Construction technologies in Japan

June 2017

Building Research Institute,
Japan

Matsutaro SEKI

Contents

What is the Concrete?

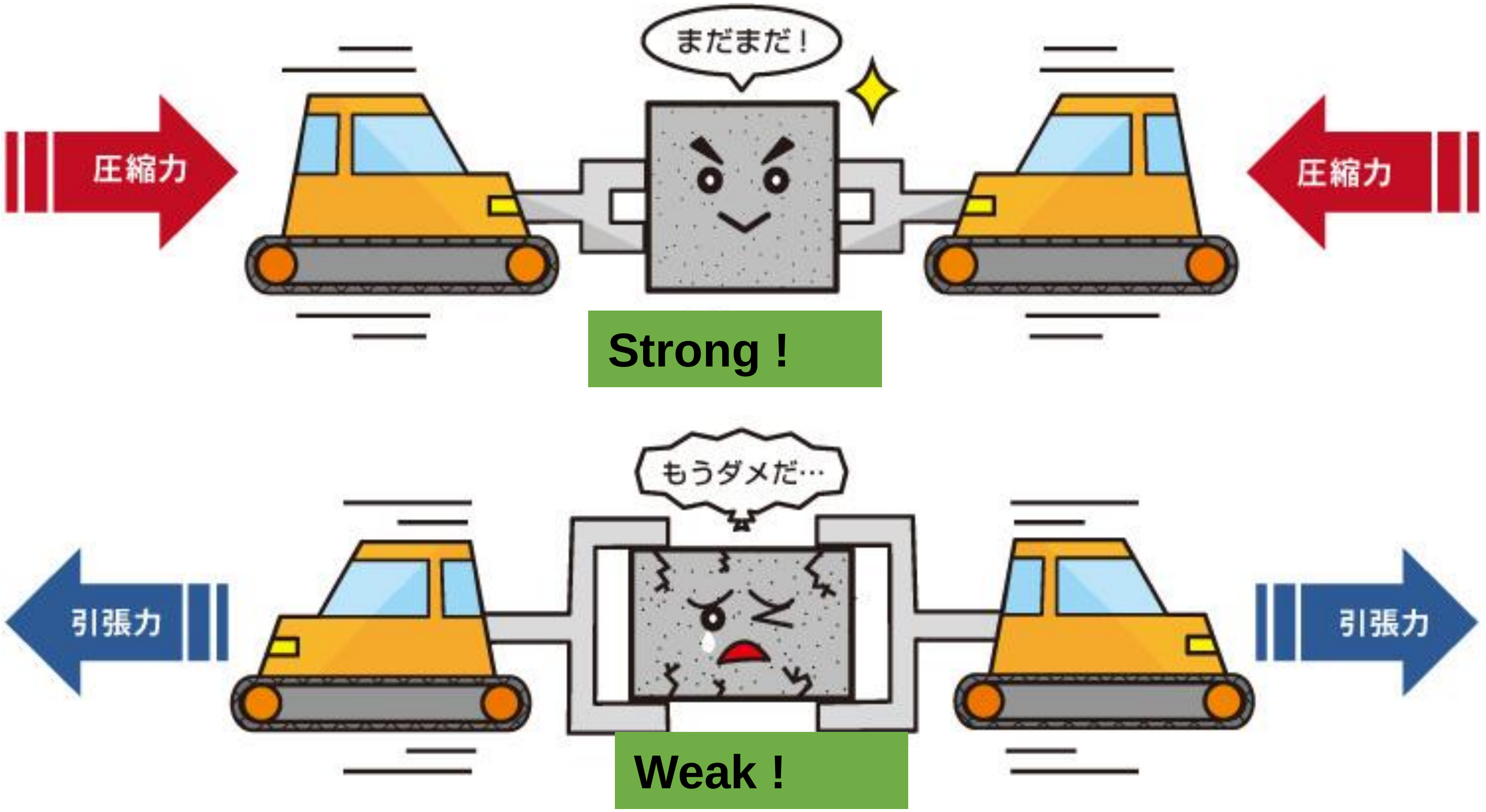
http://kenken-pc.com/intro/

Compressive force

Compressive force

Tensile force

Tensile force

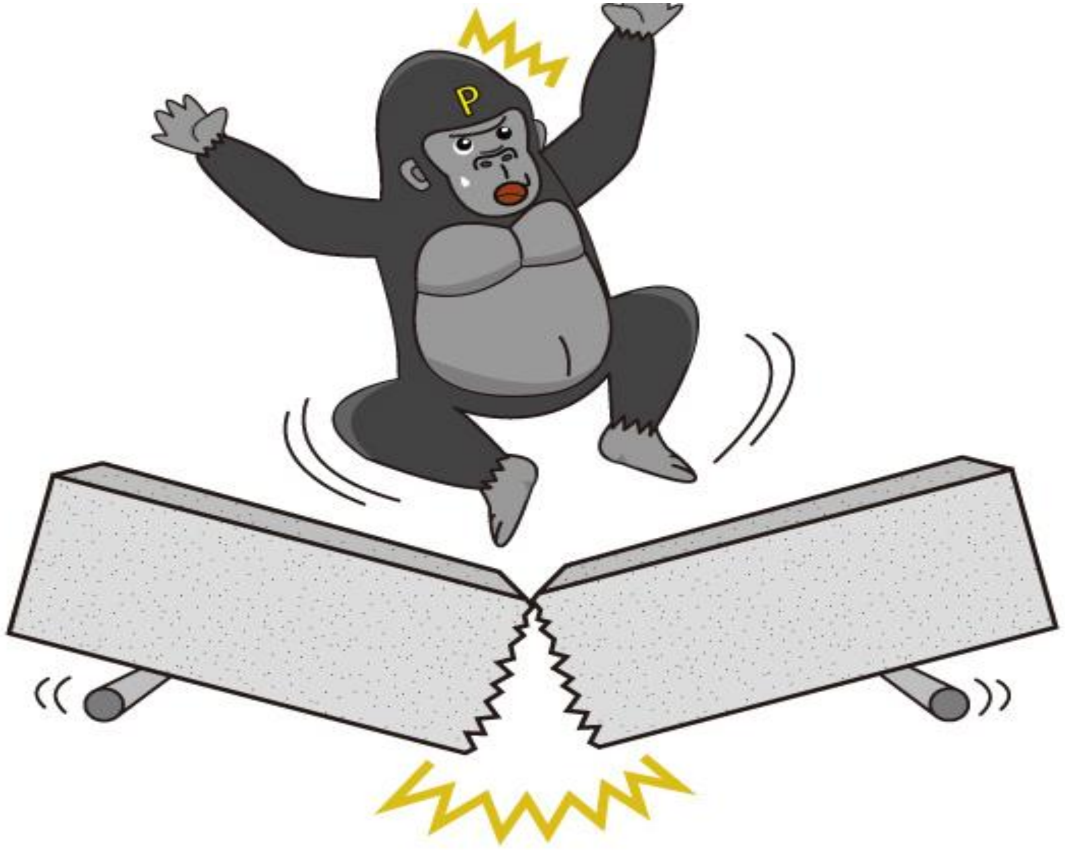


Property of concrete

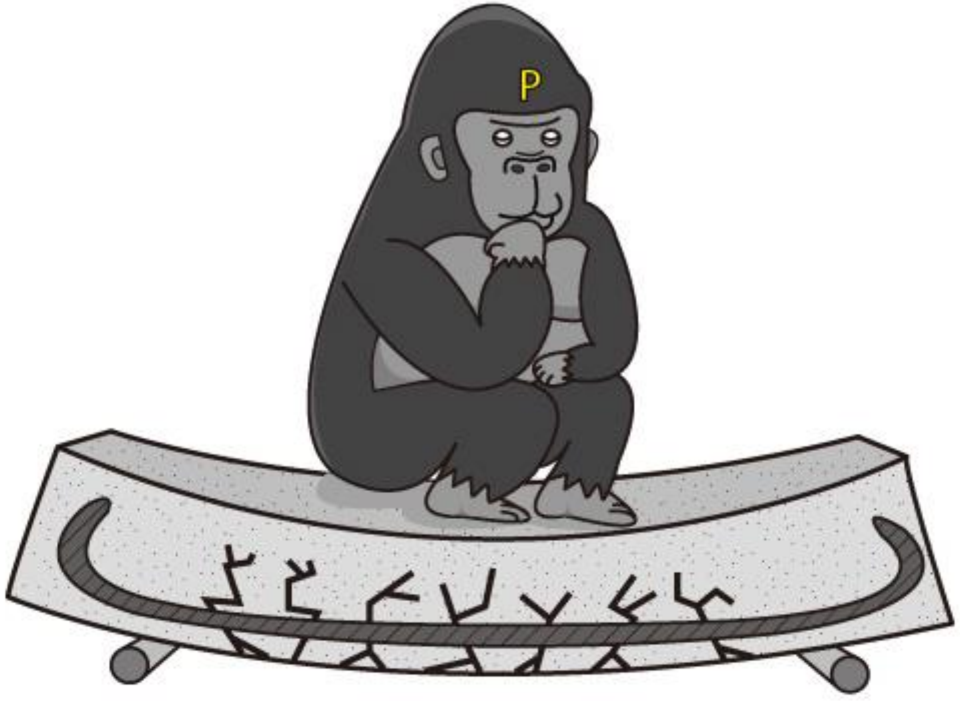
What is the PC structure?

Concept

http://kenken-pc.com/intro/



Concrete Beam



Reinforced concrete Beam

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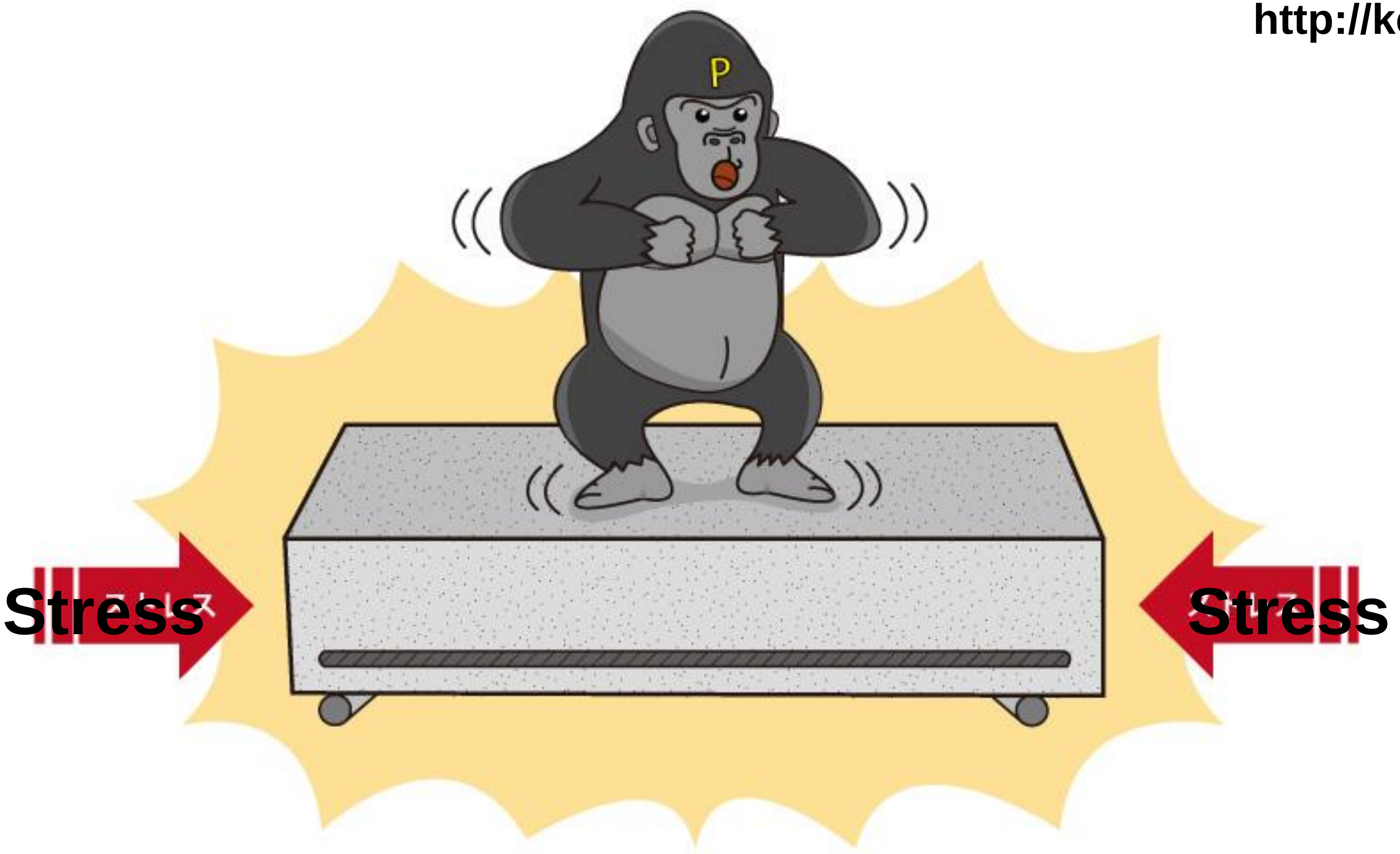
What is the PC structure?

Concept

http://kenken-pc.com/intro/



Prestressed concrete beam

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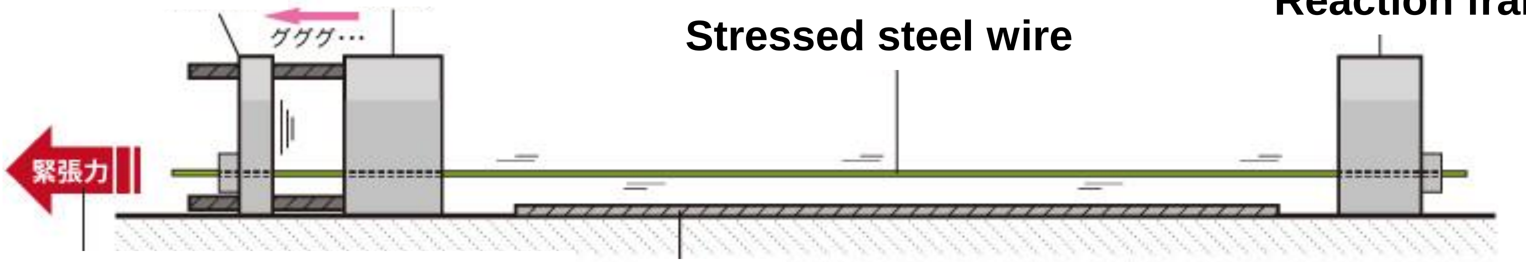
How to make the PC member?

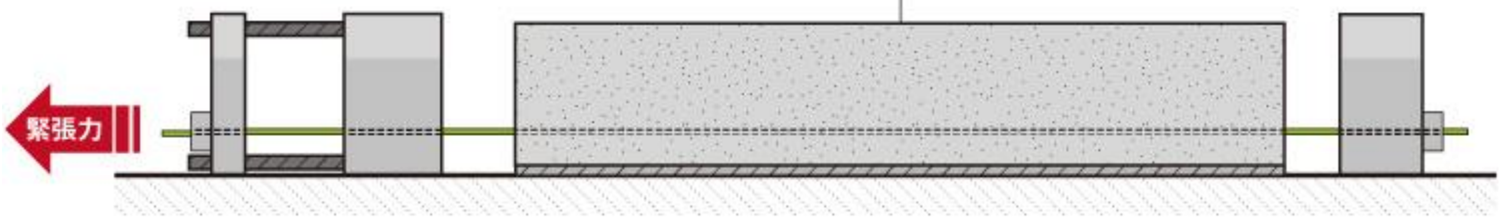
Prestressed Concrete

http://kenken-pc.com/intro/

1. Stressing PC steel wire



2. Casting concrete and curing



How to make the PC member?

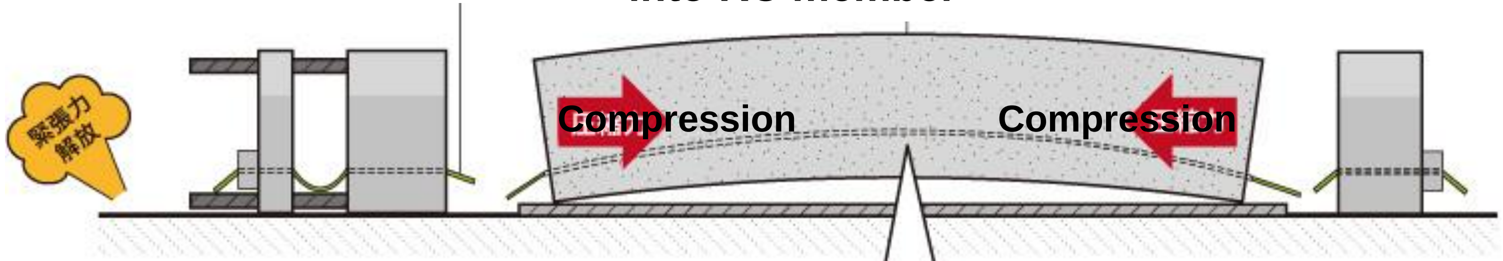
Prestressed Concrete

http://kenken-pc.com/intro/

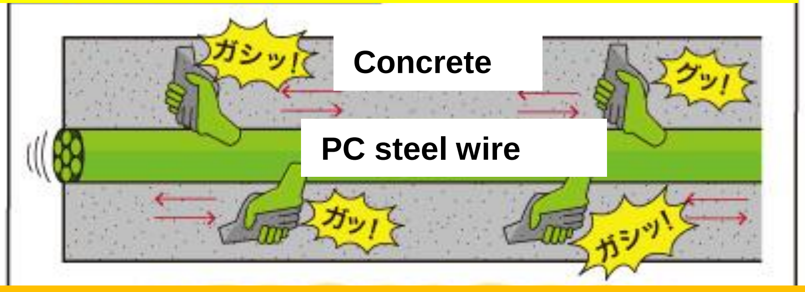
3. Cutting the PC steel wire

Cutting PC steel wire

Relieving the stress of PC wire by cutting introduces prestress force into RC member



Mechanism of anchorage of PC steel wire



After cutting the PC steel wire, Prestress is introduced by the anchorage between PC steel wire and concrete.

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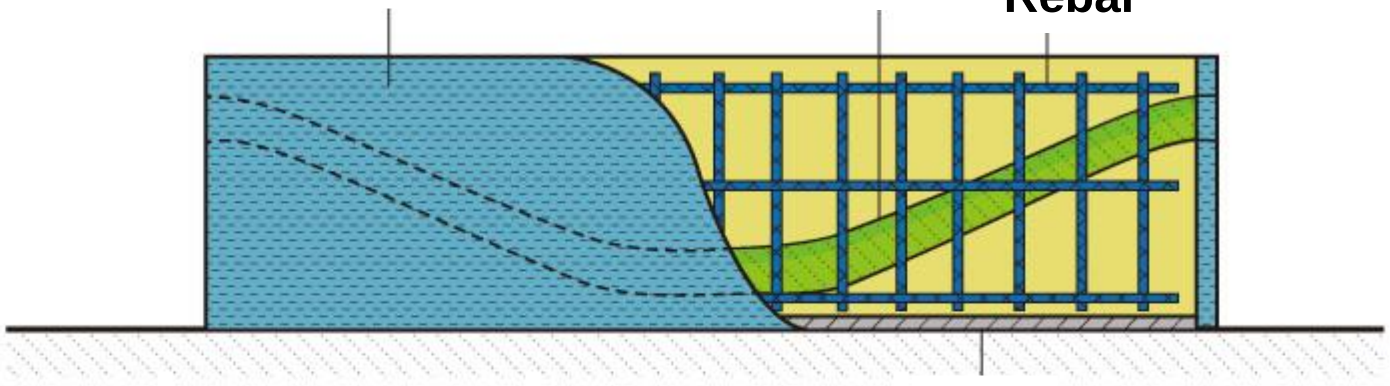
How to make the PC member?

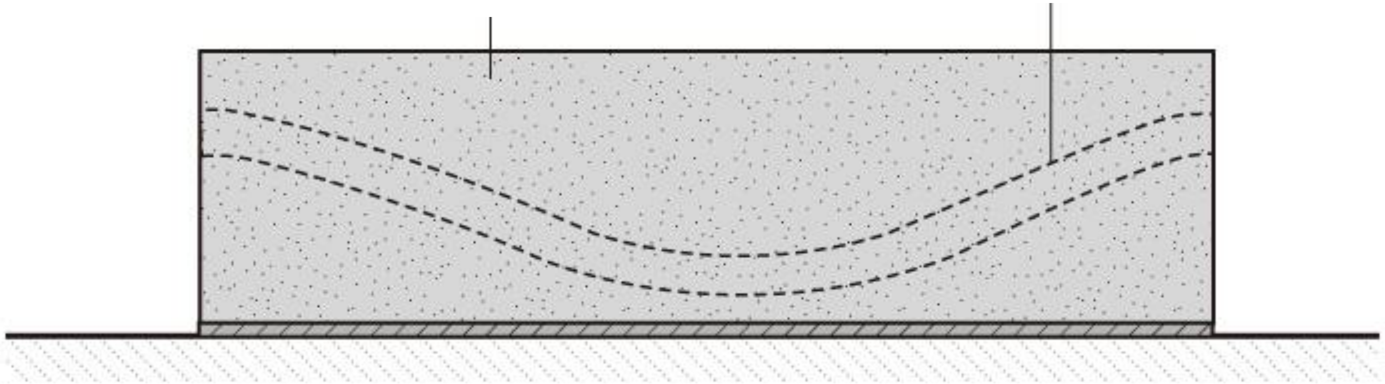
Posttensioned concrete

http://kenken-pc.com/intro/

1. Construction of rebar, sheath pipe and form



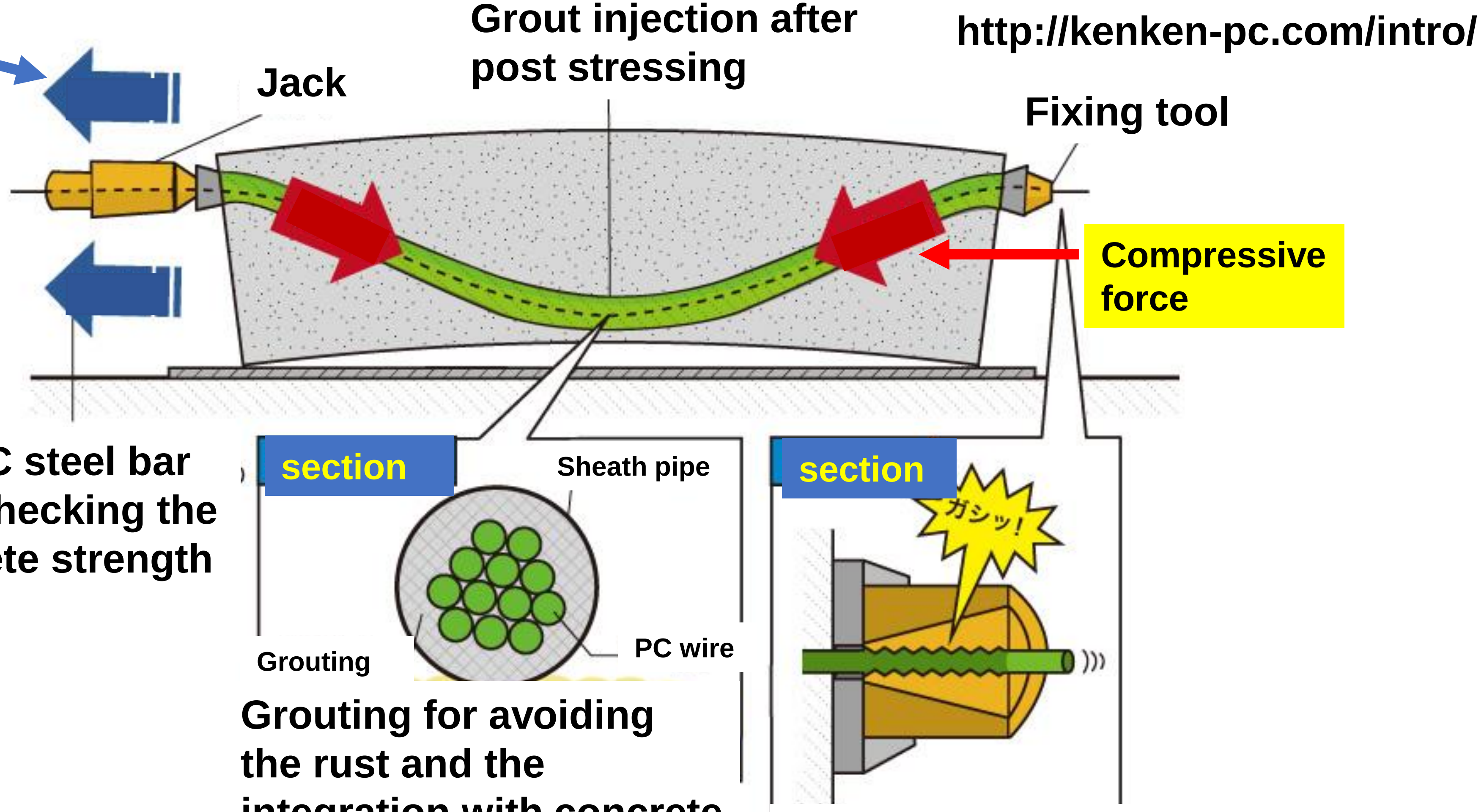
2. Casting of concrete and cure



How to make the PC member?

Posttensioned concrete

3. Post stressing PC steel wire and grout injection



Grouting for avoiding the rust and the integration with concrete

In case of post stressing method

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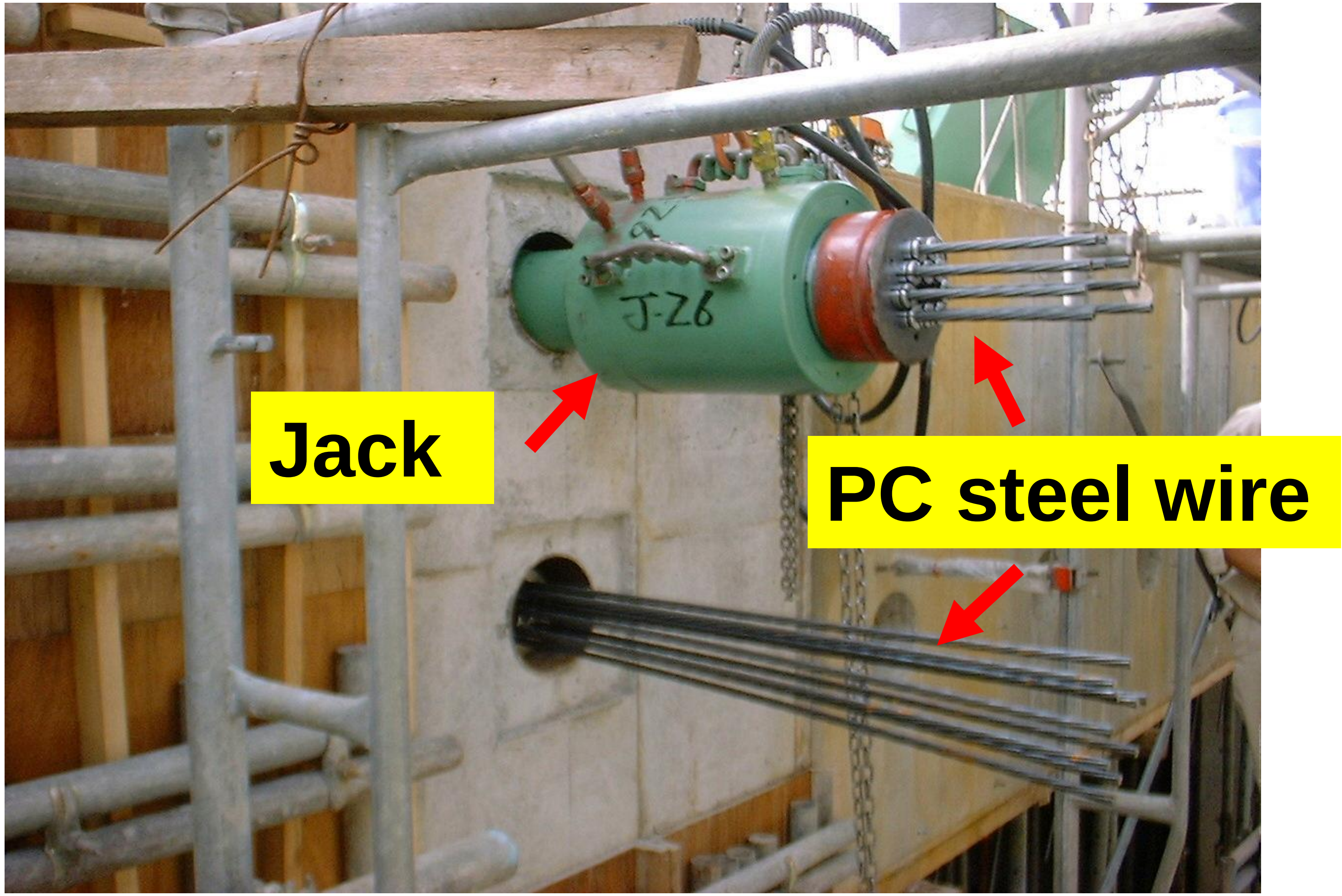
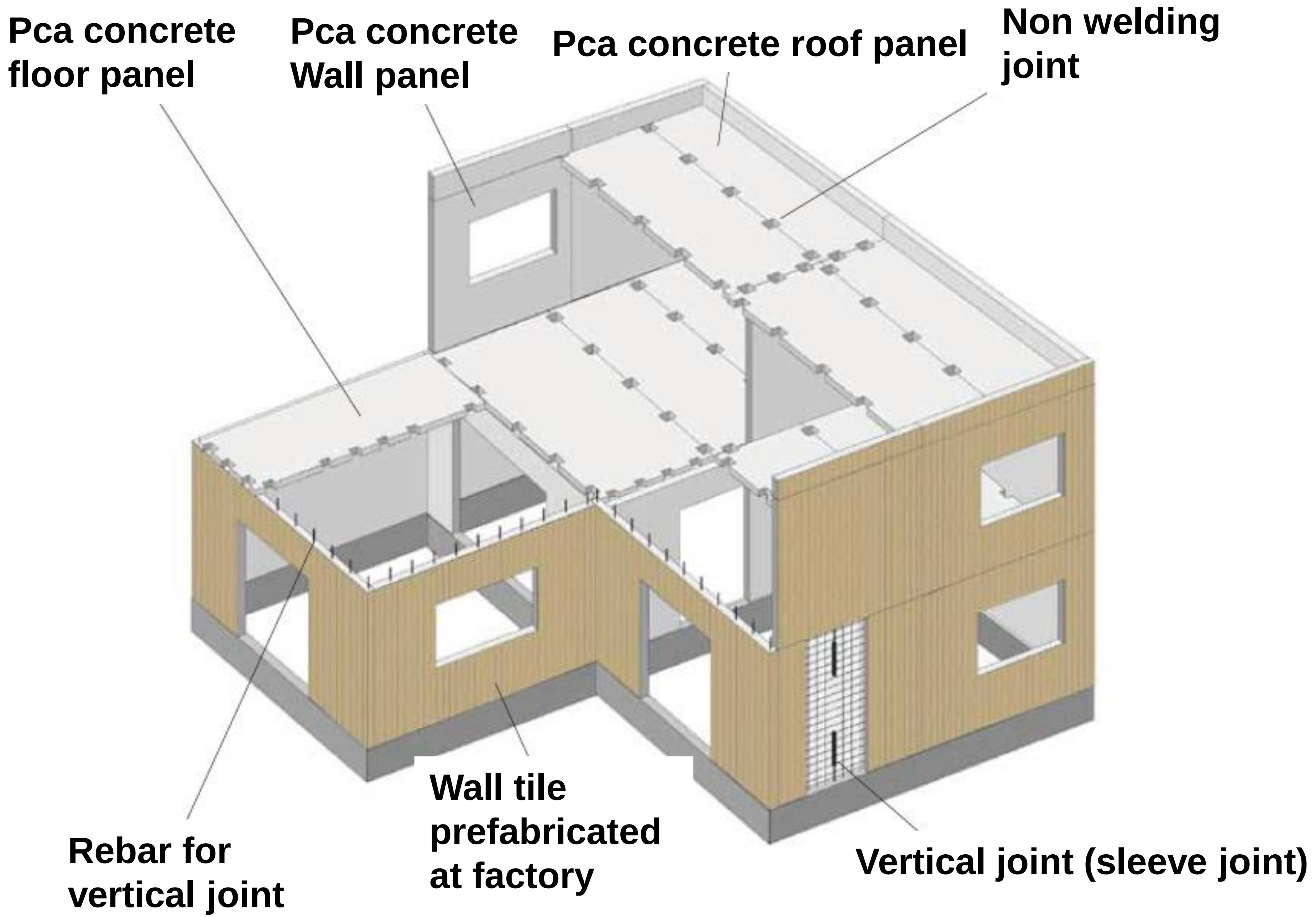
How to make the PC member?

Posttensioning by jack



http://www.geocities.jp/ars_ksj/kanri/kanri1.html

What is the PCa structure?



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Comparison of PC and RC structure (E-Defense)

PC

RC

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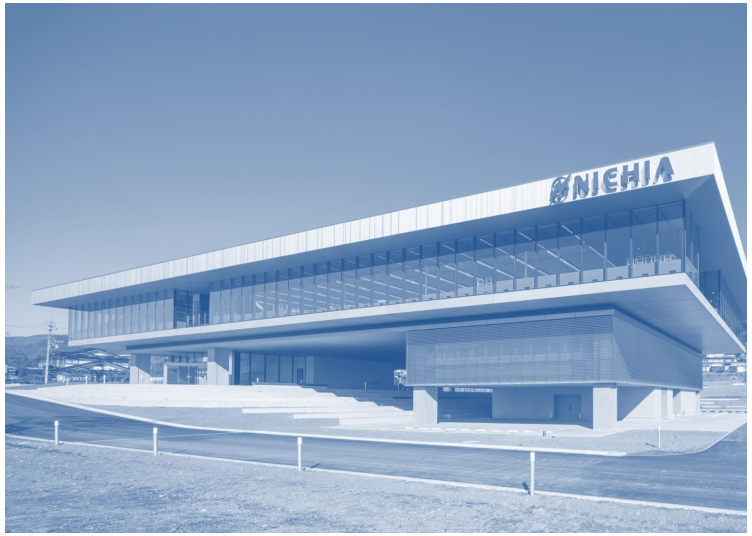
How to make the PCa member?

Construction of PCa panel at factory

PRECAST PRESTRESSED CONCRETE BUILDINGS IN JAPAN




By.

MASAYOSHI IMAMURA

P.S. Mitsubishi Construction Co., Ltd. Japan

2017-Cleveland, Ohio. USA.

PRESENTATION CONTENT

1. Precast prestressed concrete moment-resisting frame building
2. Building consisting of precast prestressed concrete and steel moment frames
3. Super high-rise precast prestressed concrete building

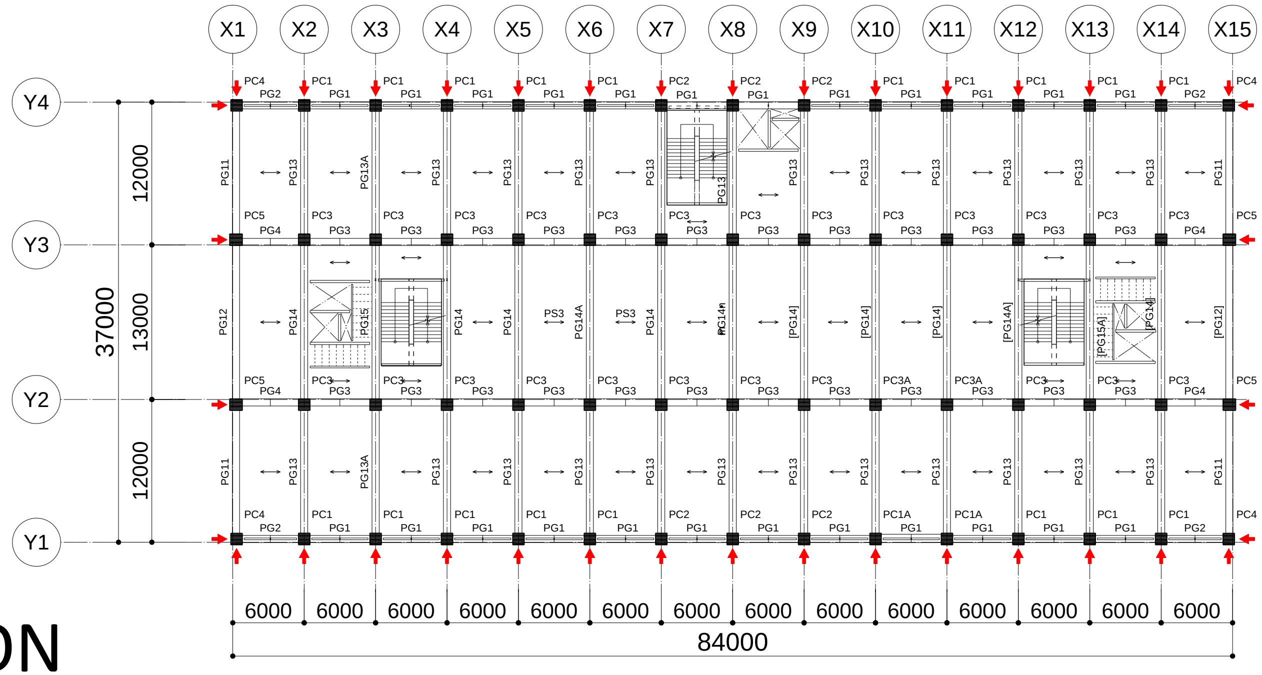
PRECST PRESTRESSED CONCRETE MOMENT-RESISTING FRAME BUILDING

INTERNATIONAL UNIVERSITY OF HEALTH AND WELFARE NARITA CAMPUS

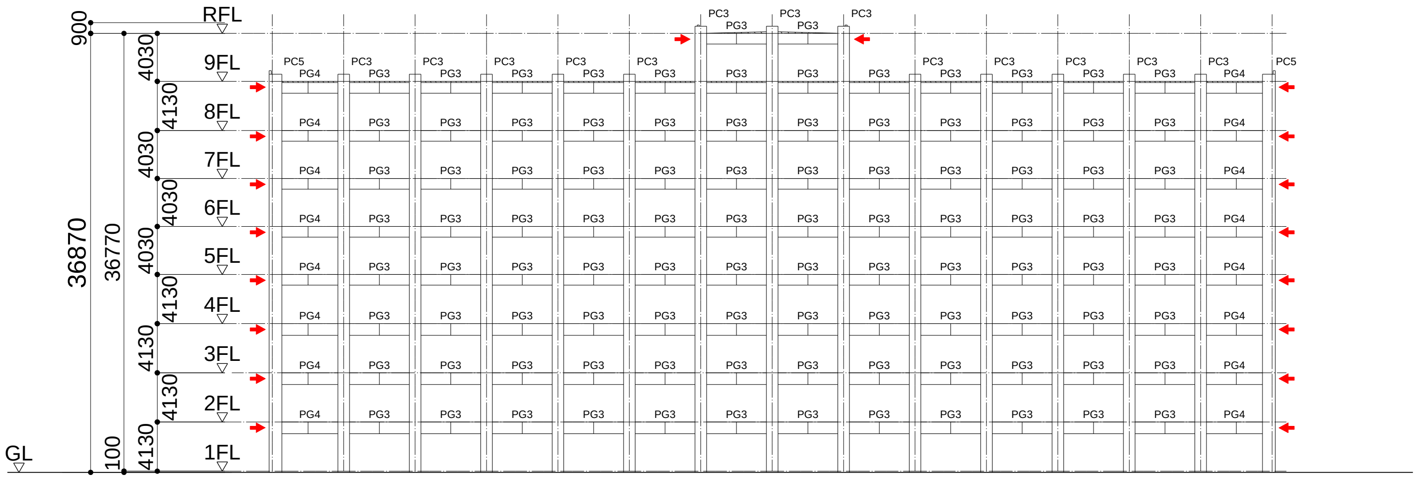
Building Summary

Owner	: International University of Health and Welfare
Design and Site Supervision :	P.S.Mitsubishi Construction Co.,Ltd.
Construction	: P.S.Mitsubishi Construction Co.,Ltd.
Usage	: University
Location	: Narita-city, Chiba prefecture, Japan
Floors	: 9-story with basement
Structure	: Precast Prestressed Concrete
Structural System	: Moment-resisting frame

