Seismic Repair Technology

-Basics of repair work and examples-

General Manager, Artes Corp., Japan
Hisashi Maesaka

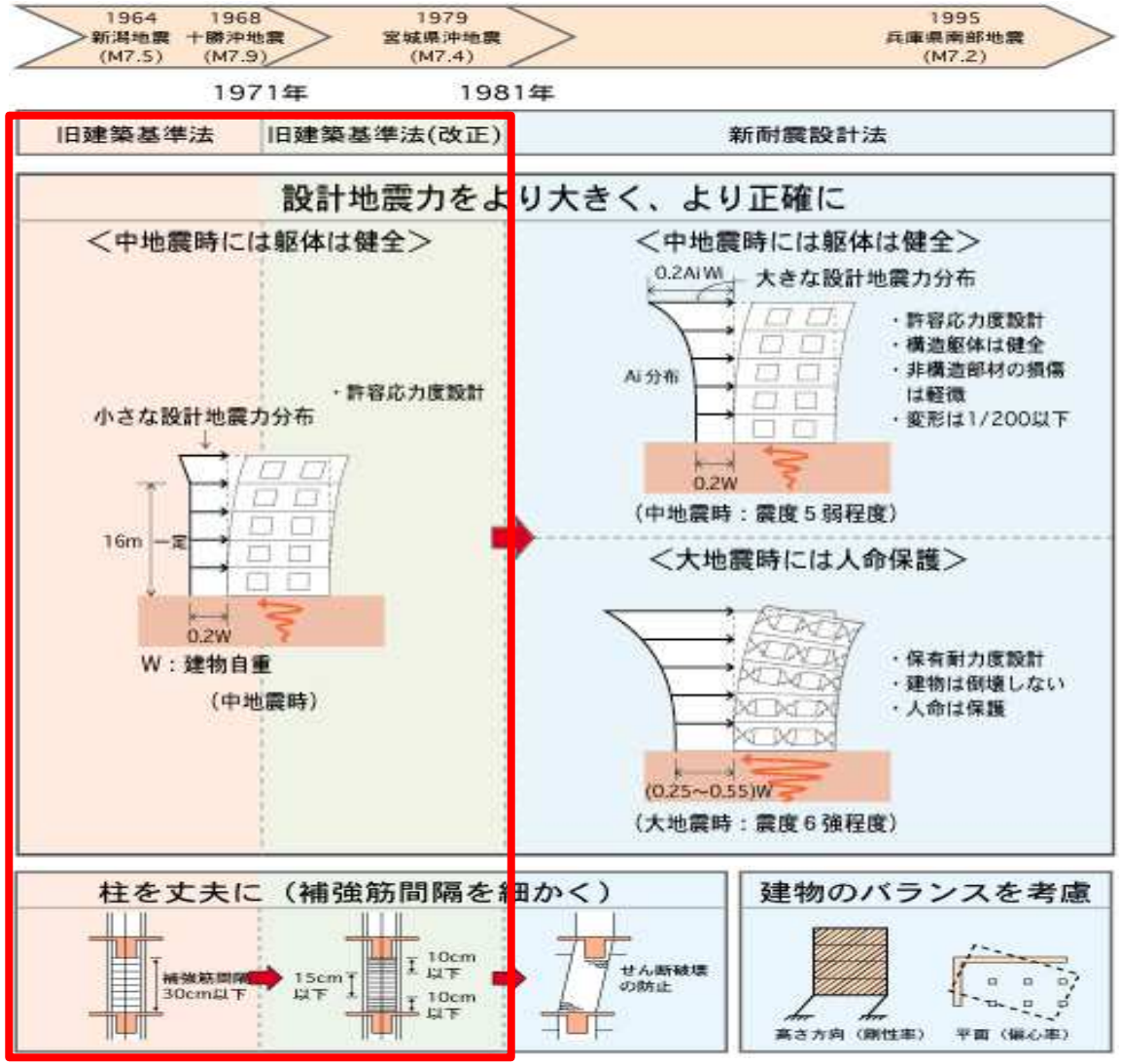
Contents

[Seismic diagnosis]

1. Seismic diagnosis is for those building by old design code

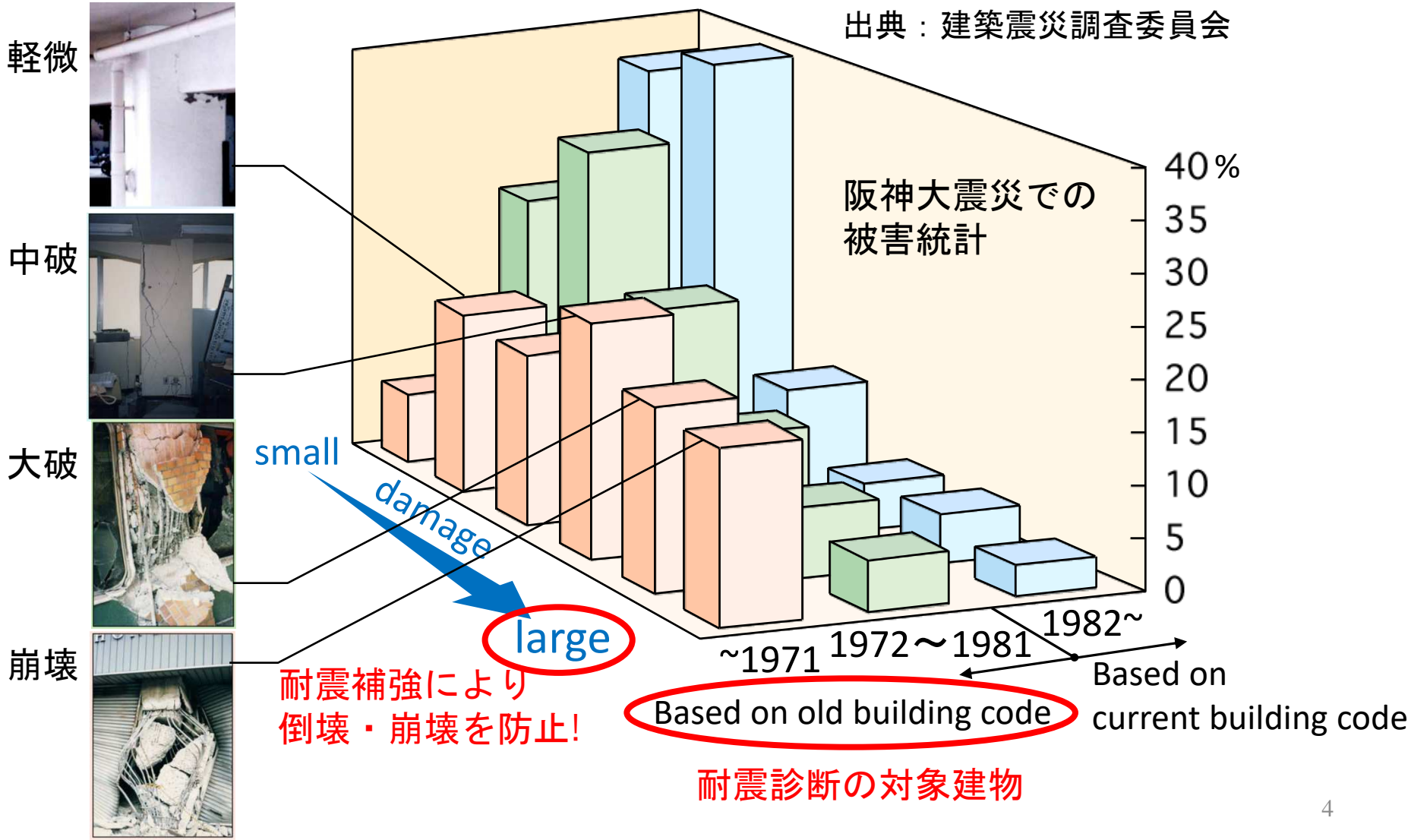
Major Earthquakes

Target of seismic diagnosis



[Seismic diagnosis]

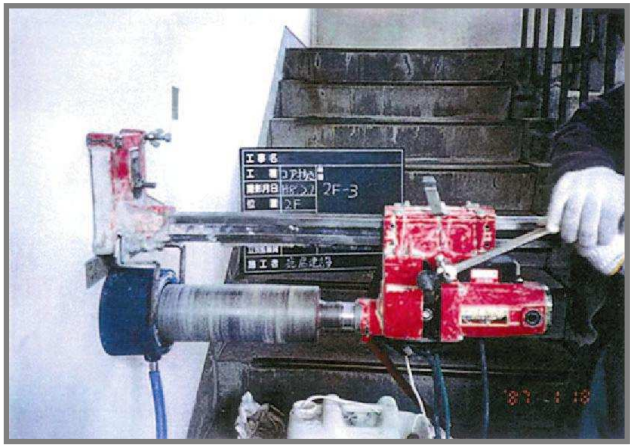
1. Necessity of seismic diagnosis for building by old design code



[Seismic diagnosis]

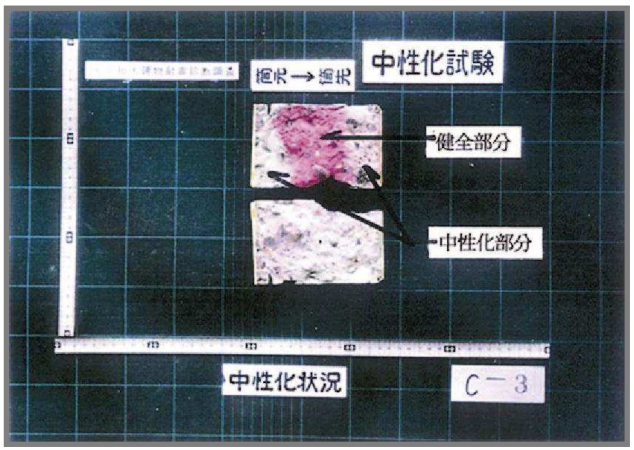
1. Site Survey and Document Check

Re-bar exploration



Sampling concrete test piece

Compressive strength test



Concrete neutralization test

[Seismic diagnosis]

2. Codes and Guidelines for Diagnosis

2017年改訂版　既存鉄筋コンクリート造建築物の耐震診断基準・同解説

2017年改訂版　既存鉄筋コンクリート造建築物の耐震改修設計指針・同解説

＋ 適用の手引

［（財）日本建築防災協会］

←For RC structures

2009年改訂版　既存鉄骨鉄筋コンクリート造建築物の耐震診断基準・同解説

2009年改訂版　既存鉄骨鉄筋コンクリート造建築物の耐震改修設計指針・同解説

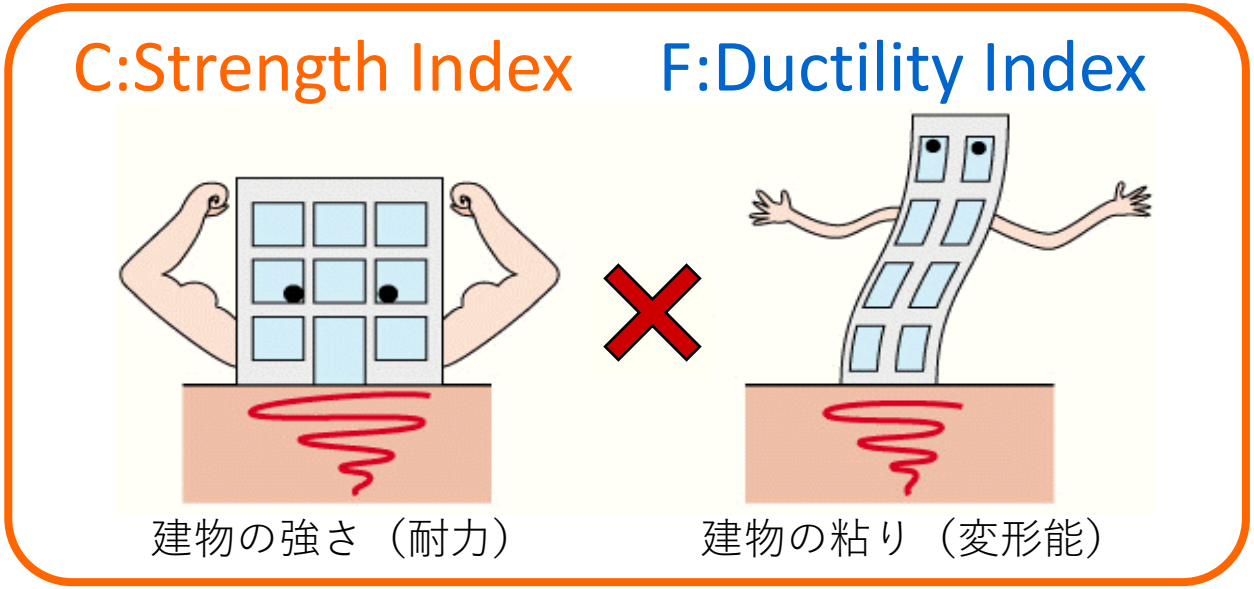
＋ 適用の手引

［（財）日本建築防災協会］

←For SRC structures

[Seismic diagnosis]

