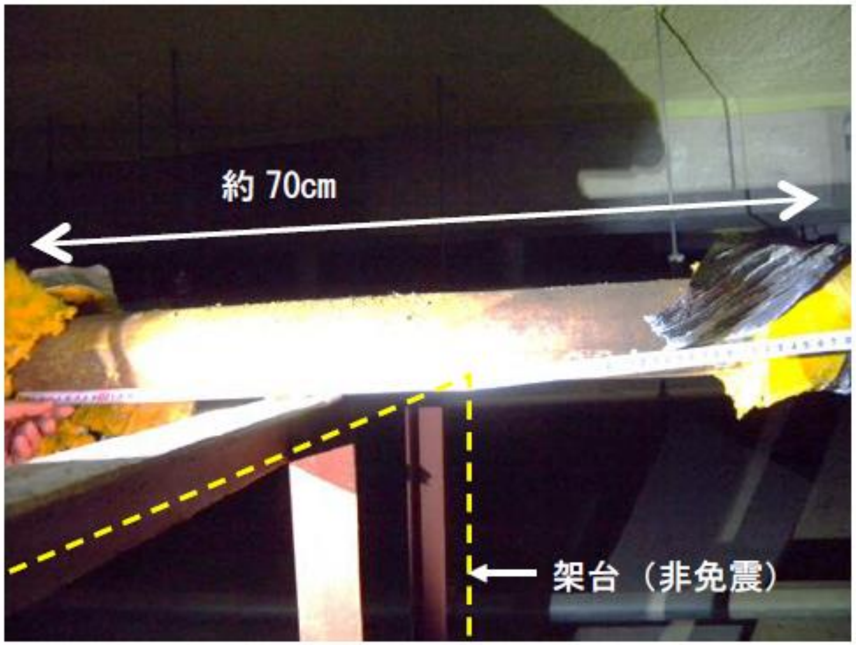
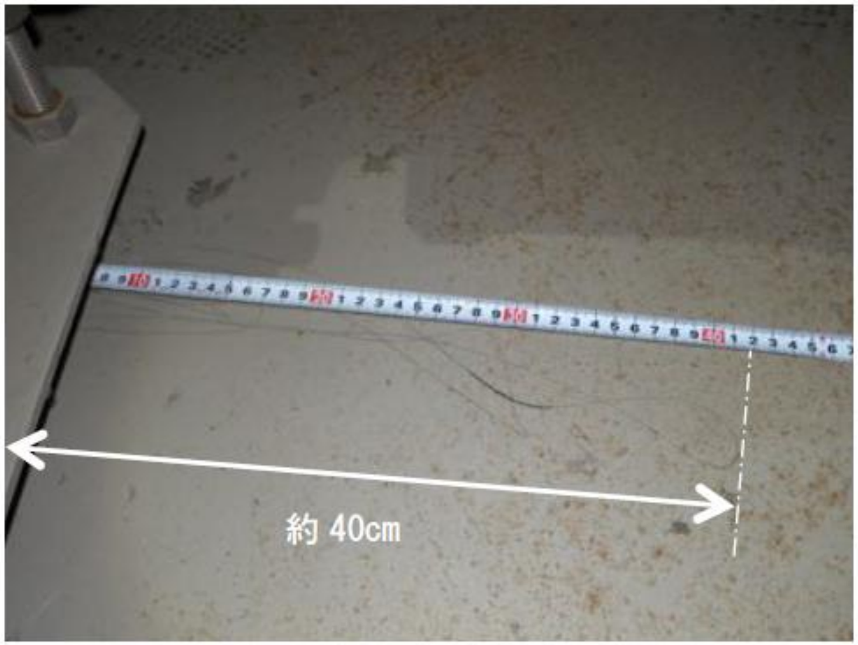
G building: Damage of connecting corridor (2nd floor)