PLAN

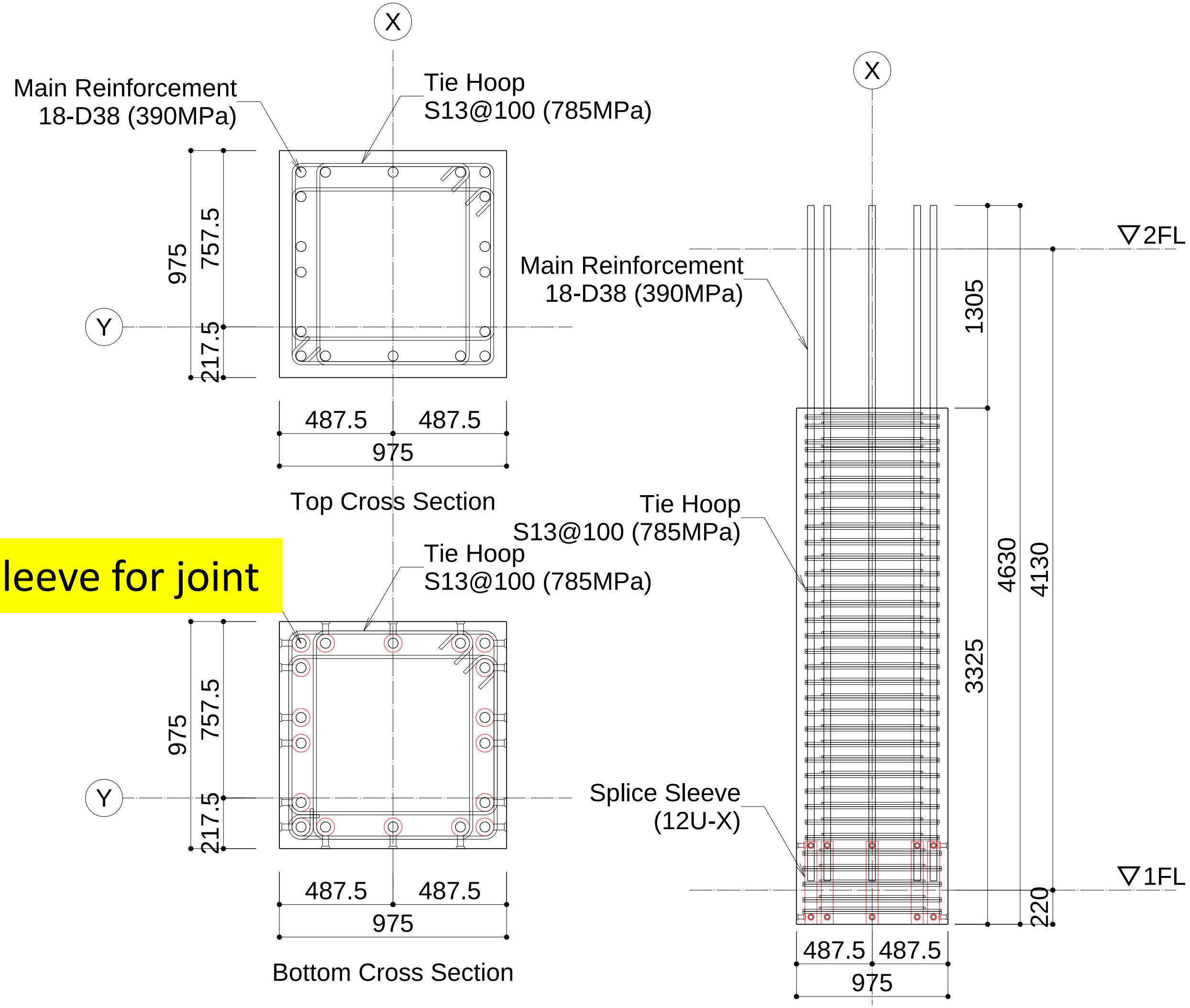


SECTION

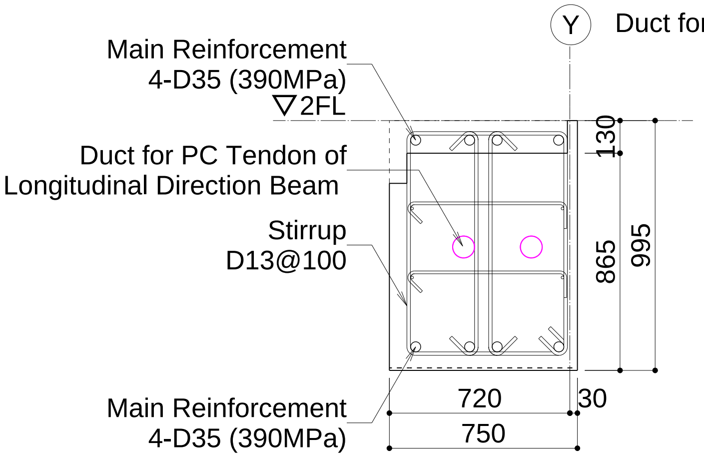


Column

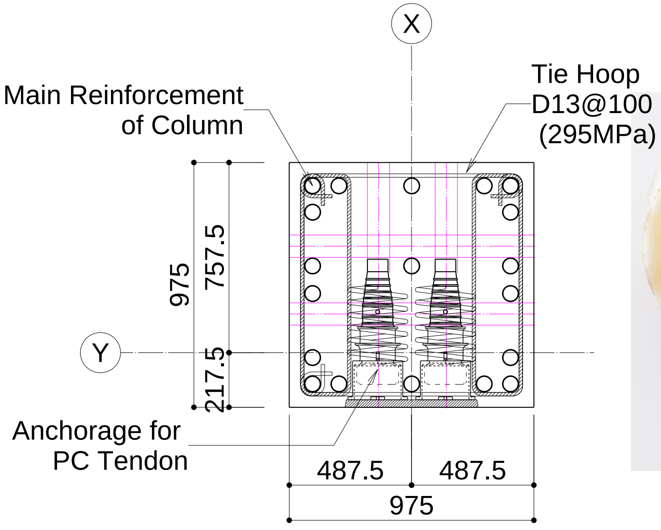
Splice sleeve for joint



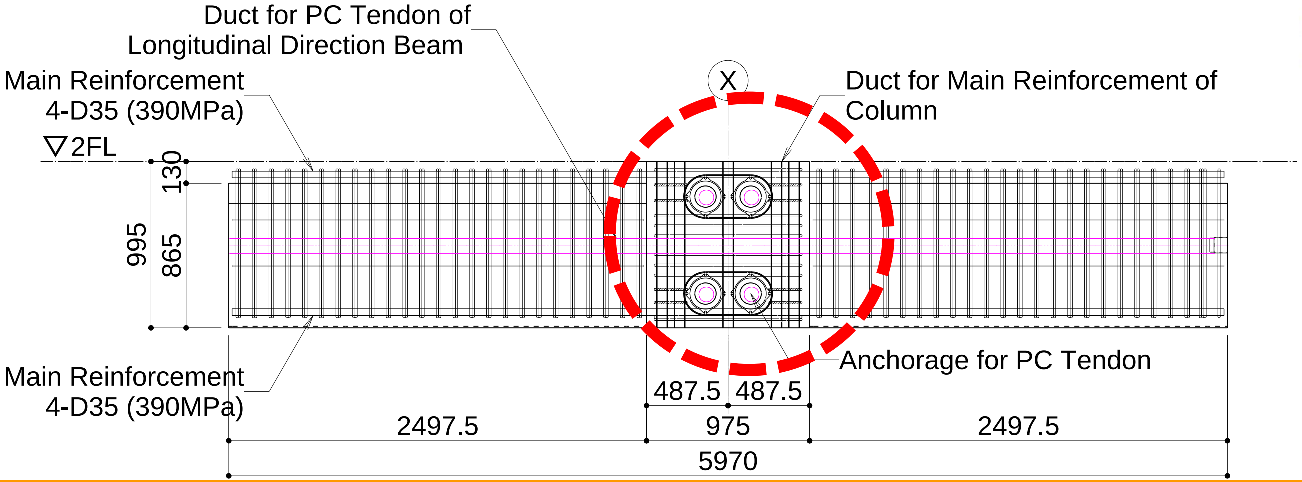
"Lotus Root" unit (beam unit with beam-column joint)

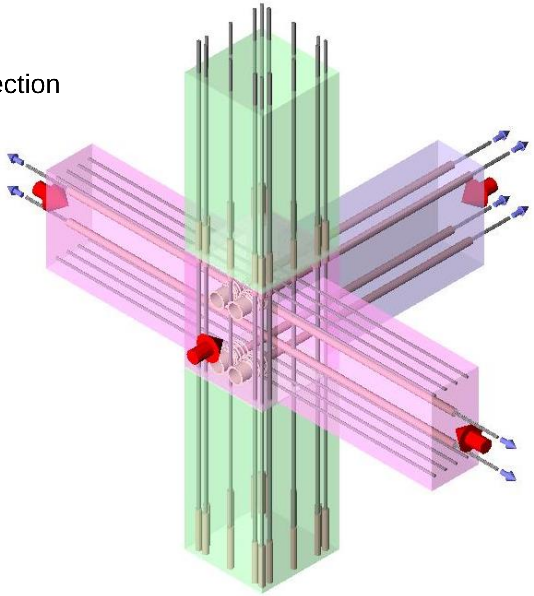


Beam Cross Section

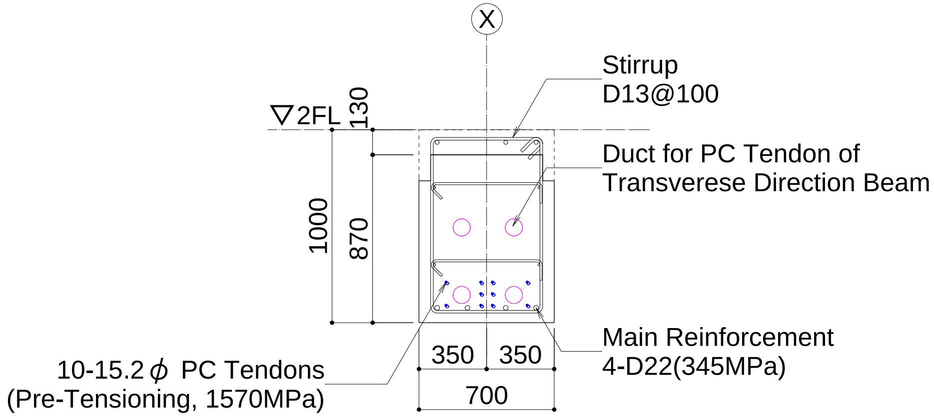


Beam-Column Connection Cross Section

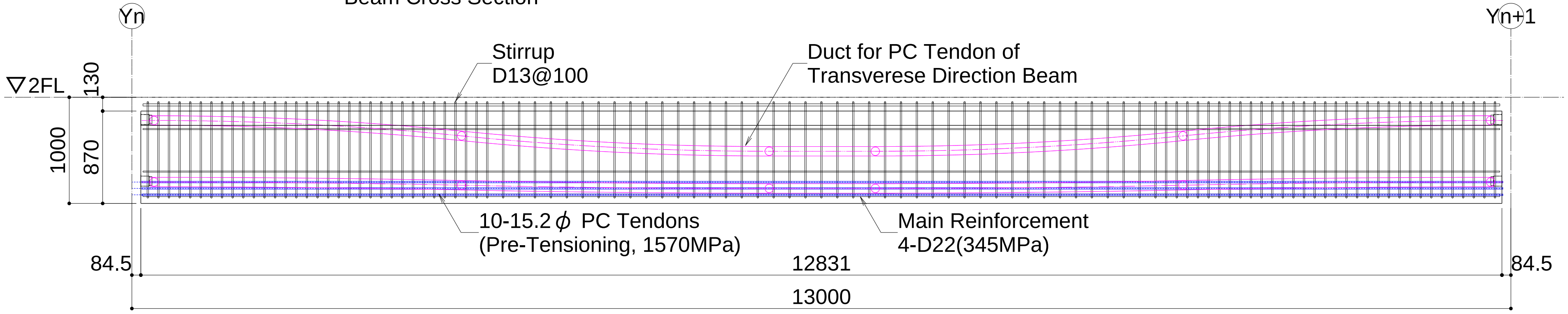




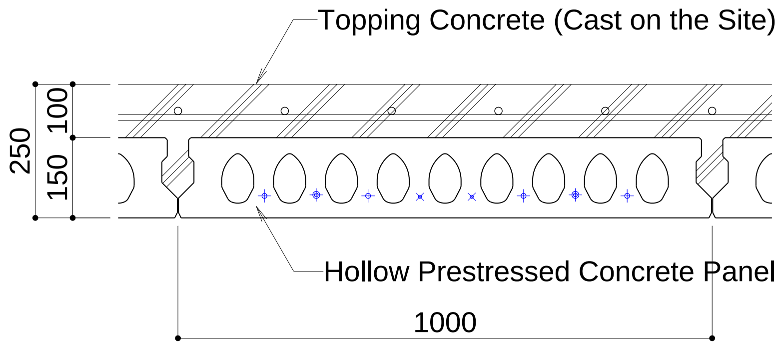
Beam unit for 13m span



Beam Cross Section



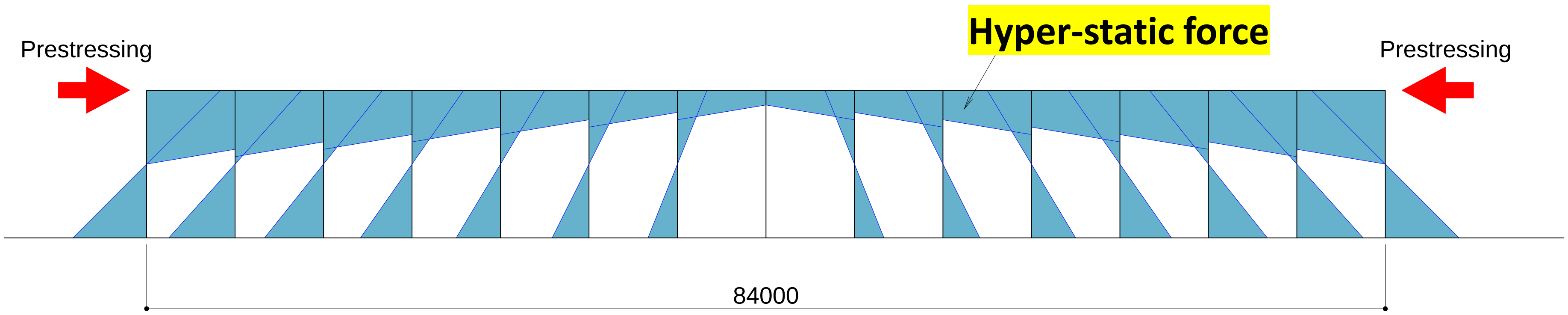
Slab Element

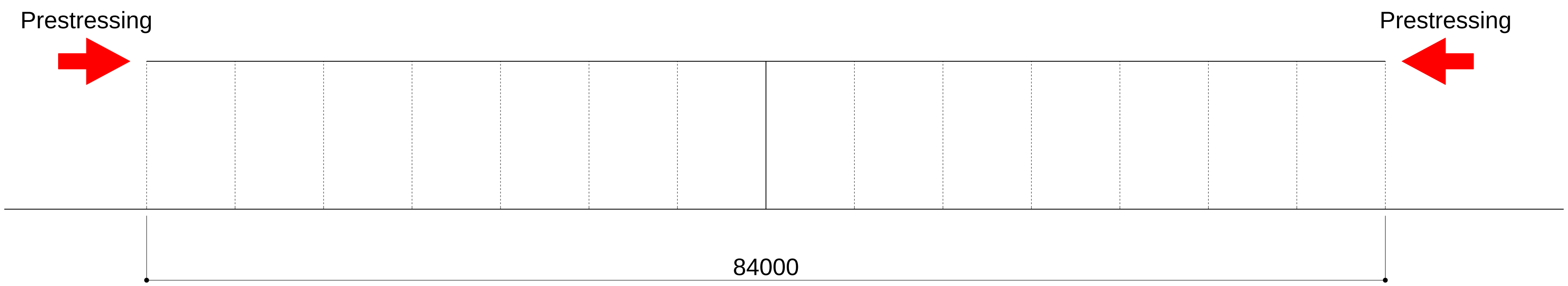


Construction Procedure

Construction Procedure

Introduction of prestressing force in the Longitudinal Direction in order to avoid the Hyper-static force in the transverse direction

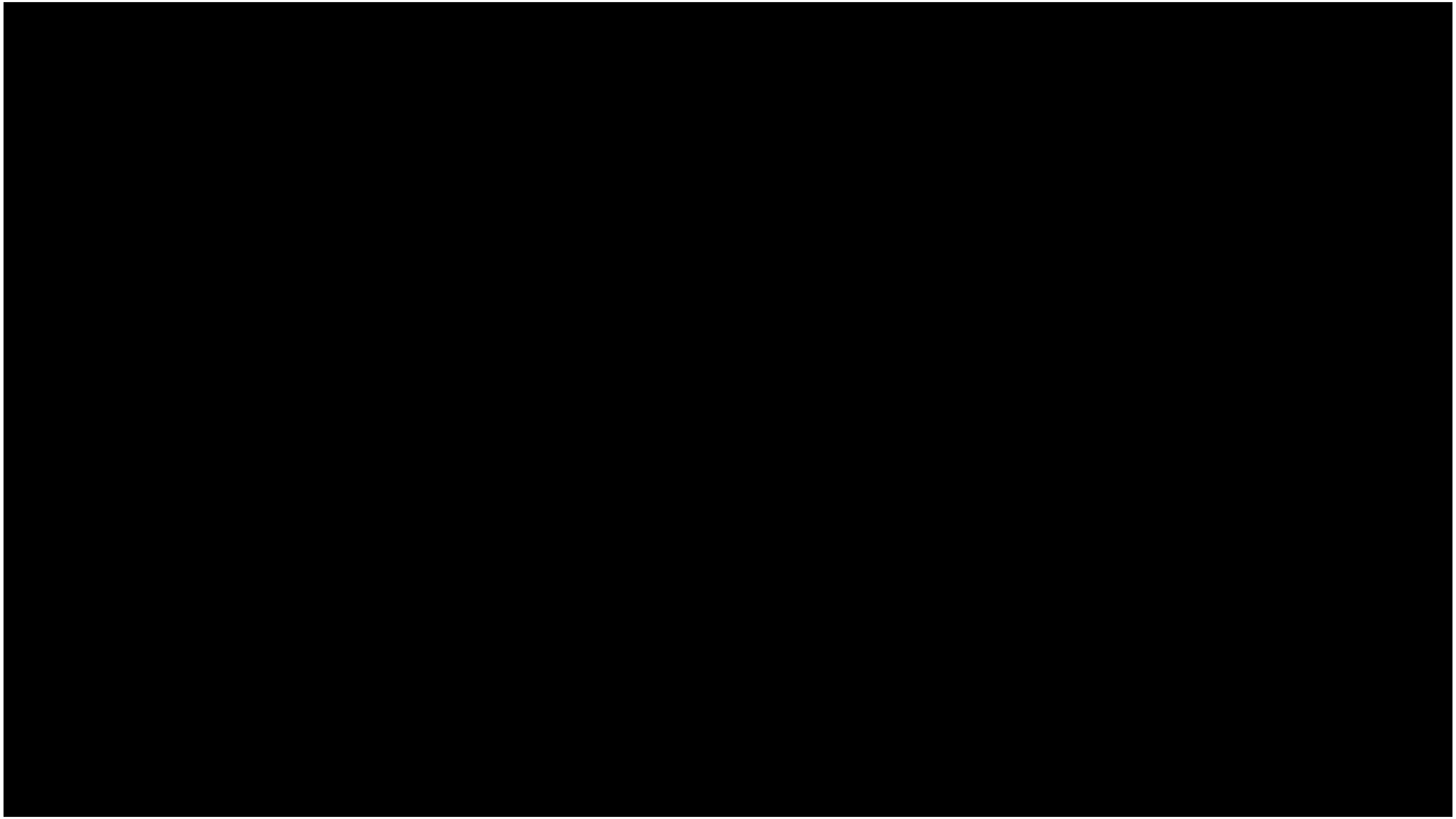




IUHW NARITA CAMPUS

Video

PC, Pca Structure



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Summary

1. **Improve the quality control**
2. **Avoid the lack of labor man power**
3. **Shortening the construction term**


NICHIA SUWA
TECHNOLOGY CENTER
NICHIA

NICHIA SUWA TECHNOLOGY CENTEER

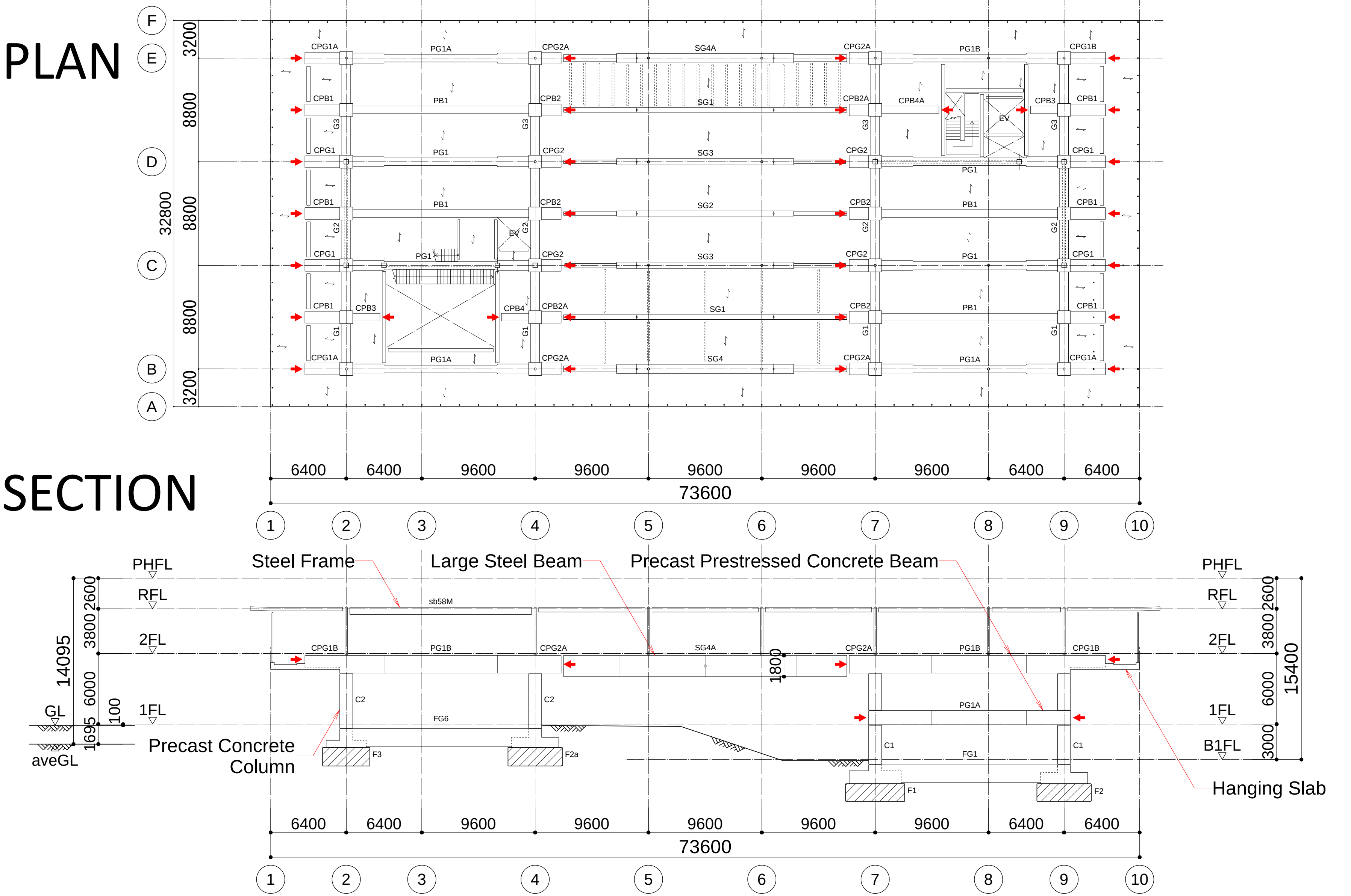
Building Summary

Owner : NICHIA Corporation
Design and Site Supervision :
Takenaka Corporation, Osaka
Construction : Takenaka Corporation, Tokyo
PC Construction : P.S.Mitsubishi Construction Co.,Ltd.
Usage : Research Center
Location : Suwa-city, Nagano prefecture, Japan
Floors : Two-story and basement
Structure : Precast Prestressed Concrete,
Reinforced Concrete and Steel Frames

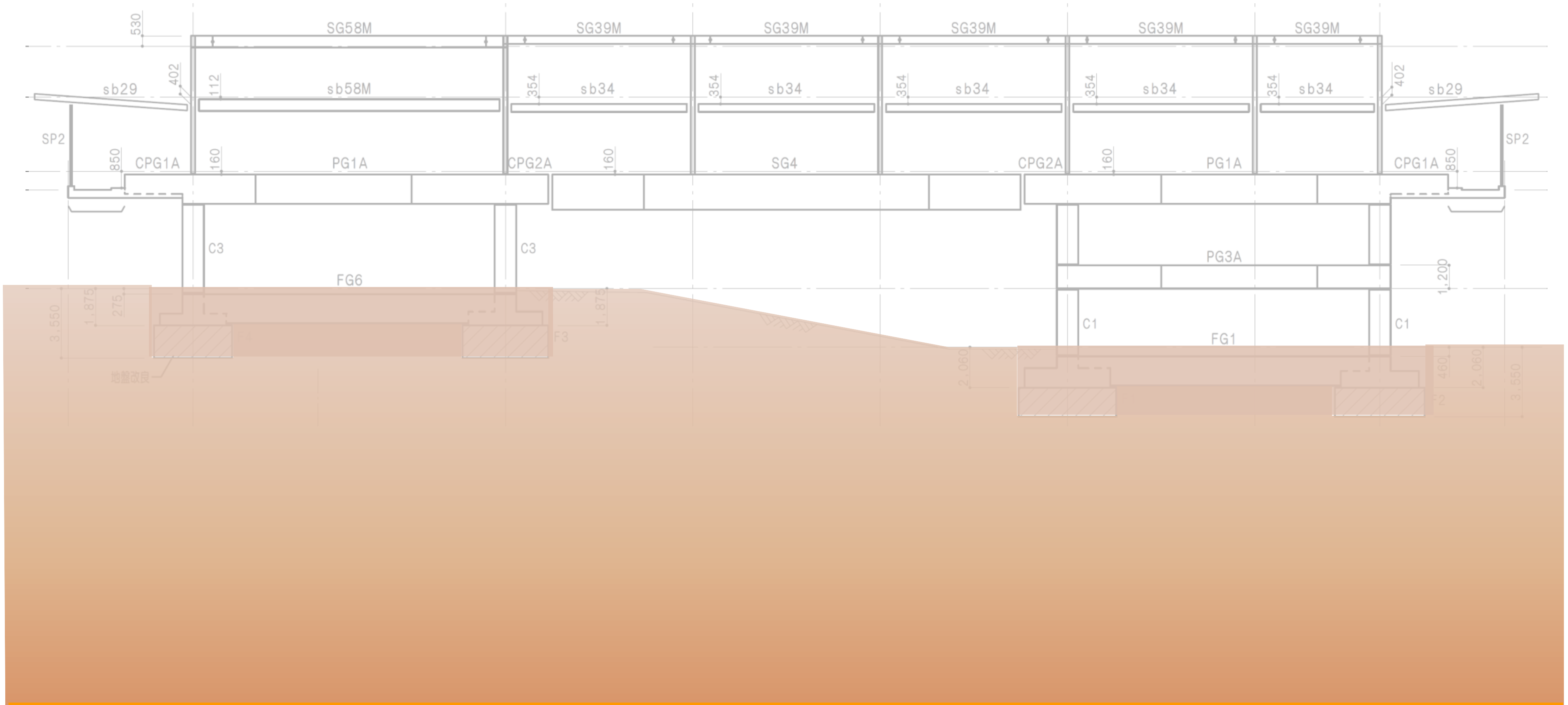
NICHIA SUWA TECHNOLOGY CENTEER

PLAN

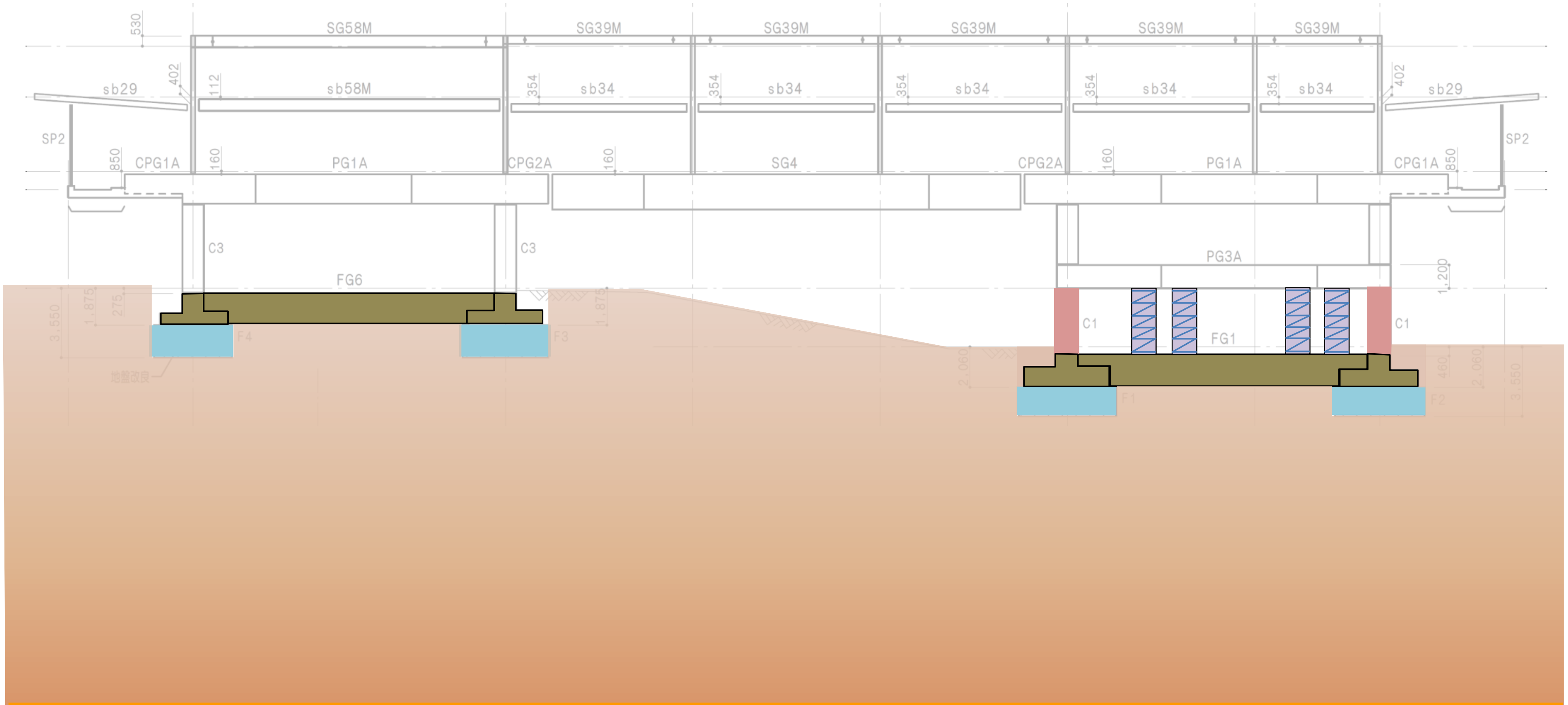
SECTION



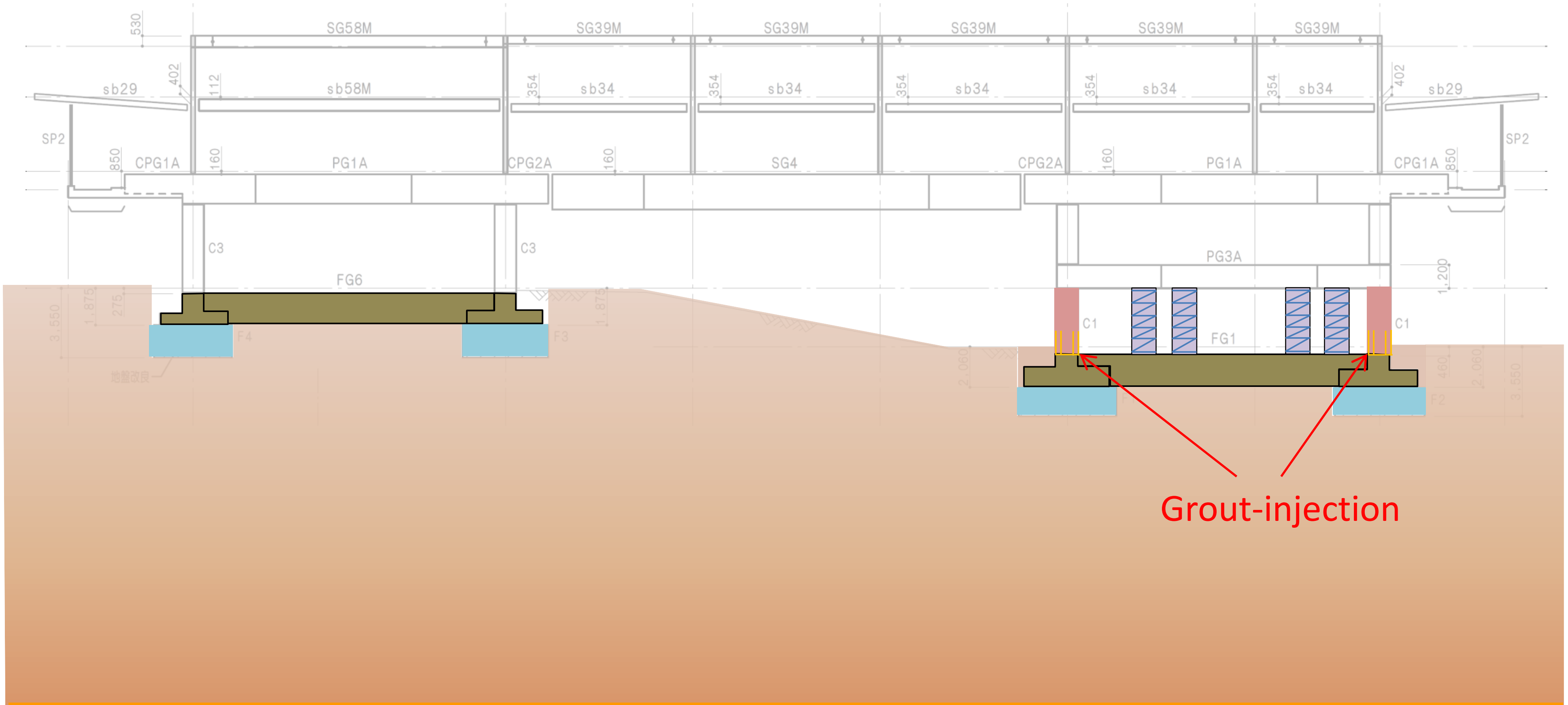
Excavation


SG58M
SG39M
SG39M
SG39M
SG39M
SG39M
sb29
sb58M
sb34
sb34
sb34
sb34
sb34
sb29
SP2
SP2
CPG1A
PG1A
CPG2A
SG4
CPG2A
PG1A
CPG1A
C3
C3
FG6
PG3A
C1
C1
FG1
F3
530
402
112
354
354
354
354
354
402
850
160
160
160
850
1,200
3,550
1,875
275
1,875
2,060
400
2,060
3,550

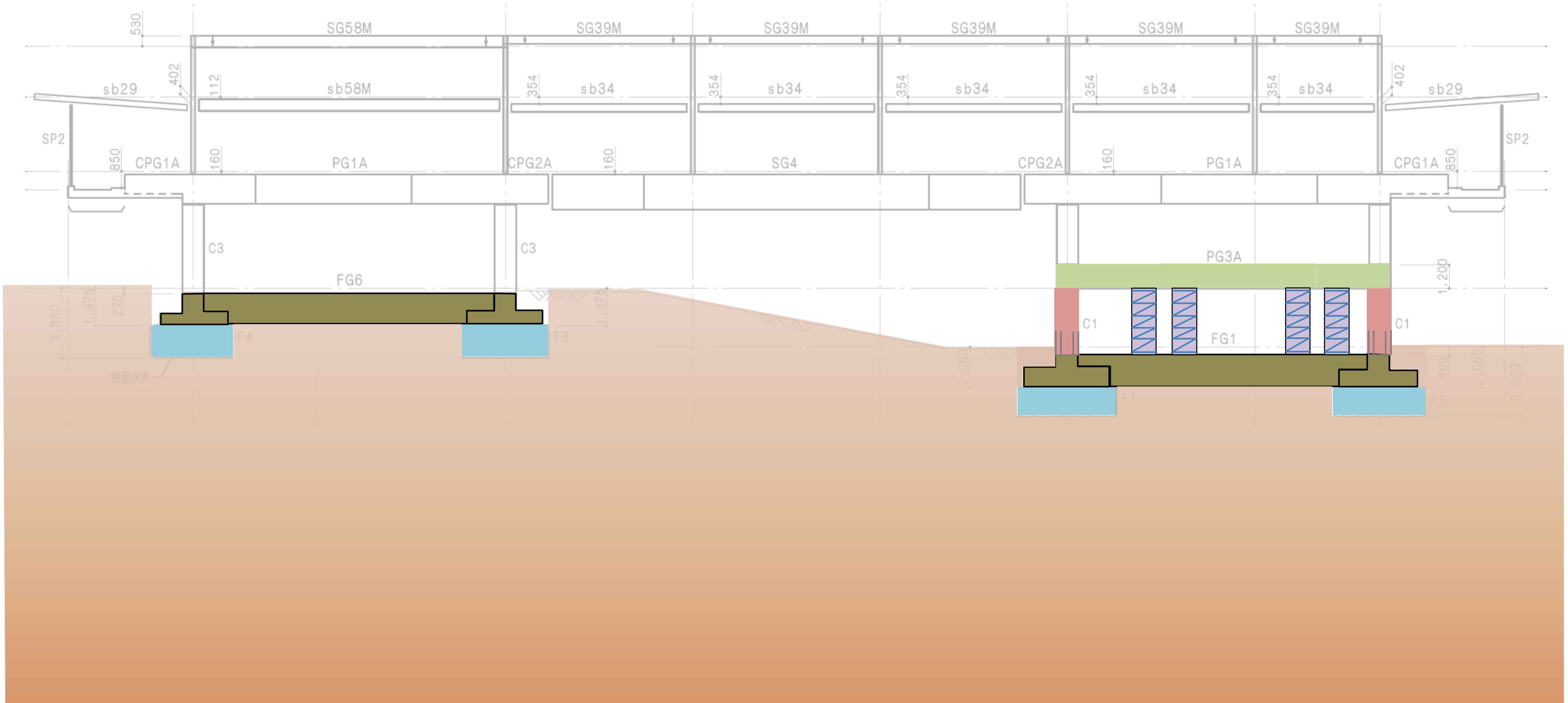
Precast Concrete Column Erection



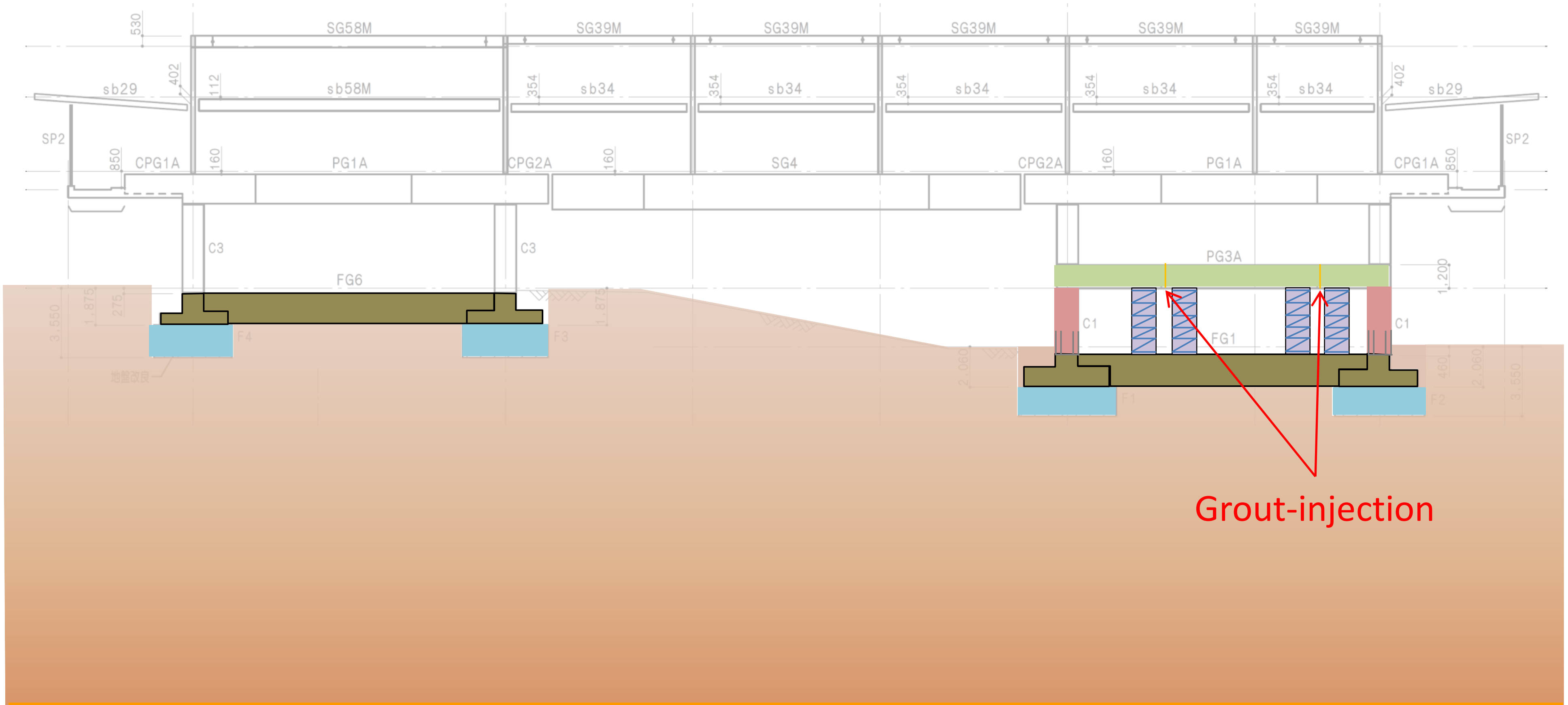
Grout injection into joints at the column base