3. Strength Index and Ductility Index



C × F

×

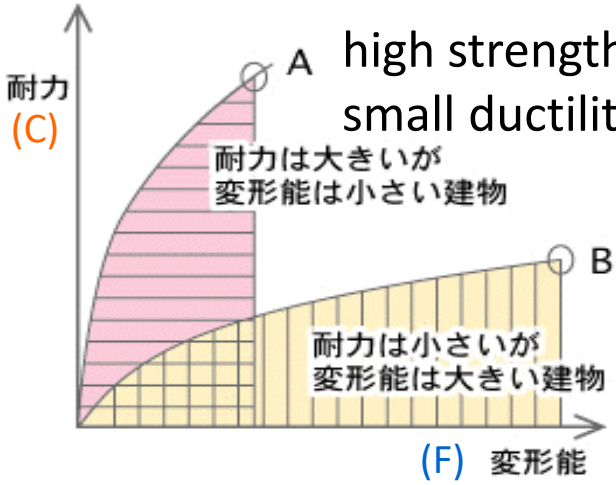
Shape factor , eccentricity factor : S_D

×

Deterioration factor : T

II

Is

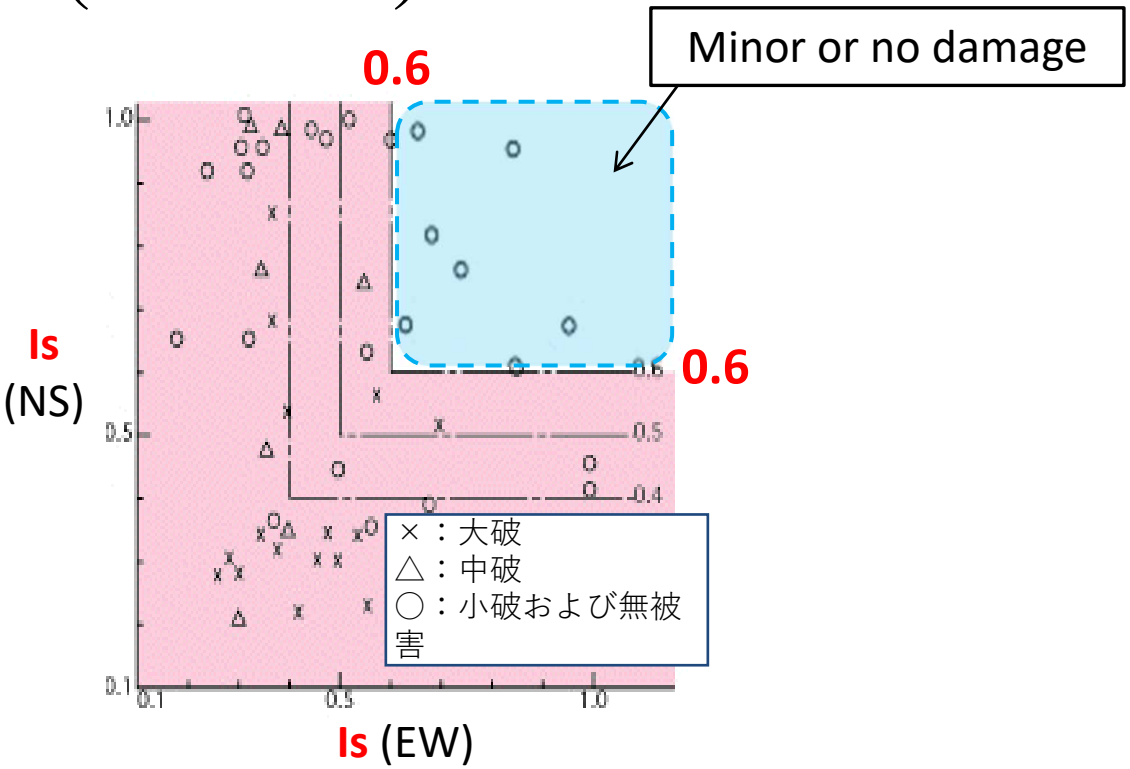


high strength , small ductility

small strength , high ductility

[Seismic diagnosis]

3. Structural Earthquake-Resistance Index (Is value)



Relationship between Is and actual building damages

十勝沖地震（1968）、宮城県沖地震（1978）、伊豆大島近海地震(1978)、千葉県東方沖地震(1987)による被害に基づく

[Seismic diagnosis]

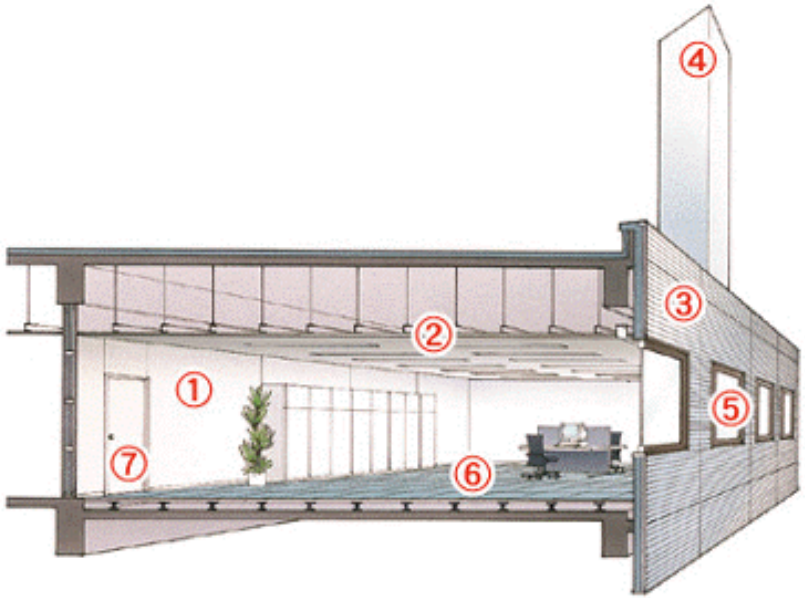
4. Diagnosis of Non-Structural Elements

Partition walls

Ceiling

Outer wall finishing

Ad. tower



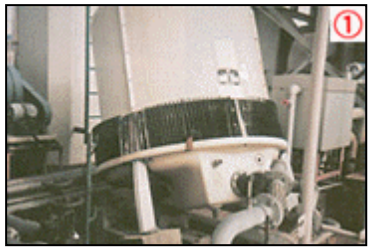
Window glasses

Furniture

Door openings

[Seismic diagnosis]

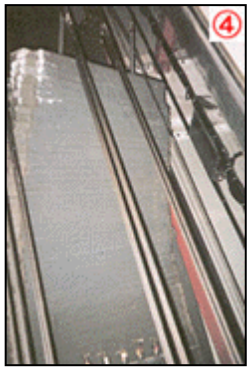
4. Diagnosis of Equipments



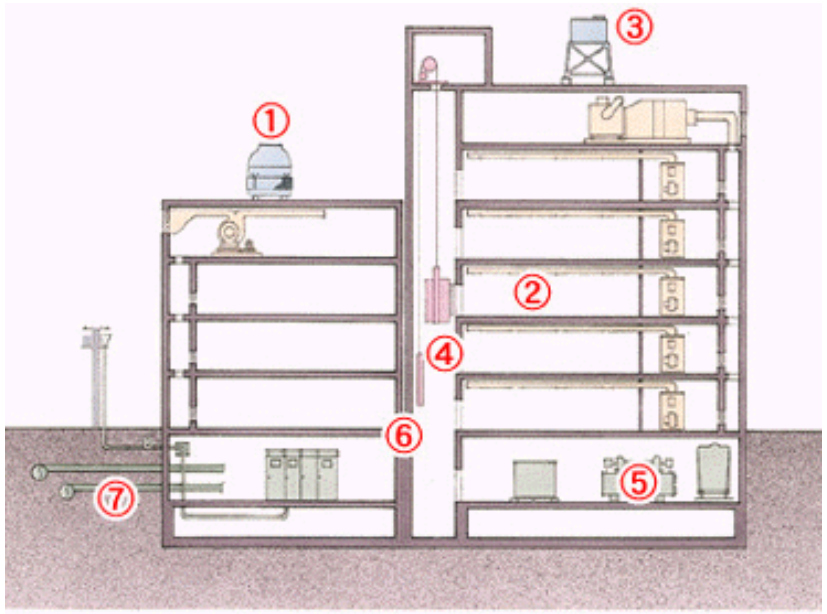
Cooling Tower

Ceiling

Elevated water tank



Elevators



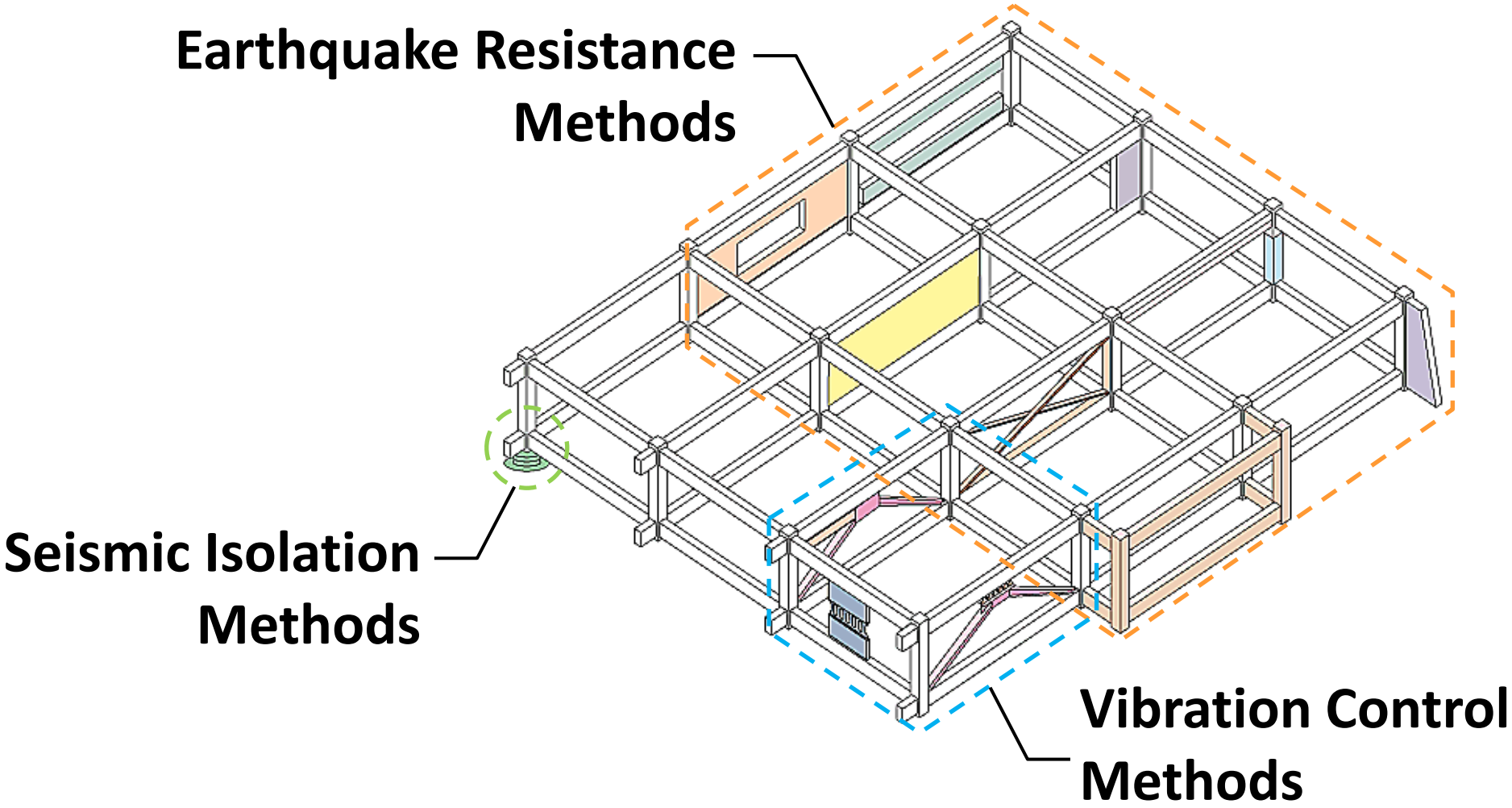
Boiler/Chiler

Underground plumbing

Exp. joints

[Seismic repair]