BRI, MLIT Report, 2016.9

H building: Movement of cover sheet of pipe, movement of flexible equipment



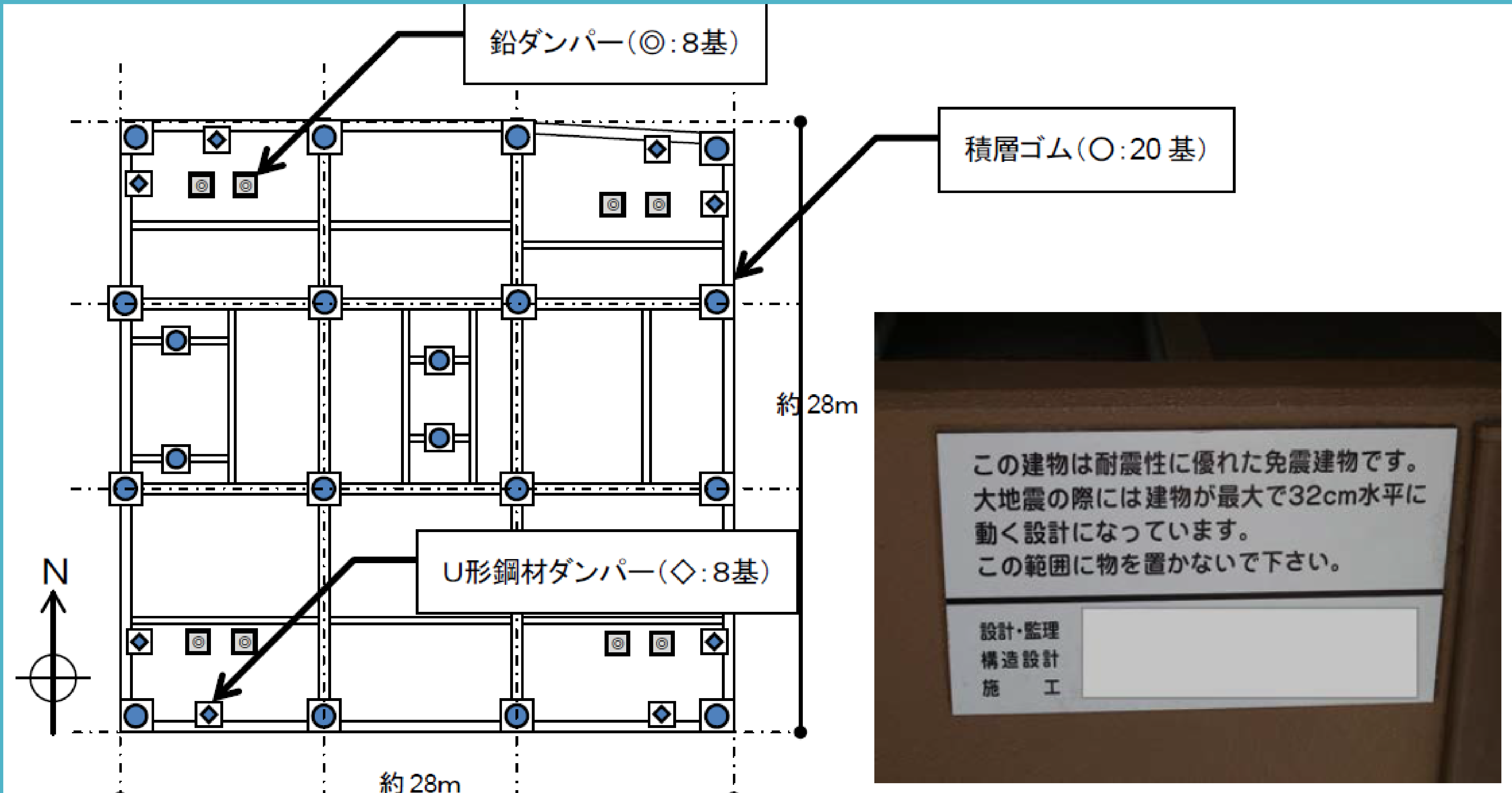


BRI, MLIT Report, 2016.9

H building: Damage of expansion joint (ceiling)

BRI, MLIT Report, 2016.9

H building: Location of isolators and dampers



BRI, MLIT Report, 2016.9

H building: Damage of supporting portion of lead plug damper

BRI, MLIT Report, 2016.9

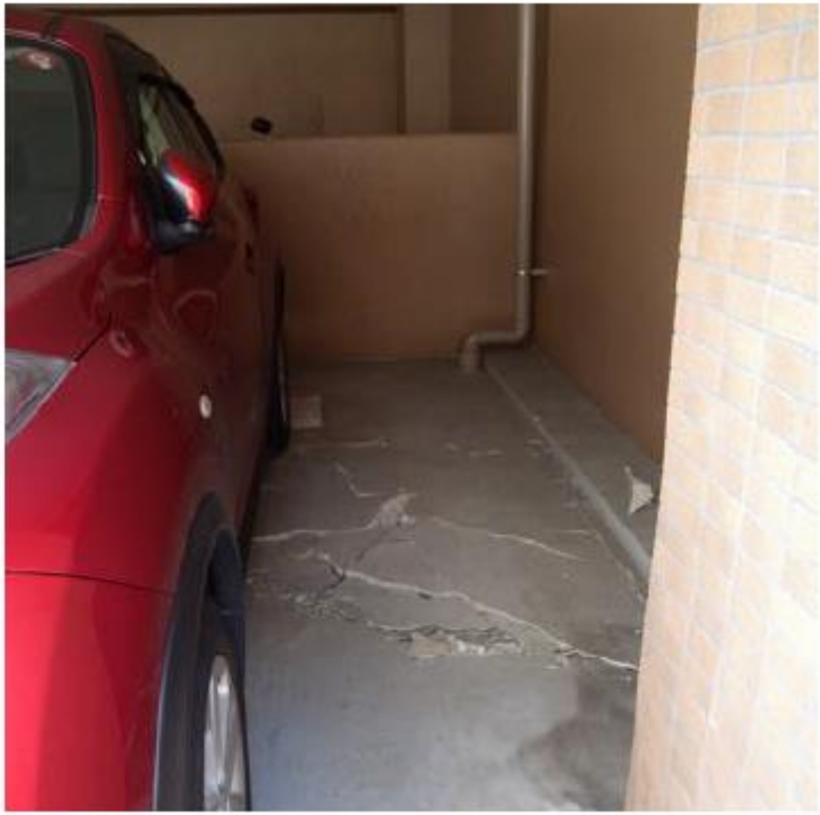
H building: Comparison of damage portion and no damage portion of steel damper

BRI, MLIT Report, 2016.9

H building: Damage portion of steel damper

BRI, MLIT Report, 2016.9

H building: Damage of the upper floor's slab



BRI, MLIT Report, 2016.9

Conclusions

1. Damage of Structural members

- **Isolator and damper supporting member**
- **Exterior stair**
- **Careful structural design should be done.**

2. Deformation of damper

- **Structural capacity and durability should be reconfirmed after earthquake.**

3. Damage of expansion joint is inevitable.

4. Movement of building should be promoted by simple monitoring system in order to verify the structural design.

5. Site investigation of small size residential houses should be done.

BRI, MLIT Report, 2016.9

Conclusions

1. The seismic isolation technology is innovative and effective solution for seismic damage mitigation.

2. This technology became spread stage in Japan and increase in the future.

3. But the careful structural design and construction work should be done.

Thank you for your attention.