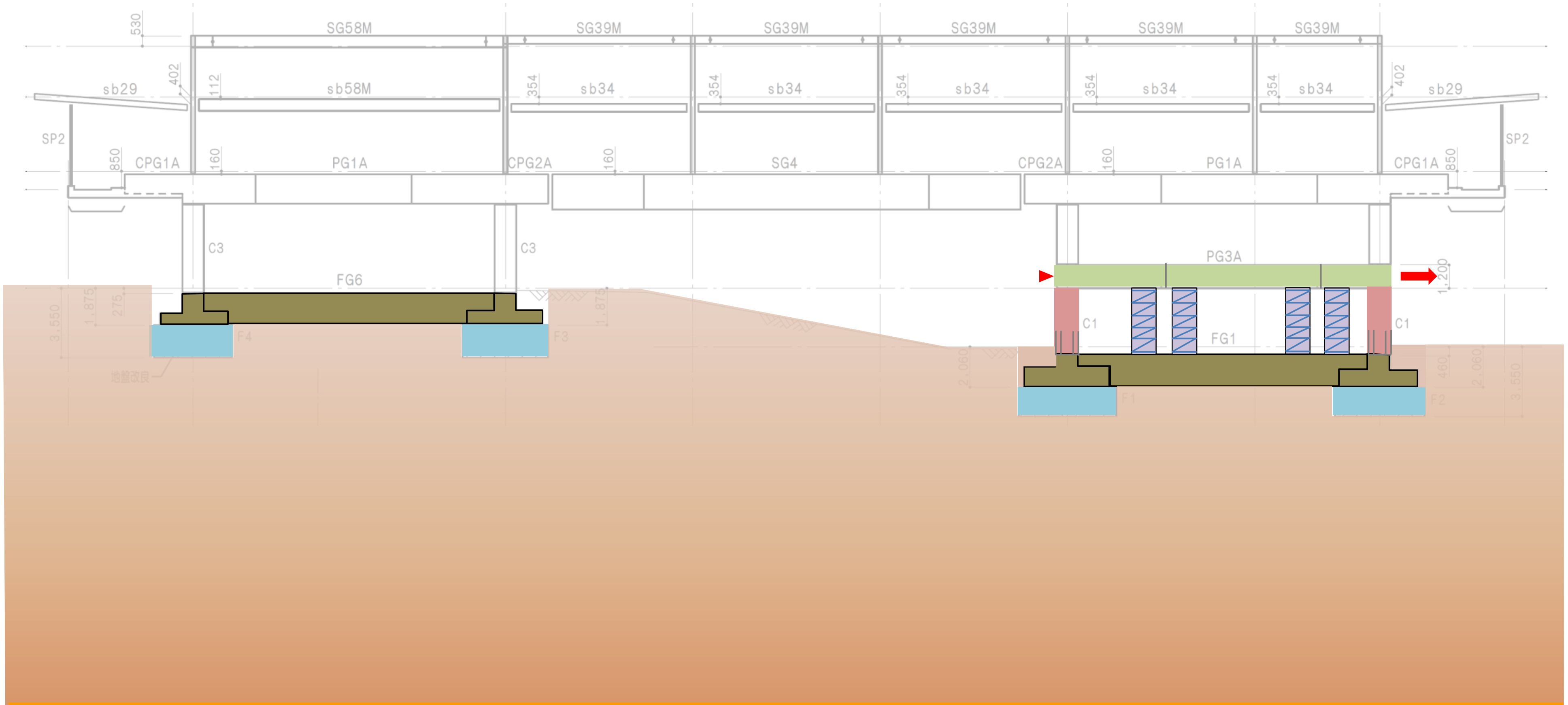
Precast Prestressed Concrete Beam installation



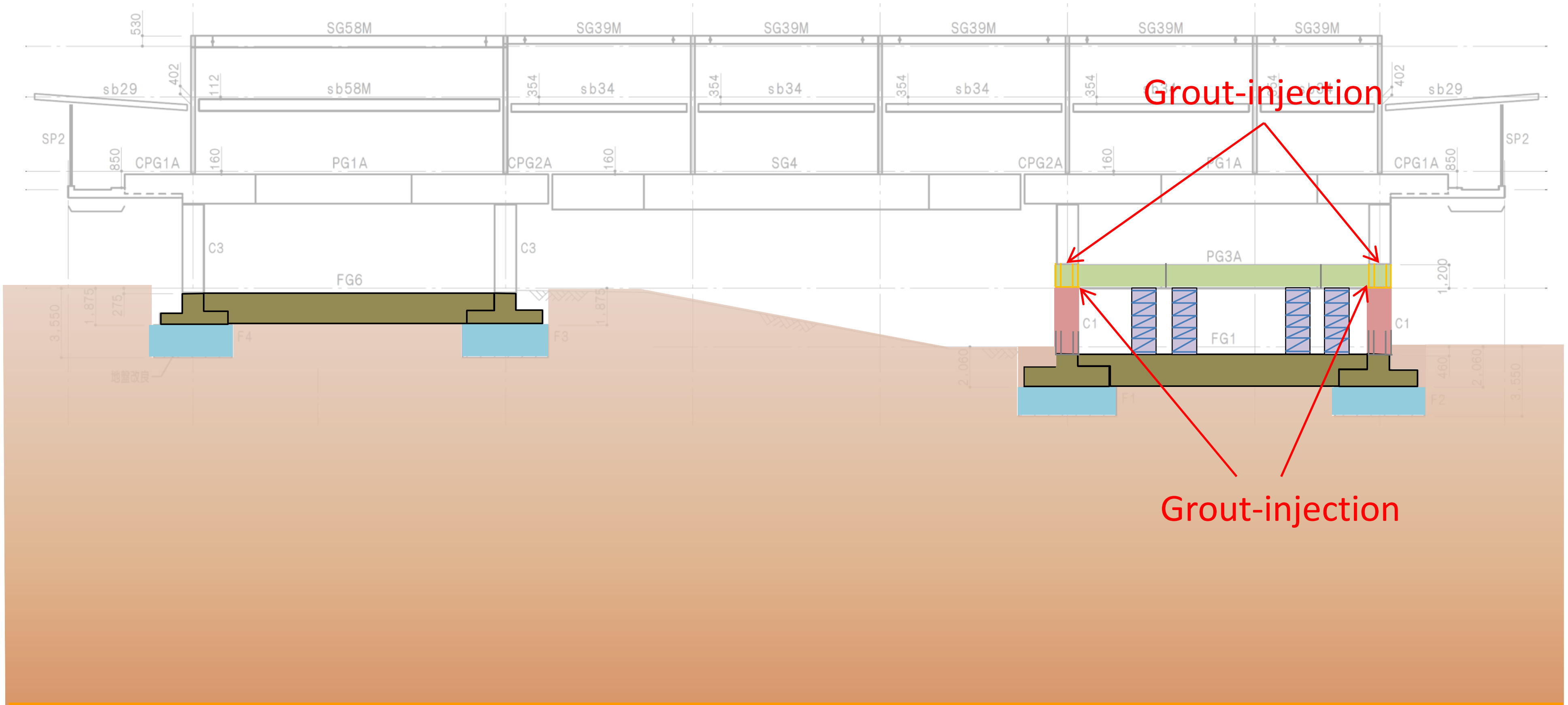
Grout injection into joints between beam units



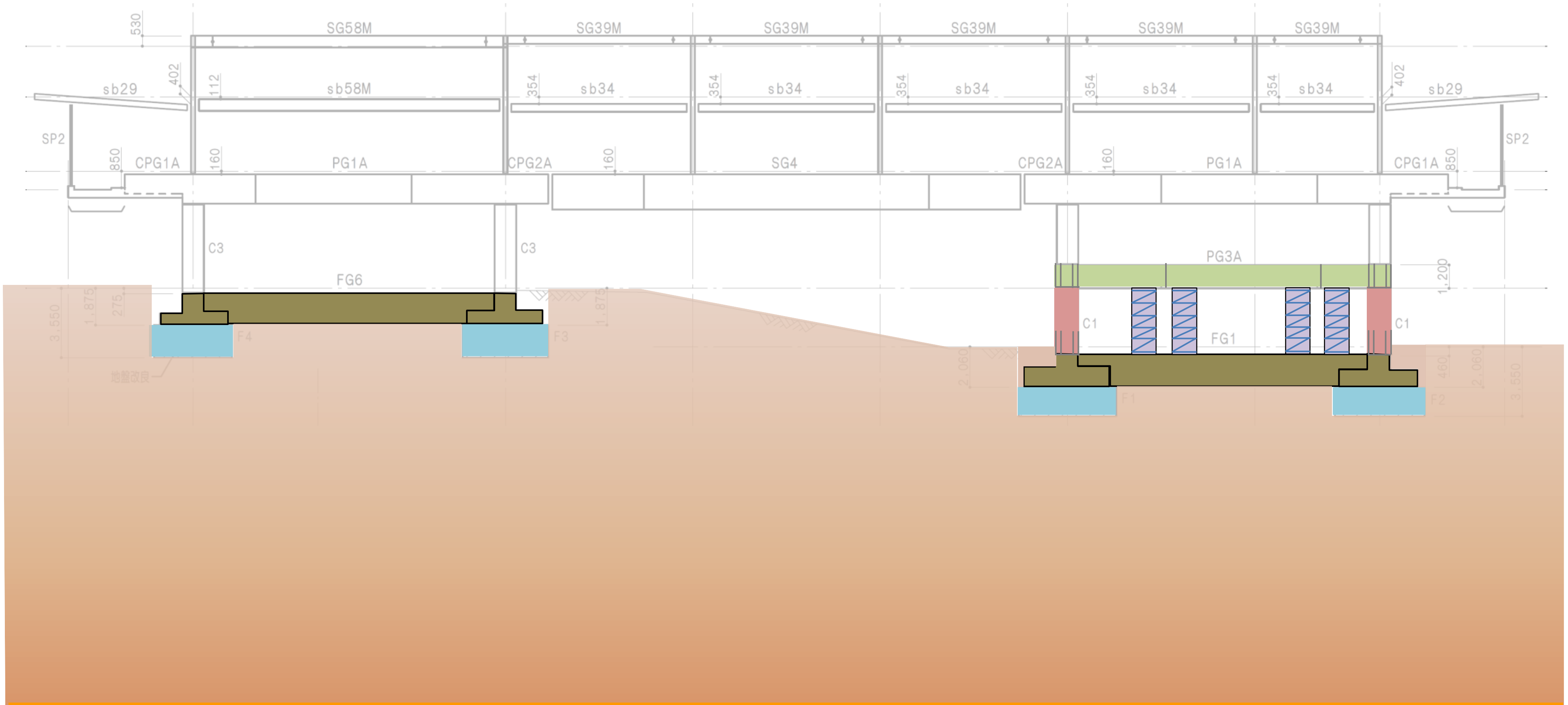
Post-tensioning



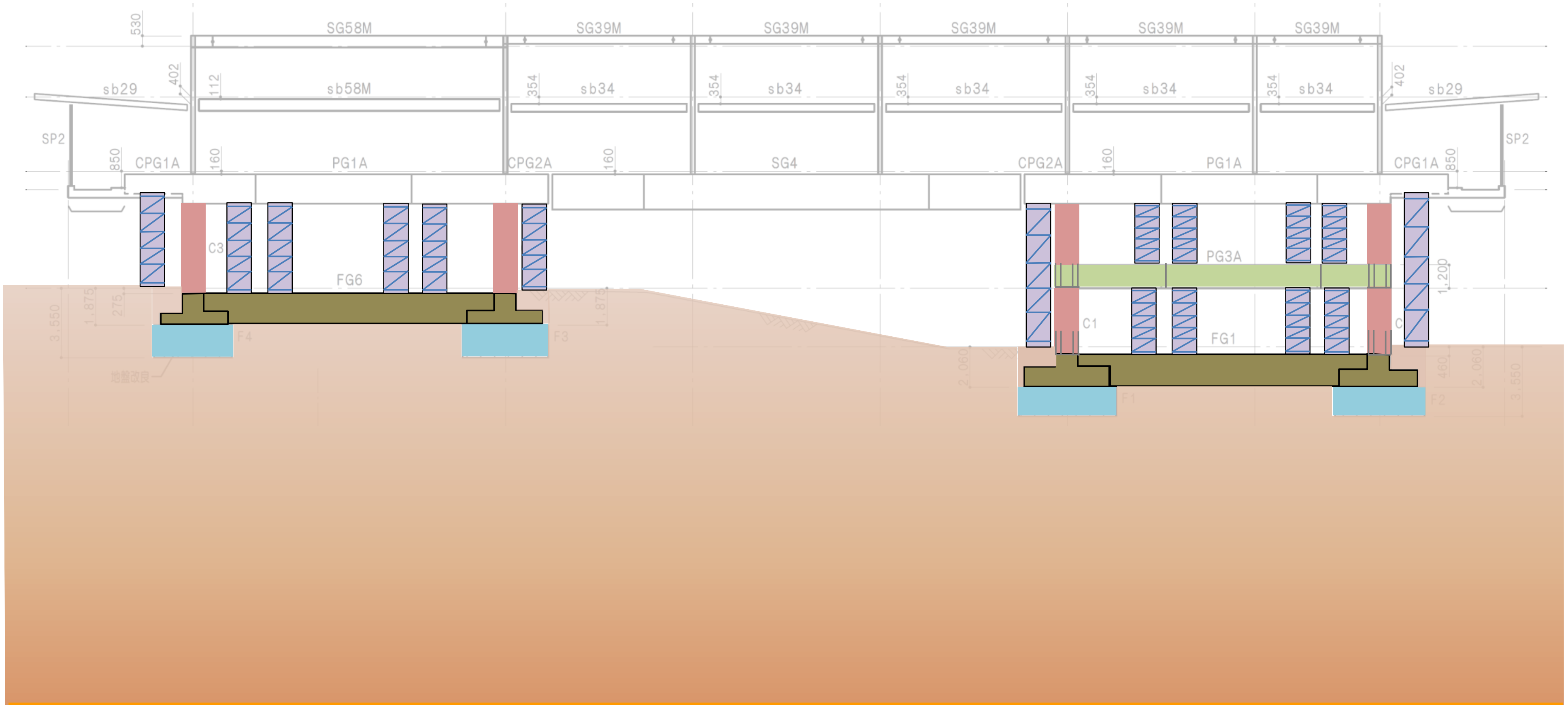
Grout injection into beam-column connections



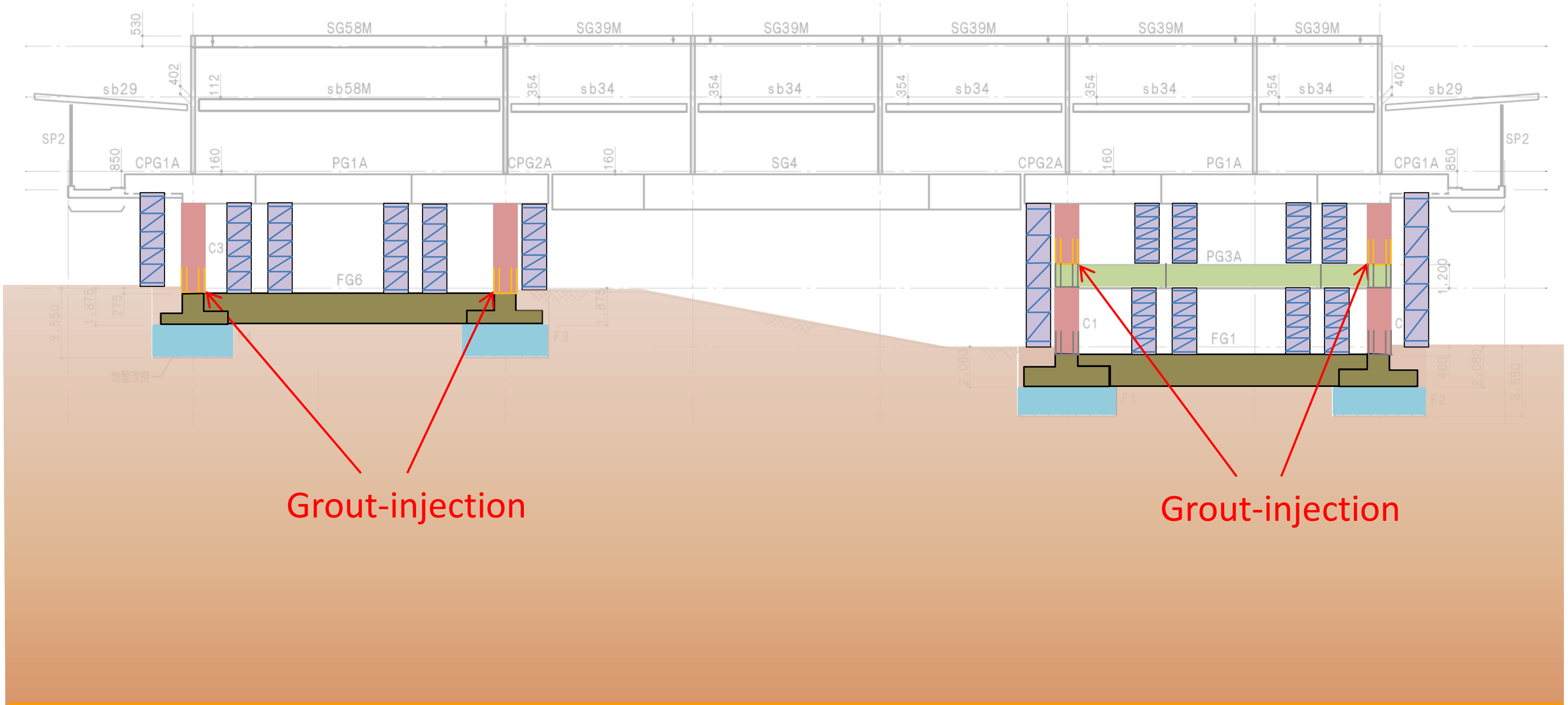
Steel deck plate arrangement and topping concrete cast



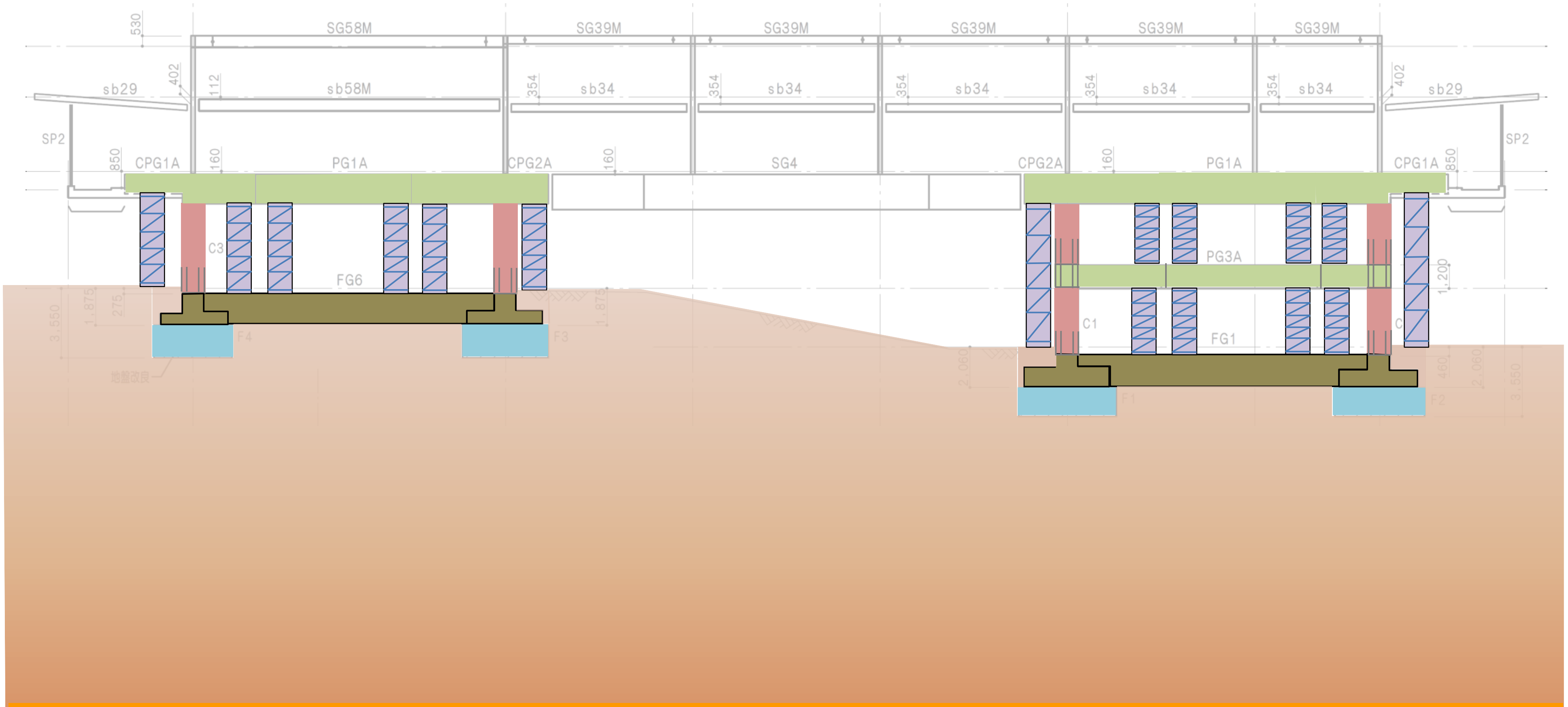
Precast Concrete Column Erection



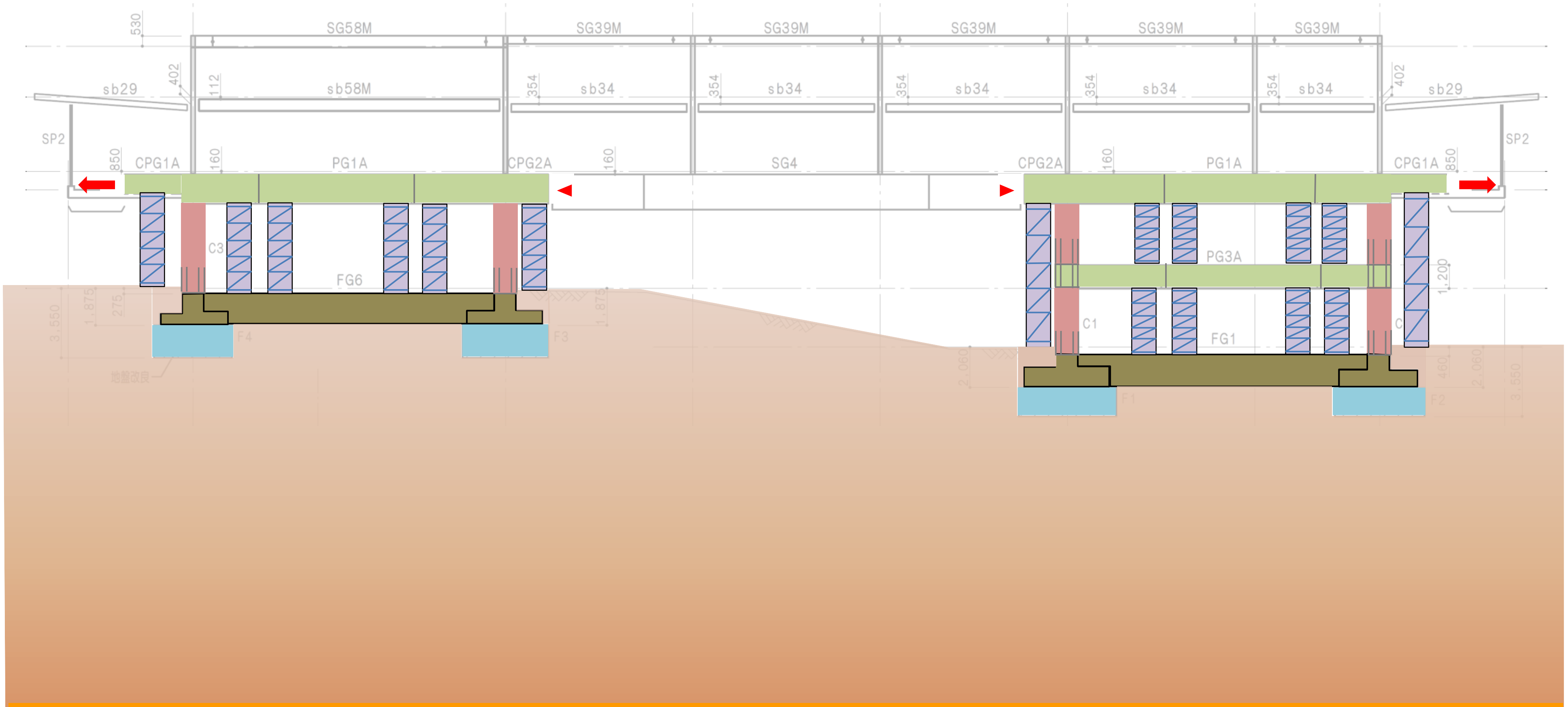
Grout injection into joints at the column base



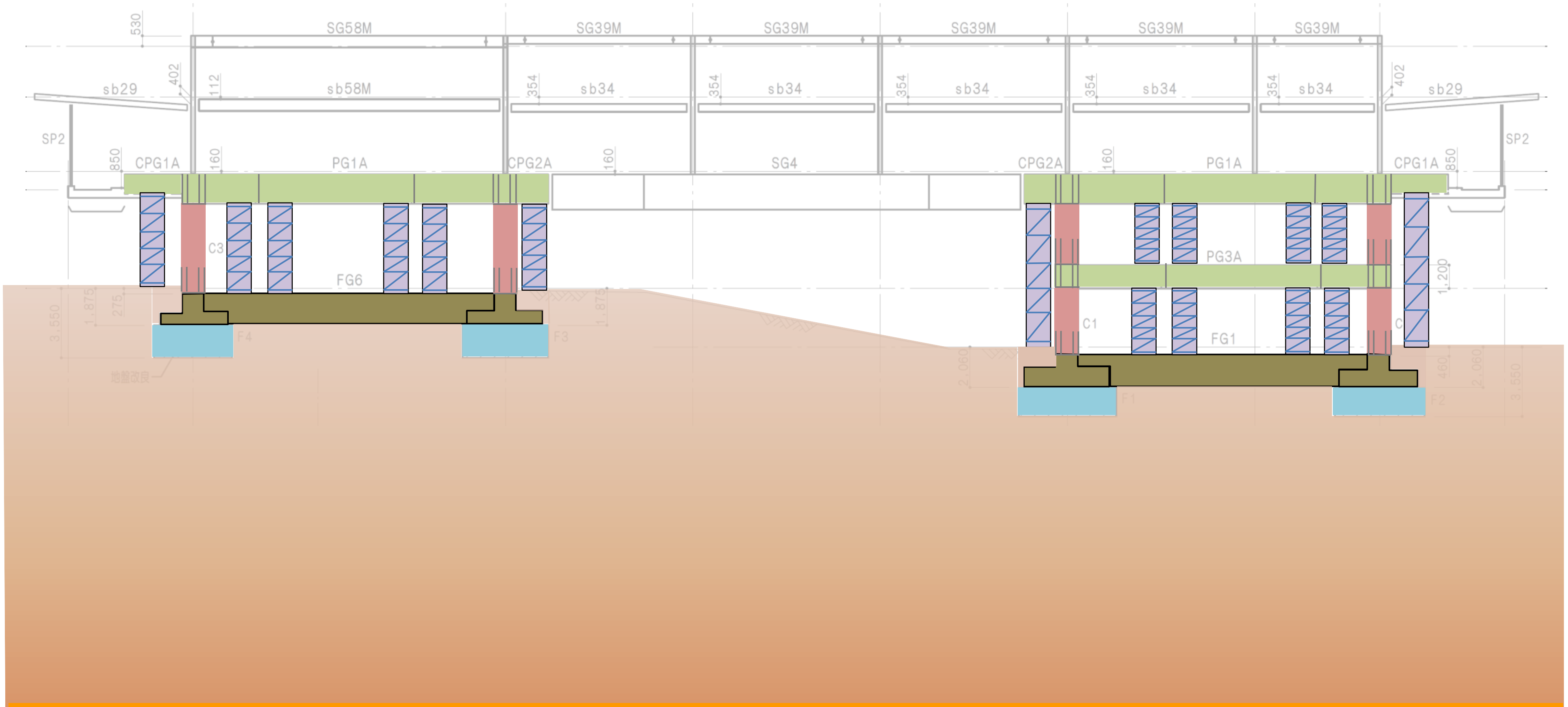
Precast prestressed concrete beam installation, and
Grout injection into connections between beam units



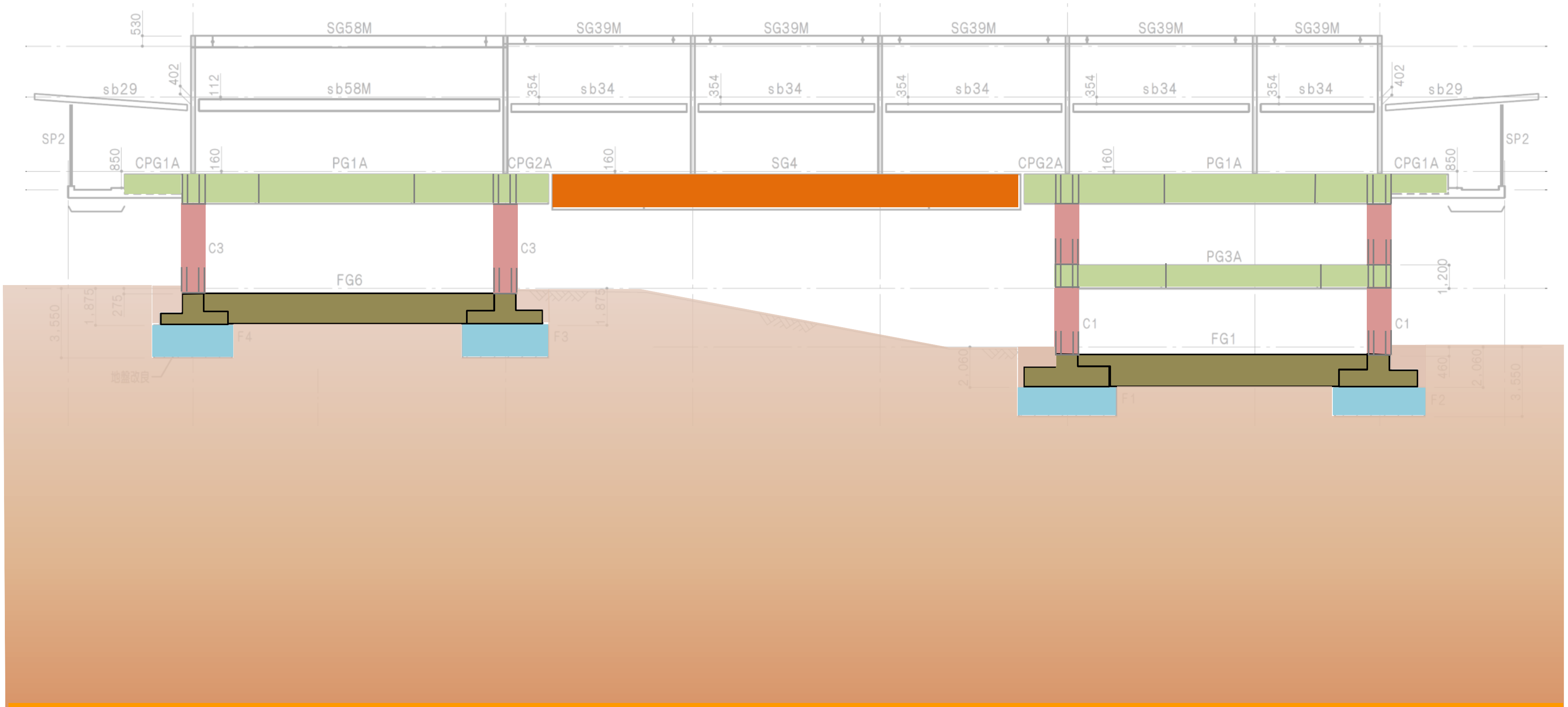
Post-tensioning, and
Grout injection into connections between beam units



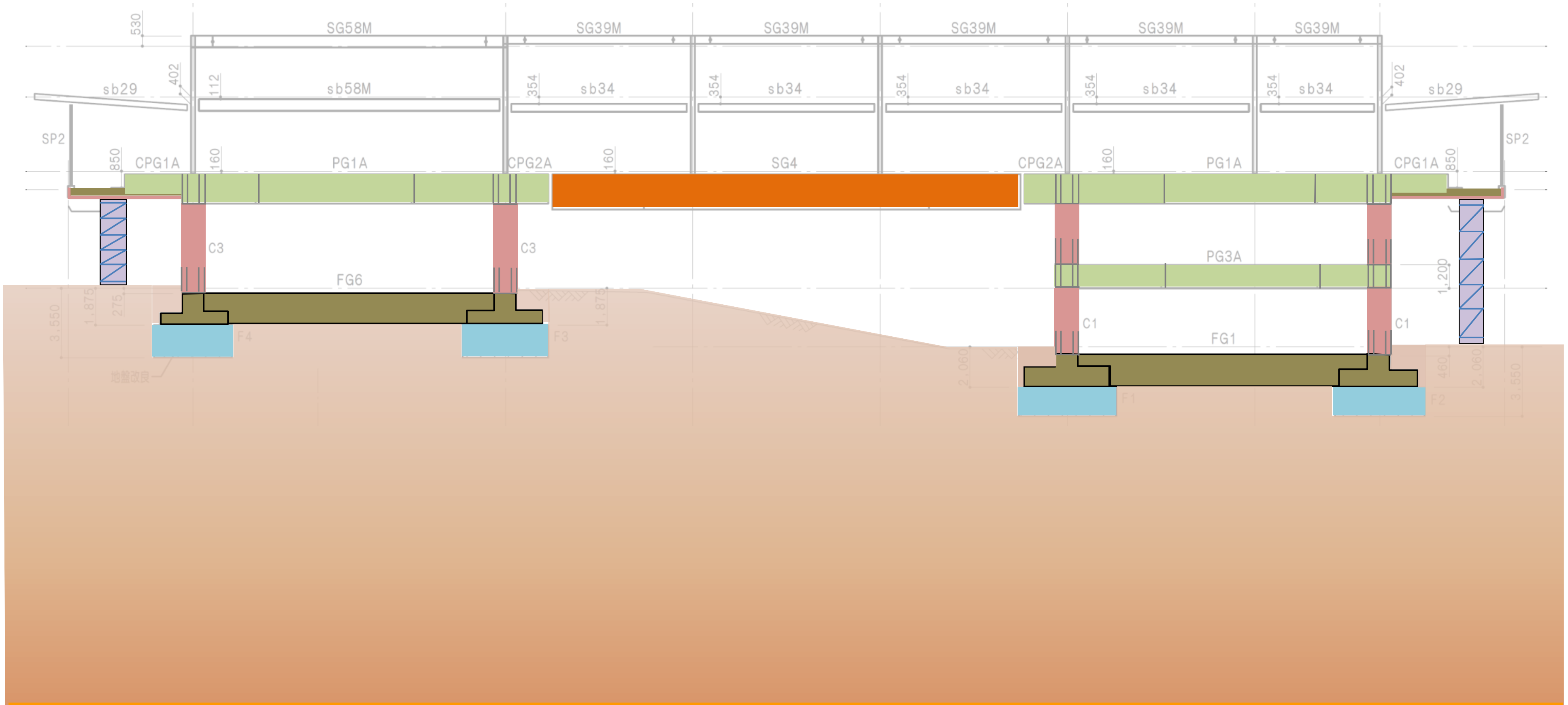
Support removal



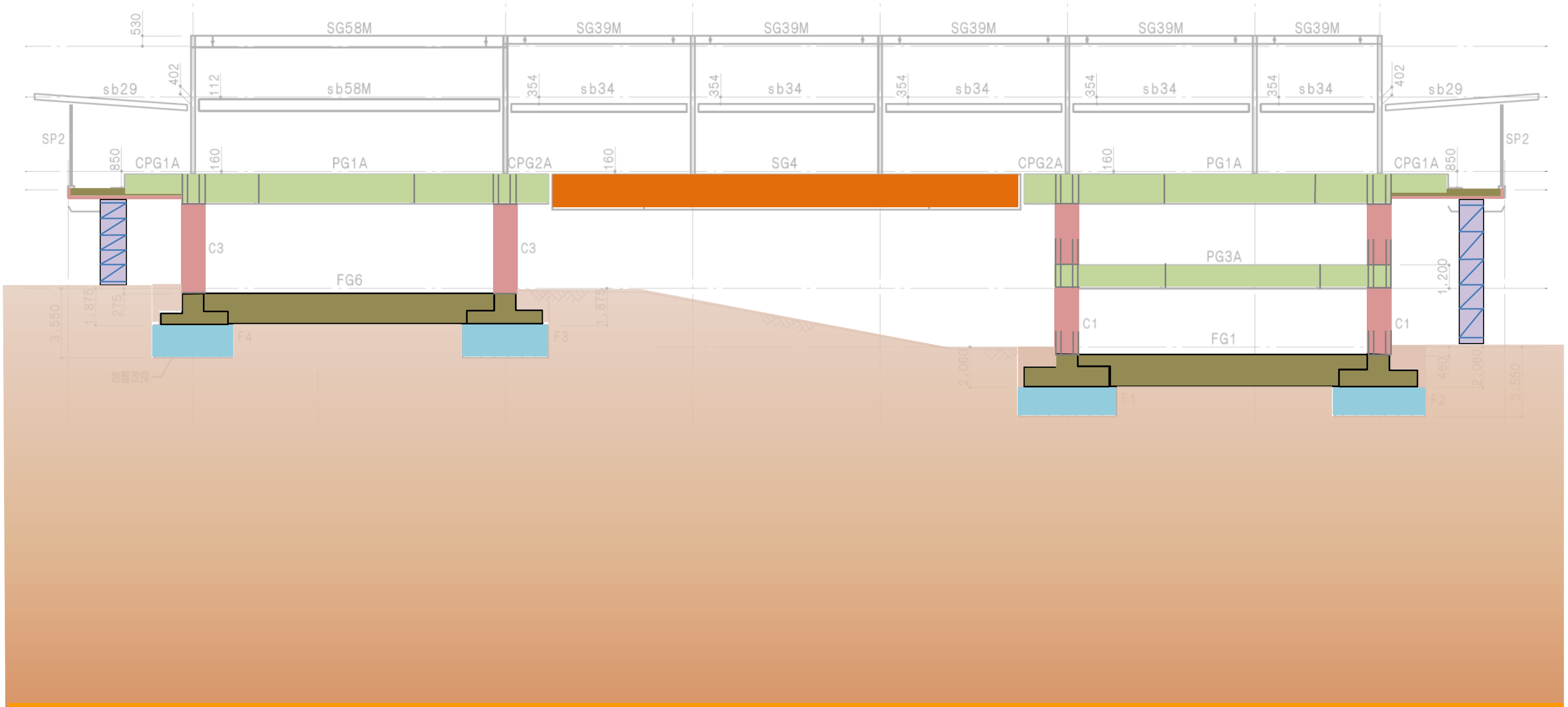
Large Steel Beam installation



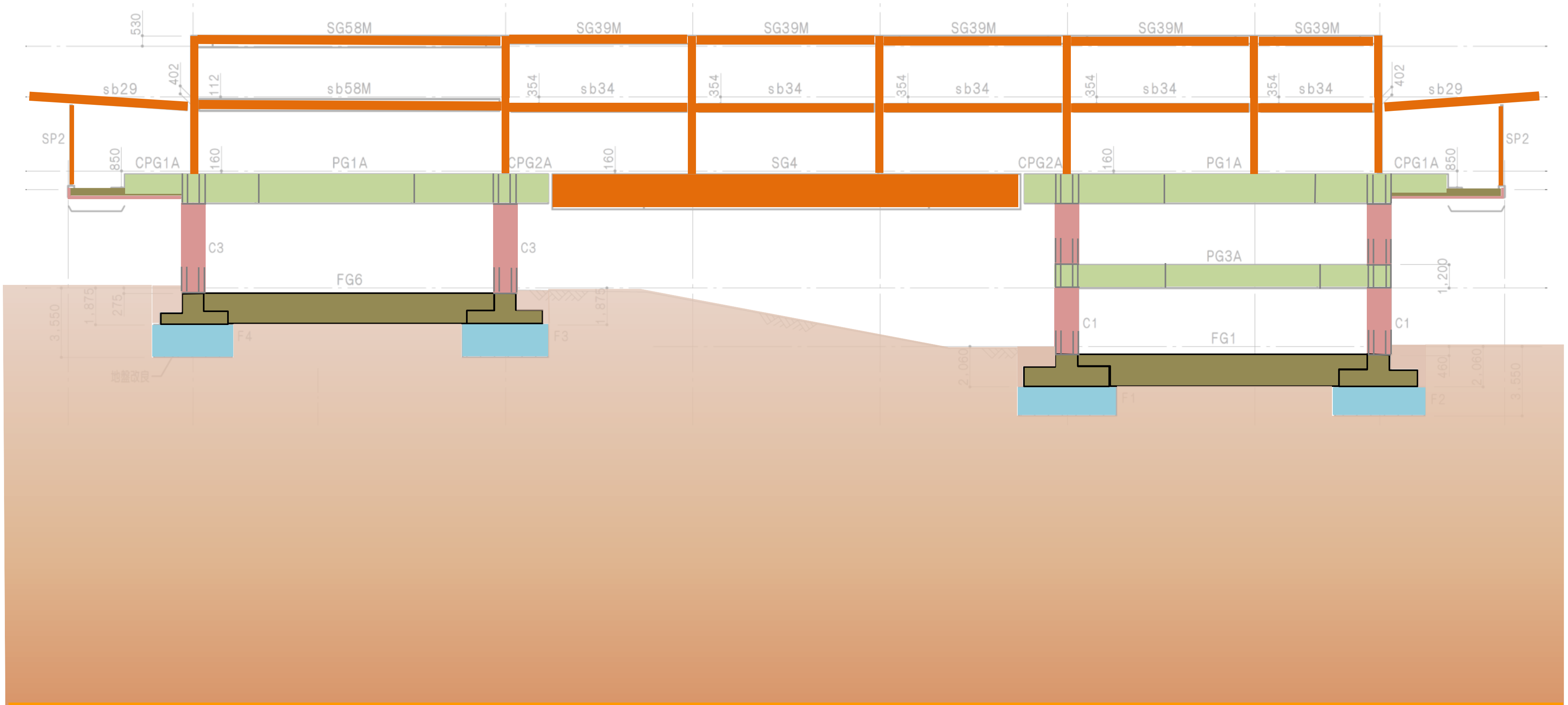
2nd floor Precast Concrete Slab arrangement