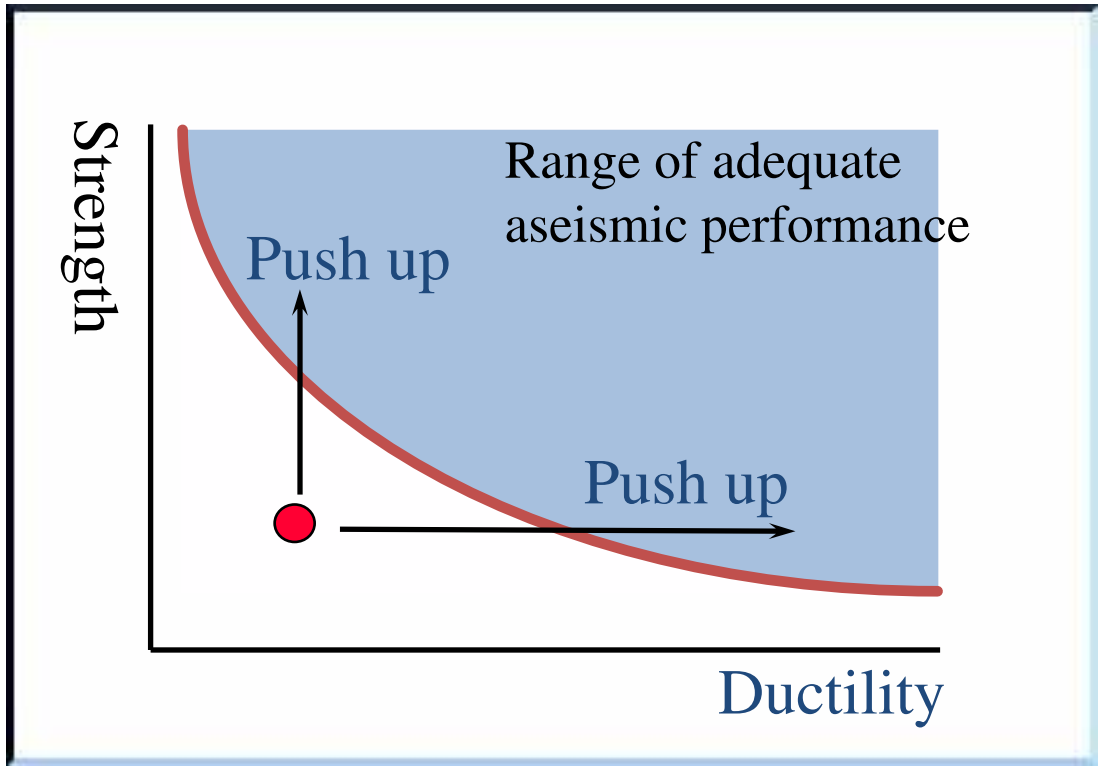
5. Seismic Repair methods



[Seismic repair]

5. Earthquake Resistance Methods

Improving strength and/or ductility of buildings



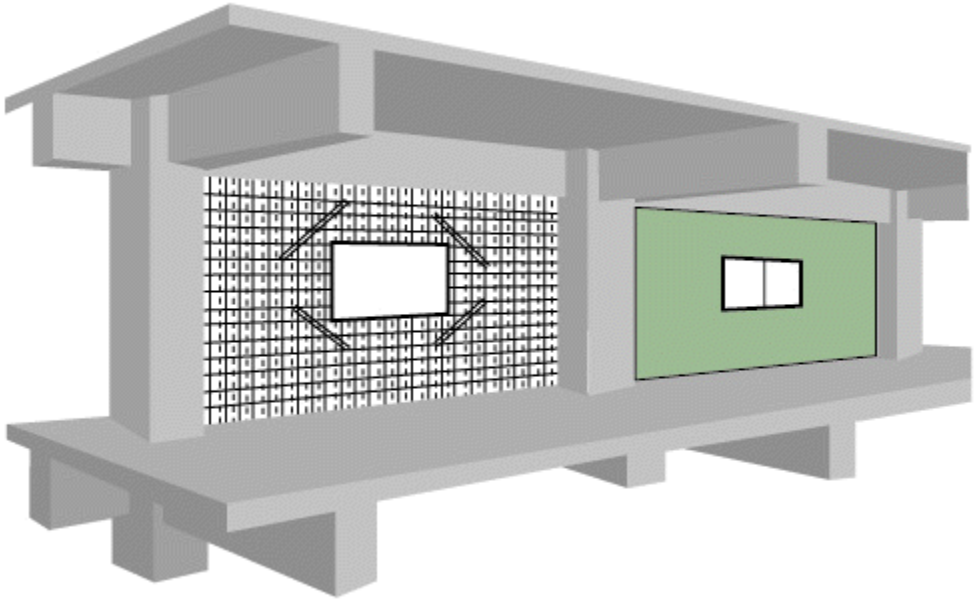
耐震壁増設
そで壁増設
ブレース増設
バットレス増設
骨組増設
柱補強
梁補強

腰壁・たれ壁
のスリット

Concept of improvement of strength/ductility

[Seismic repair]

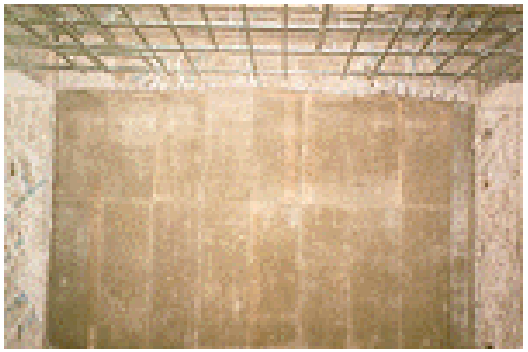
5. Addition of RC Walls



Chemical anchors

Re-bar

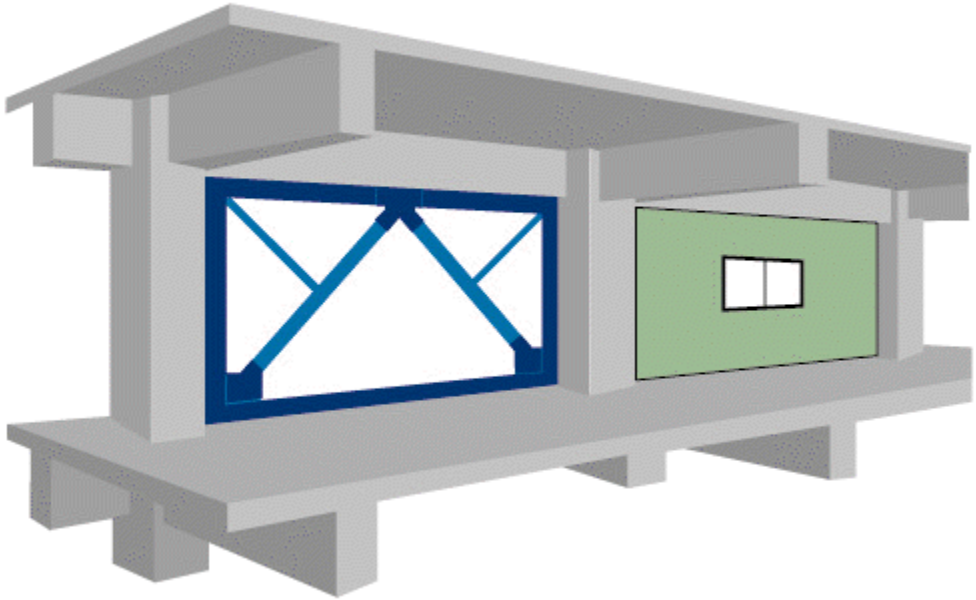
Form work



Completion

[Seismic repair]

5. Addition of Diagonal Braces



Chemical anchors

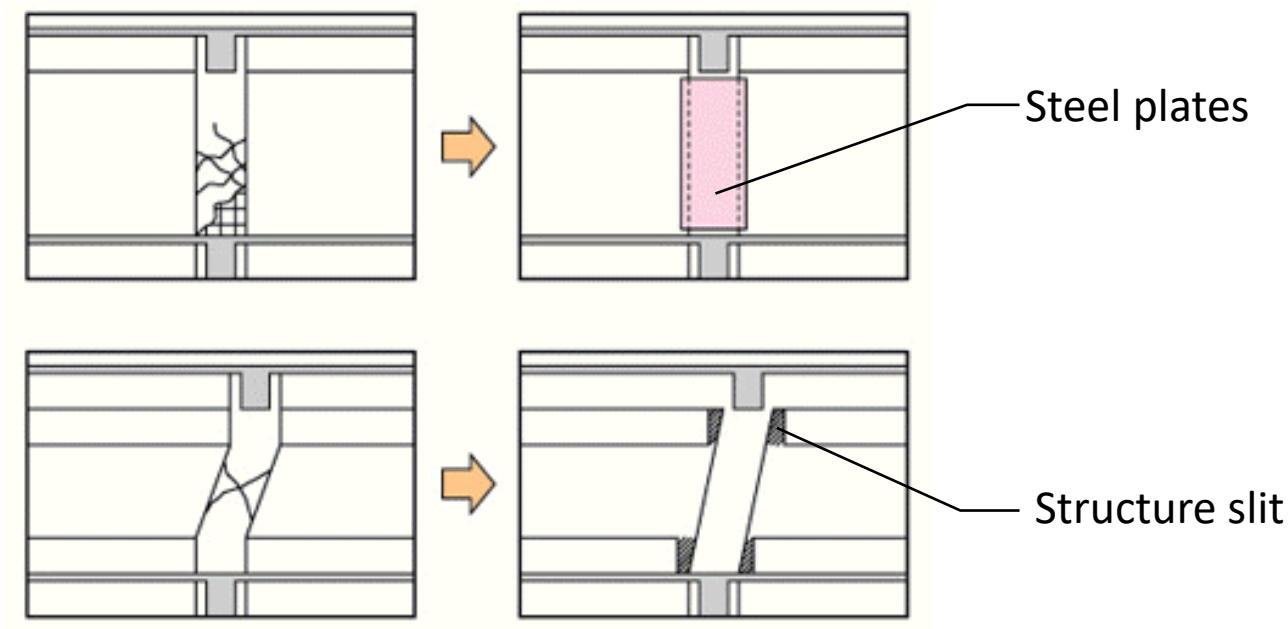
Diagonal Brace erection

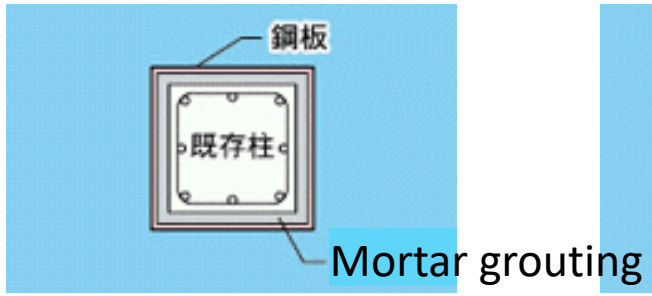
Foam work for grouting

Completion

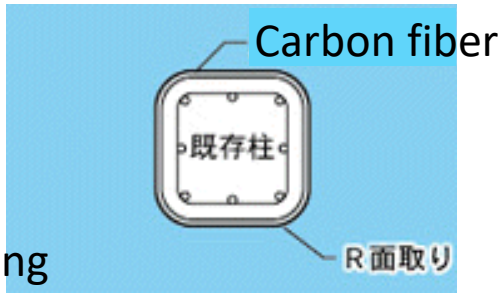
[Seismic repair]

5. Improvement of column ductility

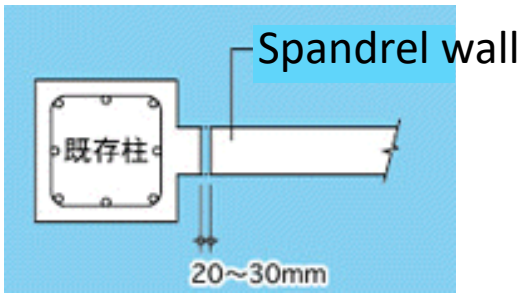




Encase by steel plate



Carbon fiber winding



Structure slit

[Seismic repair]