Topping Concrete Cast



2nd story steel frame



NICHIA SUWA TECHNOLOGY CENTER

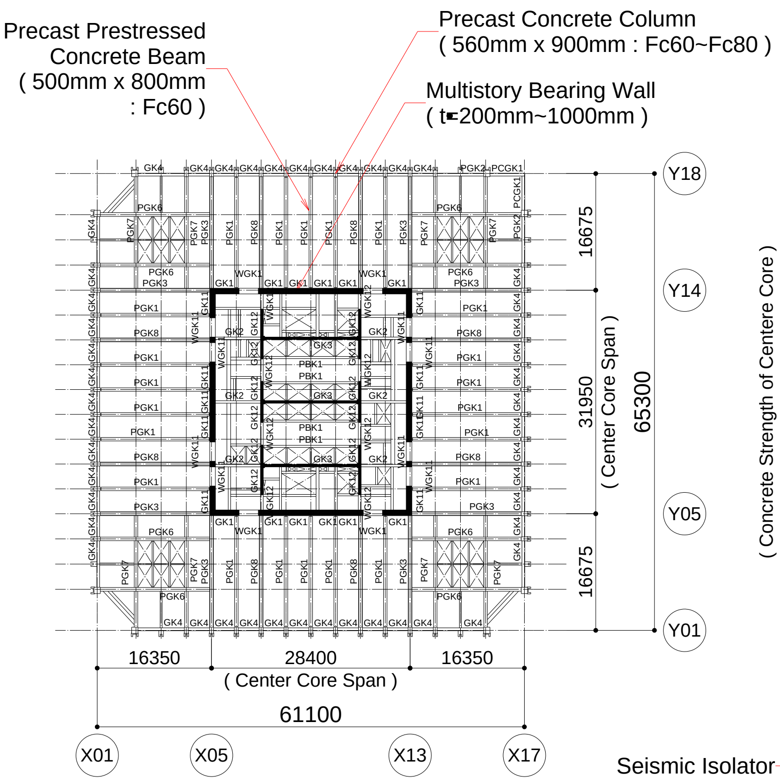

FUTAKO TAMAGAWA RISE
Ⅱ-a BLOCK

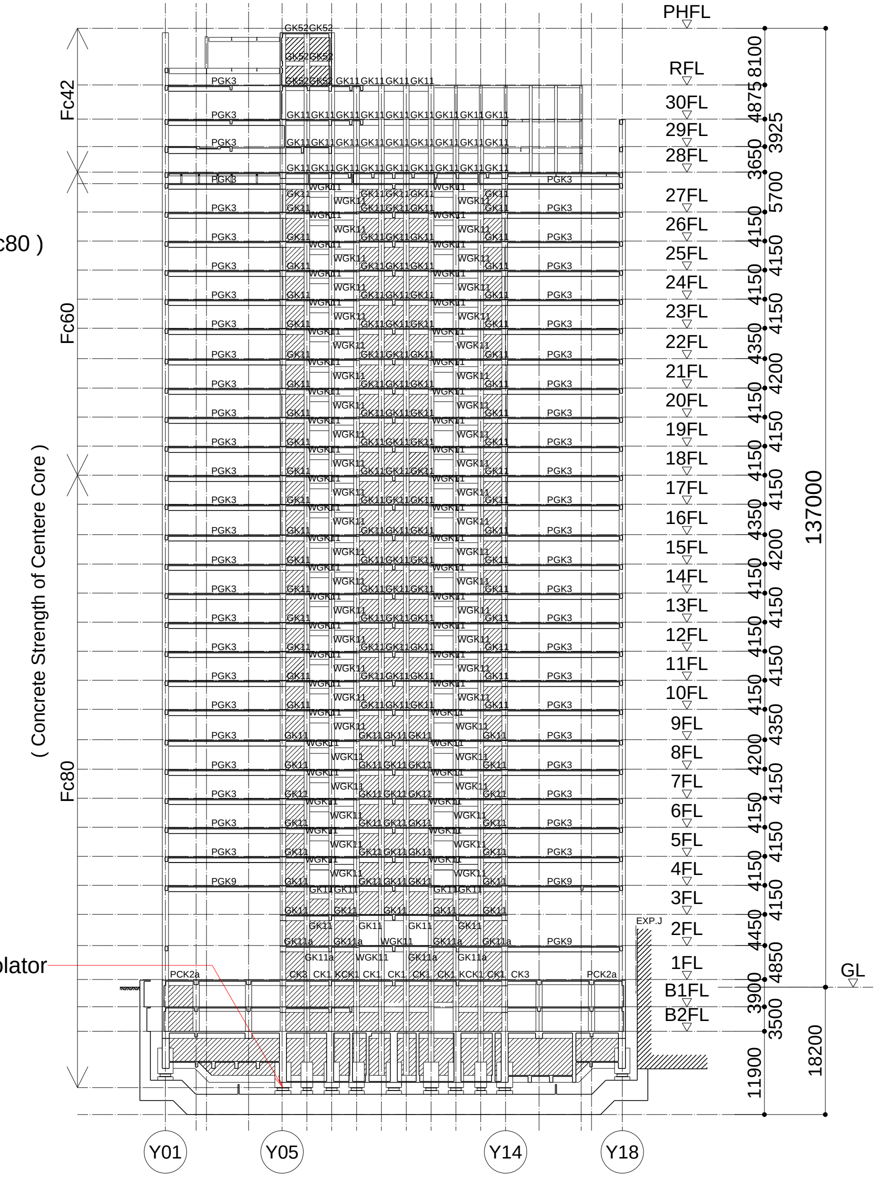
FUTAKO TAMAGAWA RISE Ⅱ-a BLOCK

Building Summary

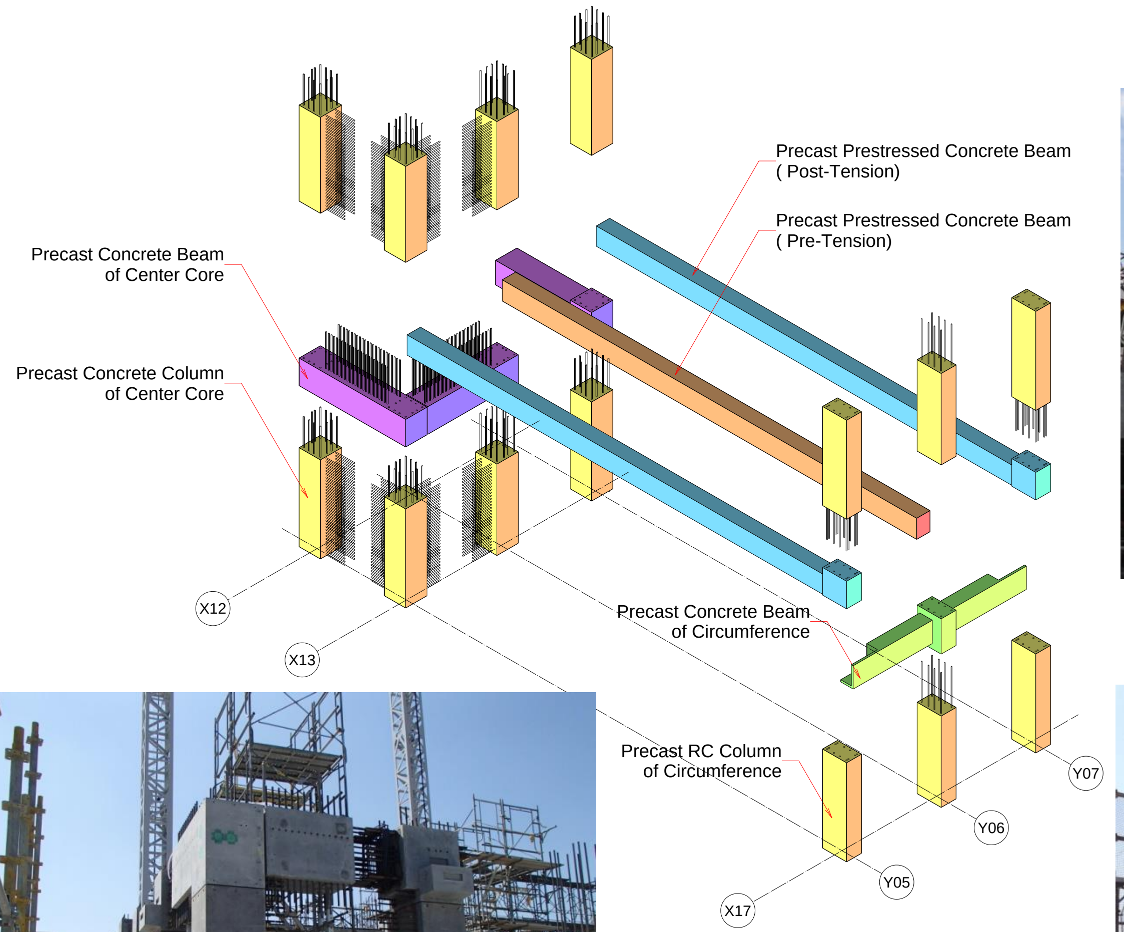
Owner	: Redevelopment Association
Design and Site Supervision	: Joint Venture of Nikken Sekkei, RIA and Tokyu Sekkei Consultant
Construction	: Kajima Corporation, Tokyo
PC Construction	: P.S.Mitsubishi Construction Co.,Ltd.
Usage	: Office and Hotel
Location	: Setagaya-ku, Tokyo, Japan
Floors	: 30-story superstructure and 2-story underground
Structure	: Precast Prestressed Concrete and cast-in-place Reinforced Concrete
Structural System	: Seismic Isolation

PLAN and SECTION



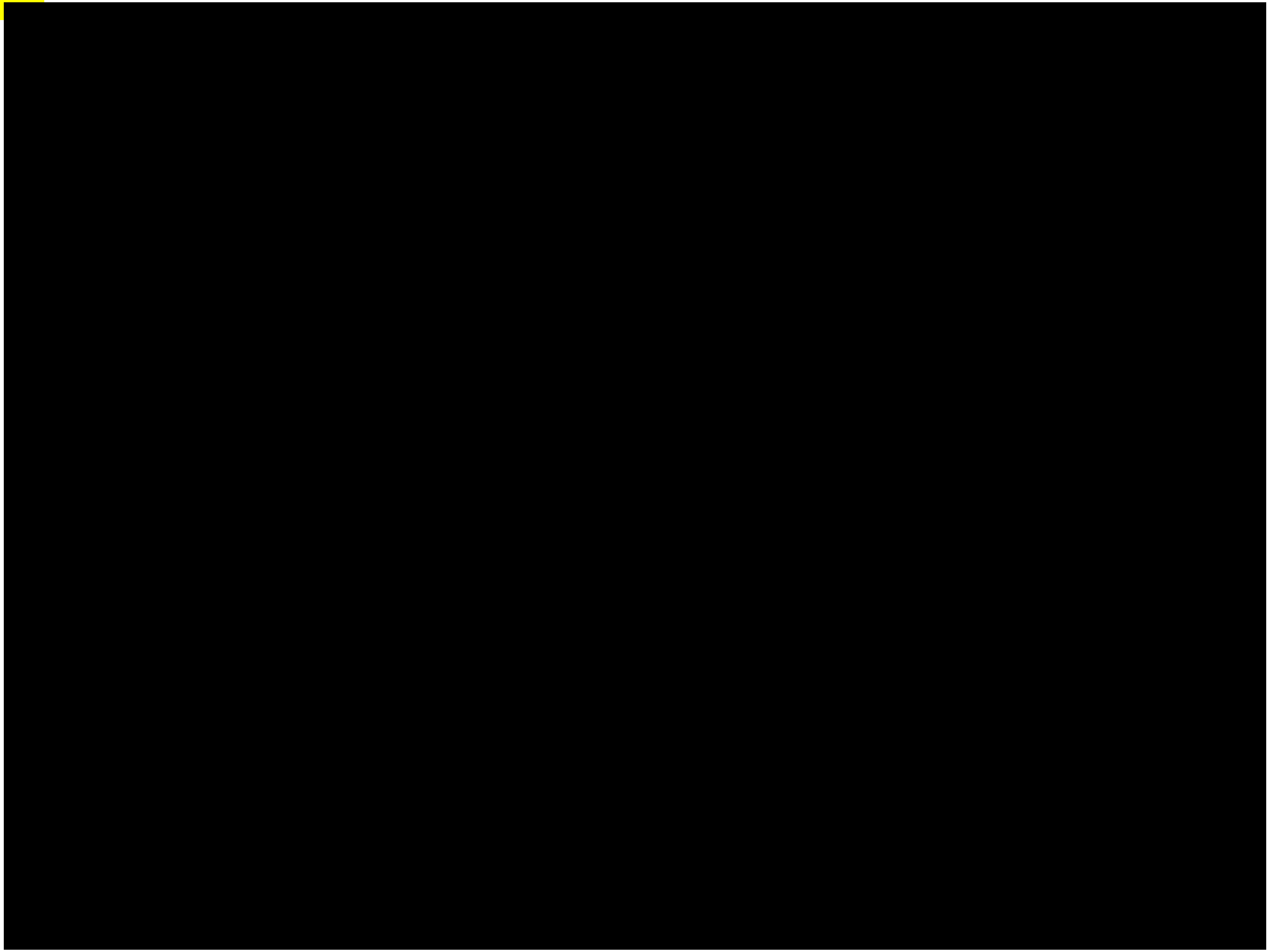


FUTAKO TAMAGAWA RISE Ⅱ-a BLOCK



Video

PC, Pca Structure



Super high rise building

OBAYASHI

Structural design of Dentsu Co.

2004.5.19 Ymanaka

Shiodome Area,
Tokyo

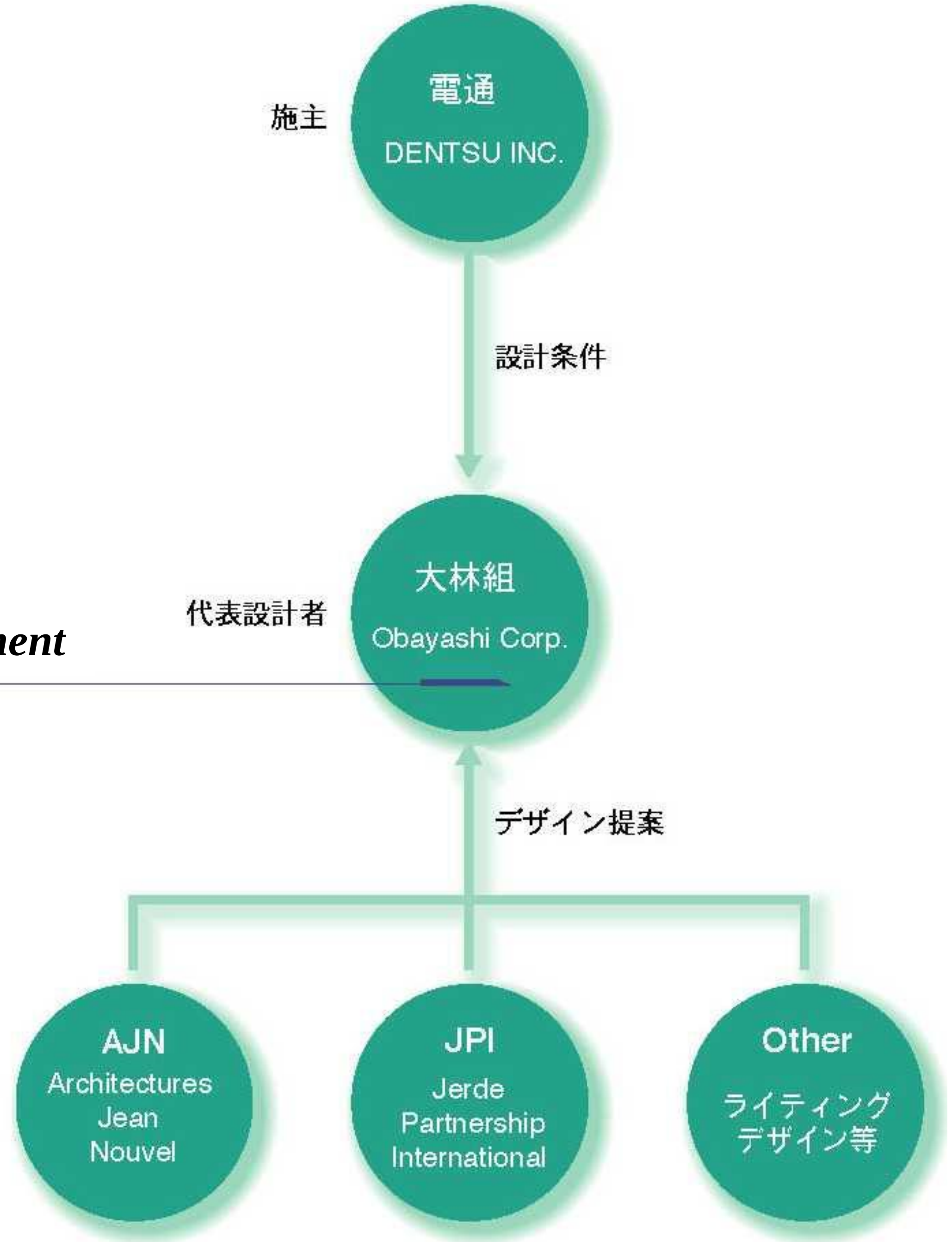
Total area of Shiodome is 300,000 m².

Development scheme was planned by Tokyo metropolitan government

Future image of Shiodome

design team

Total coordination
/Entire architectural design
/Urban planning, environmental assessment



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Jean Nouvel

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

Main building:

Total height: 210m

“ Crystal and rock”

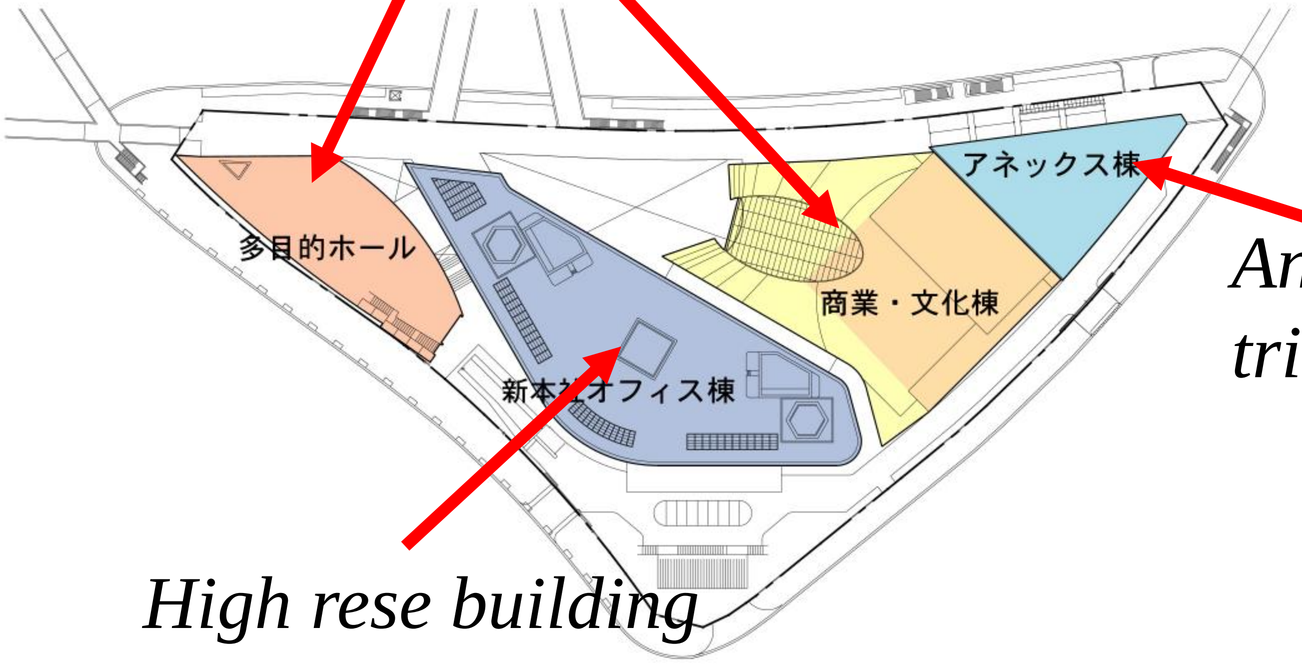
+

Complex facility

Total floor area is 240,000 m²

Outline of overall facilities

Multi-purpose and cultural buildings with organic shape



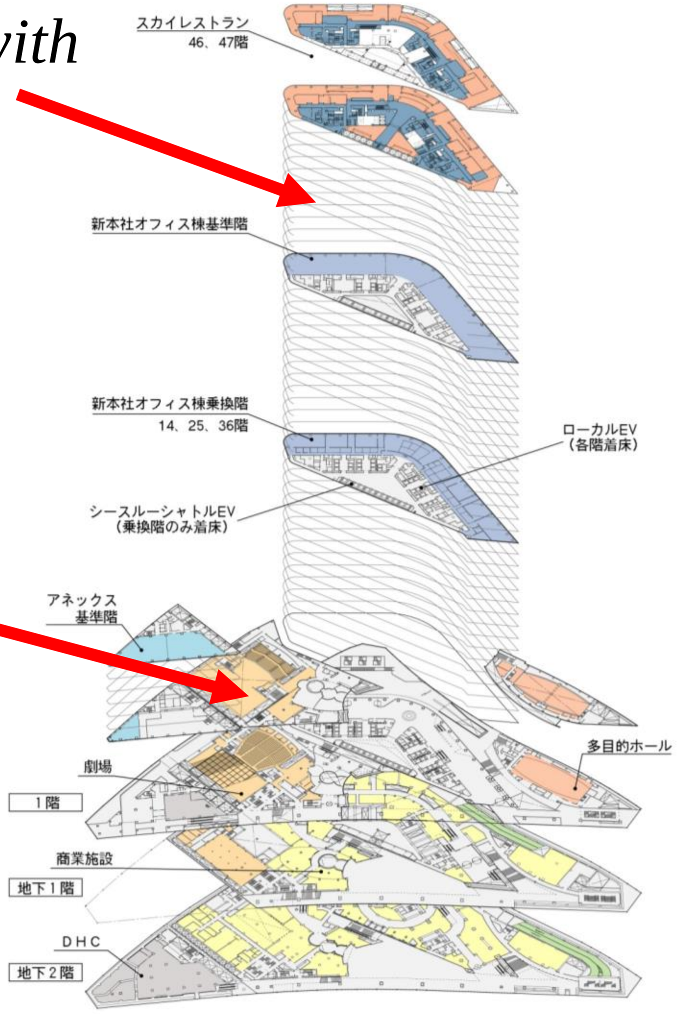
Annex building with triangular shape

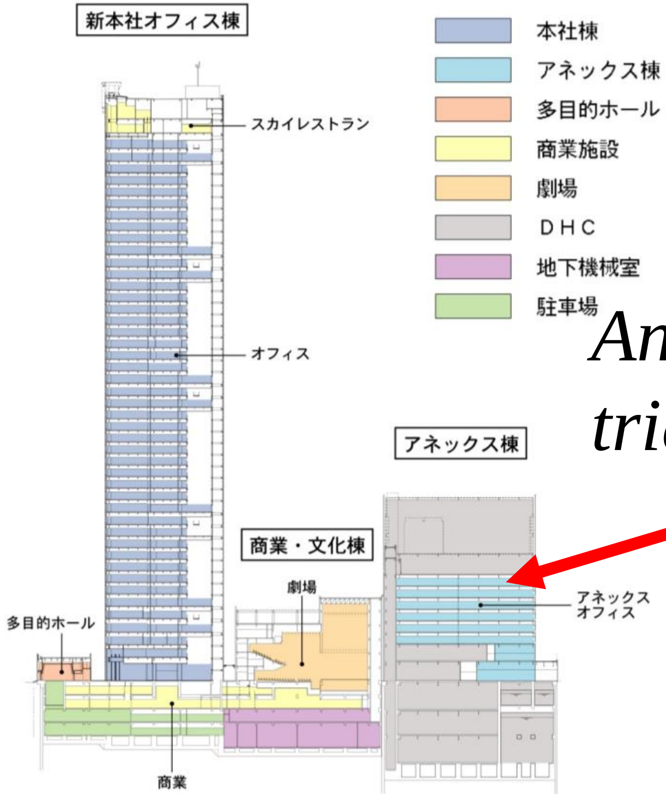
High rese building with boomerang shape

Outline of overall facilities

High rese building with boomerang shape

Multi-purpose and cultural buildings with organic shape





Annex building with triangular shape

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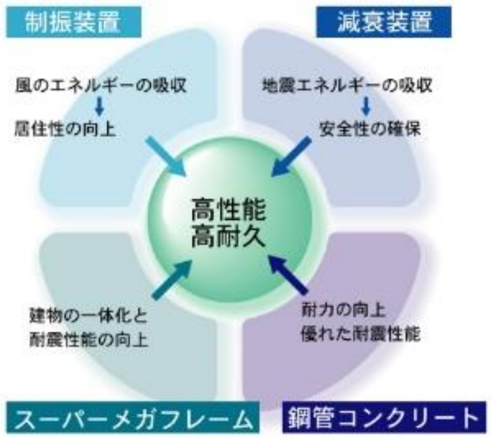
Main concept:
Safety and Stability

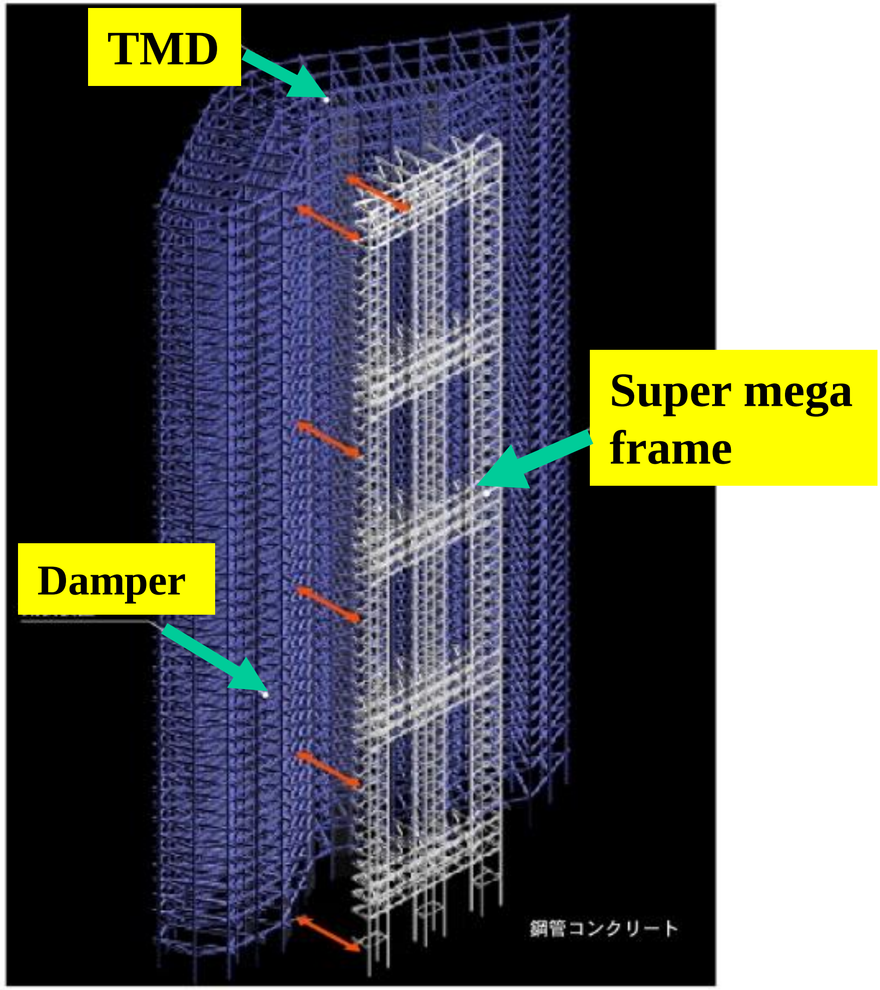
1. *Safety at the time of disaster using vibration control devices, dampers and steel concrete*

2. *100 years sustainable building using central monitoring system and disaster prevention system*

Structural Design

High capacity and high durability can be performed against wind, earthquake, etc..





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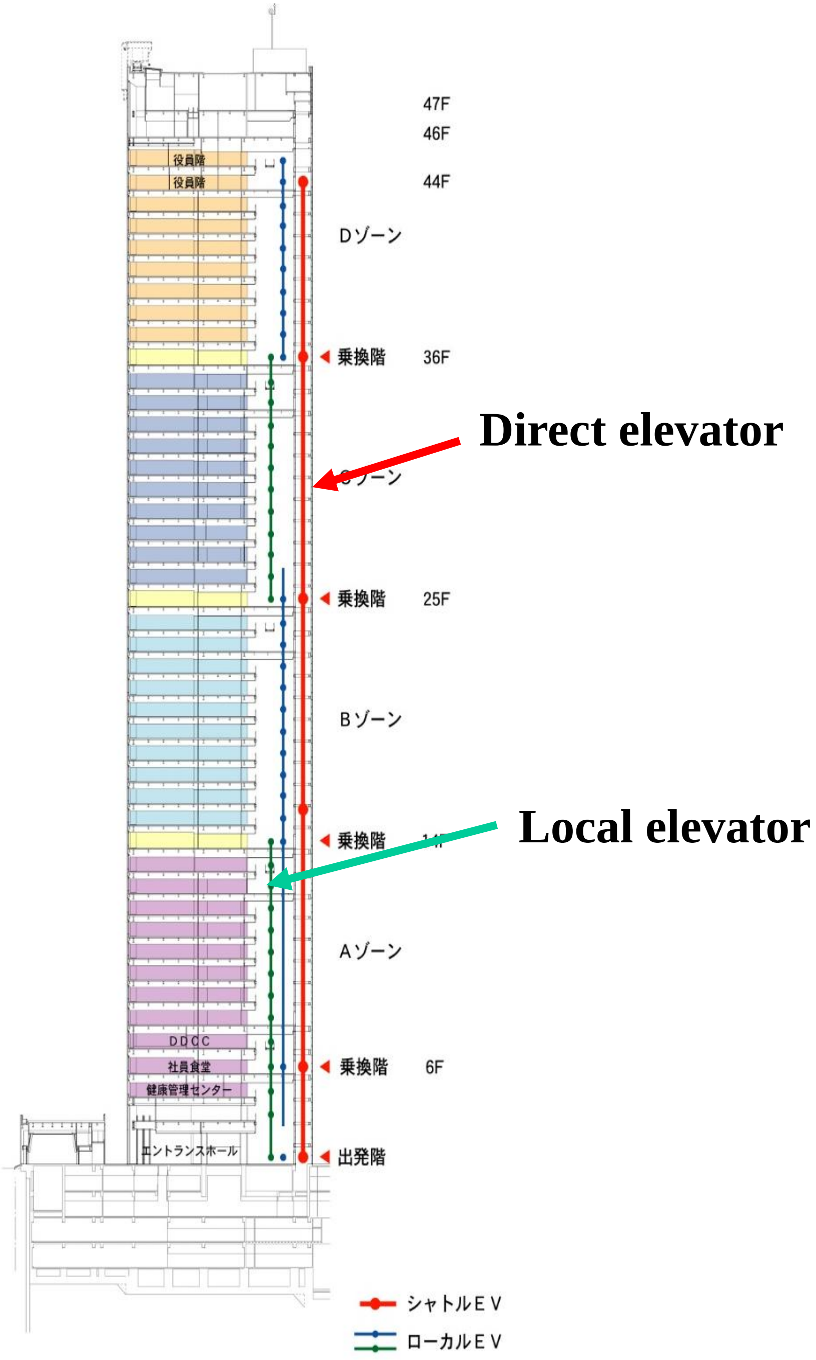
Main concept:
Shuttle elevator system

1. *Combination of high speed direct elevator and local elevators*
2. *See-through elevators can be seen from inside and outside of building.*



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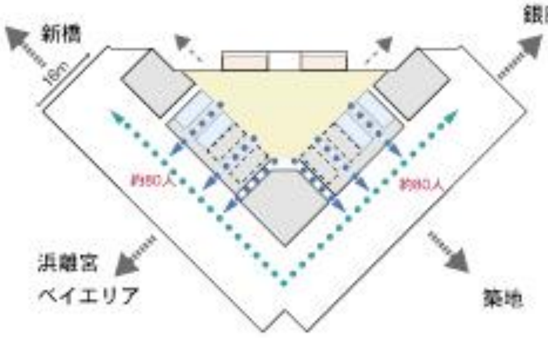
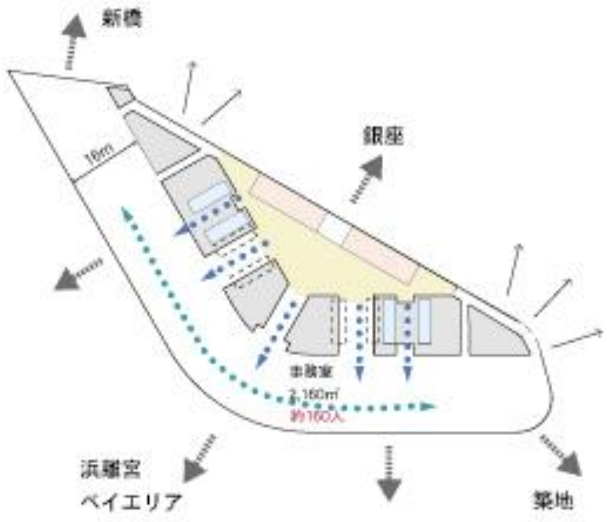
The process of creating boomerang shape

Trial plan, M.97

Given plan at kick-off meeting, July 97

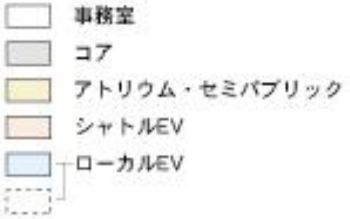
Basic plan, M.98





*一人当り執務面積　11.6m²(3.5坪)　　13.2m²(4.0坪)　　13.2m²(4.0坪)