5. Example of Earthquake Resistance methods

Precast concrete curtain wall → Aluminum curtain wall

(Improving displacement following)

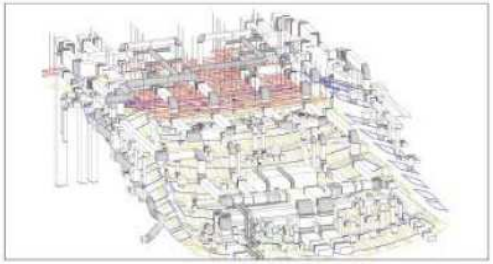
[Seismic repair]

5. Example of ceiling repair work

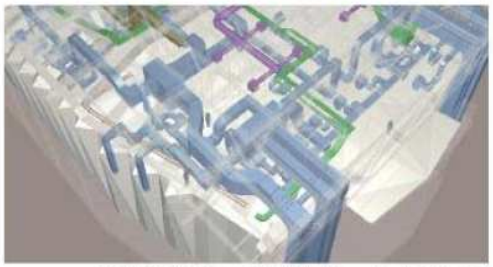
1 3Dモデルによる検討

天井構成材と諸設備との干渉は補強計画に大きな影響を及ぼすため、現地調査や施工図等をもとに既存の状態を3Dデータ化し、取り合いの検証を行いました。

point
- 建築・構造を高精度で3Dデータ化
- 設備は現場で実測しデータに反映



取り合いモデル 全体俯瞰

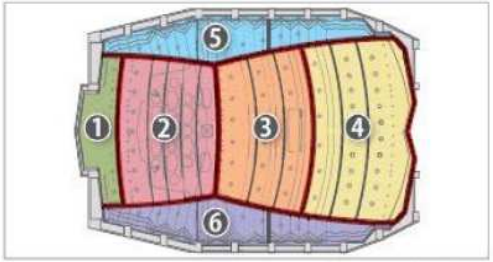


設備ダクトと天井形状(ホール上部から)

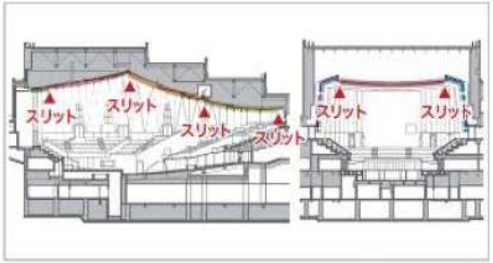
2 天井の領域分け

天井をスリットで6つの領域に分けました。領域ごとに補強を一体化し、領域境界部分は仕上げ・下地とも切断しました。

point
- 領域を分けることで地震時の接触による破損を回避



天井の領域分け

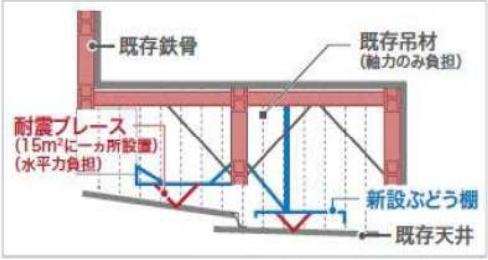


スリット位置

3 天井補強

天井面から1.5m以内に新設したぶどう棚(補強用の鉄骨製格子棚)より既存天井に対して耐震ブレースを設置し、水平力と軸力の負担を分散させました。

point
- 地震応答解析で耐震性を確認



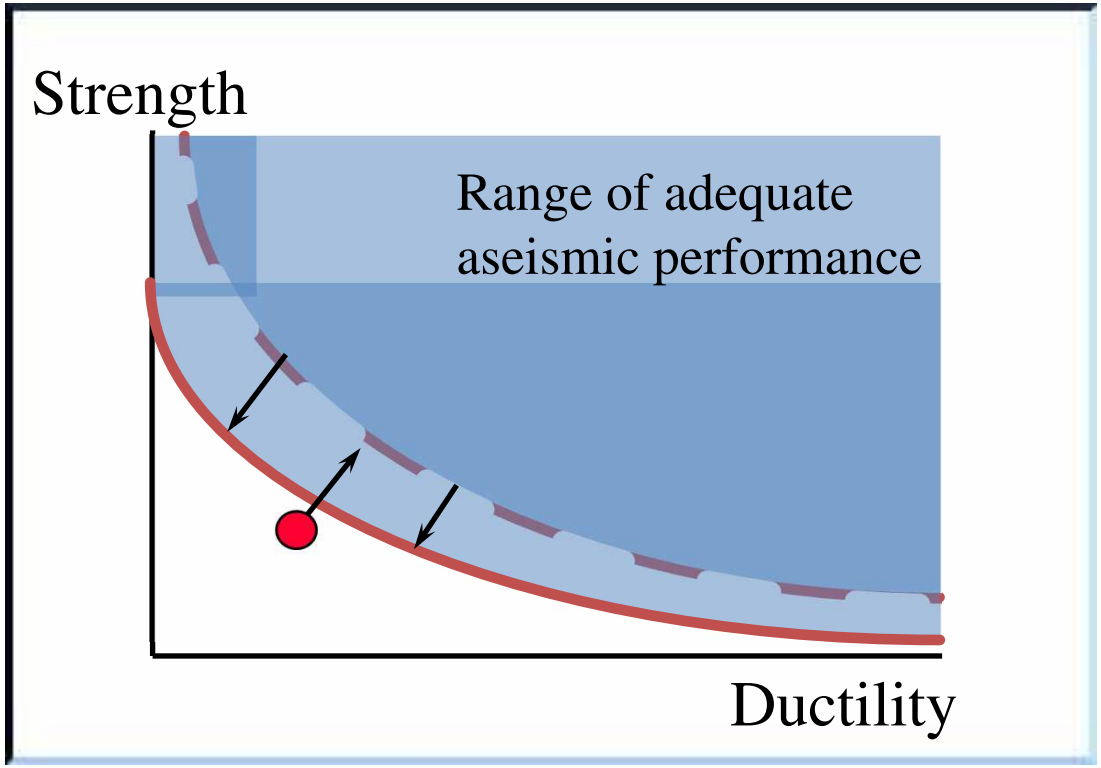
新設ぶどう棚と耐震ブレース

補強後の様子

[Seismic repair]

6. Vibration Control methods

Controlling the response of buildings



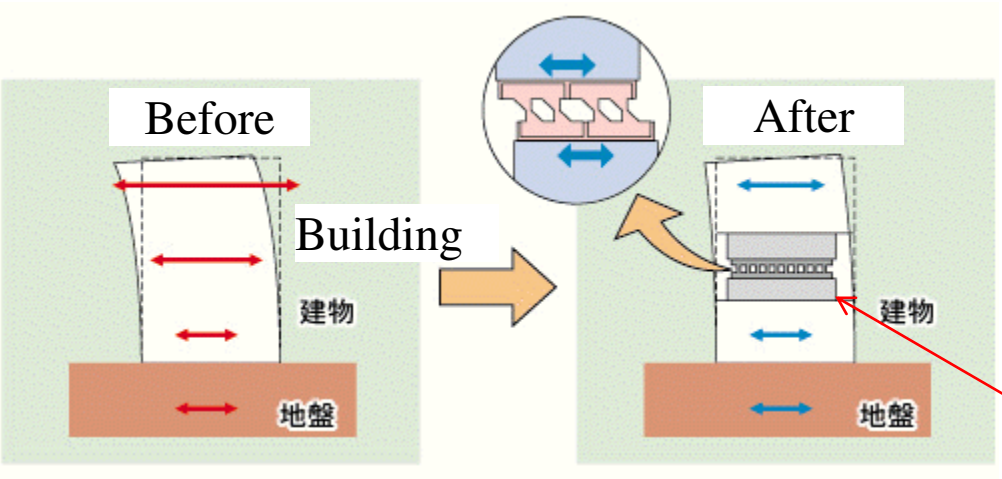
Concept of Vibration Control

制震補強間柱

制震補強ブレース

[Seismic repair]

6. Example of Vibration Control methods



Honeycomb damper
(VC device)

Before

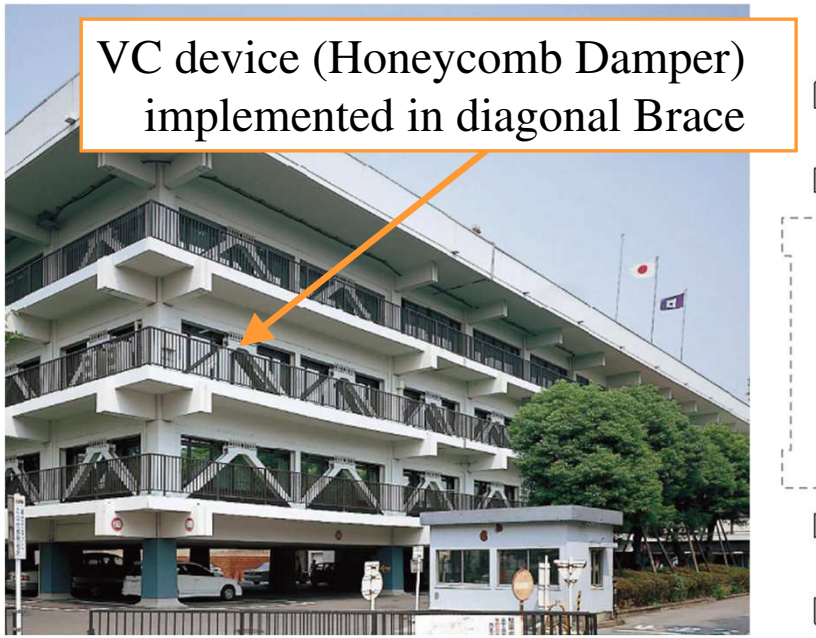
Construction stage

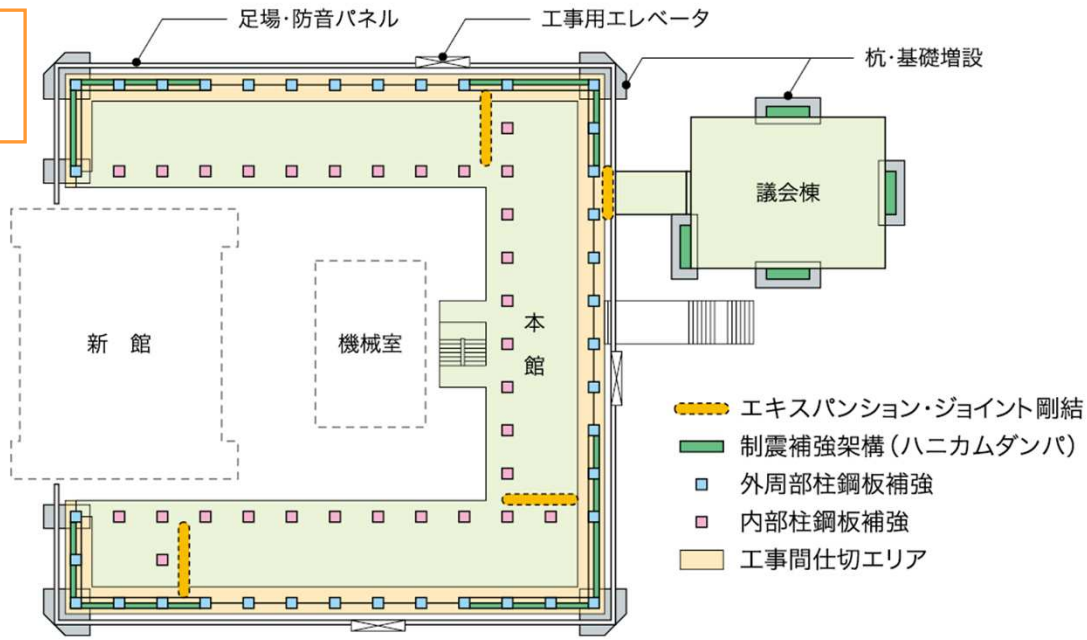
Completion

[Seismic repair]

6. Example of Vibration Control methods

District Government office





Government office should be functioned as Disaster-prevention facilities.

Therefore, Seismic retrofit by VC methods was done.

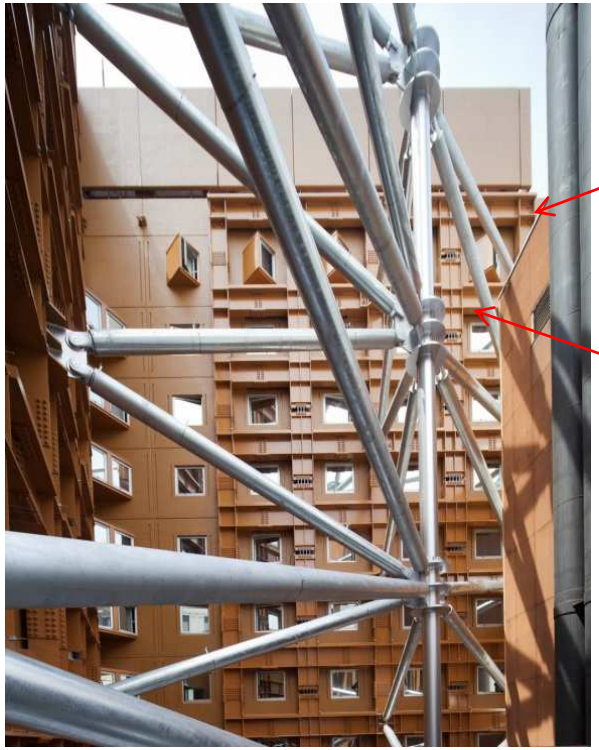
[Seismic repair]

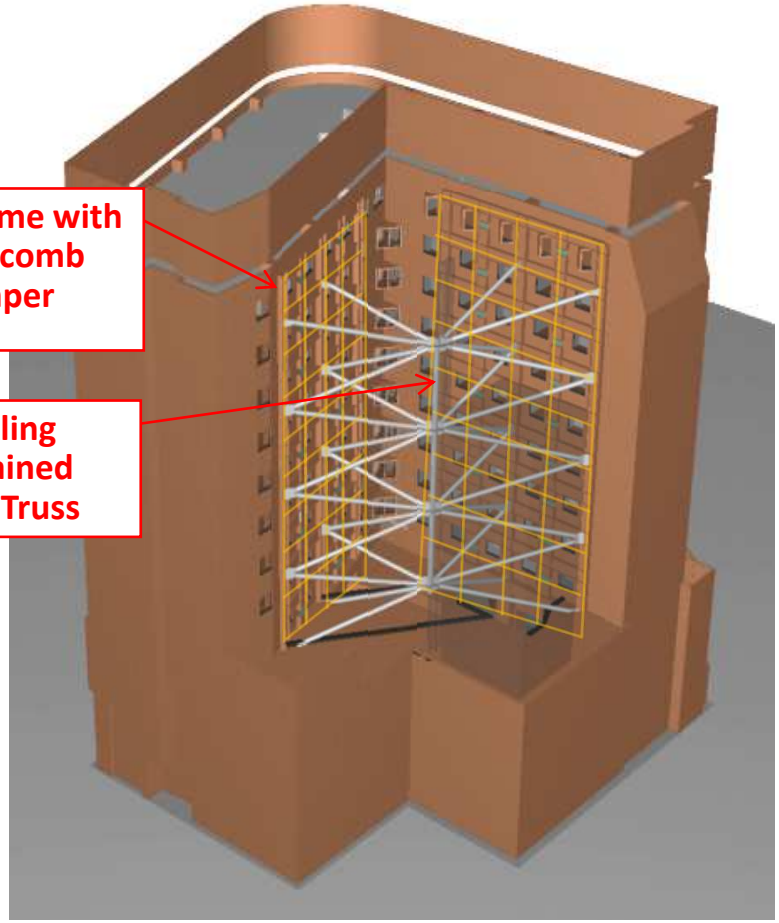
6. Example of Vibration Control methods

HOTEL (Ginza, Tokyo)

[Seismic repair]

6. Layout of V.C. devices

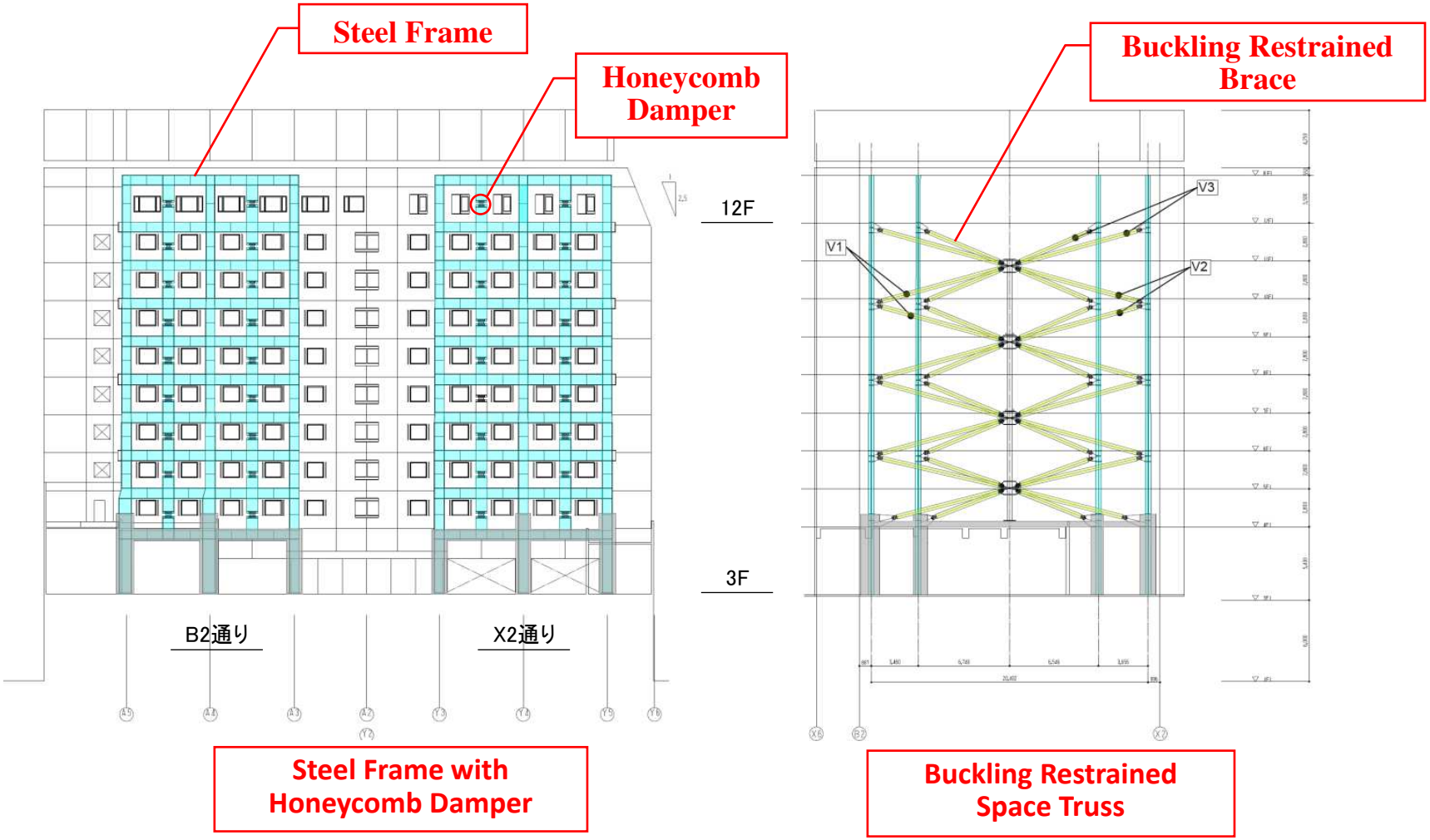




パース

[Seismic repair]

6. Layout of V.C. devices



[Seismic repair]

6. V.C. device Connection Details

独立制震トラスの最下部は低層部屋根と一体の逆梁（RC軸力梁）と取合い、壁付制震フレームは、3階～4階間はSRC造とし既存柱と一体化、変動軸力を伝達する

Buckling Restrained Brace

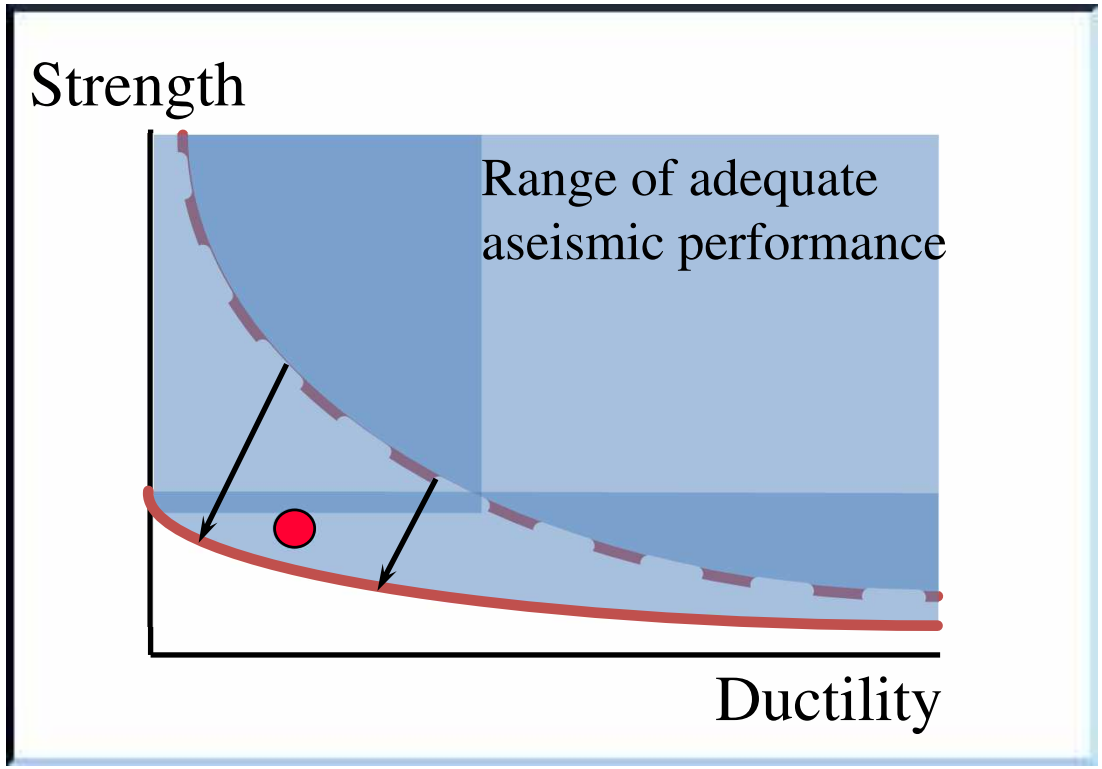
壁付制震フレームに組込んだ間柱タイプの鋼製ダンパ（ハニカムダンパ）

Steel Frame

[Seismic repair]

7. Seismic Isolation methods

Controlling Response of buildings (reduction of input motion)