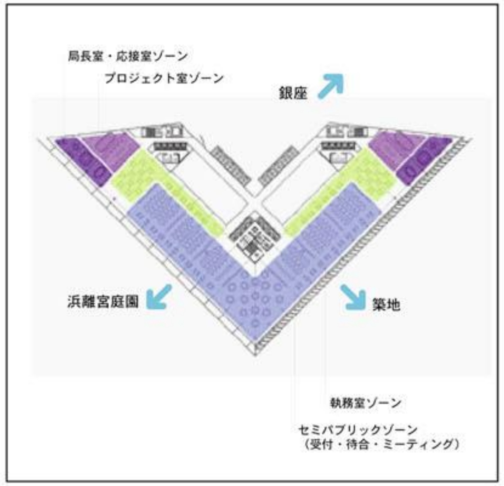
基準階面積　約3,600m²



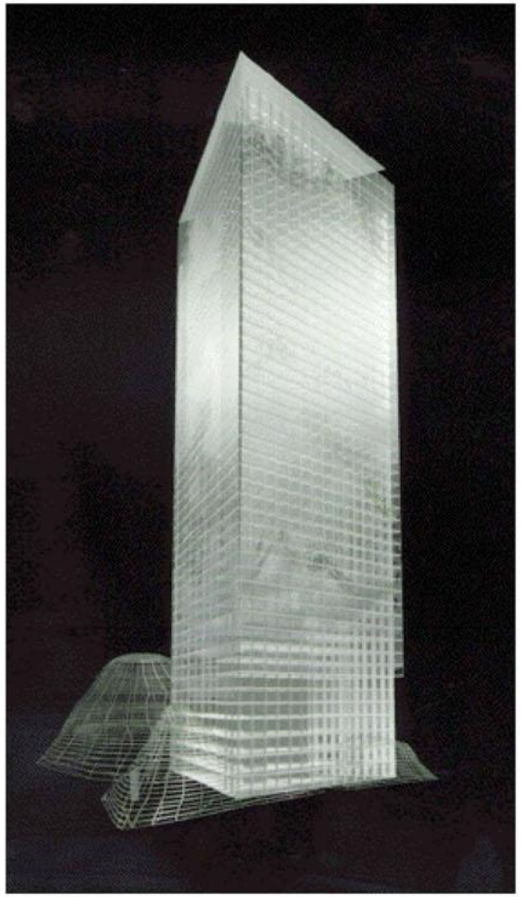
Transition of the basic plan

triangle plan study

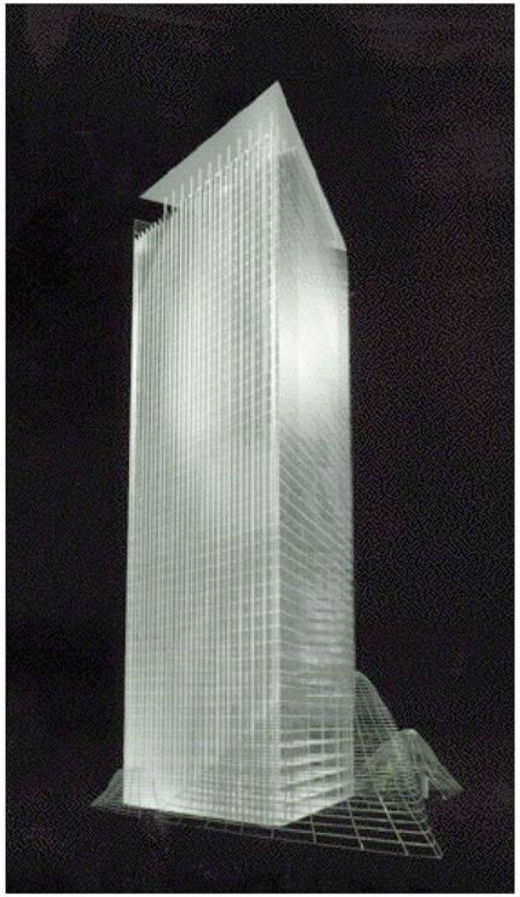
1.三角形案



基準階ゾーニング



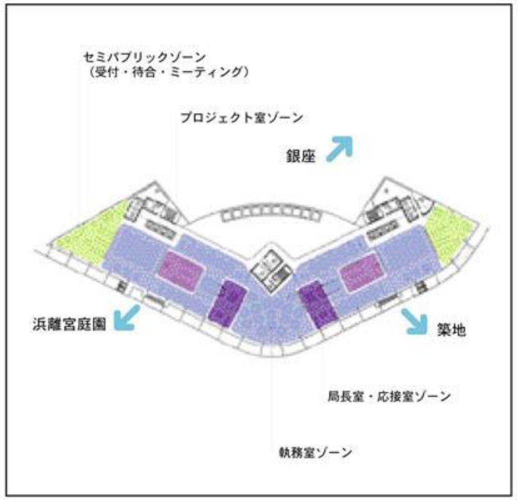
C街区南端からの外観イメージ



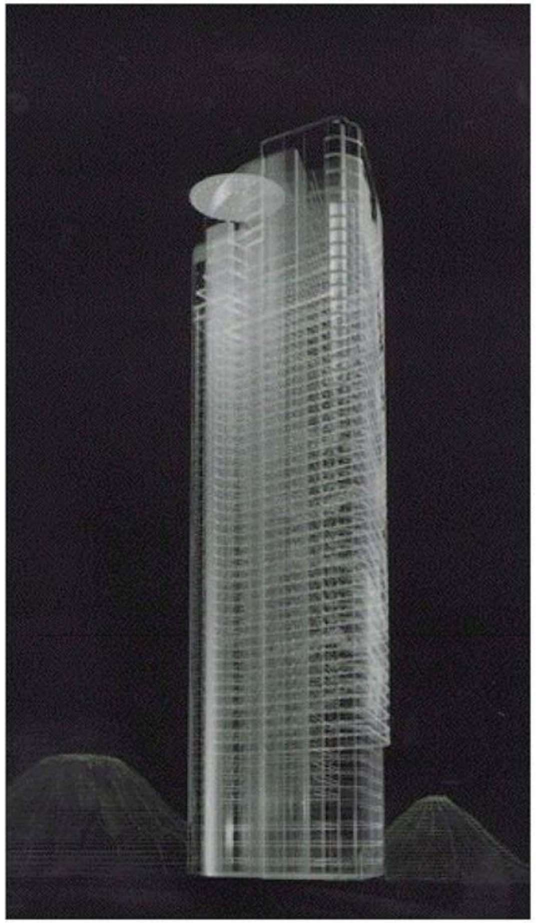
銀座からの外観イメージ

boomerang plan study

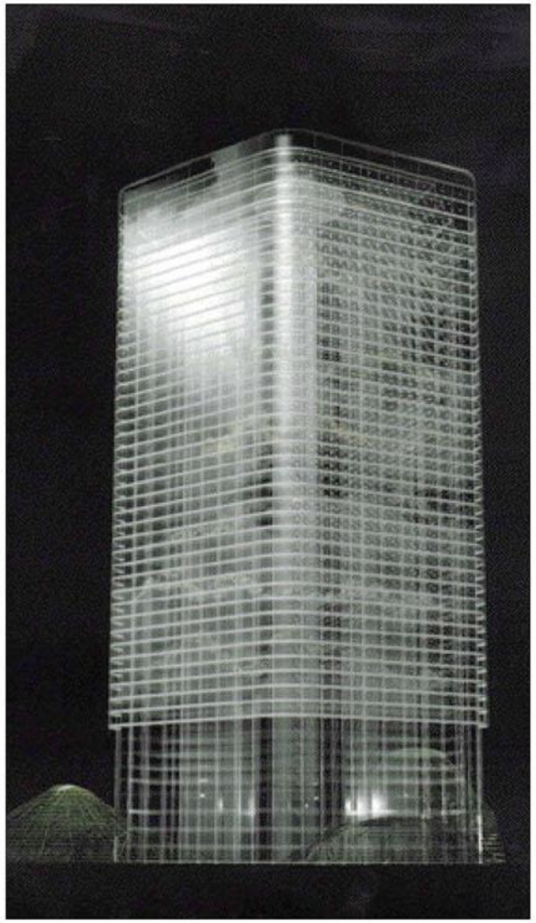
2.ブーメラン型案



基準階ゾーニング



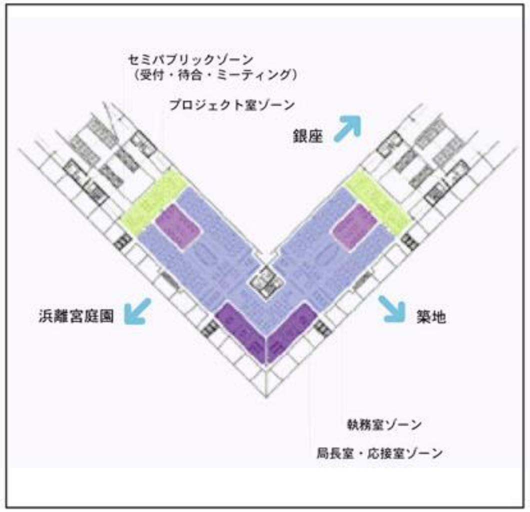
新橋駅からの外観イメージ

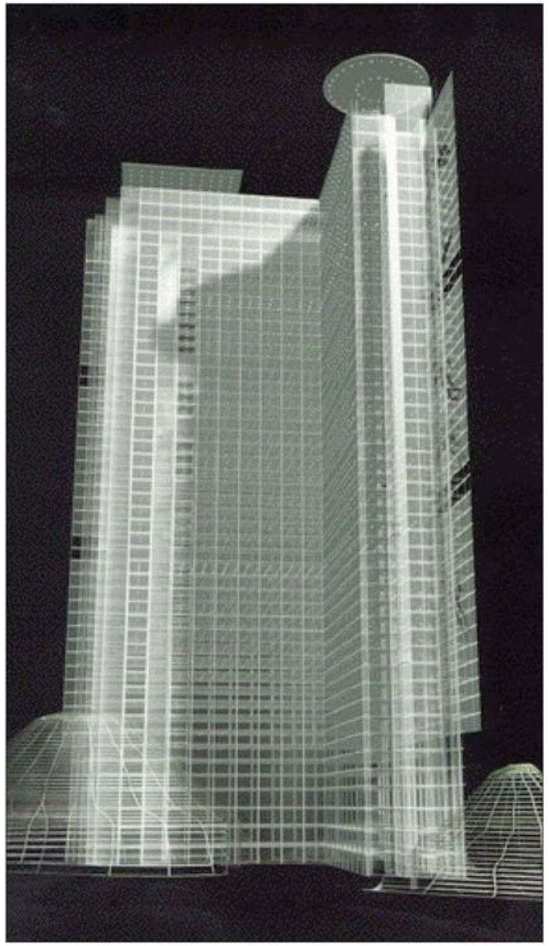


C街区南端からの外観イメージ

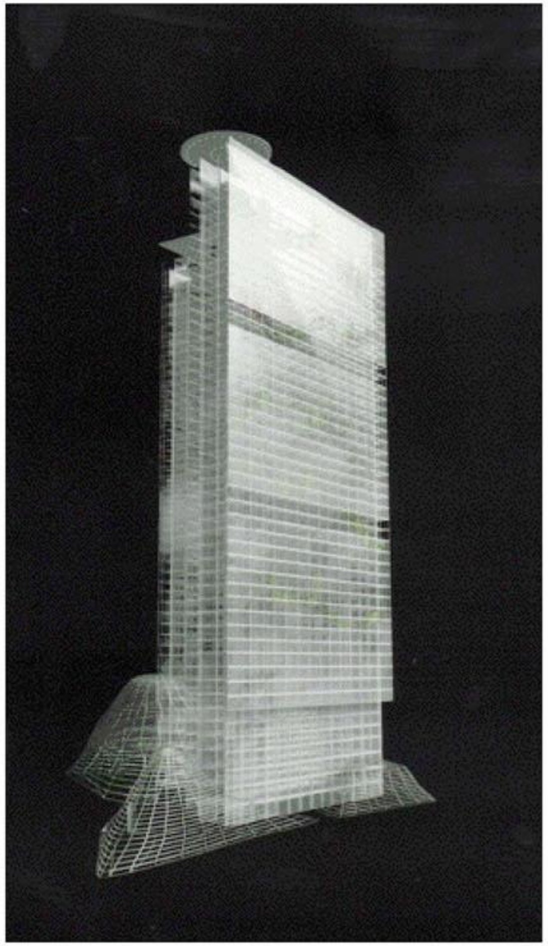
L-shape plan study

3.L字型案



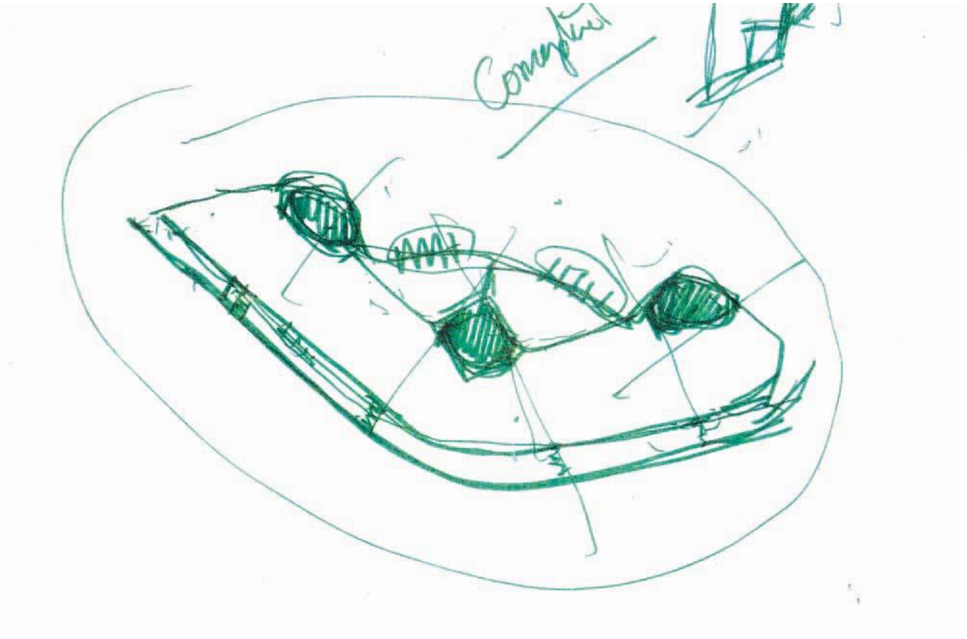


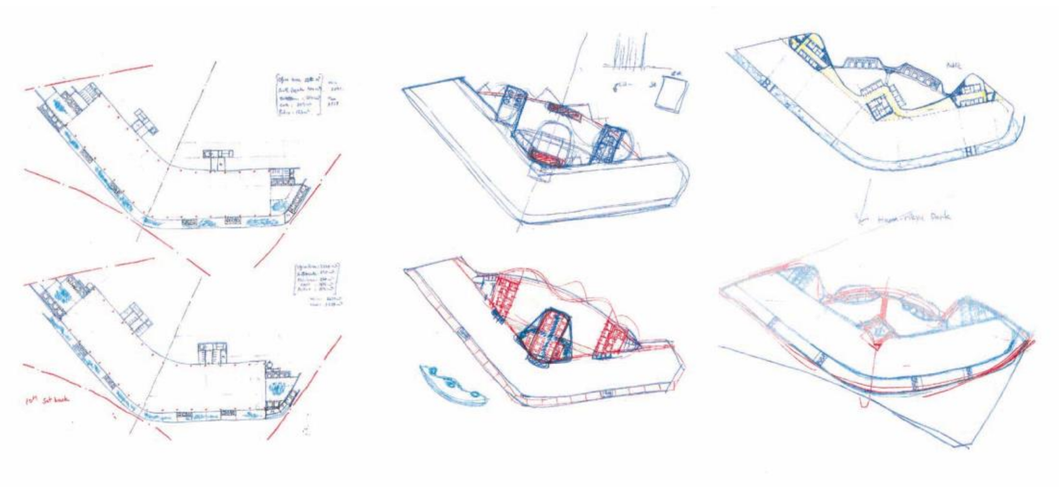
新橋駅からの外観イメージ



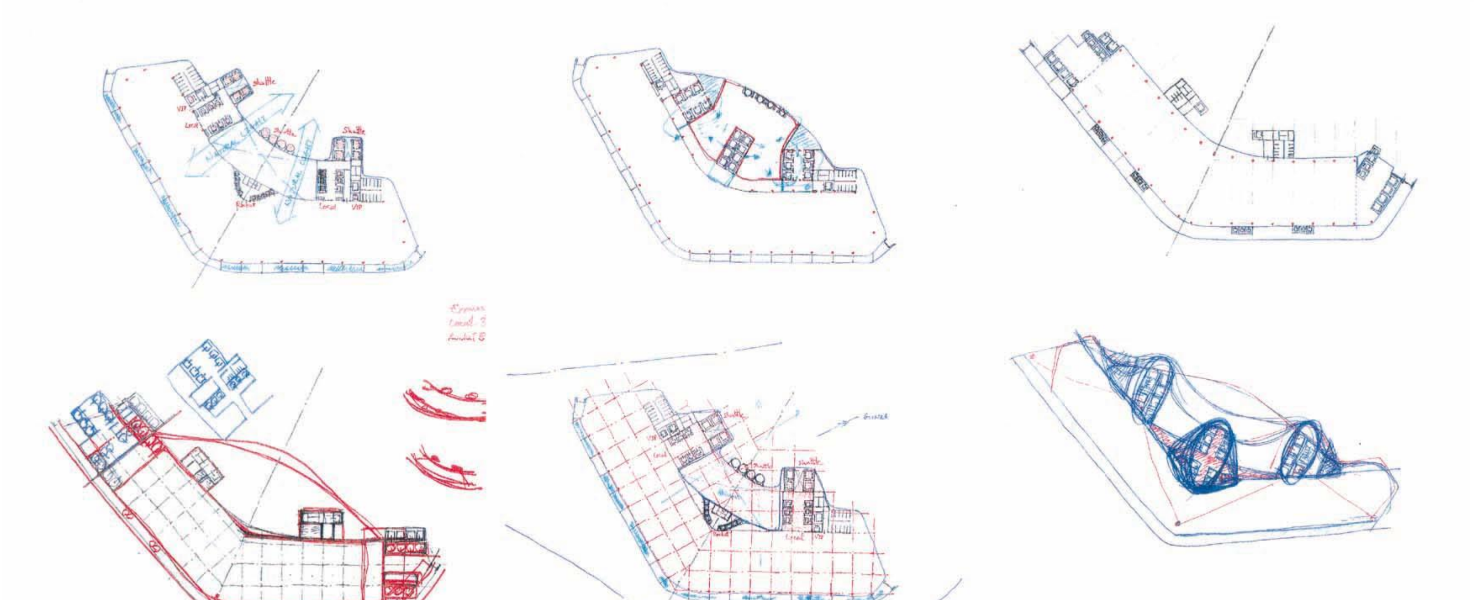
C街区南端からの外観イメージ

Communication with J. Nouvel by sketch drawings

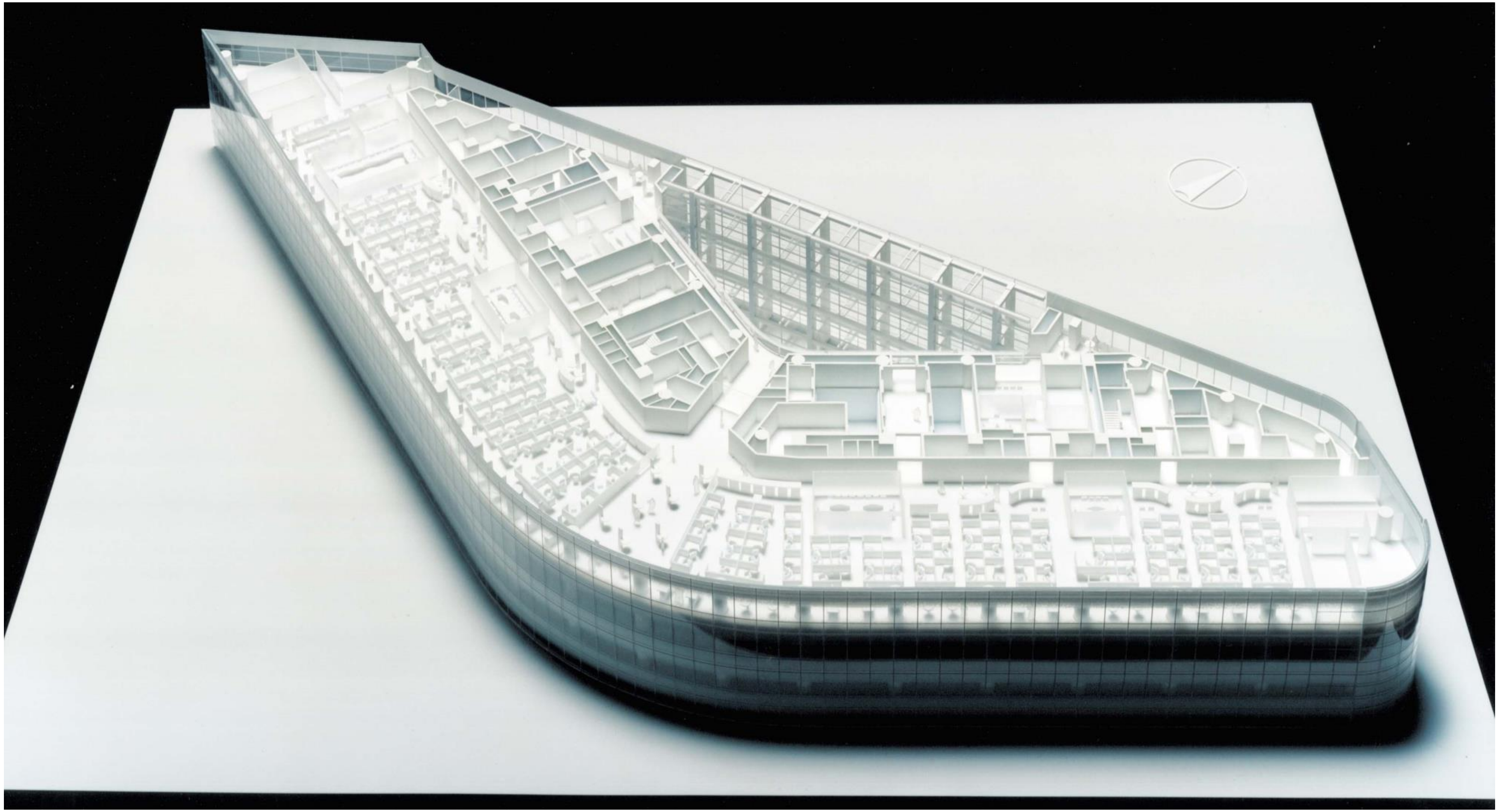




various boomerang plan study



Typical floor model:1/200



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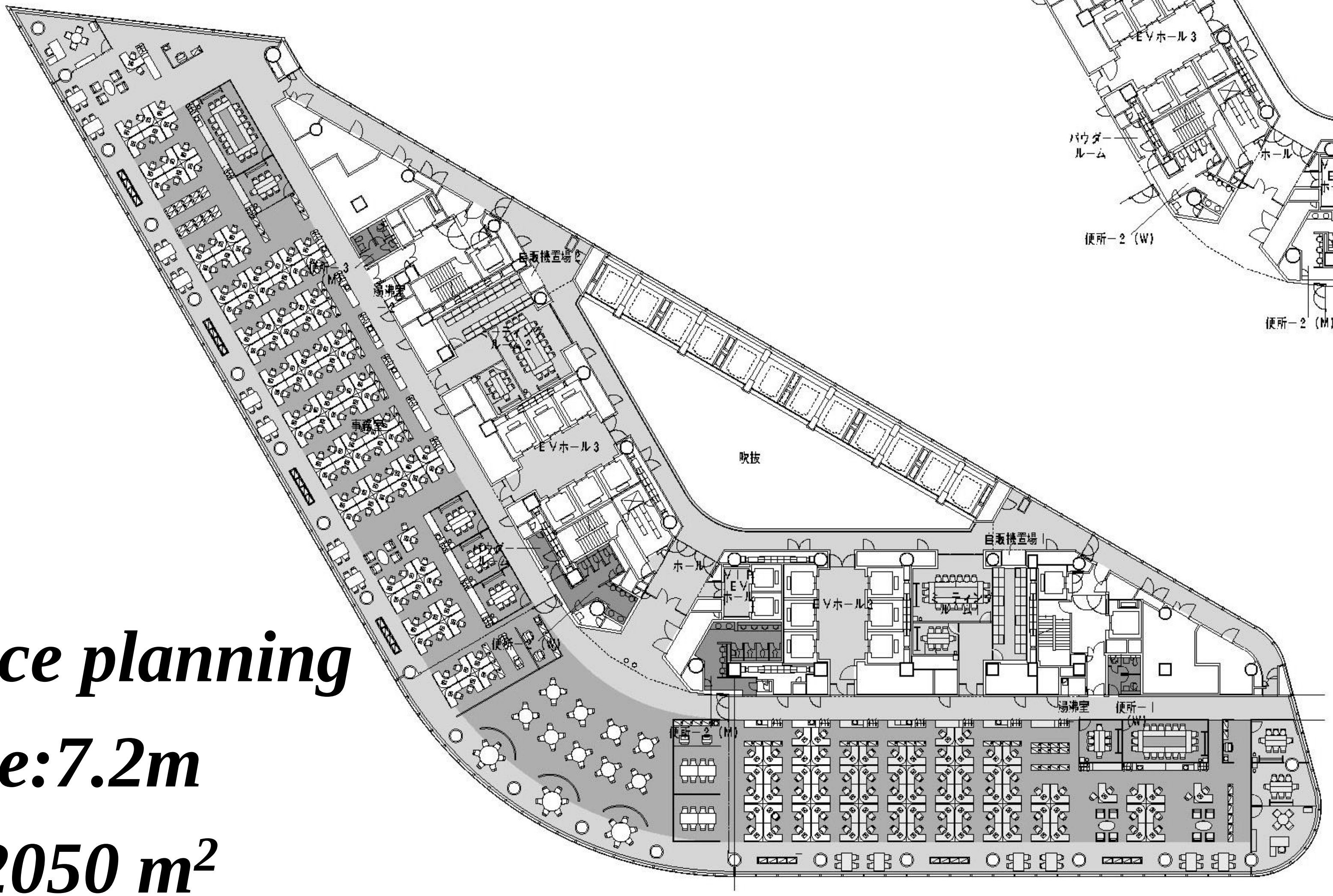
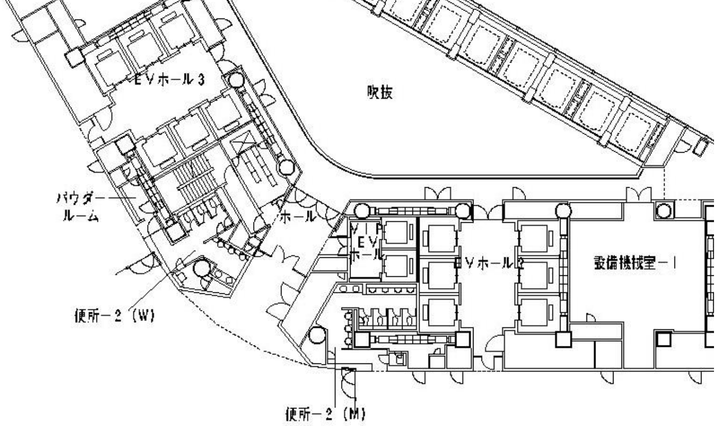




Typical office planning

module:7.2m

Area :2050 m²

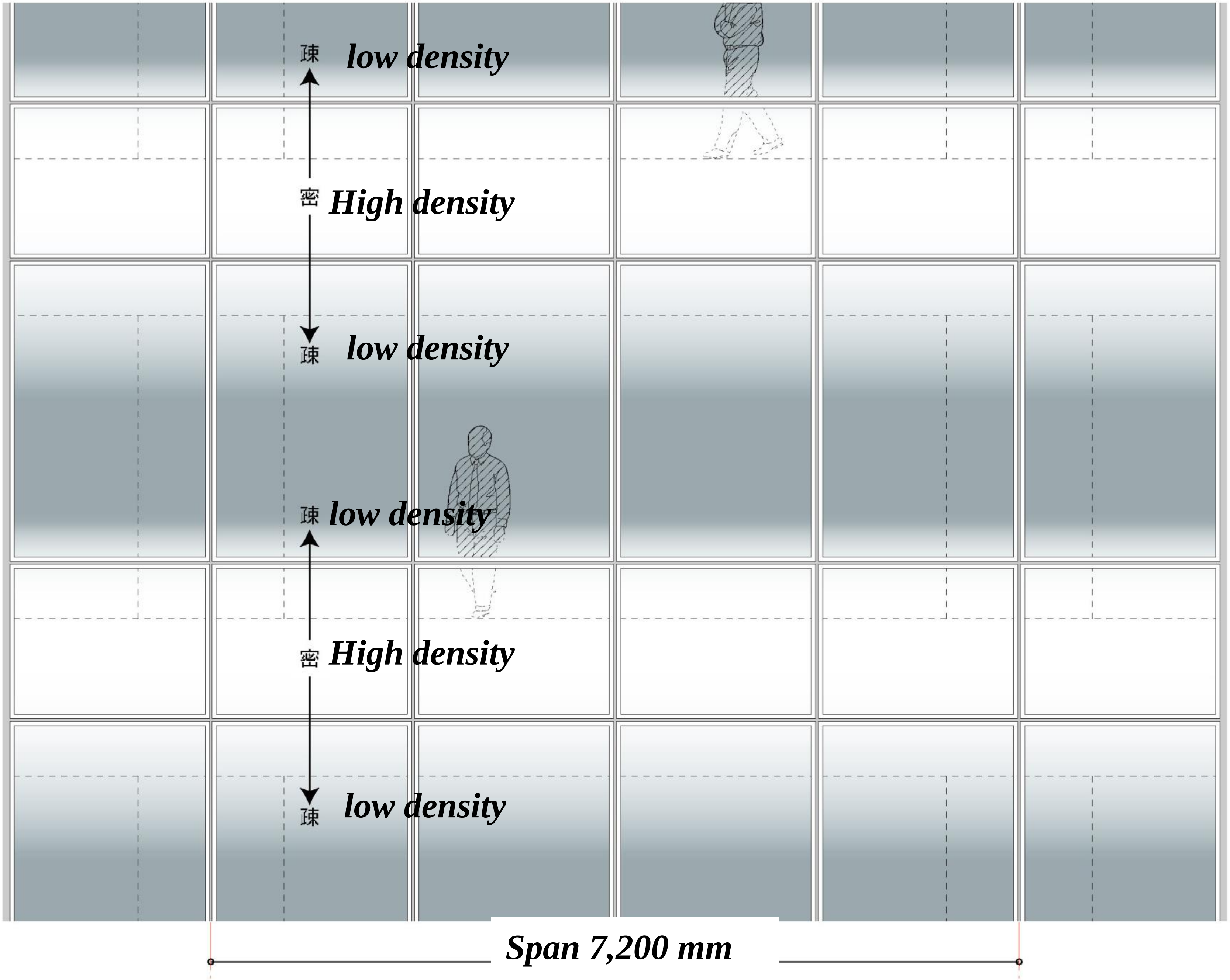
Study for facade

Basic concept of facade

Airflow window with ceramic printed glass creates transparency, view, privacy and saving energy

↓

Proposed by Jean Nouvel



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Mock up for checking the gradation

Selenic printed glass

Gray⇒White　NCS5500、5000,4000, 3500, 3000, 2500, 2000, 1500, 1000, 500 (10 grades)

Drawing of façade concept

design partner;

Jean Nouvel

(France)

Structural design

Structural Design Concept

Design concept

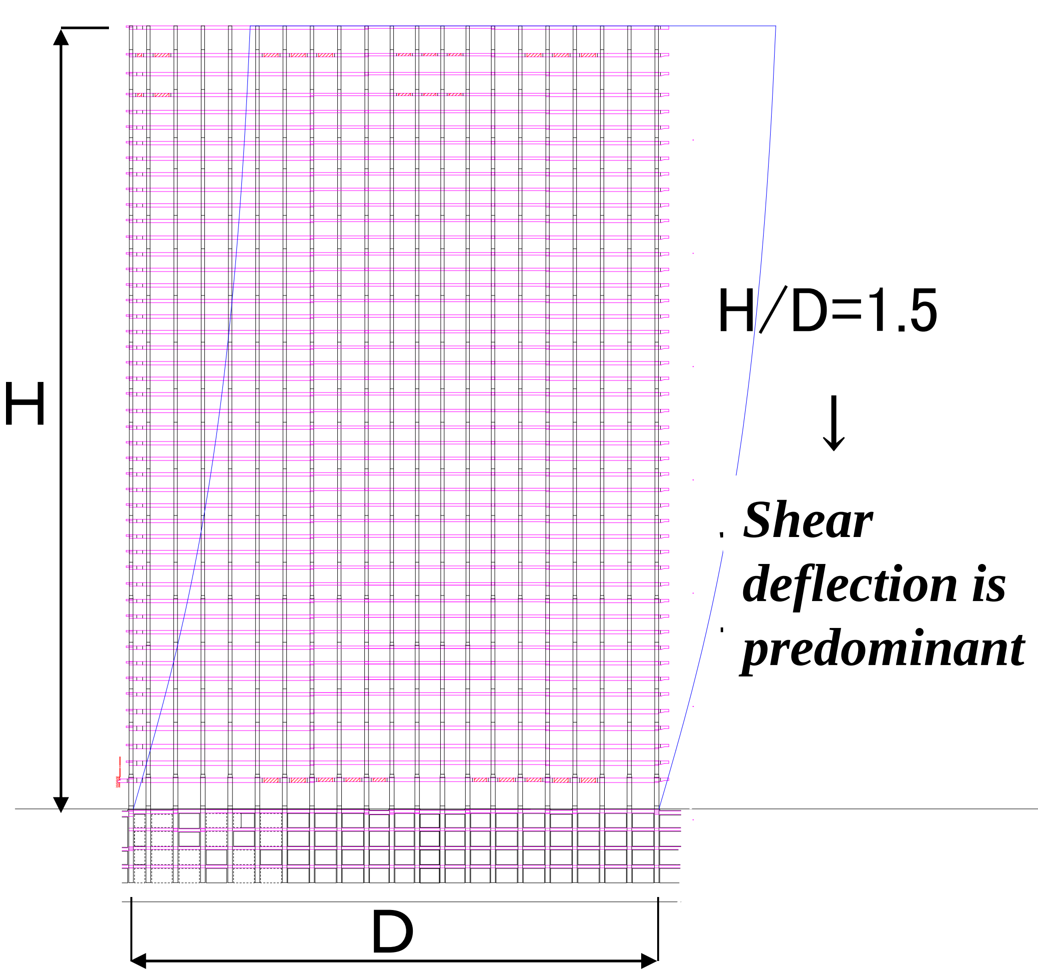
100 years sustainable building using

↓

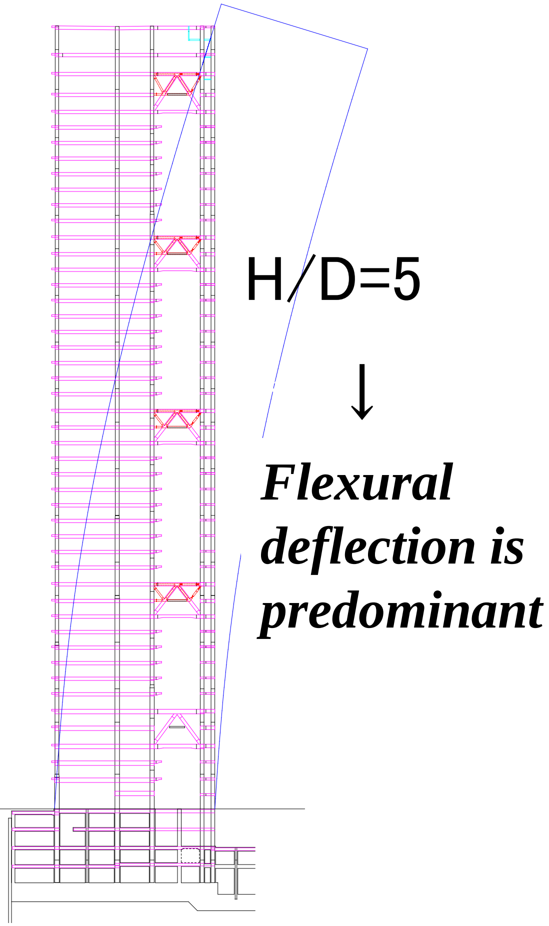
Structural technologies to assure the safety against earthquake and wind

Longitudinal direction

Transverse direction



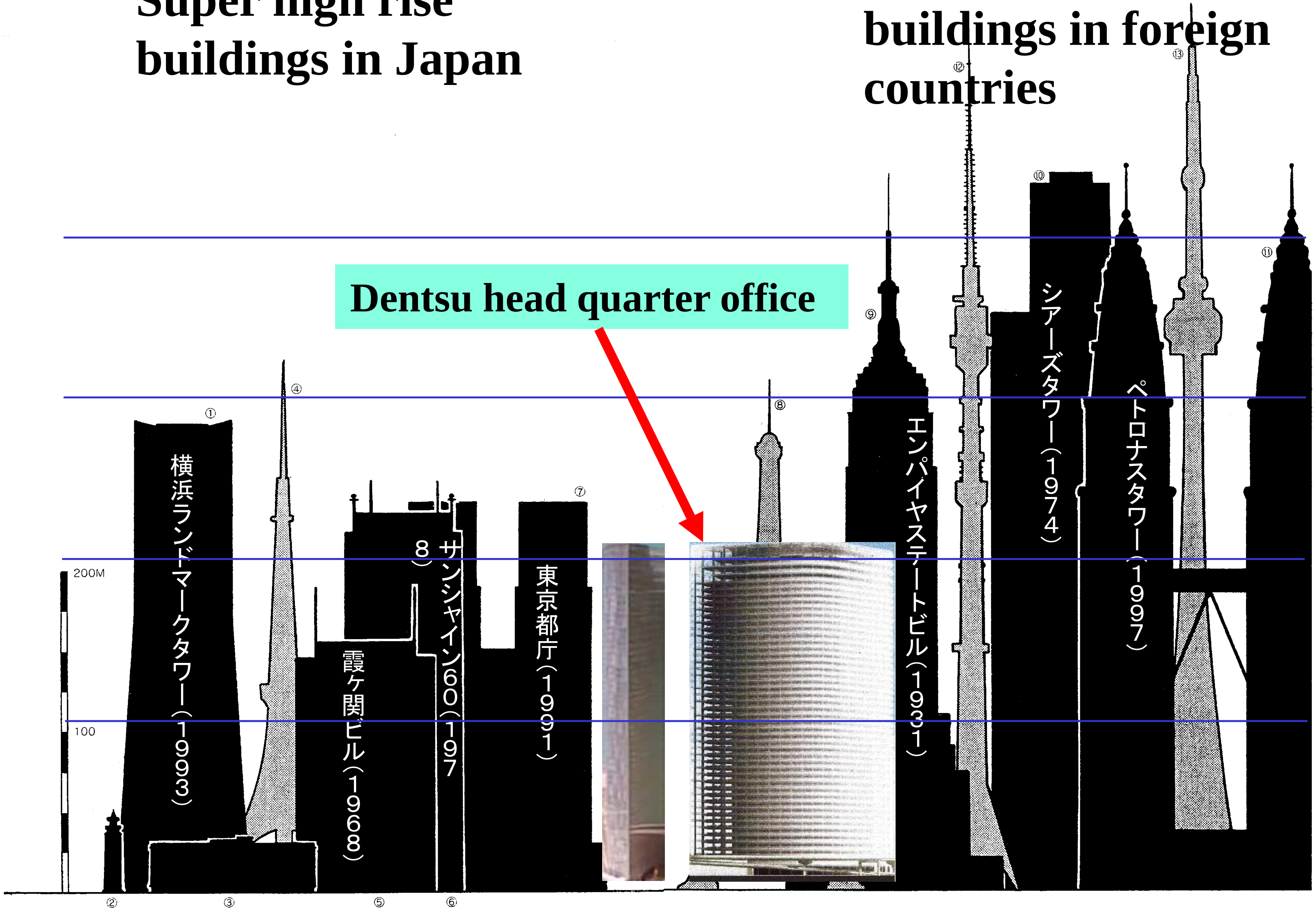
Natural period
T1=4.6sec



Natural period
T1=5.4sec

Super high rise buildings in Japan

Super high rise buildings in foreign countries



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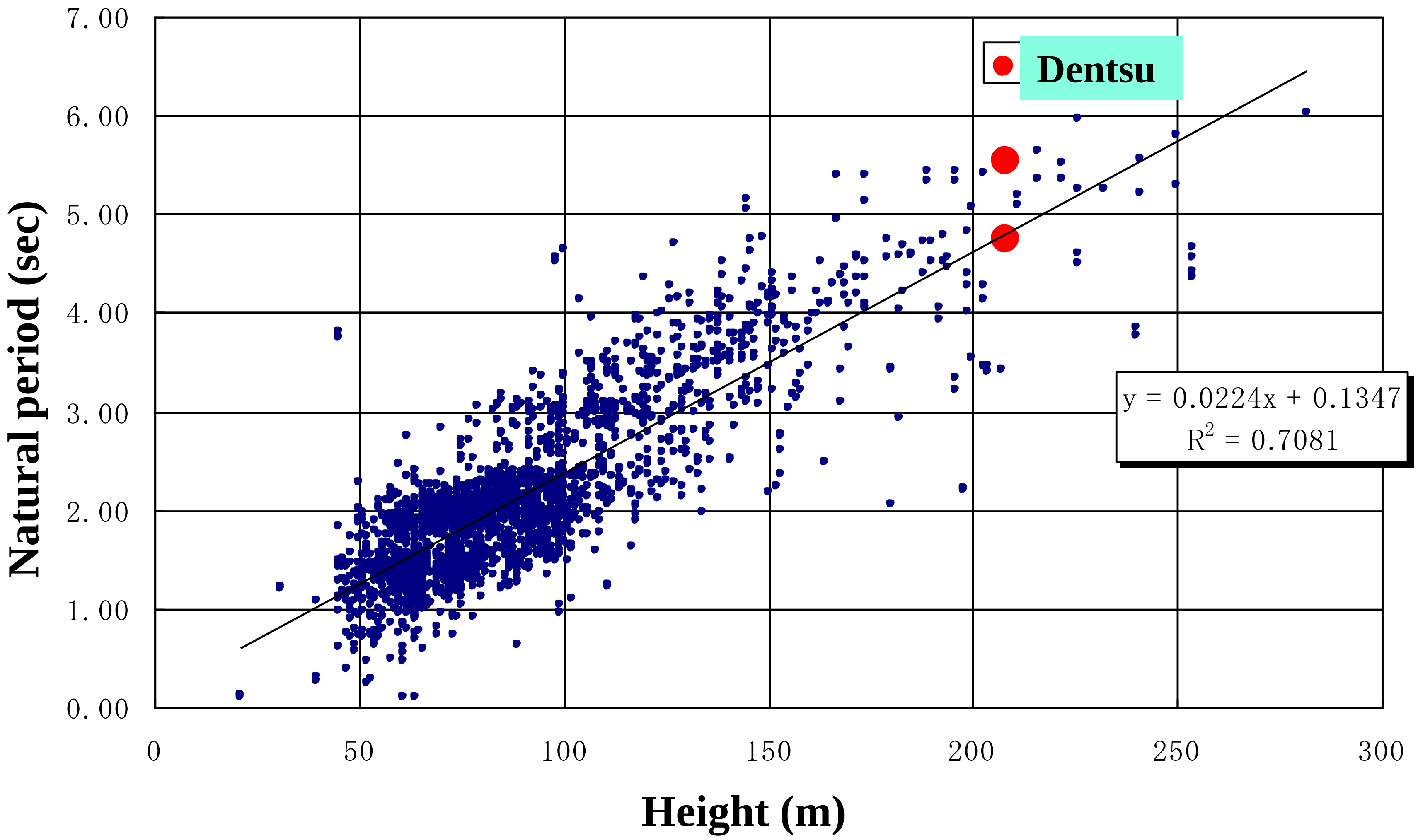
Height of building VS Natural period



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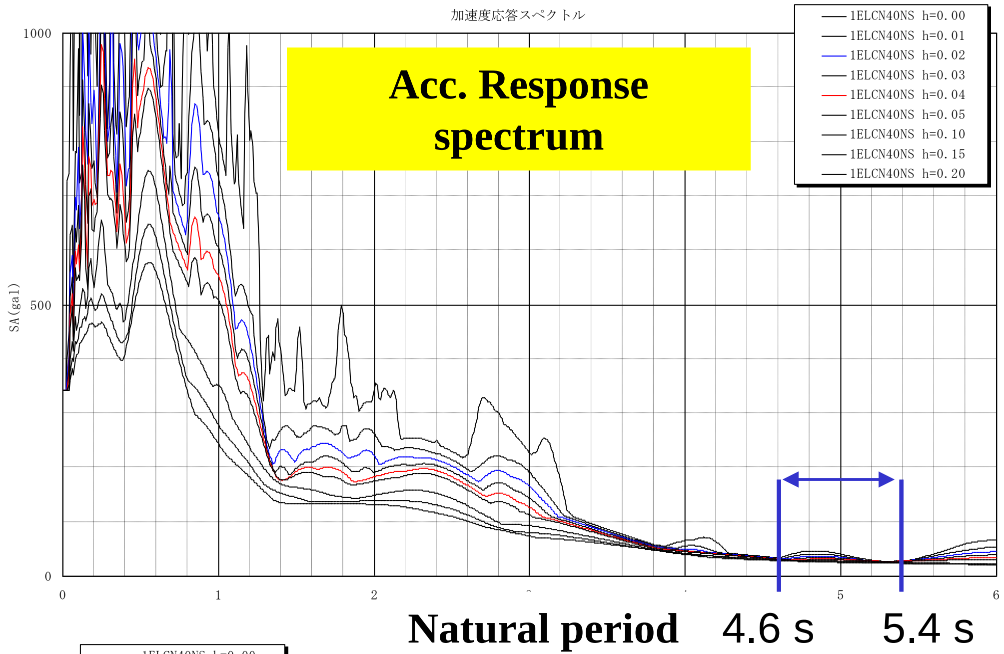
Building natural period VS Elastic response spectrum

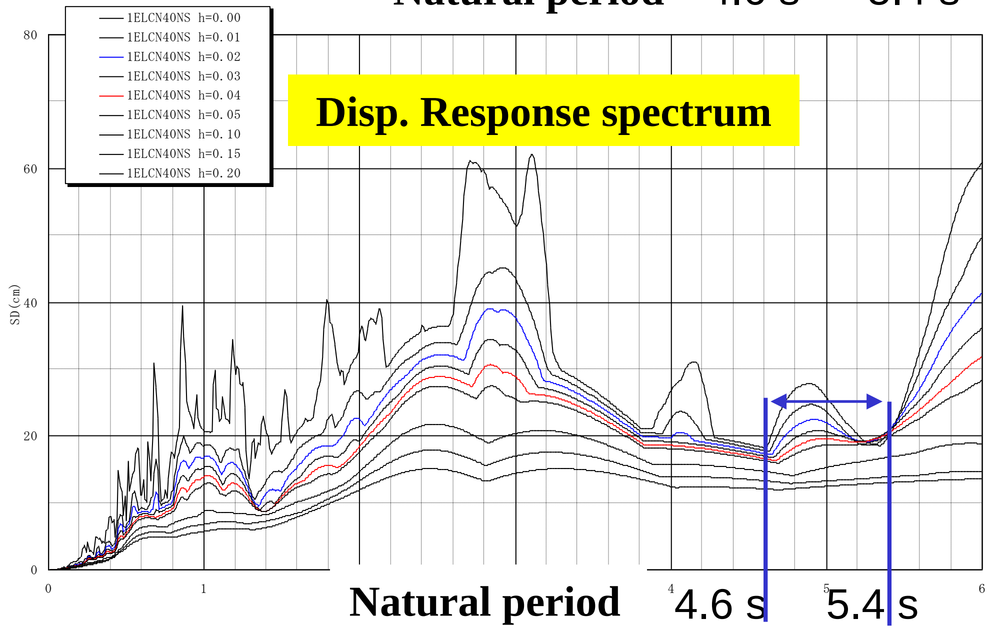
Response acceleration

→ Input earthquake force

Response displacement

→ Vibration displacement





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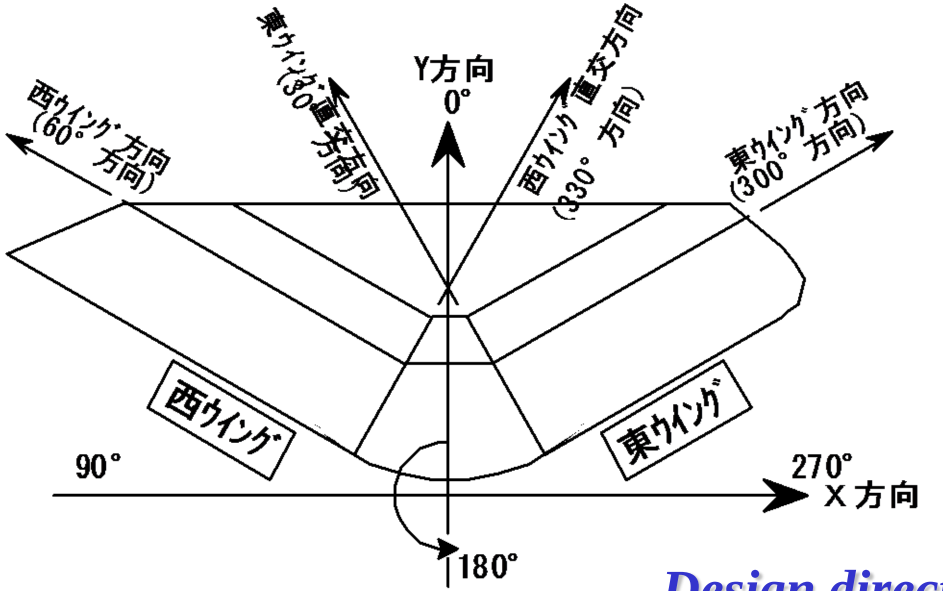
Design concept and procedure