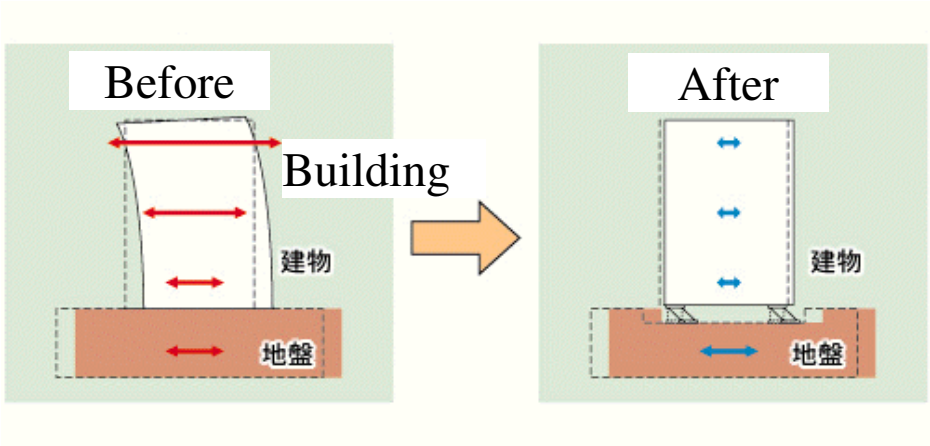


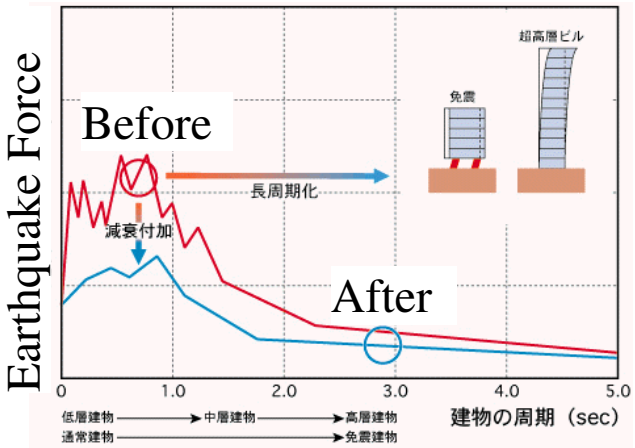
免震補強

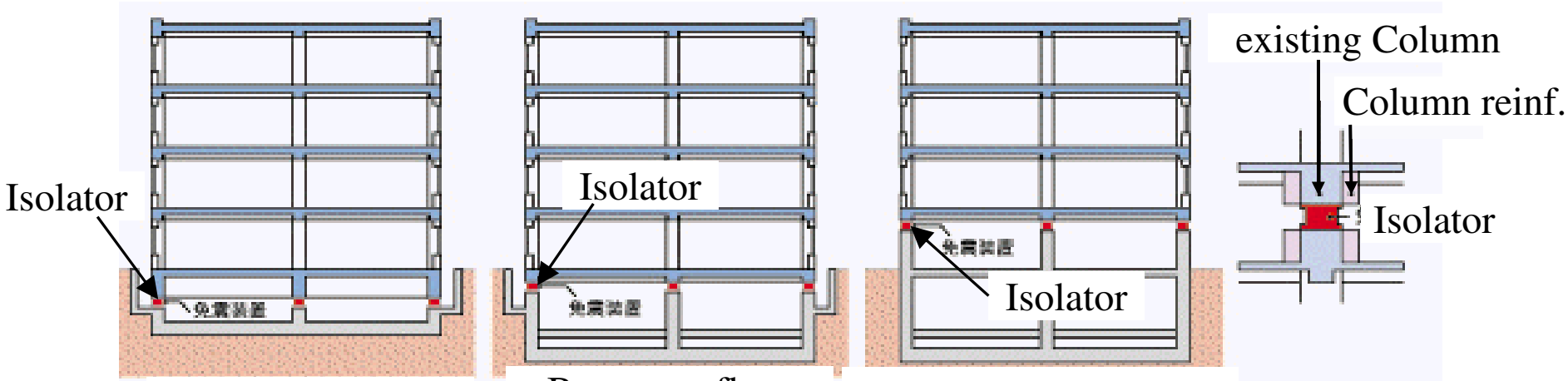
Concept of reduction of input motion

[Seismic repair]

7. Seismic Isolation methods







Foundation level

Basement floor ceiling level

upper structure ceiling level

Variation of the level of isolation layer

Merits of Seismic Isolation methods

- Seismic reinforcement without changing appearance, architectural features and interior space of the existing buildings.

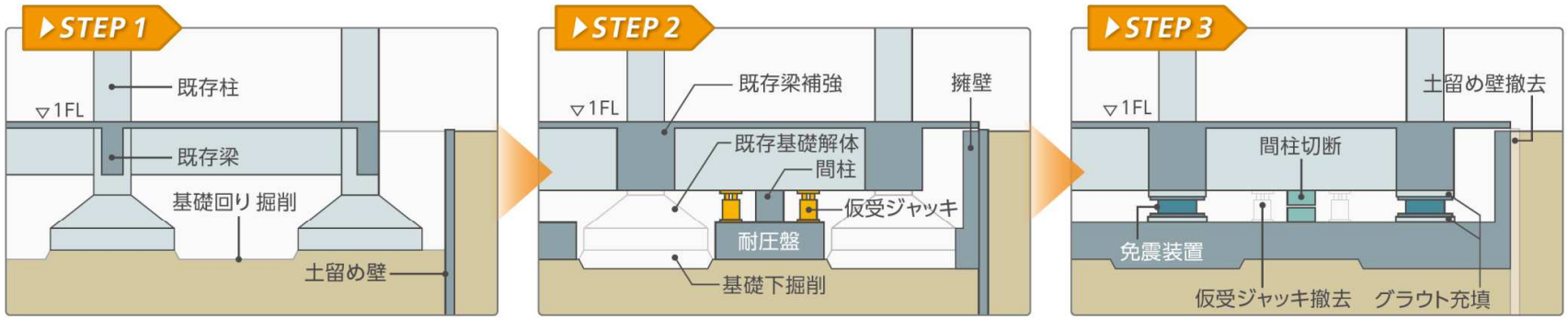
- Suitable for historical architecture and public sector buildings with high importance.

- Technically possible to provide aseismic resistance beyond the current building codes require.

[Seismic Isolation Methods]

Merits/Demerits of Bottom-Level isolation

- Merits: All floors are seismically isolated. Conversion works can be done without affecting normal operation of the building.
- Demerits: New mat foundation must be constructed to make the isolation layer. Therefore the conversion work tend to be large-scale including excavation around the building.



建物周囲に土留め壁を打設し、基礎周りの地盤を掘削します。

既存基礎周りに耐圧盤と擁壁を新設します。既存梁を補強し、間柱と仮受ジャッキを設置したのち、既存基礎を順次解体します。

撤去部分の耐圧盤を打設し一体化したのち、免震装置を設置し、グラウトを充填します。間柱を切断し、仮受ジャッキを撤去します。

Examples of Seismic Isolation methods (Bottom-Level isolation)

Tokyo Station Marunouchi Terminal building

Central Gov't Bldg. No.1

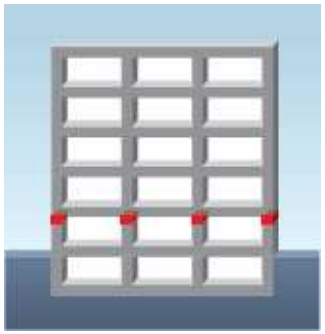
Hakone Town Office Bldg.

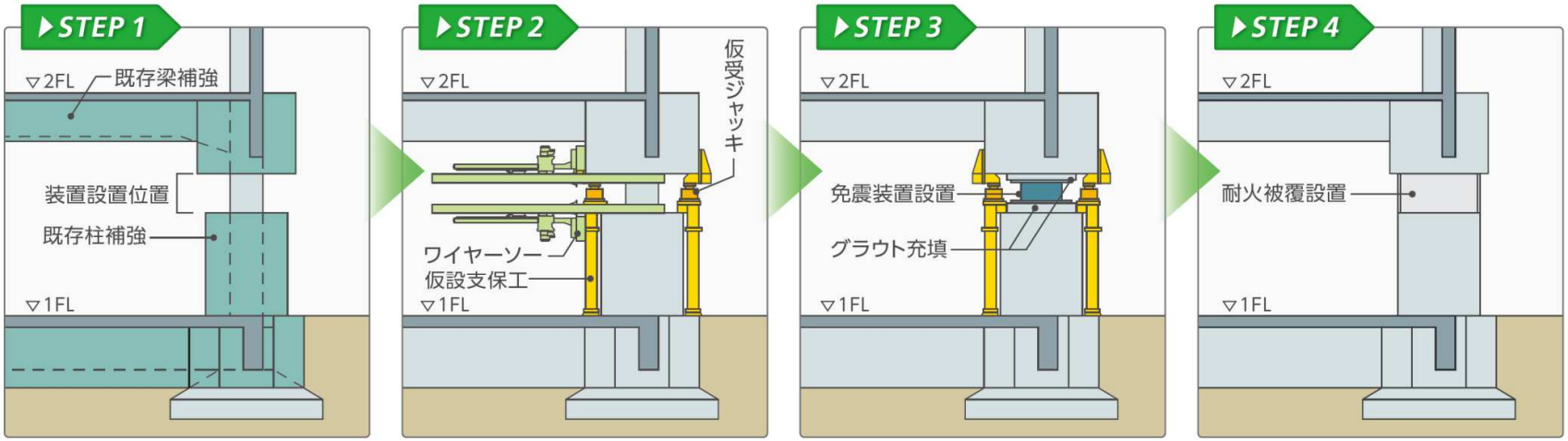
East Shizuoka Pref.
General Office Bldg.

[Seismic Isolation Methods]

Merits/Demerits of Mid-Level isolation

- Merits: Less construction terms & cost.
  Pits around the building is not required.
  Suitable for buildings with small surrounding space.
- Demerits: Only floors above newly implemented isolation layer are seismically isolated.





基礎下を掘削し、柱・梁を補強します。

仮設支保工と仮受ジャッキで既存柱を支え、ワイヤーソーで柱を切断します。

免震装置を設置し、グラウトを充填します。

ジャッキダウンを行い、仮設部材を撤去します。必要に応じて、耐火被覆を設置します。

Examples of Seismic Isolation methods (Mid-Level isolation)

Murakami City
General Office Bldg.

Nagano Pref. Office Bldg.

Yaidu City Office Bldg.

Hiroshima local
Gov't Bldg. No.1

Liberal Democratic Party
HQ

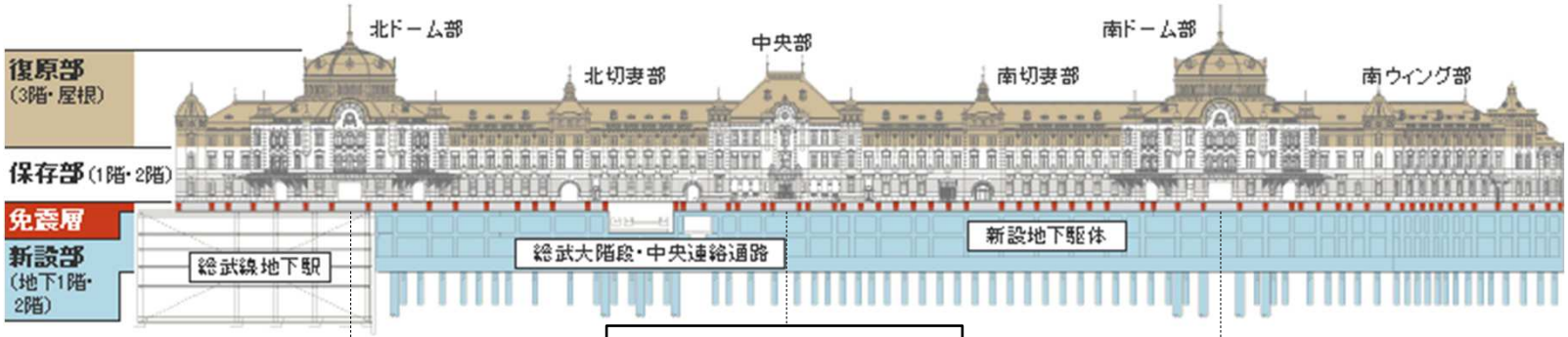
Nihon Univ.
The College of Law Bldg.

Tokyo Station Marunouchi Terminal building
preservation and restoration
by Bottom-Level isolation.