External design force

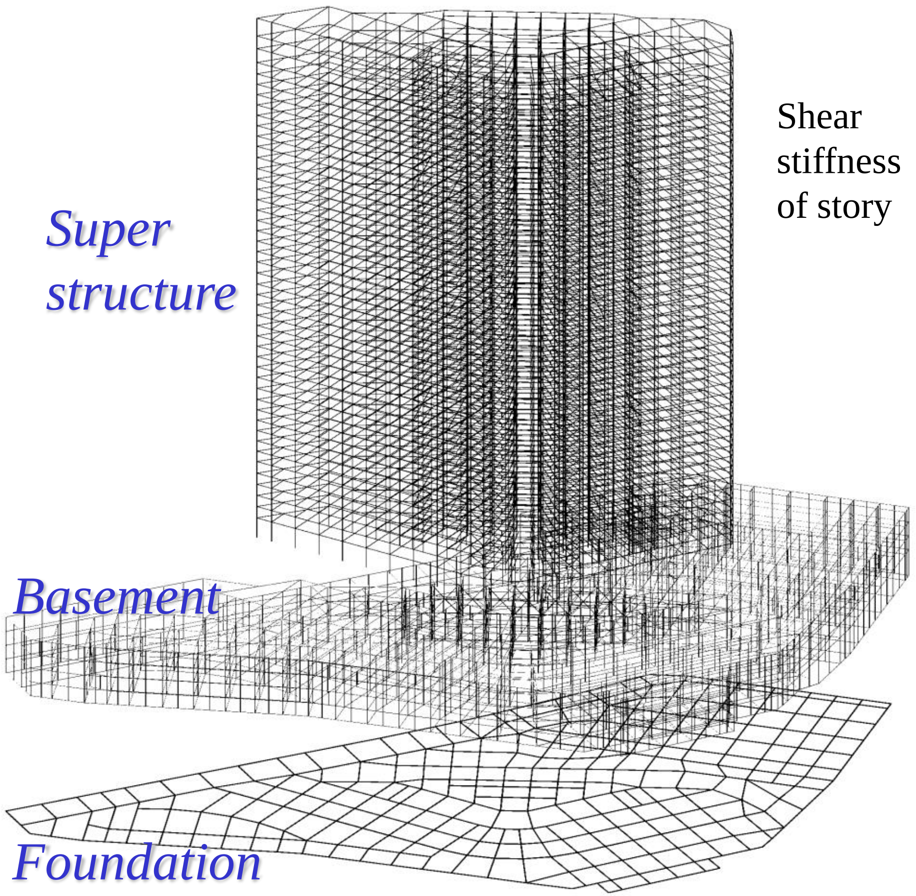
- *Dead load*
- *EQ load*
- *Wind load*
- *Damping force*

Damping factor h=0.04



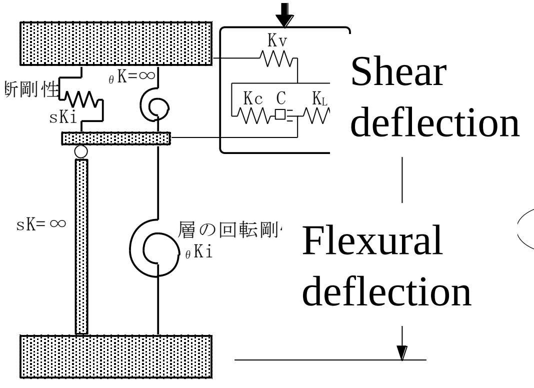
Design direction

Analytical model

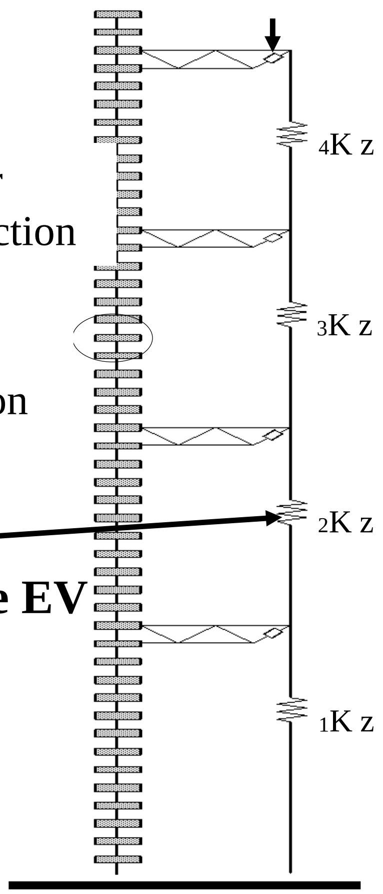


Three dimensional model for nonlinear static analysis

One freedom model



Multi freedom model



Lamped mass model for nonlinear response analysis

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Design concept and procedure

Design criteria

項目				設計クライテリア	設計目標値
地上部	静的設計	鉛直荷重時	断面設計 柱軸力比	長期許容応力度以内 0.4以下	同左
		設計用剪断力時	断面設計	短期許容応力度以内 (PY0ダンパーのリンク材は降伏可とする)	同左
		保有水平耐力時 (層間変形角＝1/75)	柱軸力比 全塑性ヒンジの生じる箇所	鉄骨柱：MIN(0.75, 1-λ/100, 0.25/λc2)以下 CFT柱：0.7以下 梁端部、梁水平ハンチ端部 PY0ダンパーのリンク部、1階柱脚部	同左 PY0ダンパーのリンク部
	地震外力	レベル１ (25cm/s)	応答層剪断力 層間変形角	設計用層剪断力以内 1/200以内	同左 1/300以内
		レベル２ (50cm/s)	応答層剪断力 層間変形角 全塑性ヒンジの生じる箇所	保有水平耐力以内 1/100以内 梁端部、梁水平ハンチ端部 PY0ダンパーのリンク部	弾性限耐力以内 1/150以内 全て弾性限耐力以内
	耐風設計	レベル１ (100年)	応答層剪断力 層間変形角	設計用層剪断力以内 1/200以内	同左 1/300以内
		レベル２ (500年)	応答層剪断力 層間変形角 全塑性ヒンジの生じる箇所	弾性限耐力以内 1/100以内 PY0ダンパーのリンク部	同左 1/150以内 全て弾性限耐力以内
地下部 基礎	静的設計	鉛直荷重時	断面設計 最大接地圧	長期許容応力度以内 980(kN/m2)、100(tf/m2) 以内 地下水位を考慮して浮き上がりが生じない	同左
		設計用剪断力時	断面設計 最大接地圧	短期許容応力度以内 1960(kN/m2)、200(tf/m2) 以内	同左
		保有水平耐力時	断面設計 最大接地圧	終局耐力以内 耐震壁の剪断応力度は0.1Fc以内 1階以下の床スラブは短期許容剪断応力度以内 2940(kN/m2)、300(tf/m2) 以内	同左

Design force

·*Natural period*
X direction (longitudinal) : 4.6 sec
Y direction (Transverse) : 5.4 sec

·*Total design base shear coefficient*
= 0.04

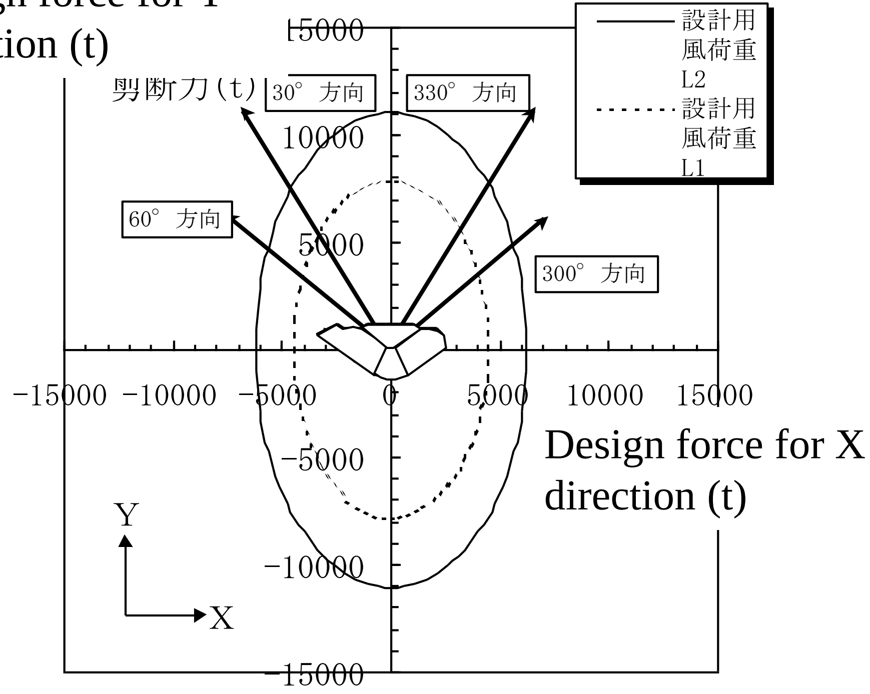
(sec)

固有周期	X	Y	60°	330°	300°	30°
1次	4.643	5.363	4.826	5.257	4.925	5.176
2次	1.627	2.098	1.838	2.042	1.876	2.013
3次	0.954	1.303	1.140	1.269	1.164	1.250
4次	0.667	0.930	0.817	0.907	0.835	0.890

Design force for each direction

Design force:
Y direction: Maximum shear force
X direction: Minimum shear force

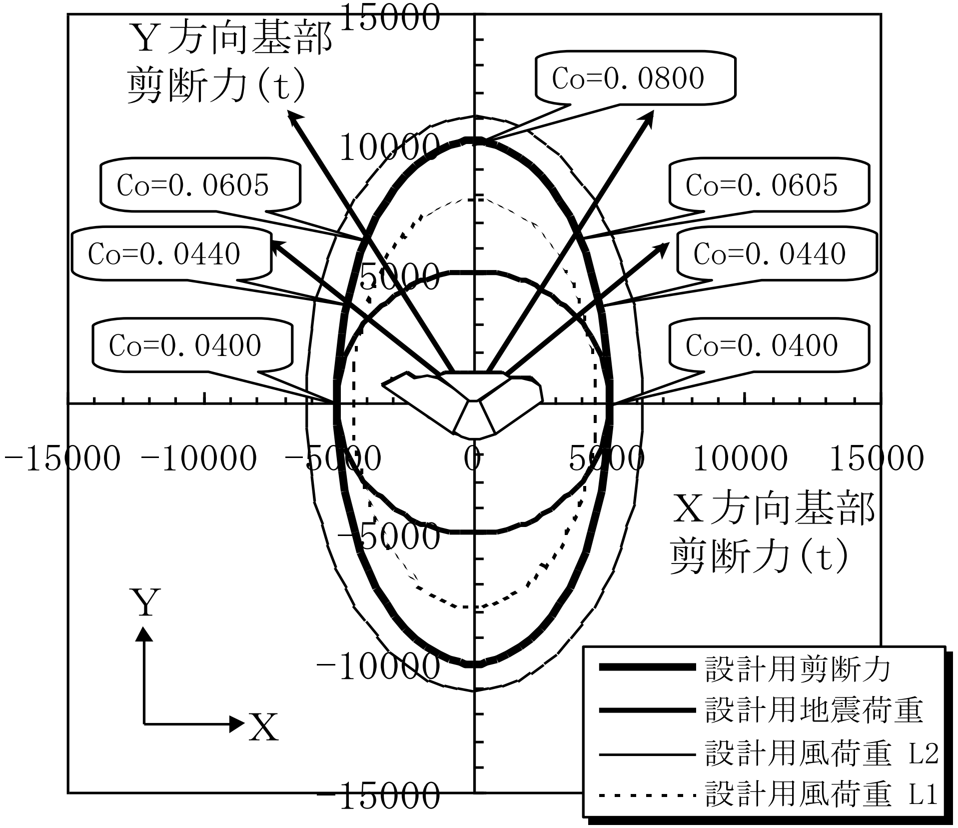
Design force for Y direction (t)



Design force for X direction (t)

Design base shear coefficient;

- Y direction :Co＝0. 080
- X direction :Co＝0. 040



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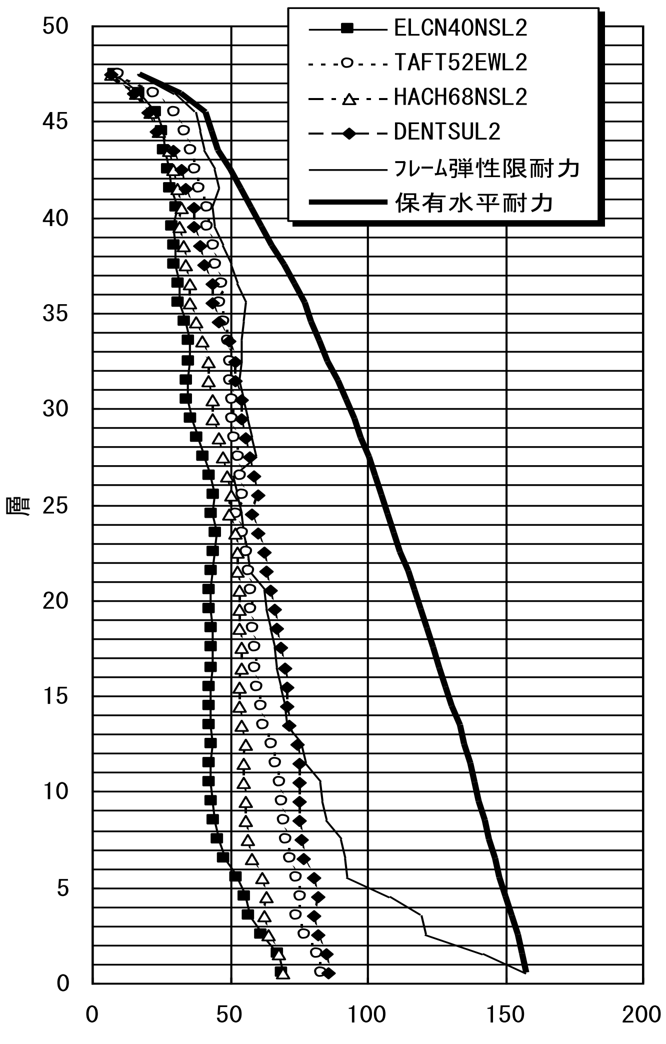
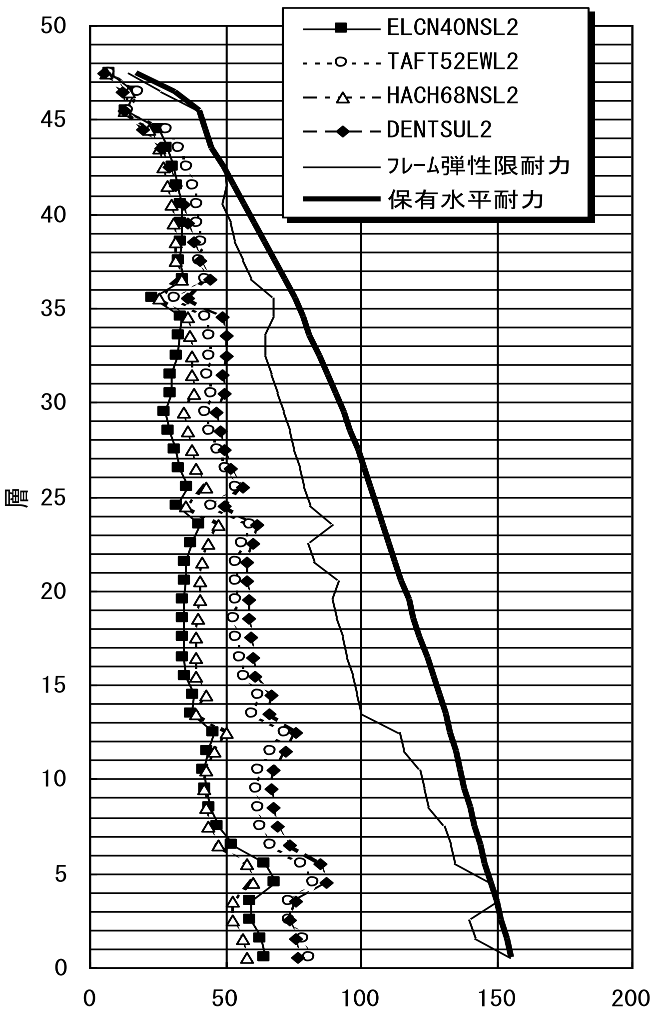
Maximum response shear force (ton)

X direction



Qi（×10³kN）

Y direction



Qi（×10³kN）

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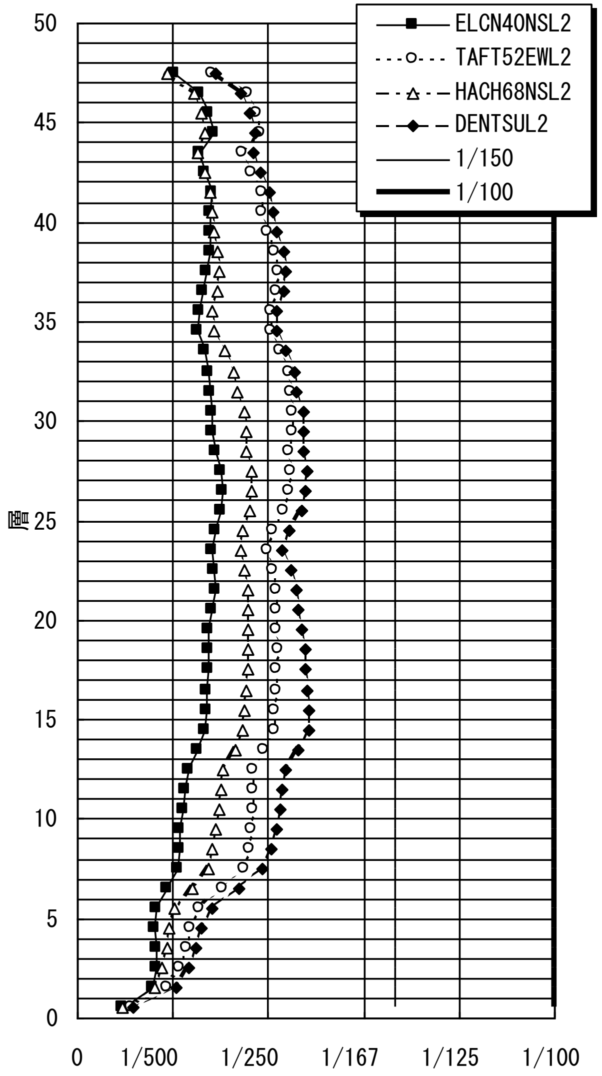
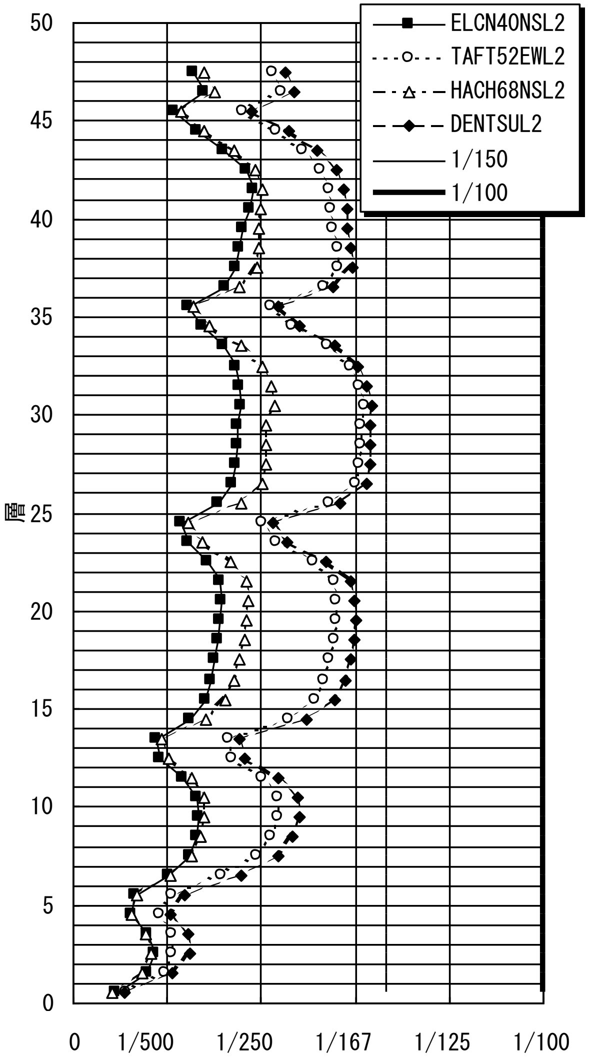
Maximum response story drift angle

X direction



Maximum response story drift angle

Y direction



Maximum response story drift angle

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Adopted technologies

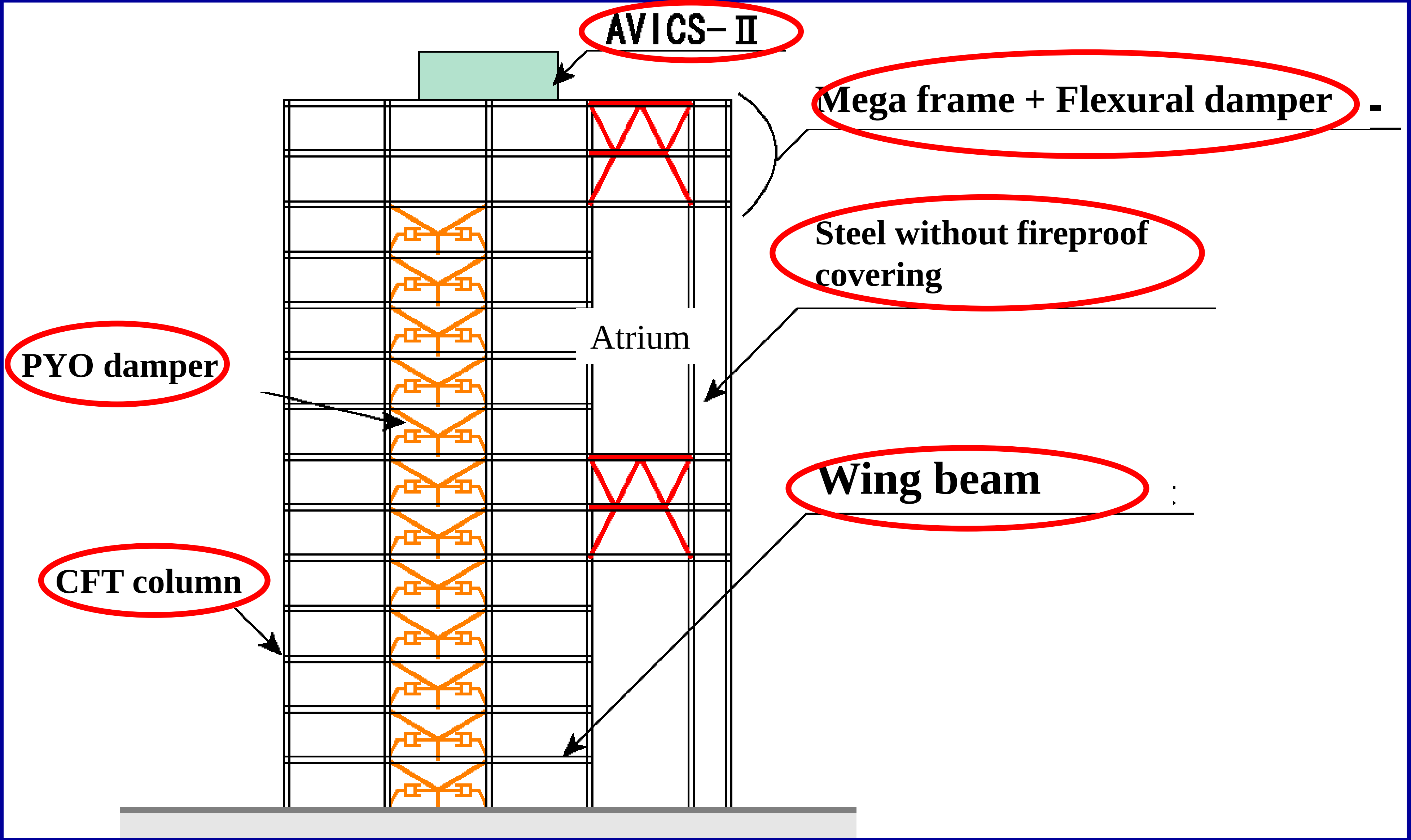
Vibration control technology

- Hybrid damper (PYO damper)
- Mega frame + Flexural damper
- Active tuned mass damper (AVICS-II)

Structural frame technology

- Wing beam（Beam with horizontal haunch）
- CFT column（High strength concrete）
- Steel member without fireproof covering

Adopted technologies



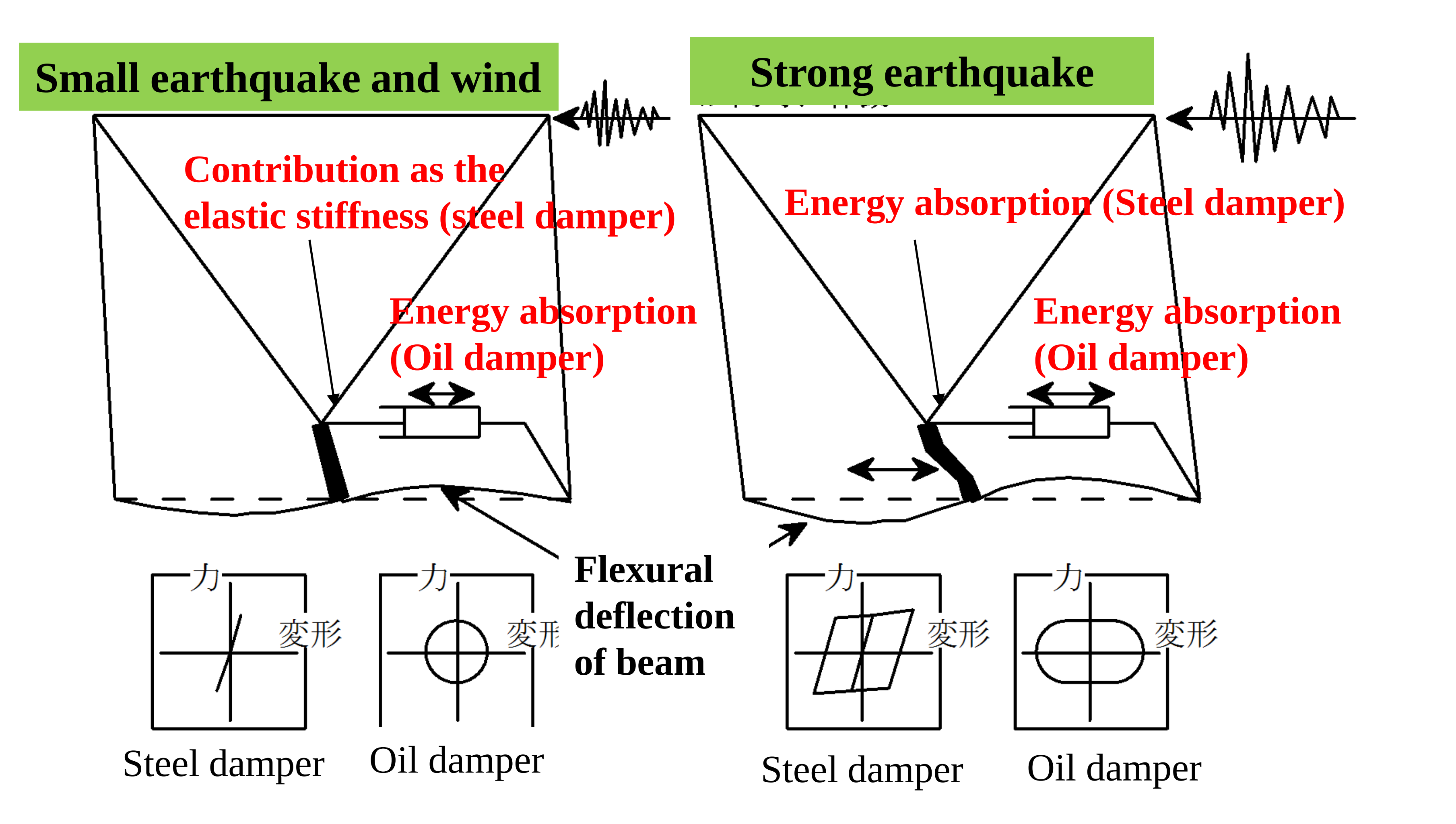
Vibration control technology

- **Hybrid damper (PYO damper)**
  Resistant static wind force and reduce earthquake force

- **Mega frame + Flexural damper**
  Increase flexural stiffness for Y direction and reduce dynamic wind force

- **Active tuned mass damper (AVICS-II)**
  Improve the habitability

Vibration control concept of PYO damper



Over all construction site (August 2000)

Setting of PYO damper

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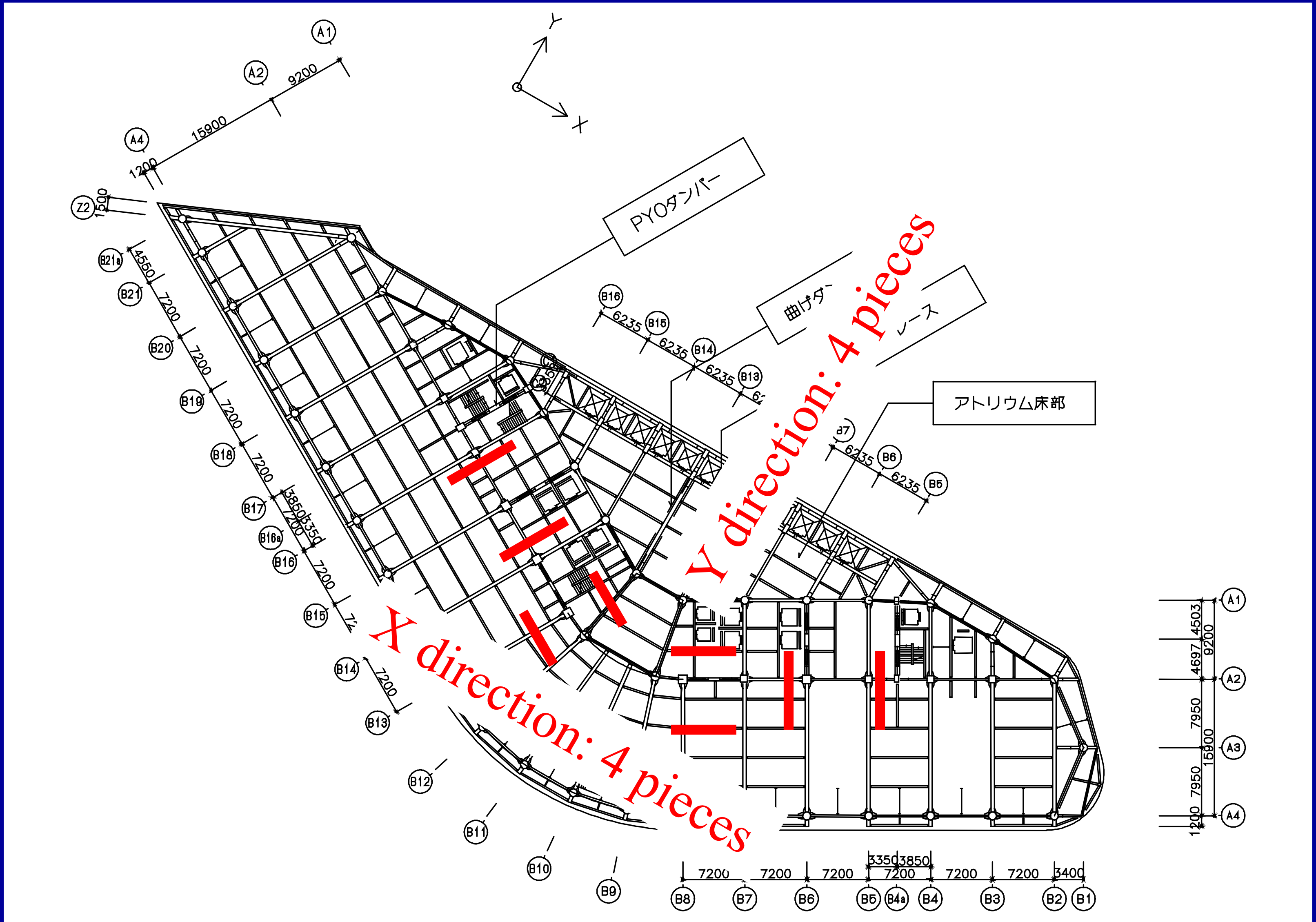
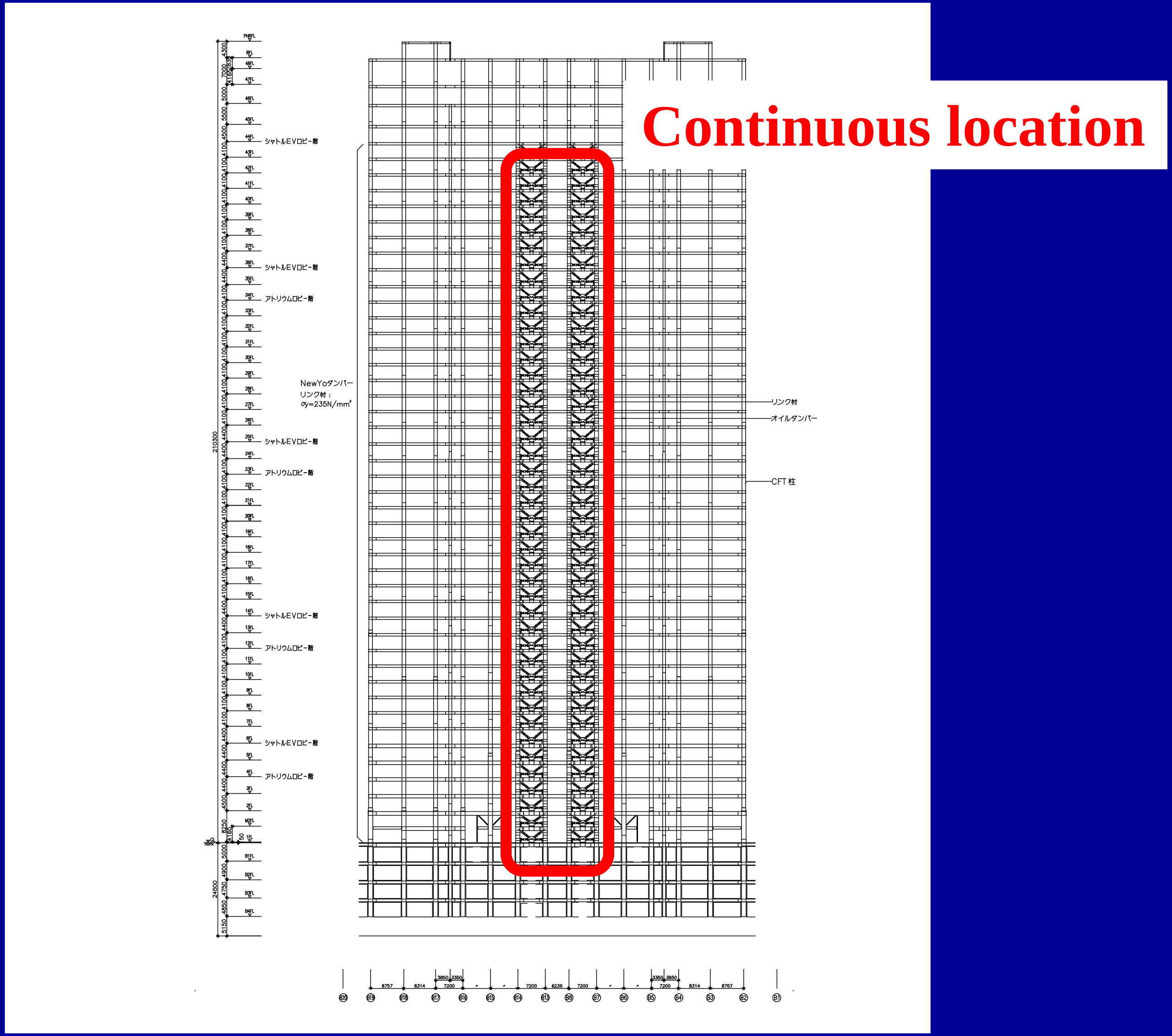
Location of PYO dampers



Location of PYO dampers



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Vibration control technology

- **Hybrid damper (PYO damper)**
  Resistant static wind force and reduce earthquake force

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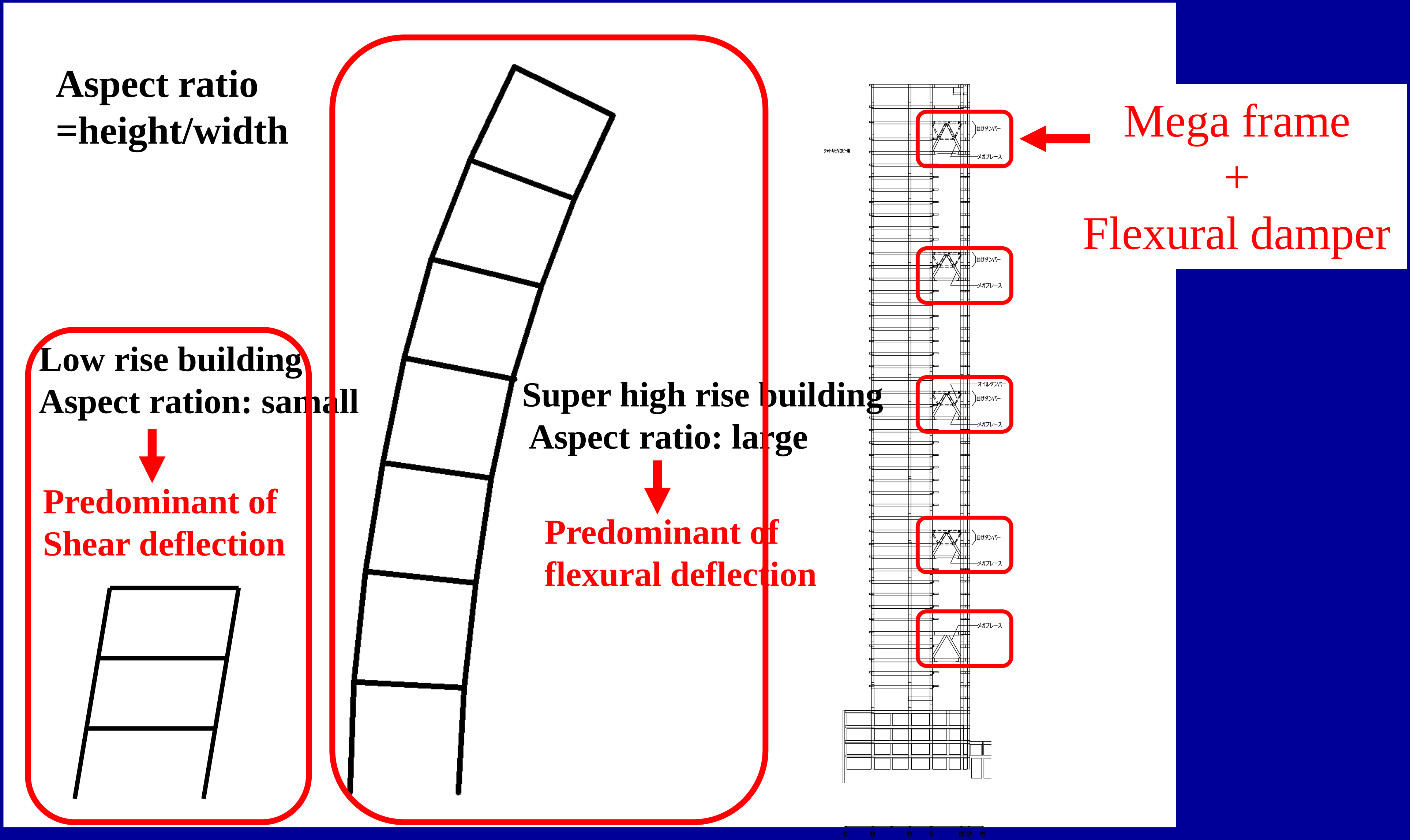
- **Active tuned mass damper (AVICS-II)**
  Improve the habitability