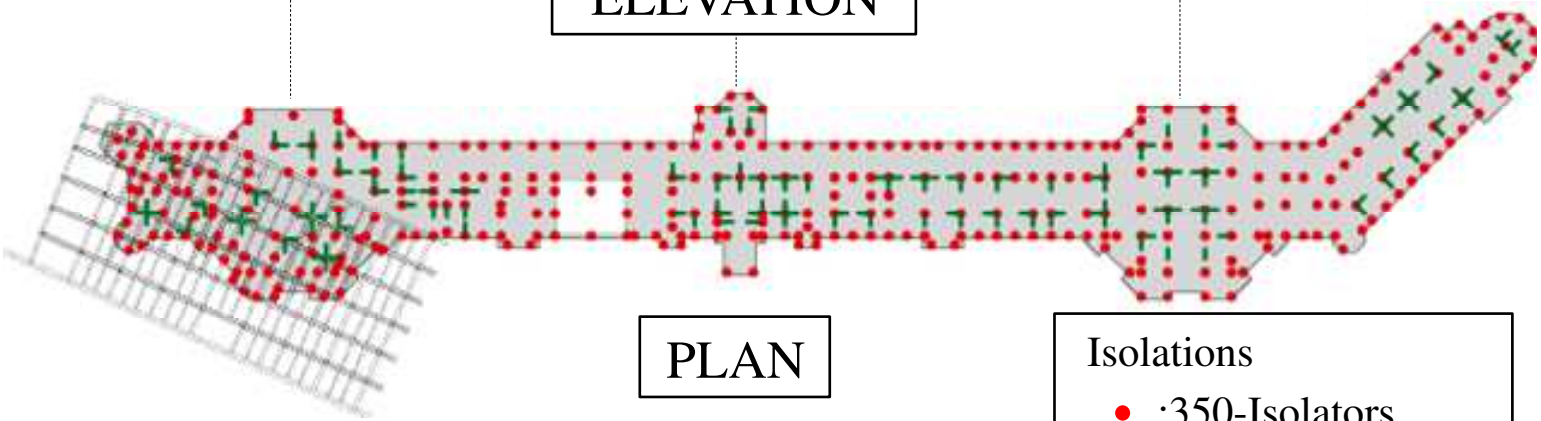
Apr. 2007 ~ Oct. 2012

Night view

[Tokyo Station Marunouchi Terminal building]



ELEVATION

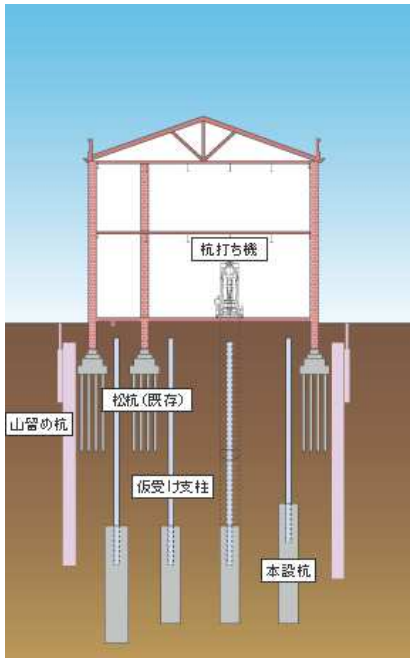


PLAN

Isolations
- :350-Isolators
- :160-Oil dampers

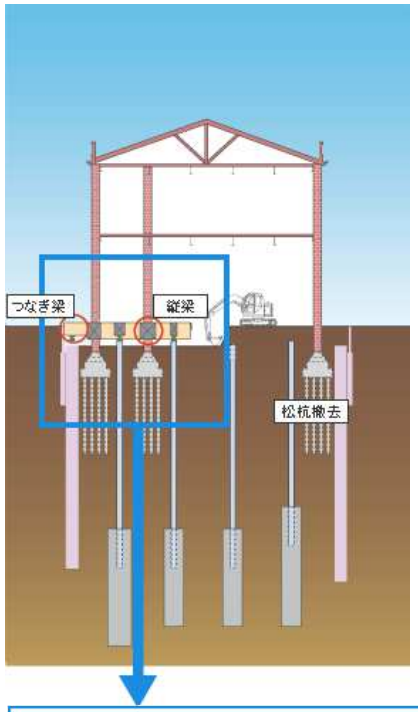
[Tokyo Station Marunouchi Terminal building]

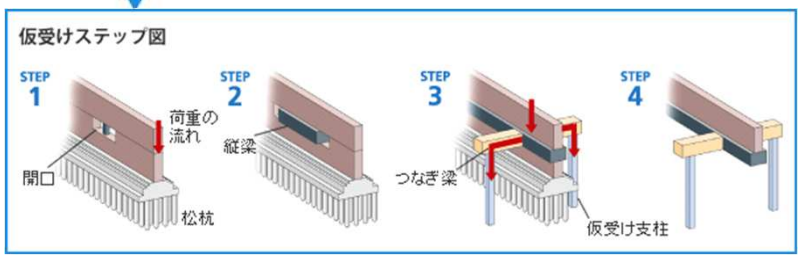
- cast-in-situ piles with temporary support columns are constructed at the first place



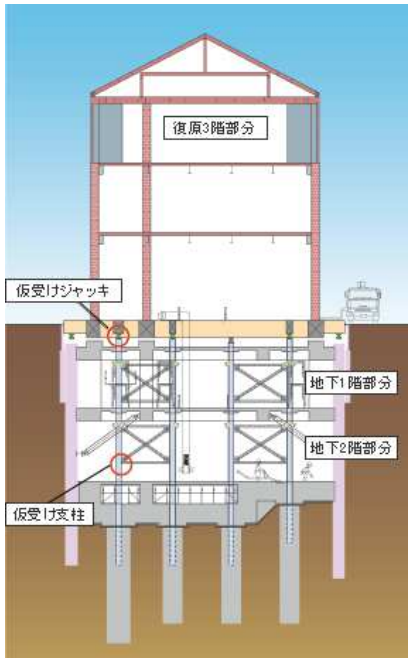
[Tokyo Station Marunouchi Terminal building]

- New concrete ground beams are constructed along existing brick walls
- New ground beams are supported by temporary support columns



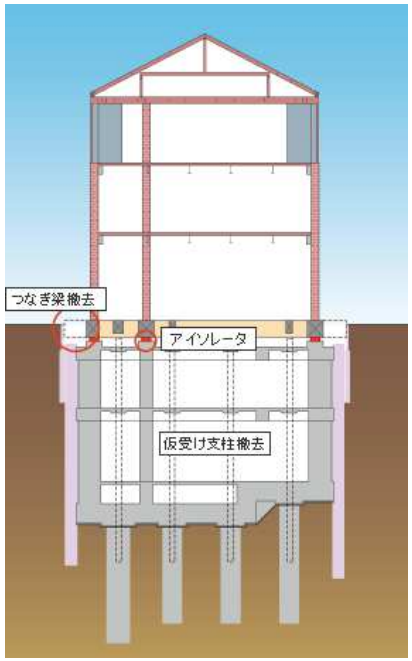


[Tokyo Station Marunouchi Terminal building]



- While supported by the temporary columns, excavation and construction of underground structure are underway

[Tokyo Station Marunouchi Terminal building]



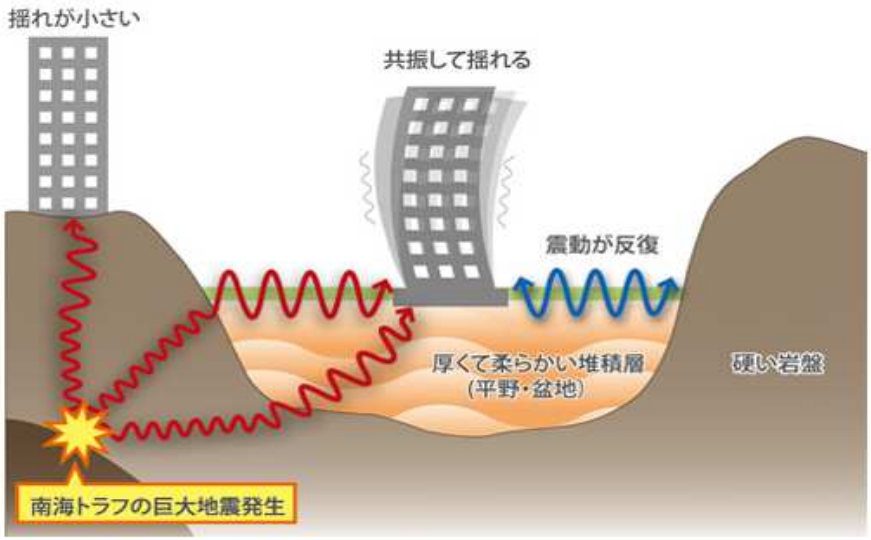
- After completion of the underground structure, isolaters arte set between the existing upper structure and the underground structure

[Tokyo Station Marunouchi Terminal building]

- Construction work during night time

Day time Night time

8. Upgrading of high-rise bldg. for Long-period ground motion



2011年の東北地方太平洋沖地震（M 9.0）では、東京都内の高層ビルで大きな揺れを観測しました。低層階に比べて高層階で大きな揺れとなりました。震源から約700km離れた大阪市（最大震度３）の高層ビルでエレベーターの停止による閉じ込め事故、内装材や防火扉が破損するなどの被害が発生しました。

[Long-period ground motion]

Shinjuku Mitsui Building Seismic Upgrading Project

KAJIMA CORPORATION

Outline of Shinjuku Mitsui Building

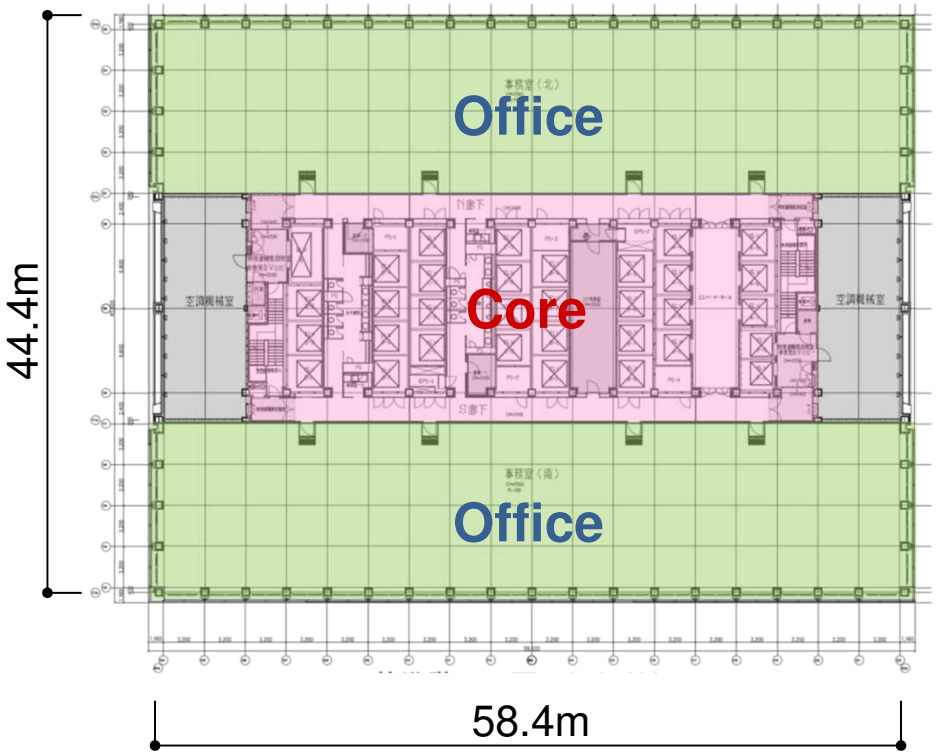
Use	: Office, Shop, Parking
Site Area	: 14,449.38 ㎡
Building Area	: 9,819.19 ㎡
Total Floor Area	: 179,578.93 ㎡
Floors	: Main Tower 55 floors
	Penthouse 3 floors
	Basement 3 floors
Height	: GL+223.60 m
Typical Floor Height	: 3.68 m
Structure type	: Steel (RC slit wall in part)
Completion Date	: September / 1974

Plan and Section

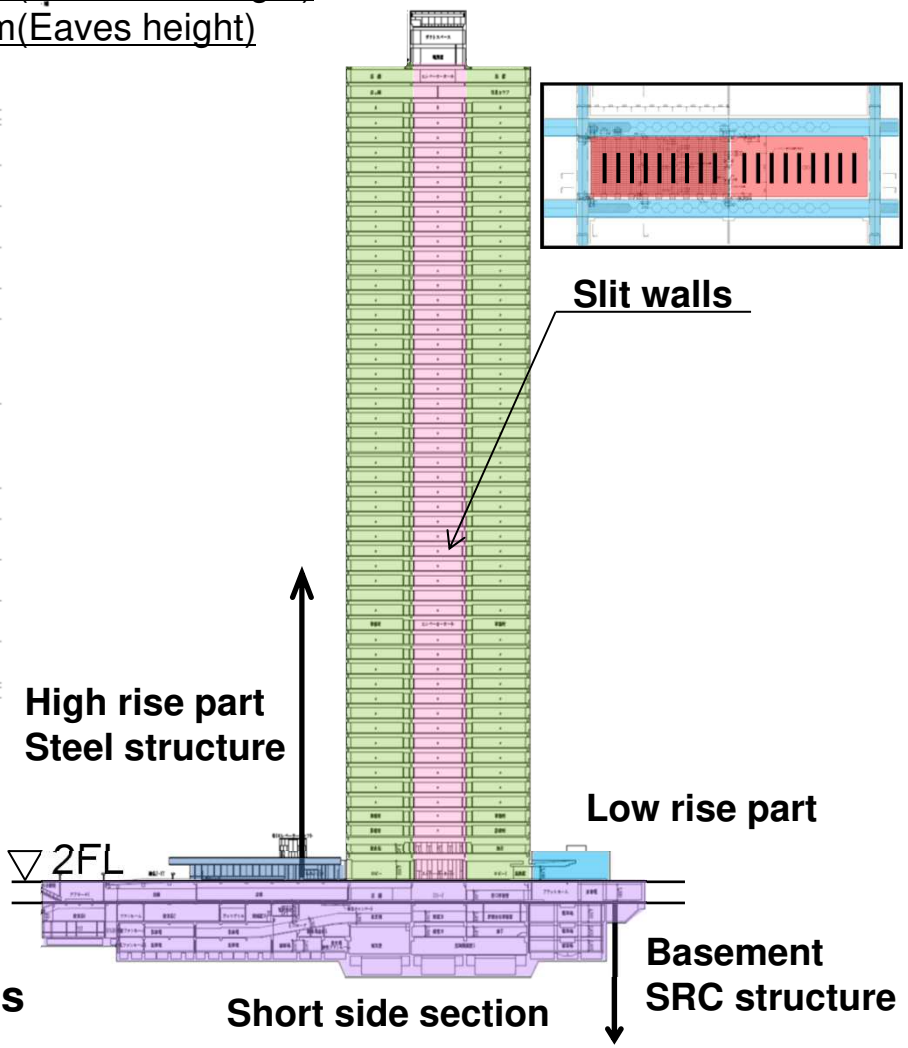
2F~60F: High rise part

1F: Low rise part

GL+225.1m(Maximum height)
GL+210.2m(Eaves height)



Typical floor plan

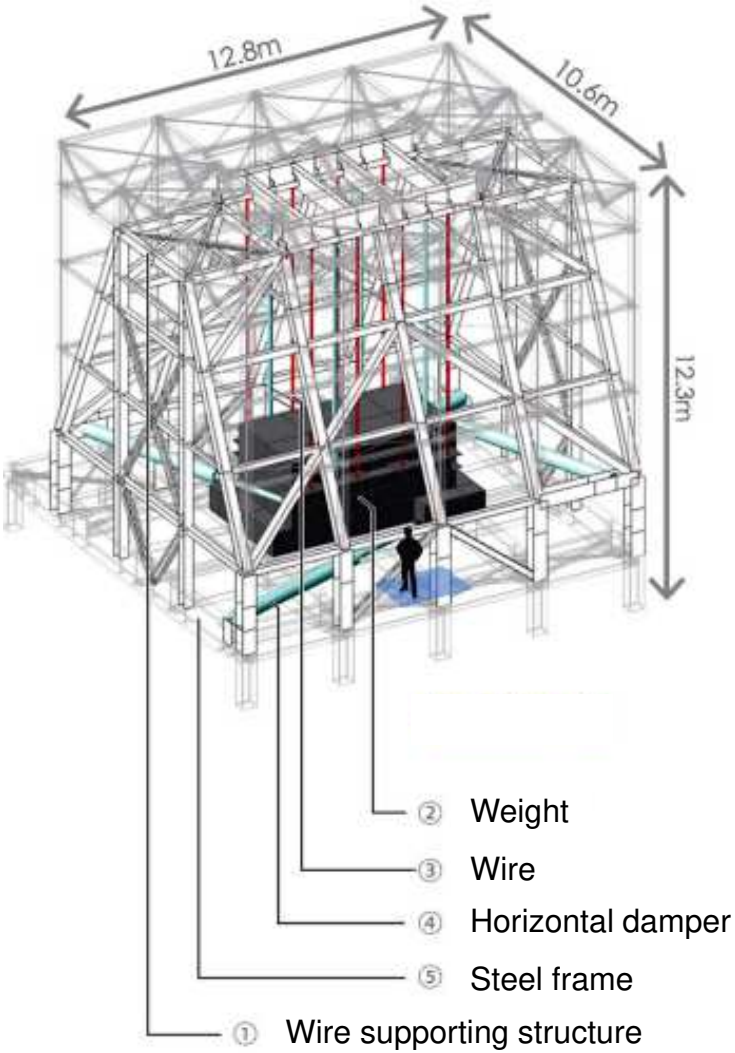


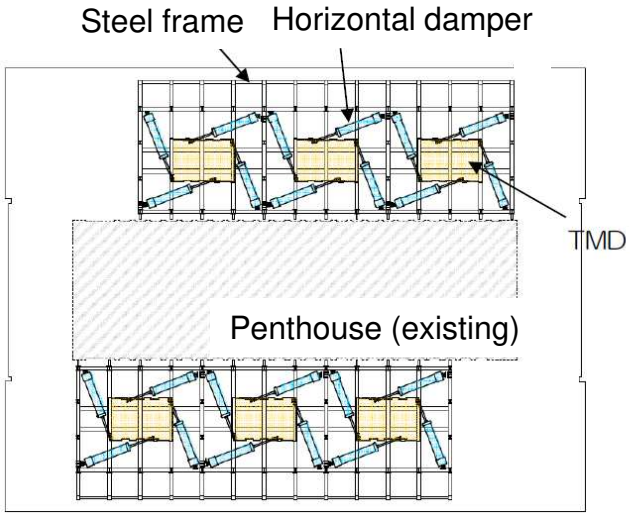
Short side section

Natural period: Short side 5.8s, Long side 5.6s

[Long-period ground motion]

■ Extra Large TMD：Tuned Mass Damper

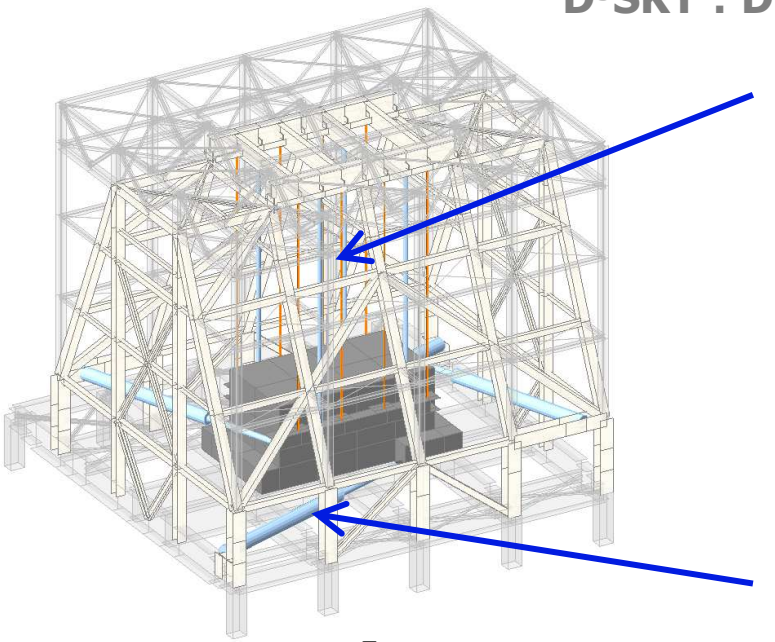




Rooftop TMD Layout

Technologies for D³SKY

D³SKY : Dual-direction **D**ynamic **D**amper of **S**imple **K**ajima st**Y**le

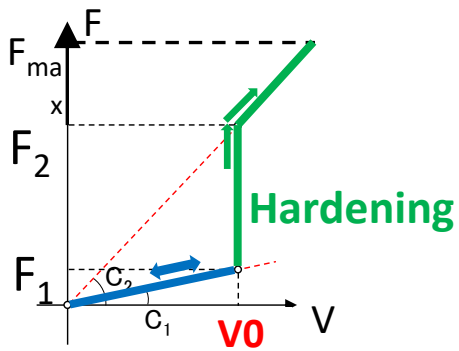


■Support Mechanism of Weight with Wires

- It keeps the heavy weight of 3000kN
- It allows the weight to move 2.0m in every direction with a target vibration period.
- Durability against repeated use is very high.

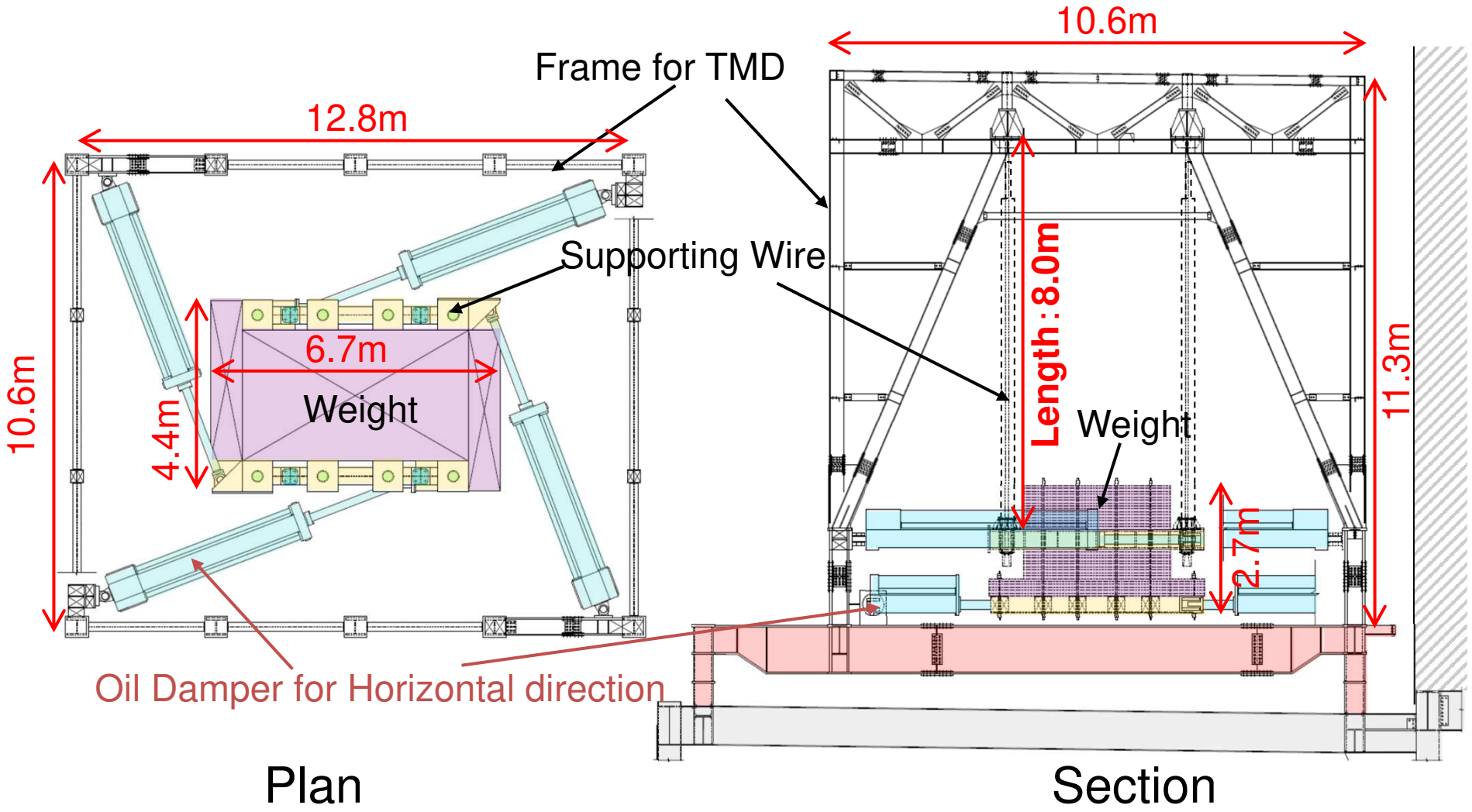
■Oil Damper with Stroke Control Function

- It follows the large displacement of 2.0m.
- It prevents damage by slowing down the weight speed smoothly in an unexpected earthquake larger than the design levels.



Specification of Oil Damper

Configuration of D³SKY



[Long-period ground motion]

■ Extra Large TMD 「D³SKY」

The energy of shaking is absorbed by a hung 300 ton weight and large horizontal dampers.

Conclusion

■High performance TMD nicknamed **D^{3}SKY** can control responses of high-rise buildings for major earthquakes.

■**D^{3}SKY** is also effective for wind induced vibration.

■**D^{3}SKY** can control the building's vibration in all directions.

■**D^{3}SKY** is a flexible system that can be applied to various buildings regardless of the shape and height of them, by adjusting the number of units or the mass of the weight.

■**D^{3}SKY** is perfectly a passive system. It does not require any outer power sources such as electricity.

Summary

1. Seismic diagnosis procedures are presented.
2. Various Seismic Repair methods are presented.
3. Examples of Seismic Isolation methods are presented including Tokyo Station Marunouchi Terminal building preservation and restoration work.
4. Upgrading of high-rise building against long-period ground motion is presented.