Mega frame + Flexural damper



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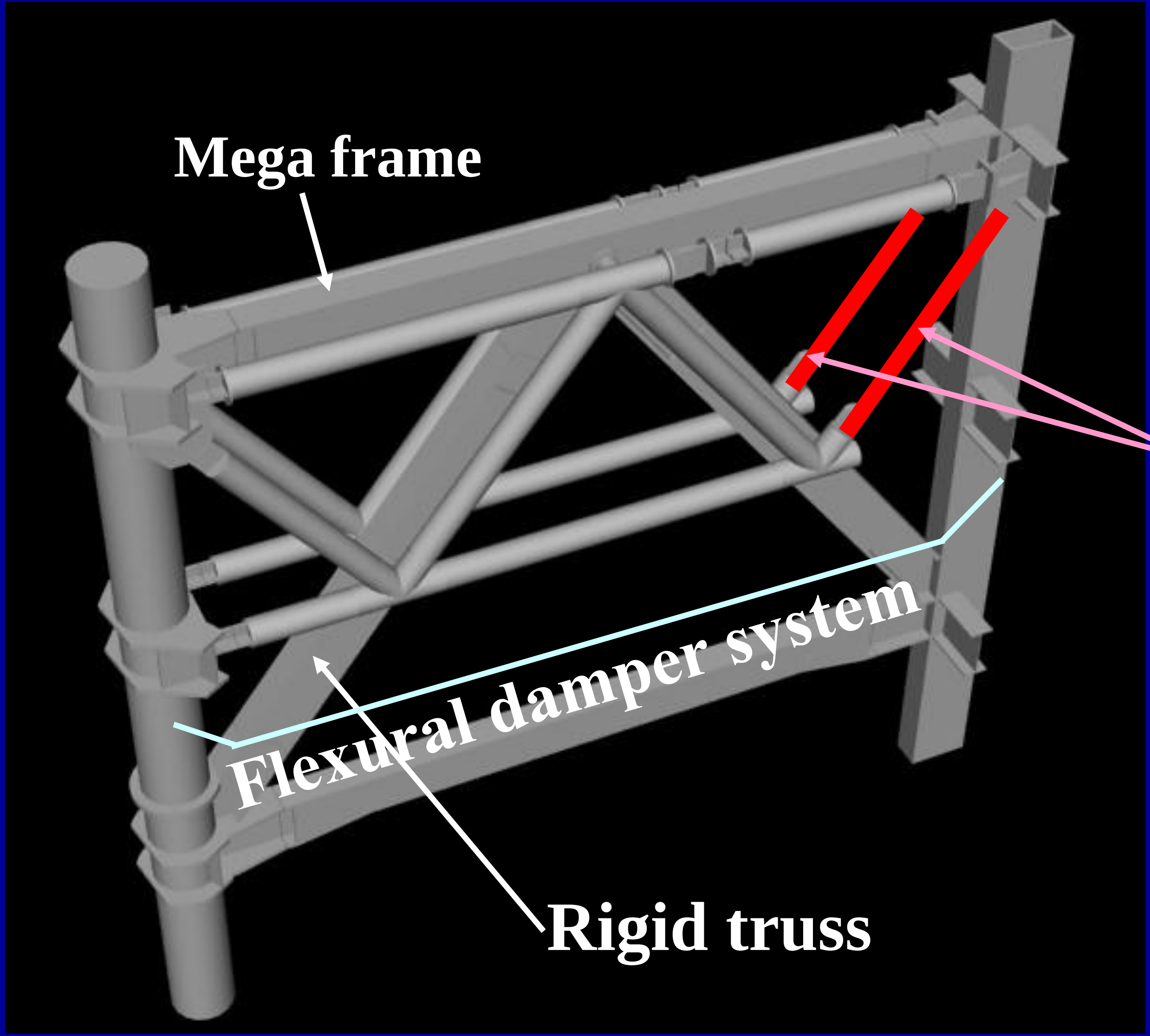
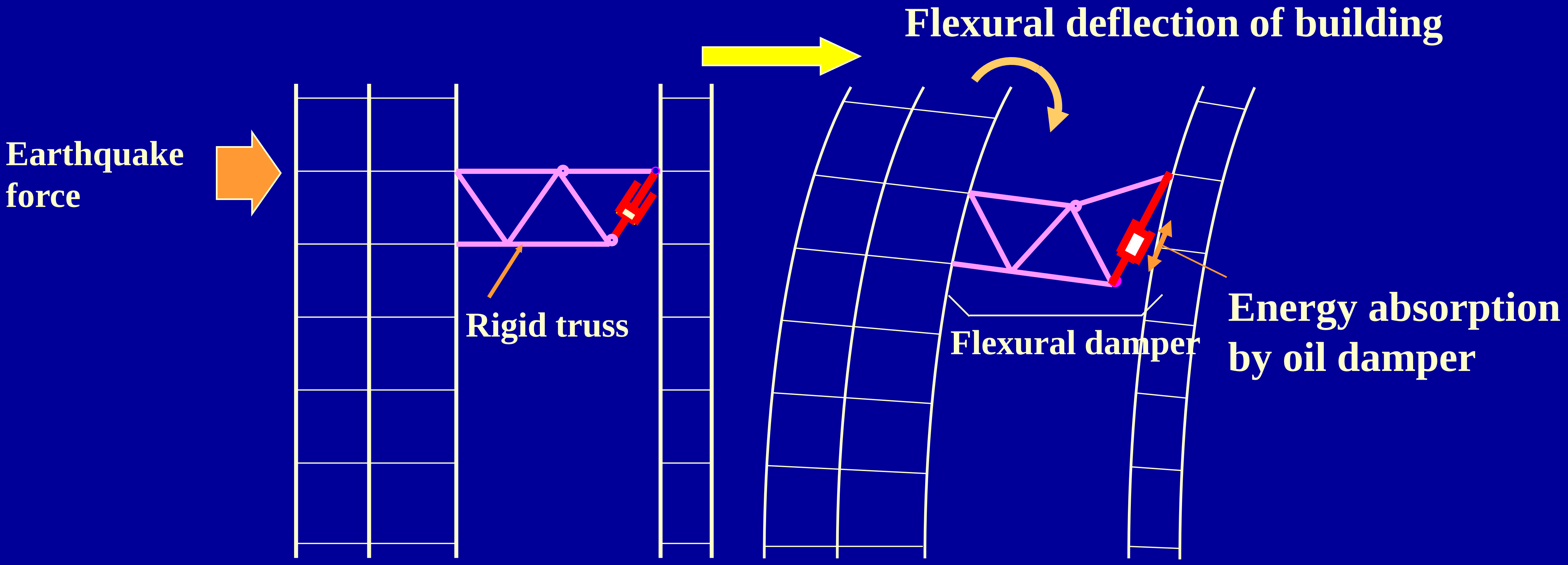
Composition of Mega frame & flexural damper



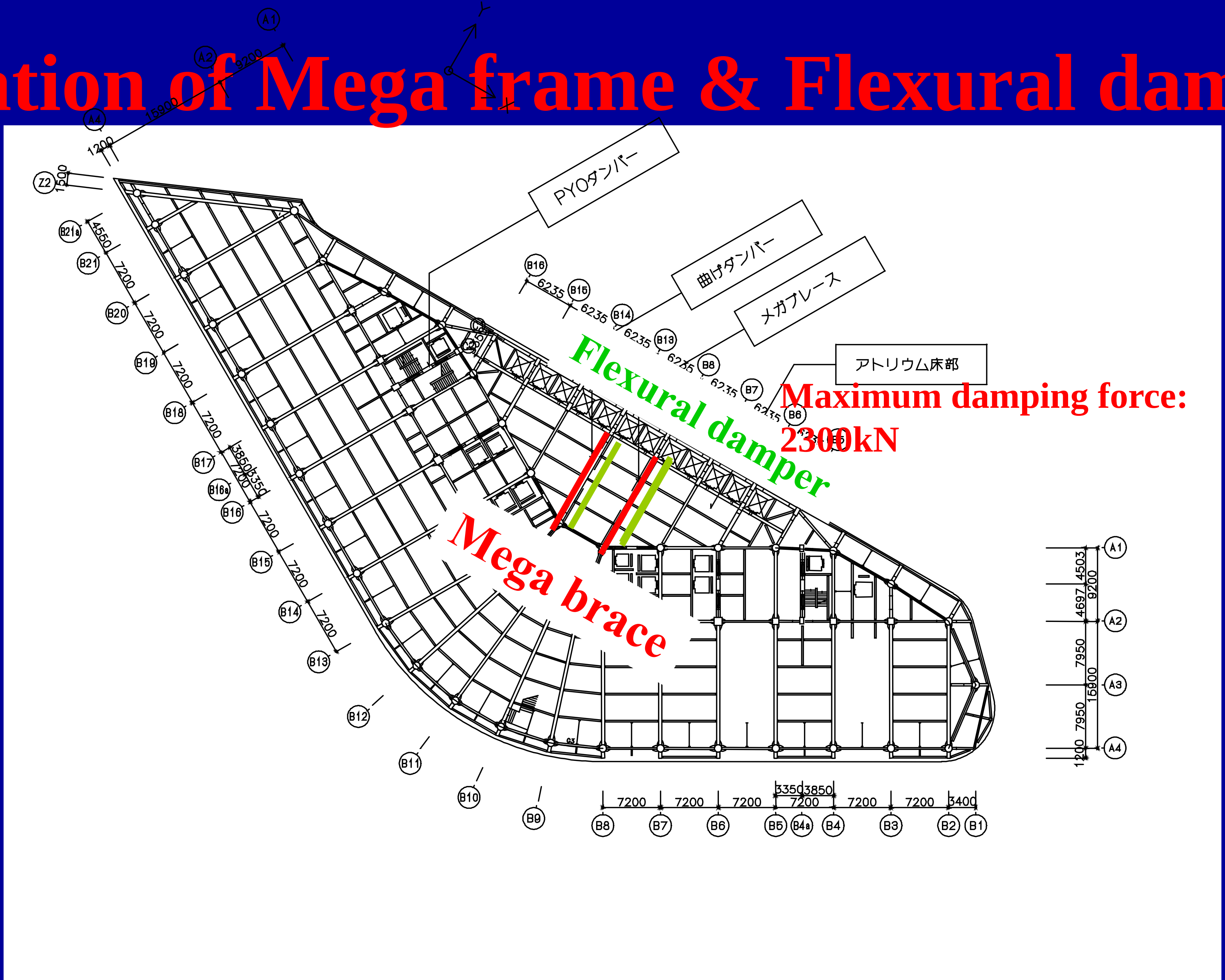
Function concept of flexural damper

Vibration control

Oil damper works due to the flexural deflection by strong earthquake and wind

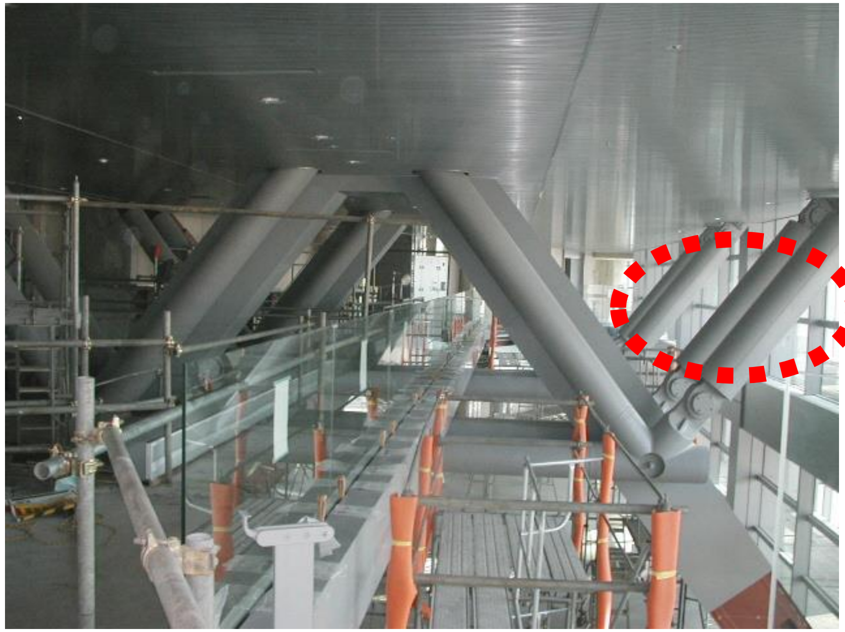


Location of Mega frame & Flexural damper



PYO damper

Mega frame & Flexural damper



Oil damper

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Mega frame & Flexural damper

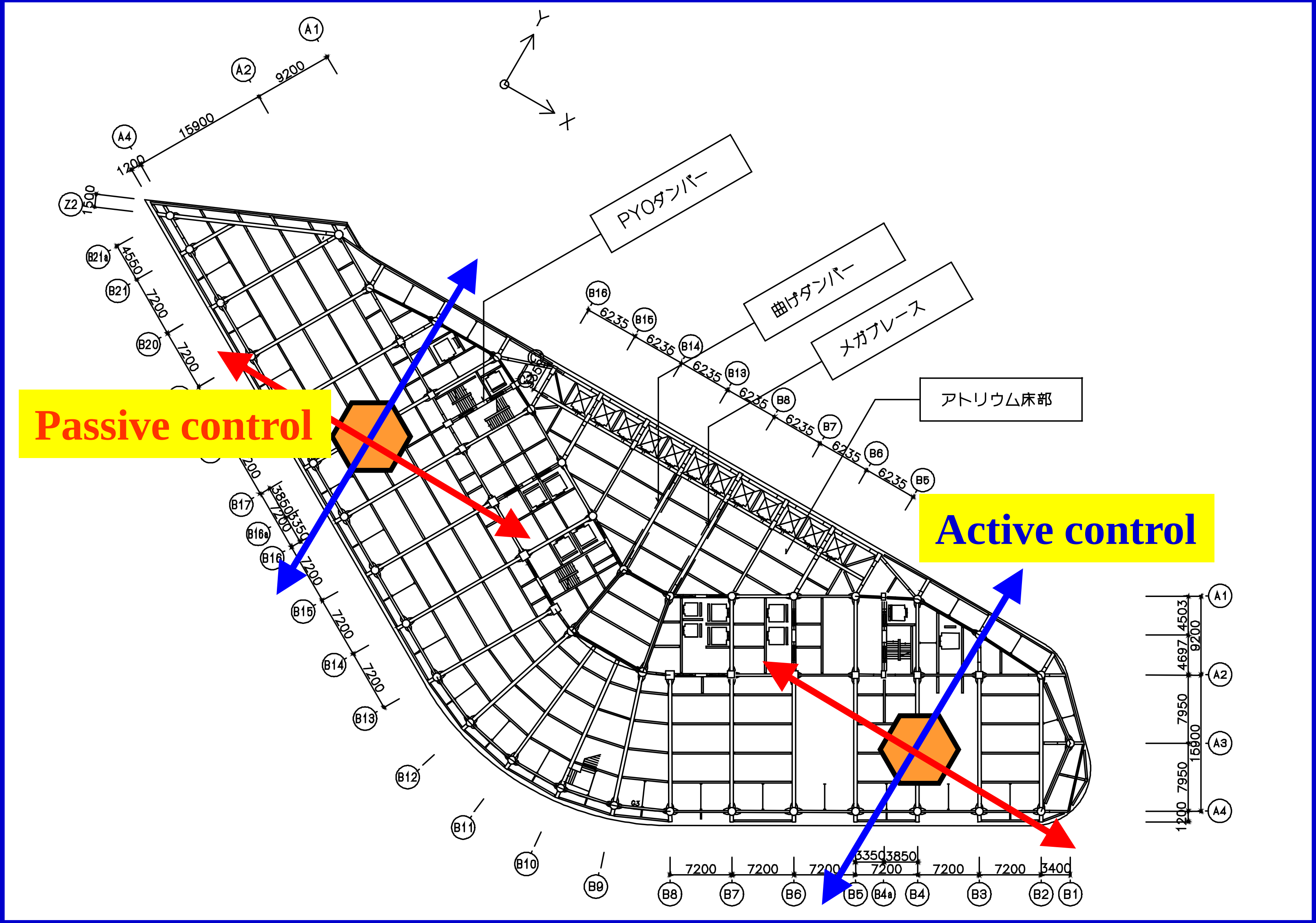
Vibration control technology

- **Hybrid damper (PYO damper)**
  Resistant static wind force and reduce earthquake force

- **Mega frame + Flexural damper**
  Increase flexural stiffness for Y direction and reduce dynamic wind force

- **Active tuned mass damper (AVICS-II)**
  Improve the habitability

Tuned mass damper (AVICS-II)



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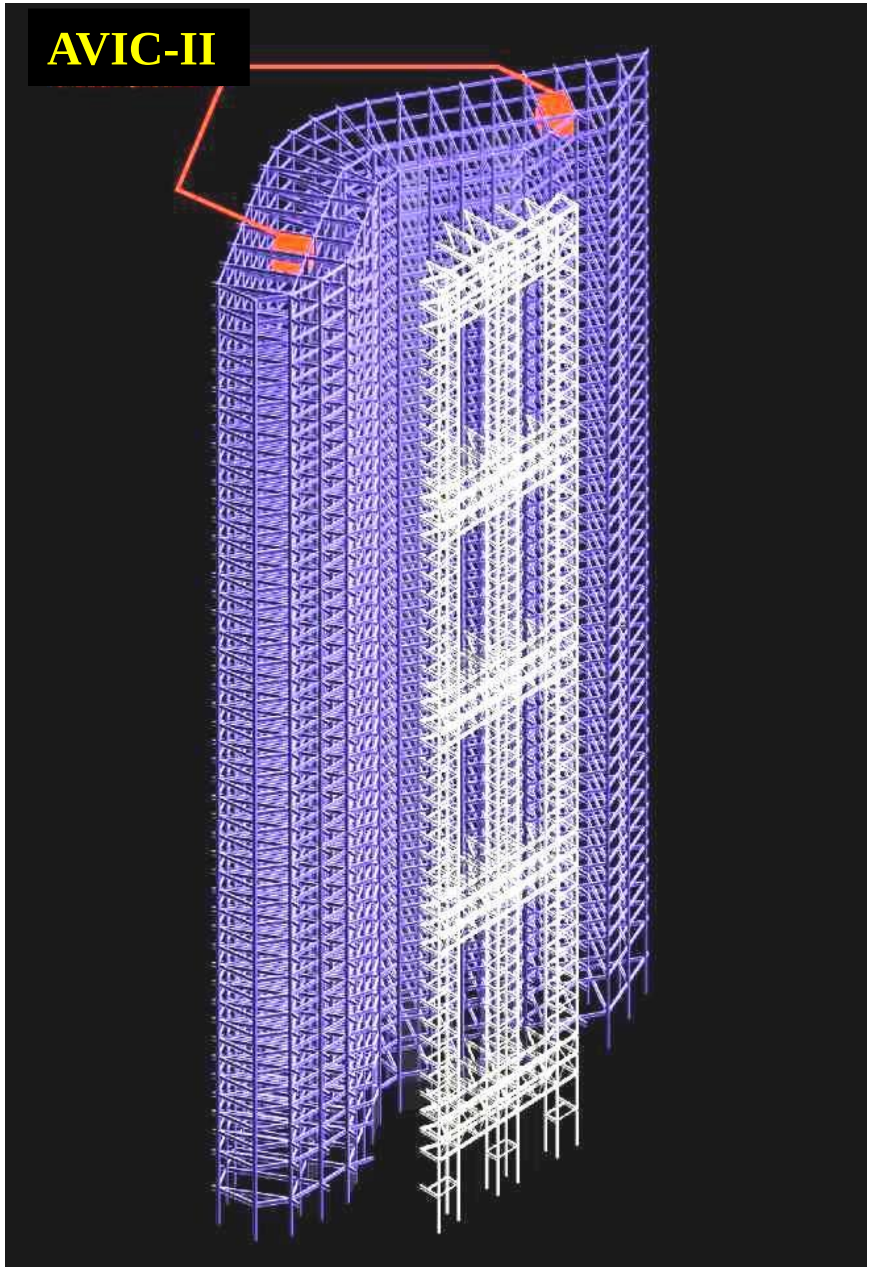

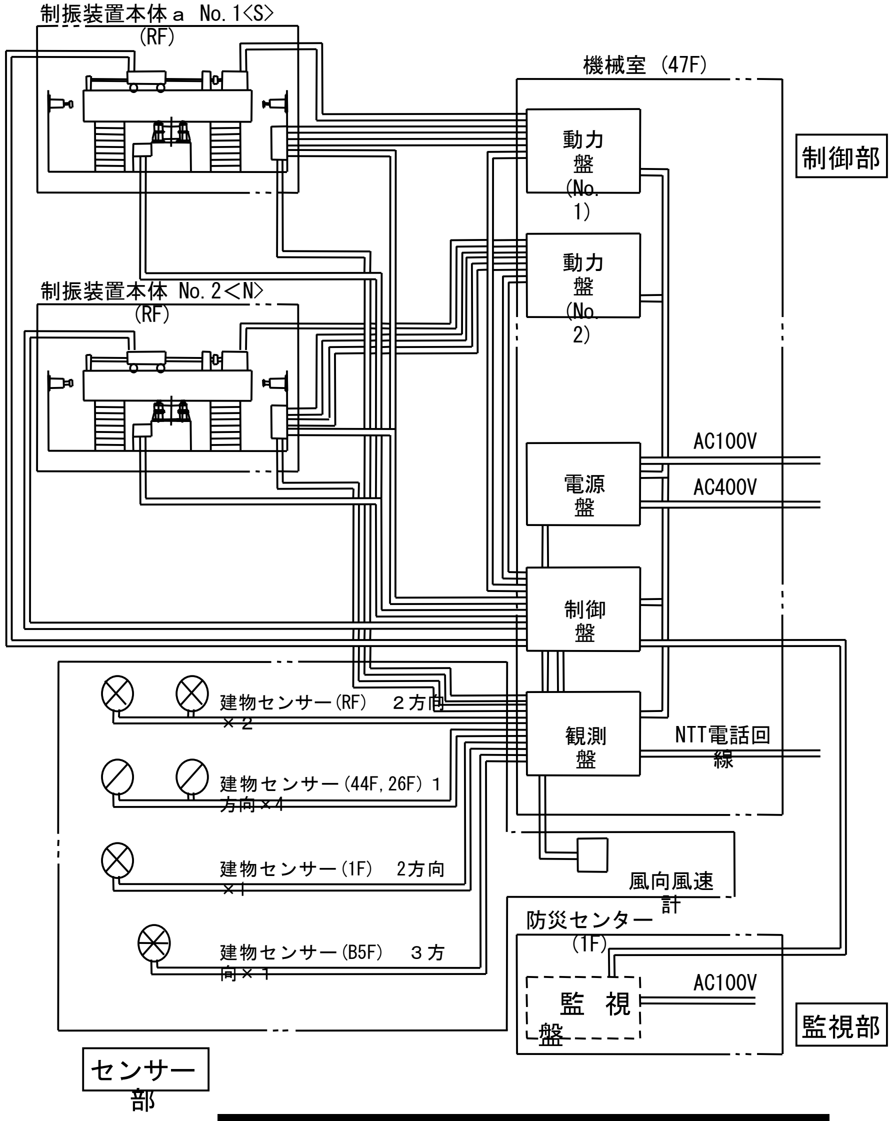

Vibration control system

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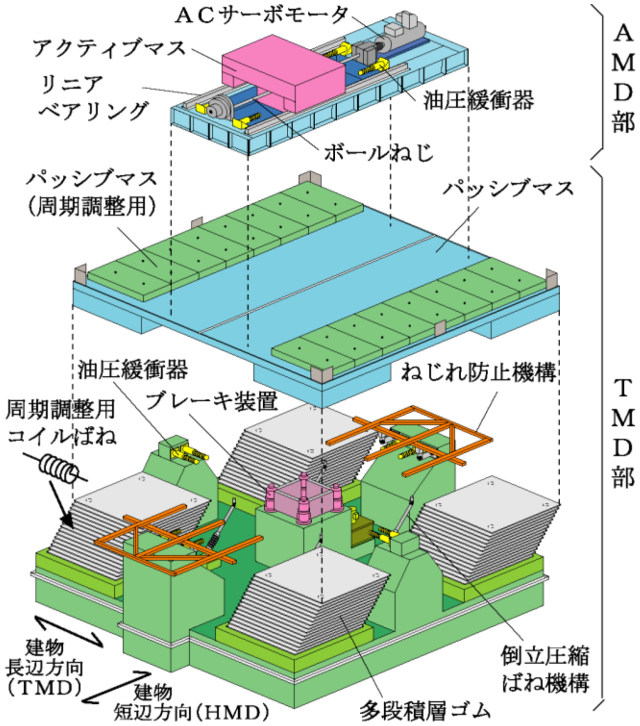
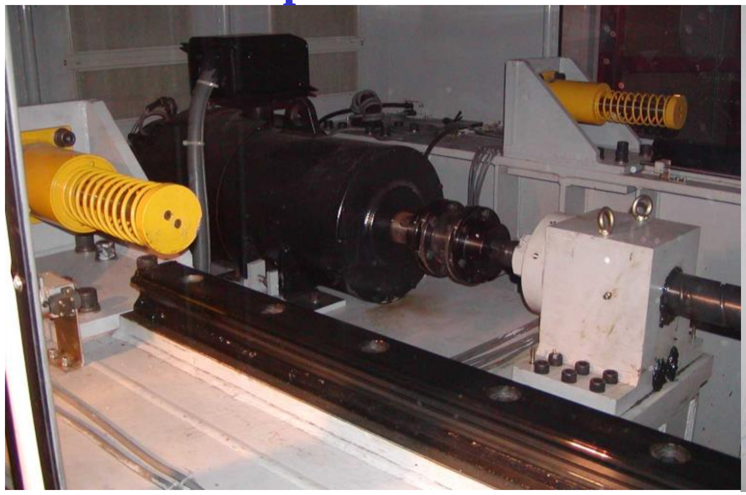
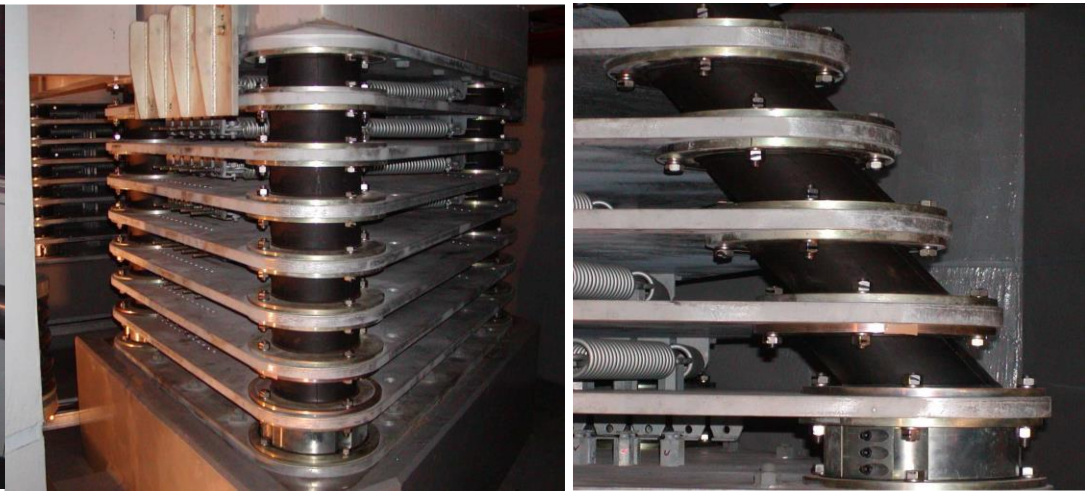


Composition of AVIC-II

Over all view of ACICS-II



AC servo motor



Multi layer rubber bearings

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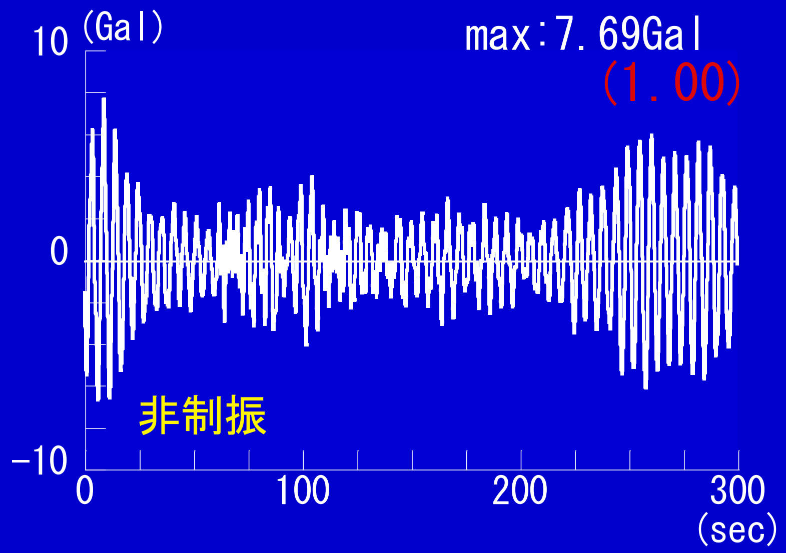
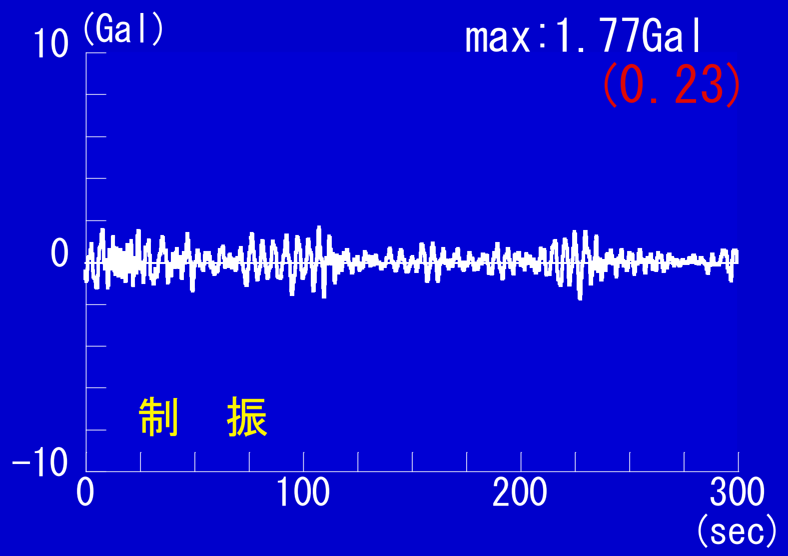
Vibration control effect against Typhoon No.21 (2002.11)

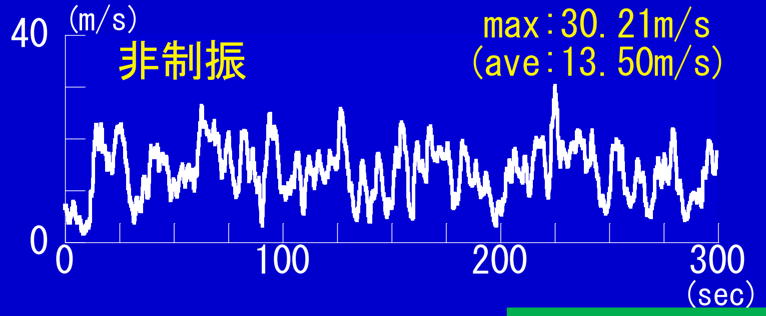
Without control

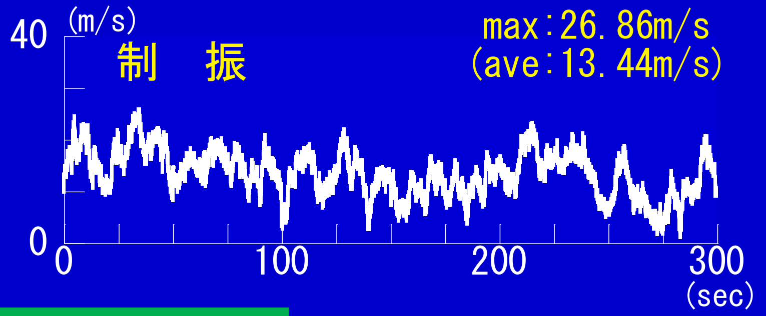


With control



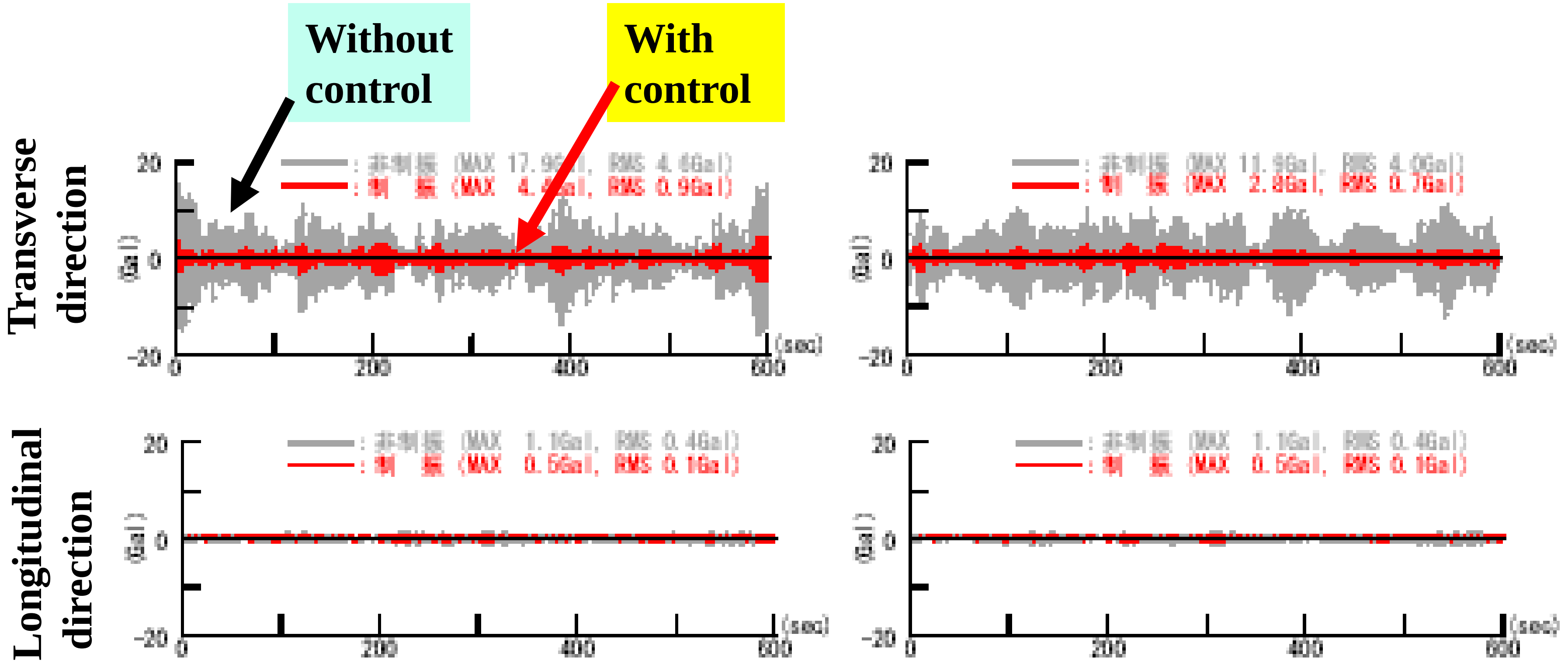
Vibration acceleration at roof level

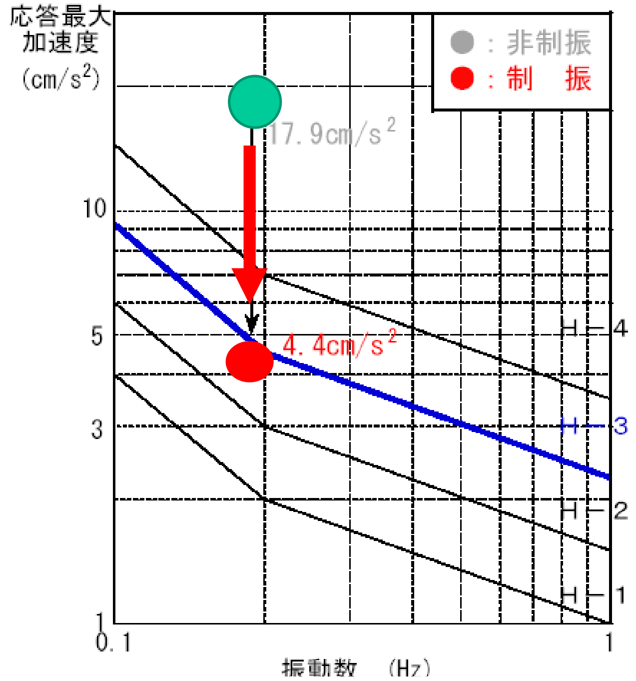




Wind force(Velocity)

Vibration control effect against Typhoon No.10 (2003.10.1)





Transverse direction

Habitability evaluation

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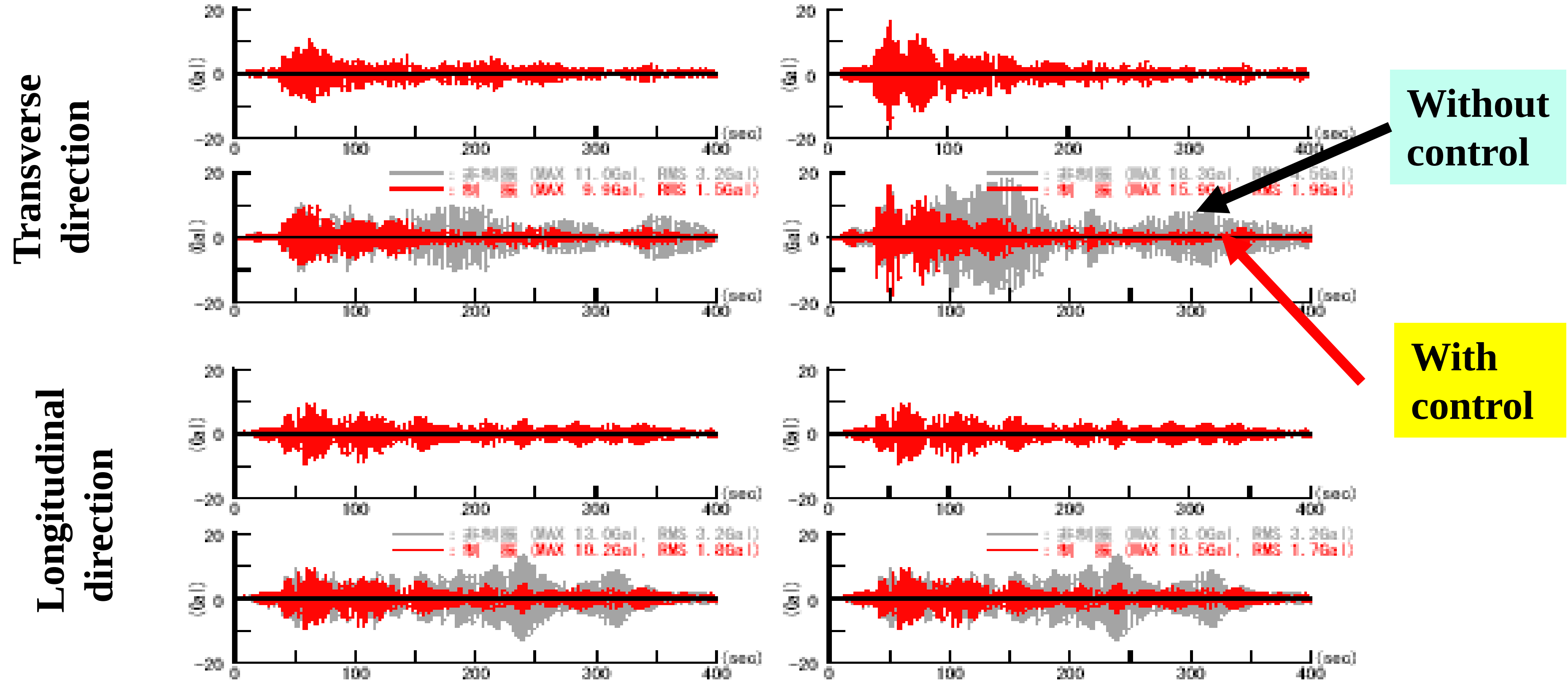
Vibration control effect against Sanriku Minami EQ (2003.5.26)



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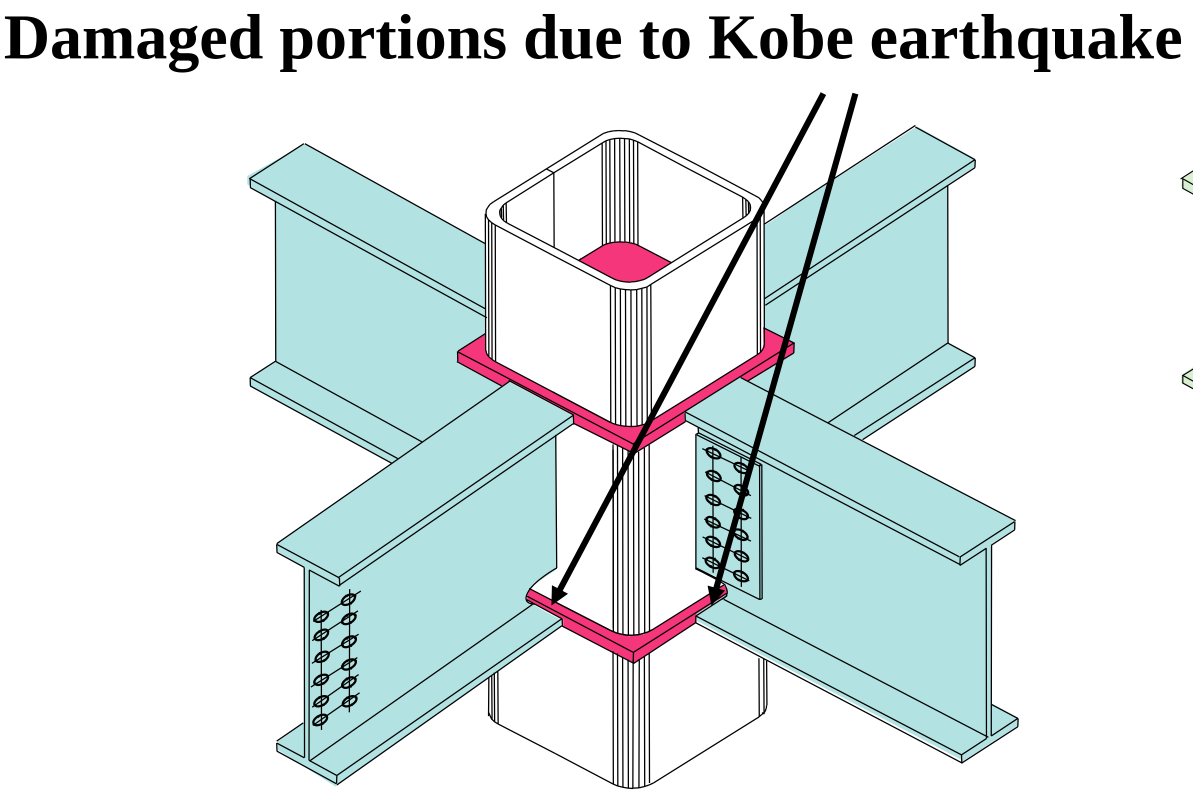
Structural frame technology

- **Wing beam（Beam with horizontal haunch）**
  Reduce the weight of steel and improve the plastic rotational capacity of beam

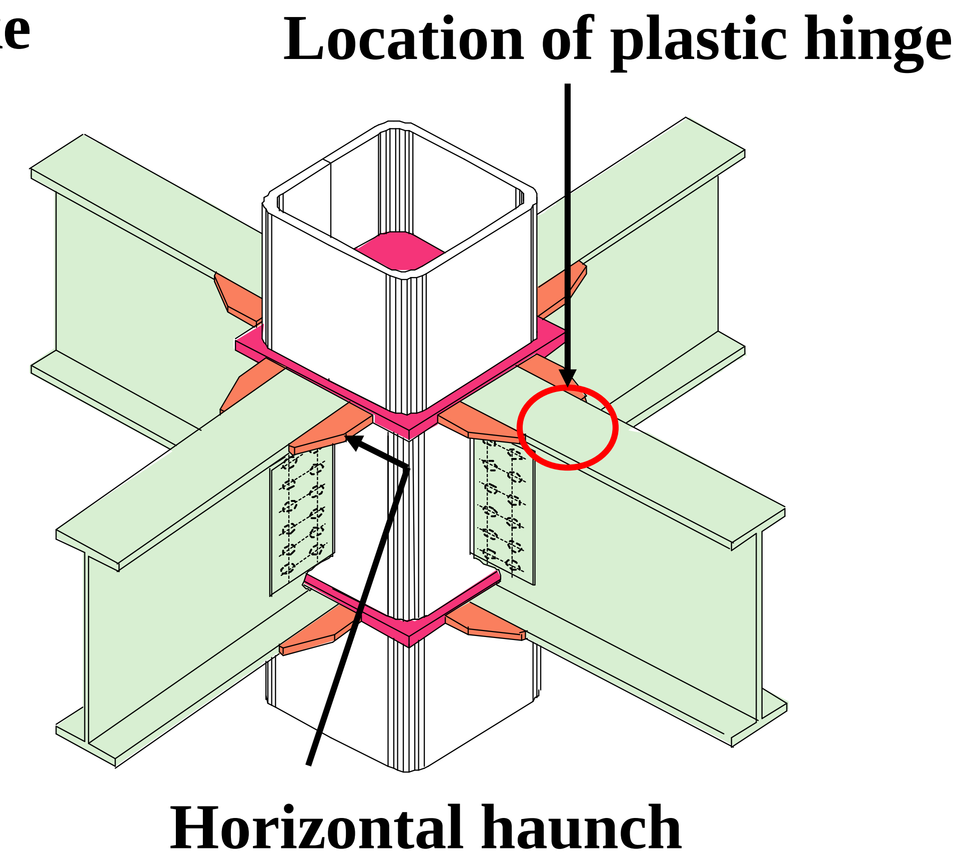
- **CFT column（High strength concrete）**
  Reduce the weight of steel member and reduce the fireproof covering

- **Steel member without fireproof covering**
  Exposed steel finishing without fireproof covering

Wing beam



Conventional beam column joint



Wing beam

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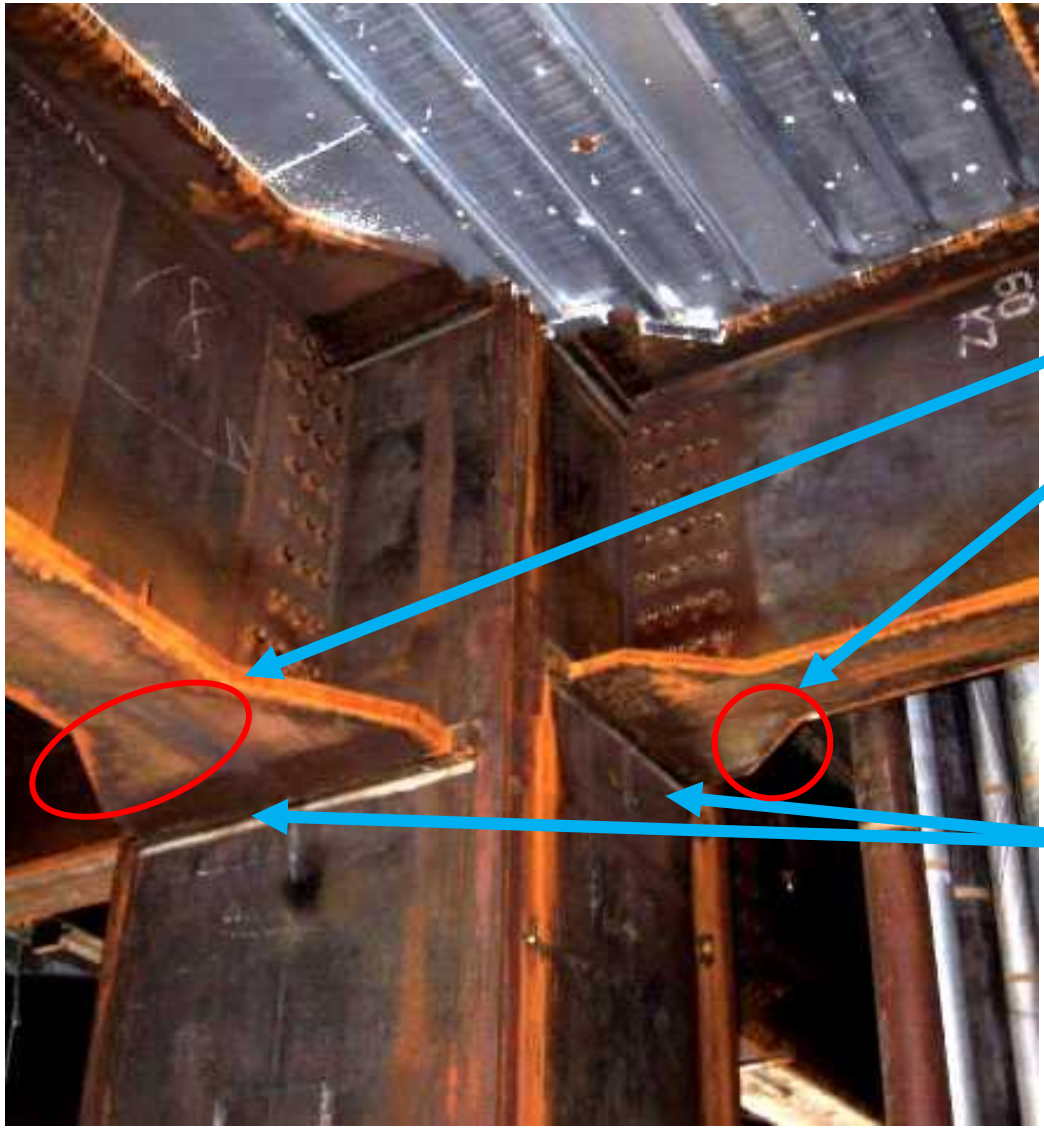
Construction of wing beam



Location of plastic hinges

Horizontal haunch

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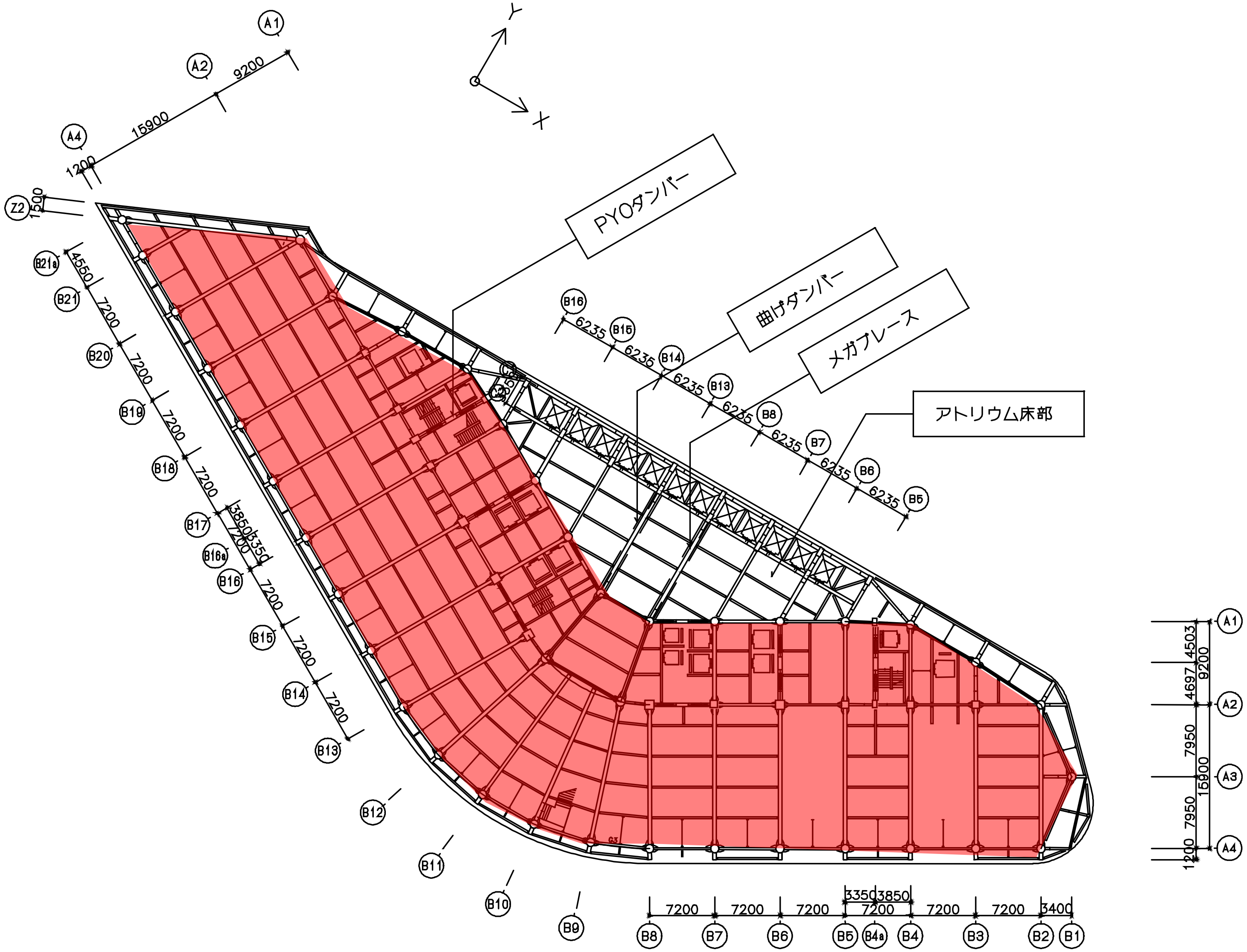
Used zone by wing beam



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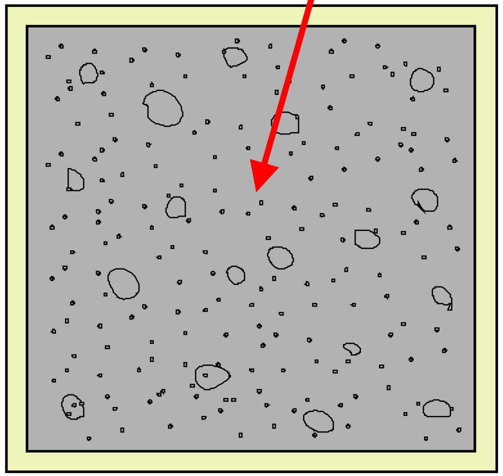
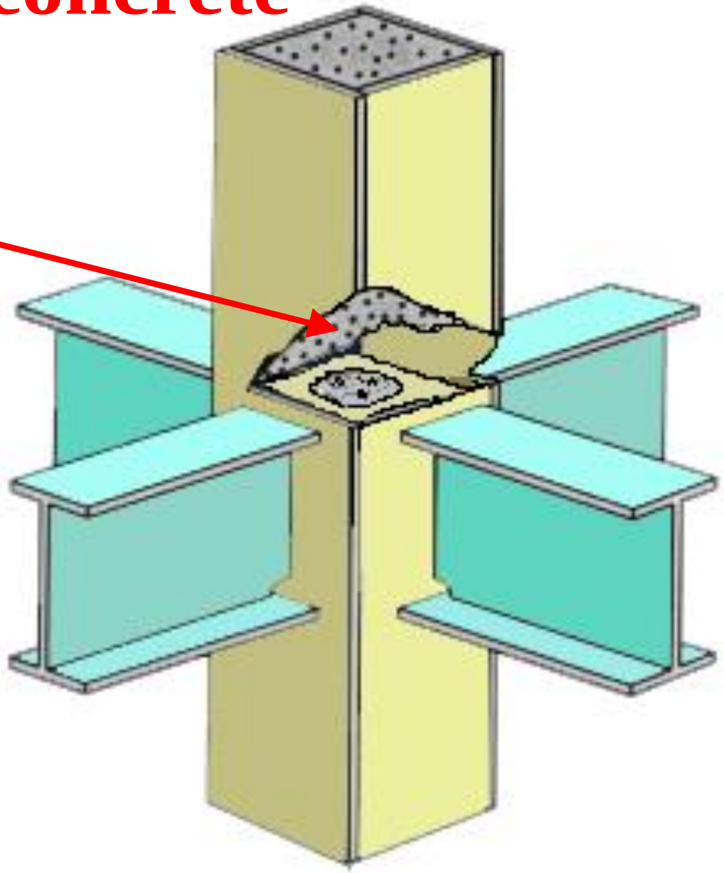
CFT column

High strength and high fluidity concrete
(Fc=50 MPa, and Fc=80 Mpa)





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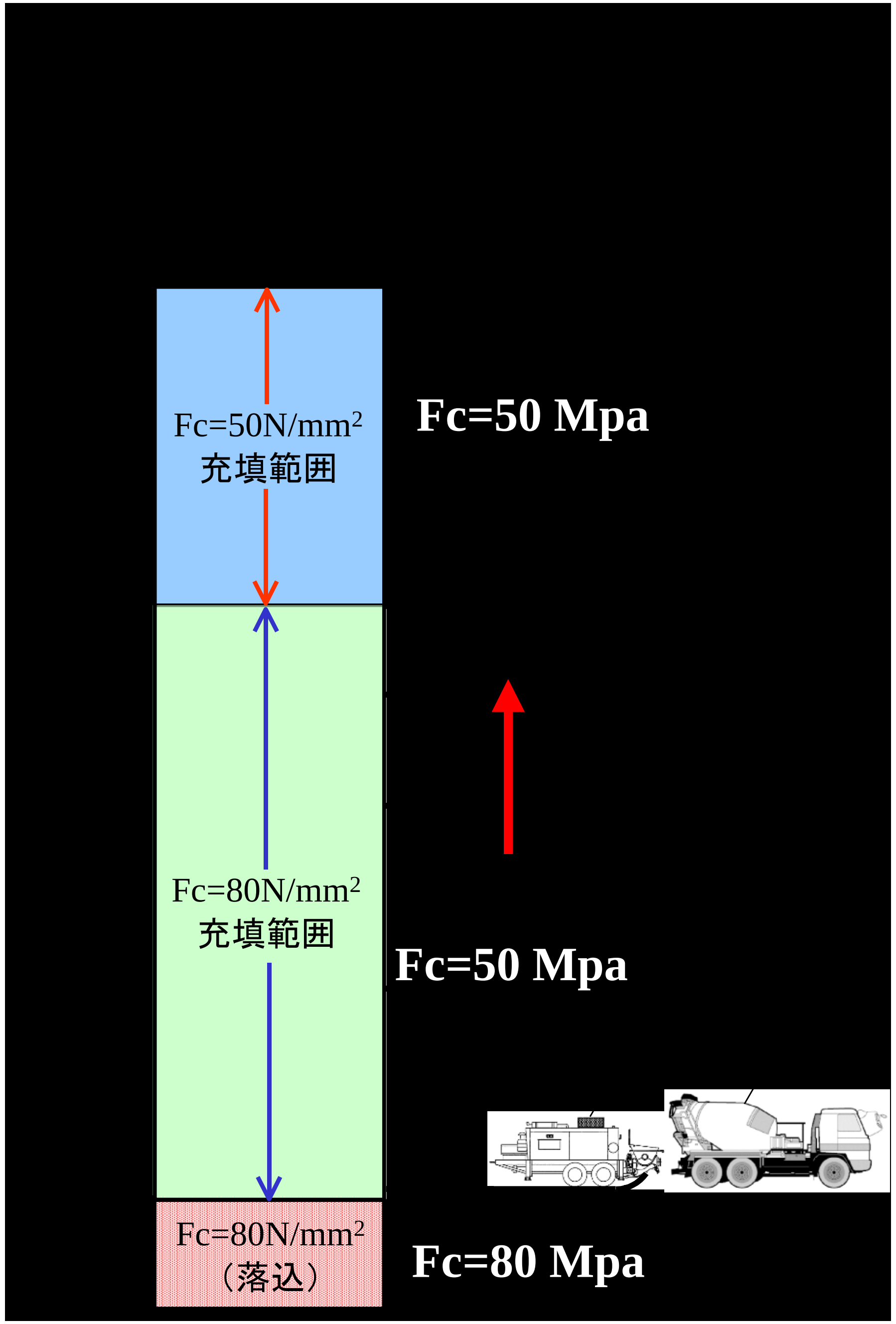
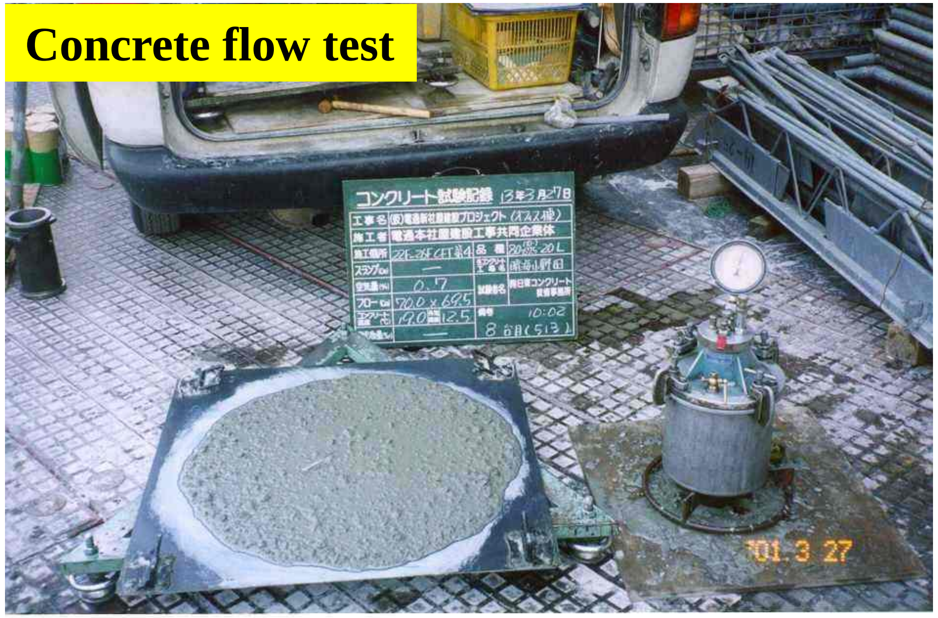
CFT Column





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Structural frame technology

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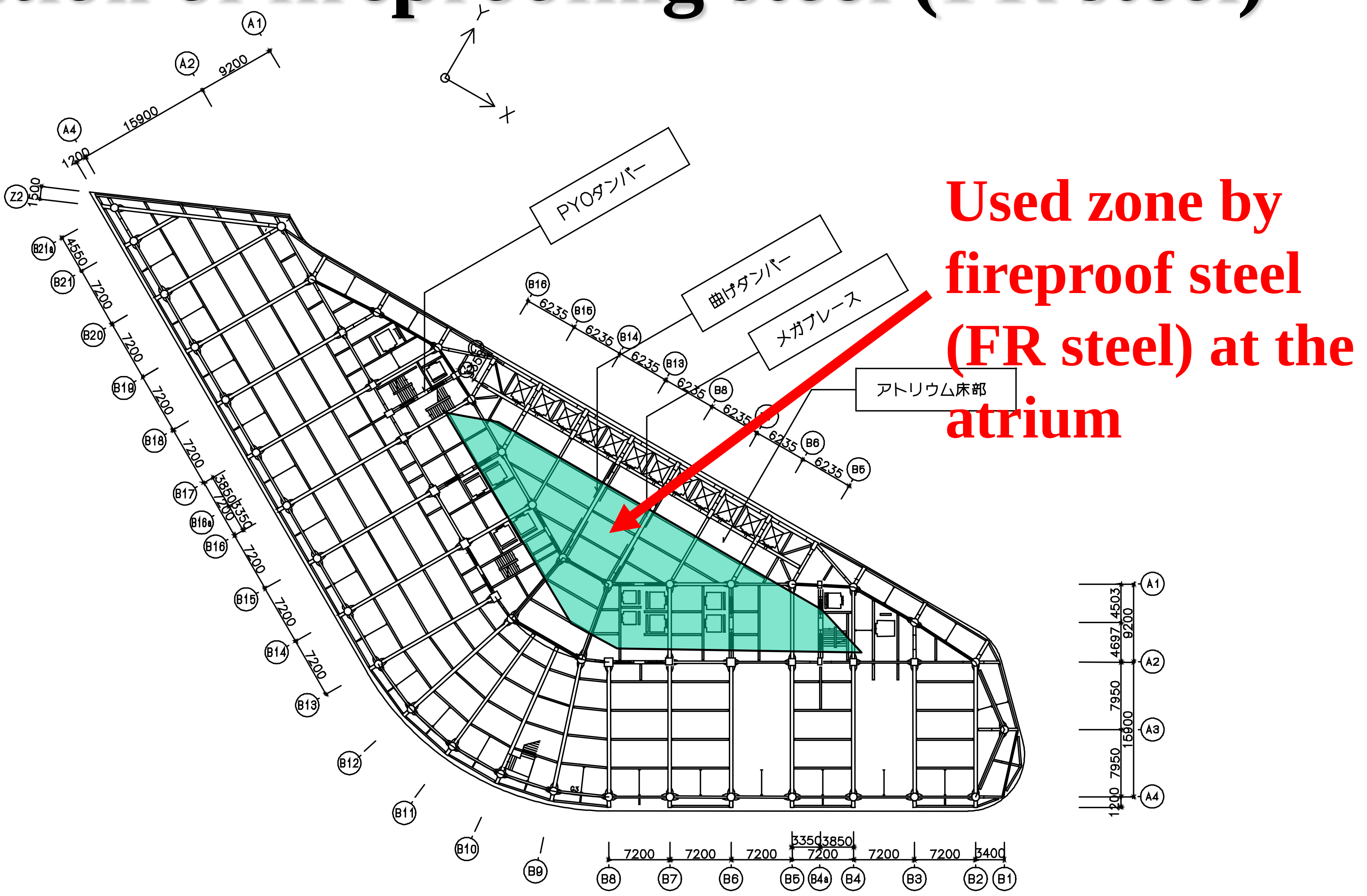
Property of fire proofing steel (FR steel)

(Nominal Yielding Strength)x2/3 is sustained at the high temperature:

Conventional steel	: 350 ℃
Fire proofing steel (FR steel)	: 600℃

Location of fireproofing steel (FR steel)



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Completion : November 1st, 2002

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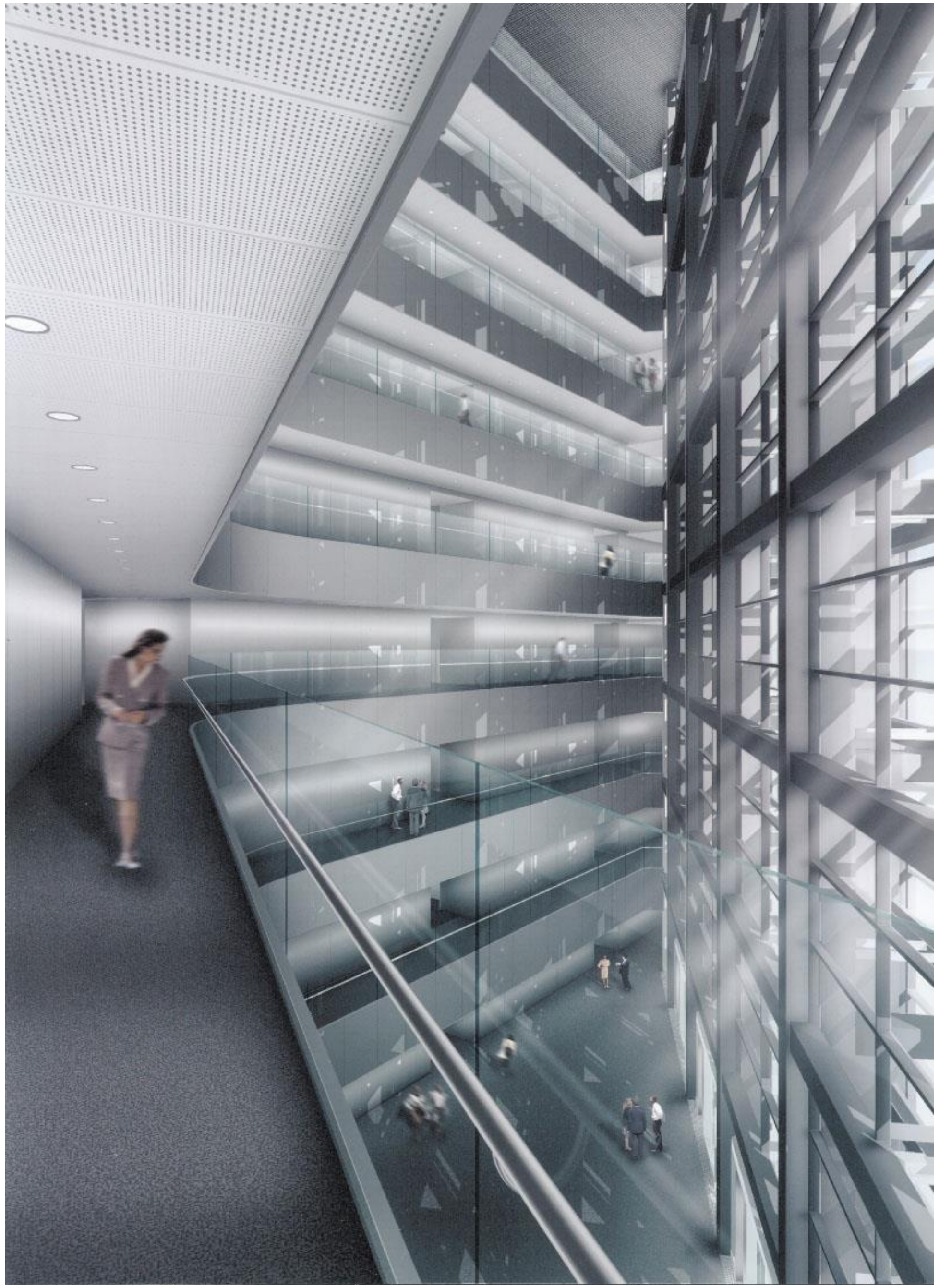
Completion :
November 1st, 2002



Atrium from the sky corridor

Completion :
November 1st, 2002

station lobby

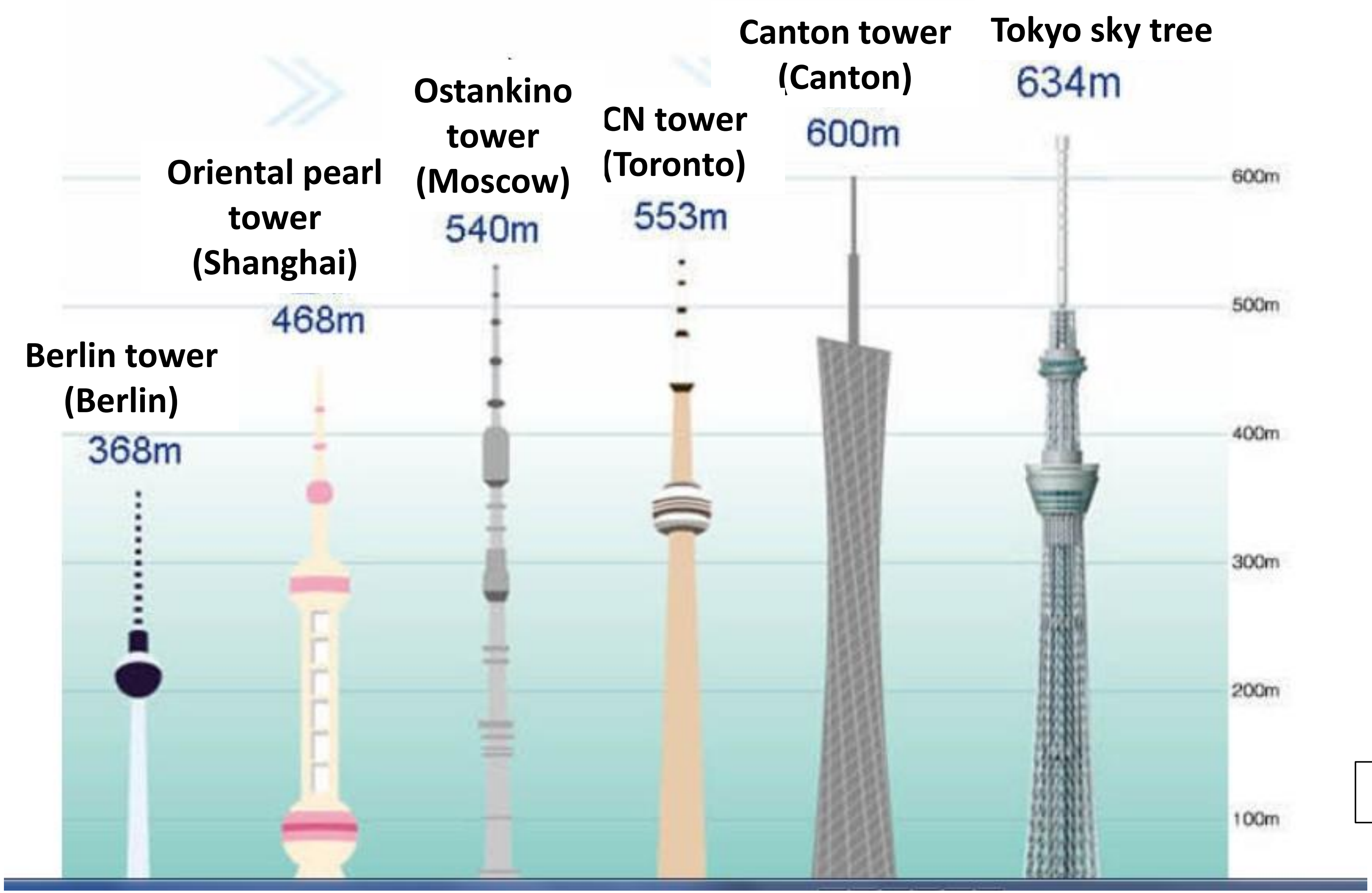
(6,14,25,36F)

Tokyo Skytree

The world's tallest free –standing broad casting tower with a height of 634m

OCAJI

High rise towers in the world



Obayashi HP

Tokyo Skytree

■Owner：Tobu Railway Co.

■Structural Design: NikkenSekkei Co.

■Construction：Obayashi Co.

■Opening: May.2012

by **SEKI**

Photo: M.Seki

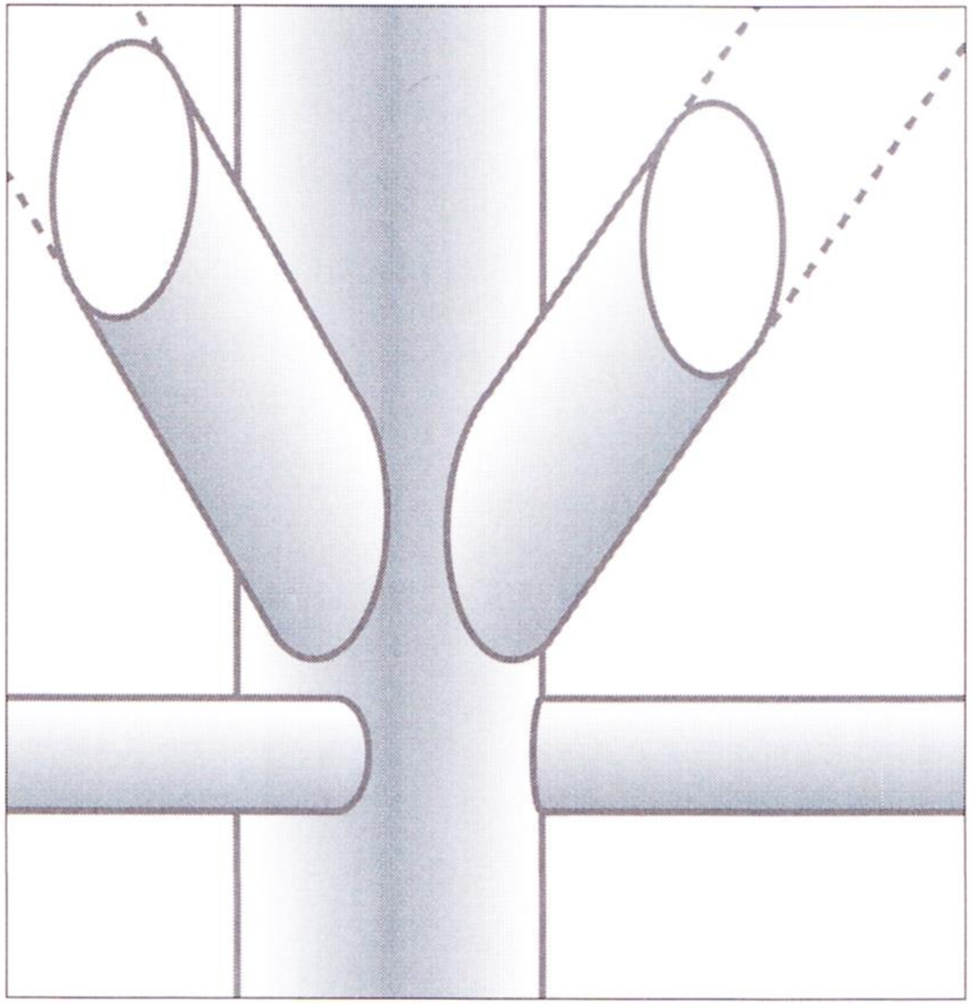
Photo: M.Seki

Feature 4 Turuss

1. A truss structure with diagonal members

2. Circular high strength steel pipe

3. Pipes are simply welded together via branch joints.



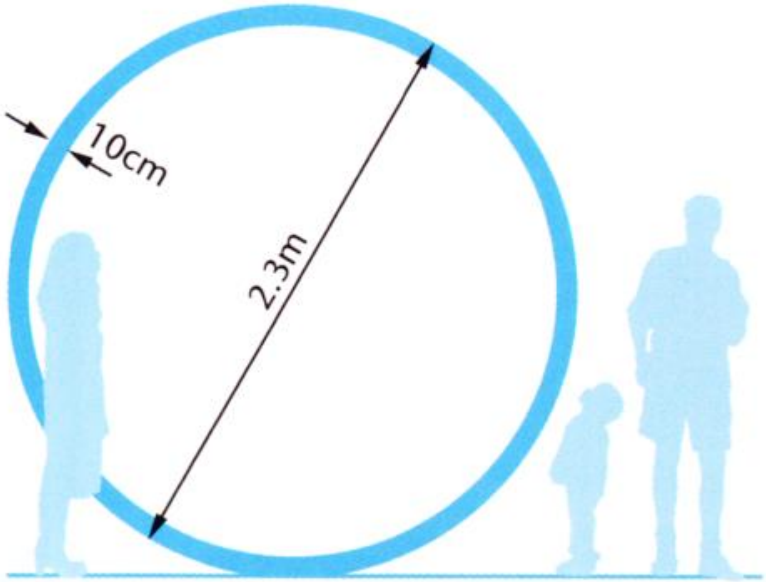
OCAJI

Feature 9 Steel frame

1. High strength circular steel pipe of large cross section were used.

2. The maximum unit weight is 30 tons for transportation.

3. The thickest steel column at bottom is 2.3 m and 10 cm thickness.



OCAJI

Feature 5 Foundation

1. The original diaphragm wall was used for the pile foundation.

2. This is used as a retaining wall to prevent sediment collapse during the construction and cut-off wall in area where ground water is predicted to occur, etc.

OCAJI

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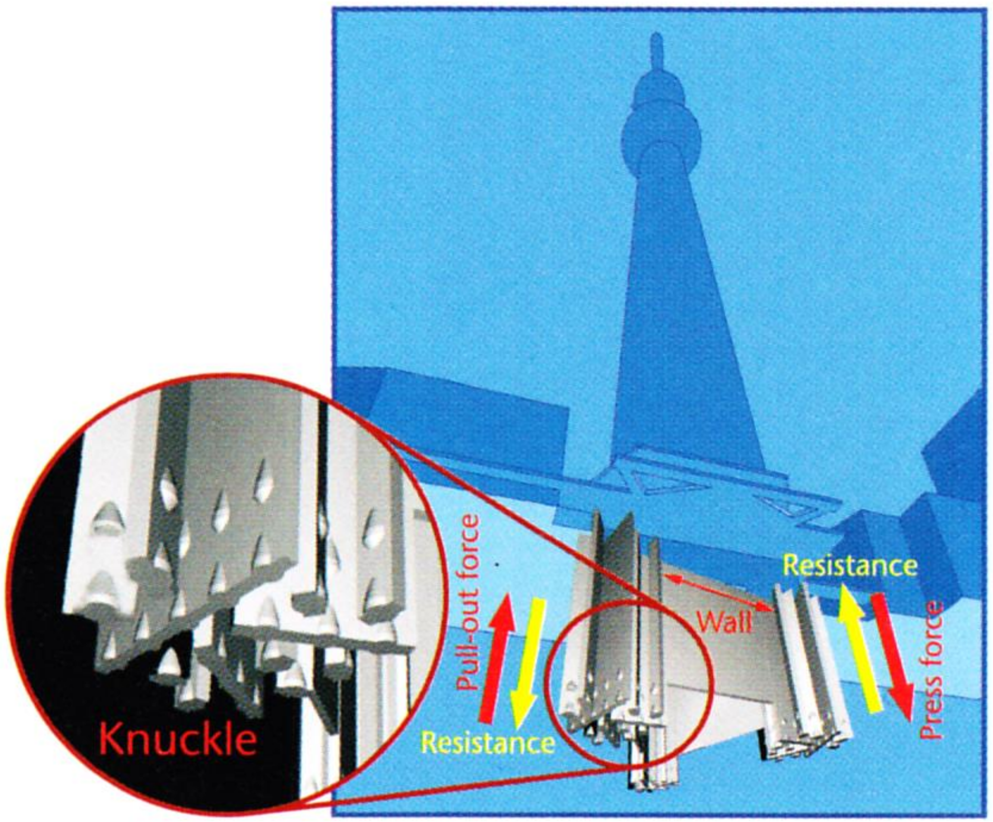
Feature 6 Knucle wall

1. Knuckle walls are wall- type piles to which projection are attached like knuckles.

2. Knuckle helps fix the pile in the ground and greatly increases load bearing capacity.

3. Wall –type piles have great stiffness and are highly resistant to seismic horizontal forces.



OCAJI

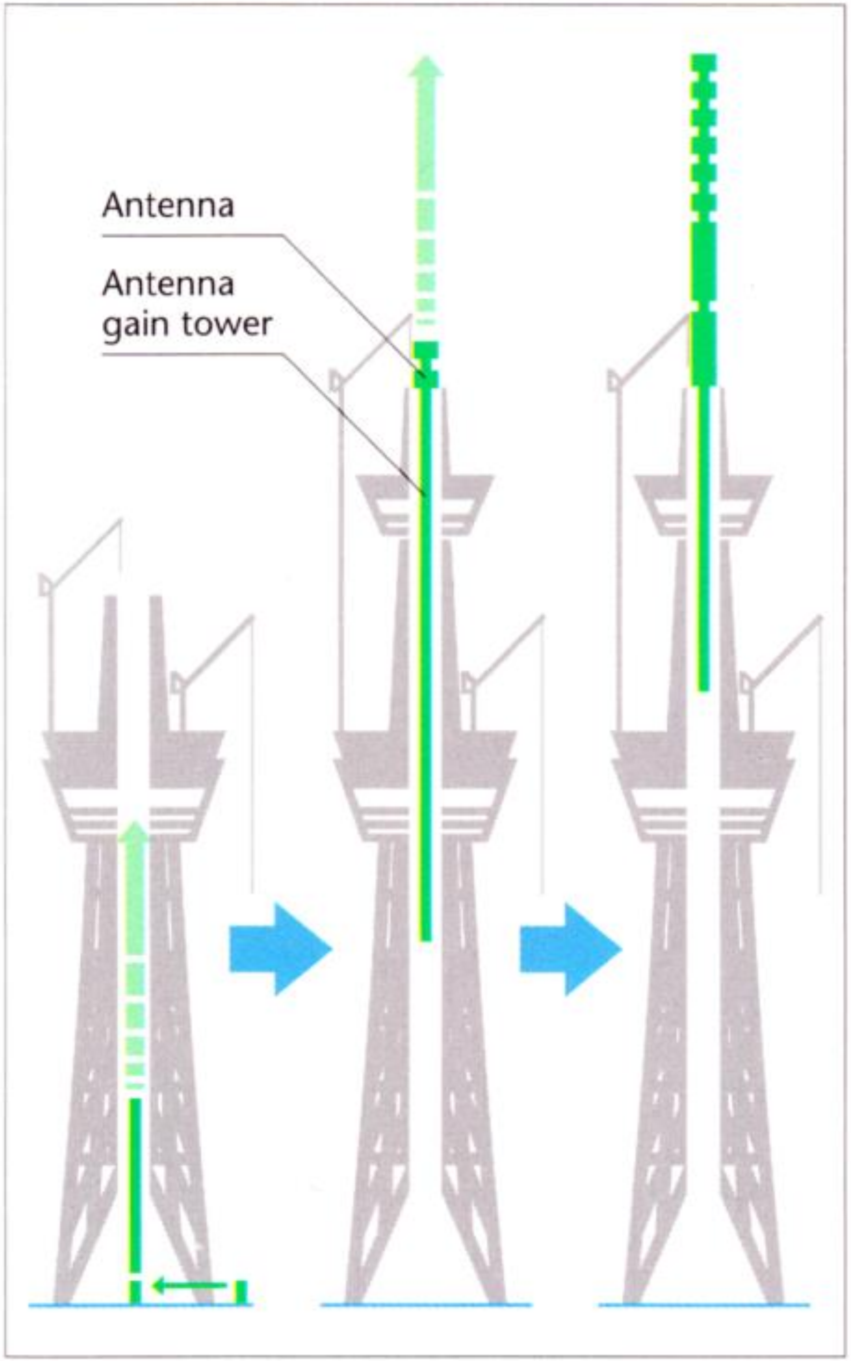
Feature 7 Lift up

1. The antenna gain tower at the top was constructed by the lift-up method.

2. Steel members were assembled at ground surface and raised inside the tower to a height of 634m.

3. The assembly was started before the construction of the central pillar.

4. The construction period could be reduced considerably.



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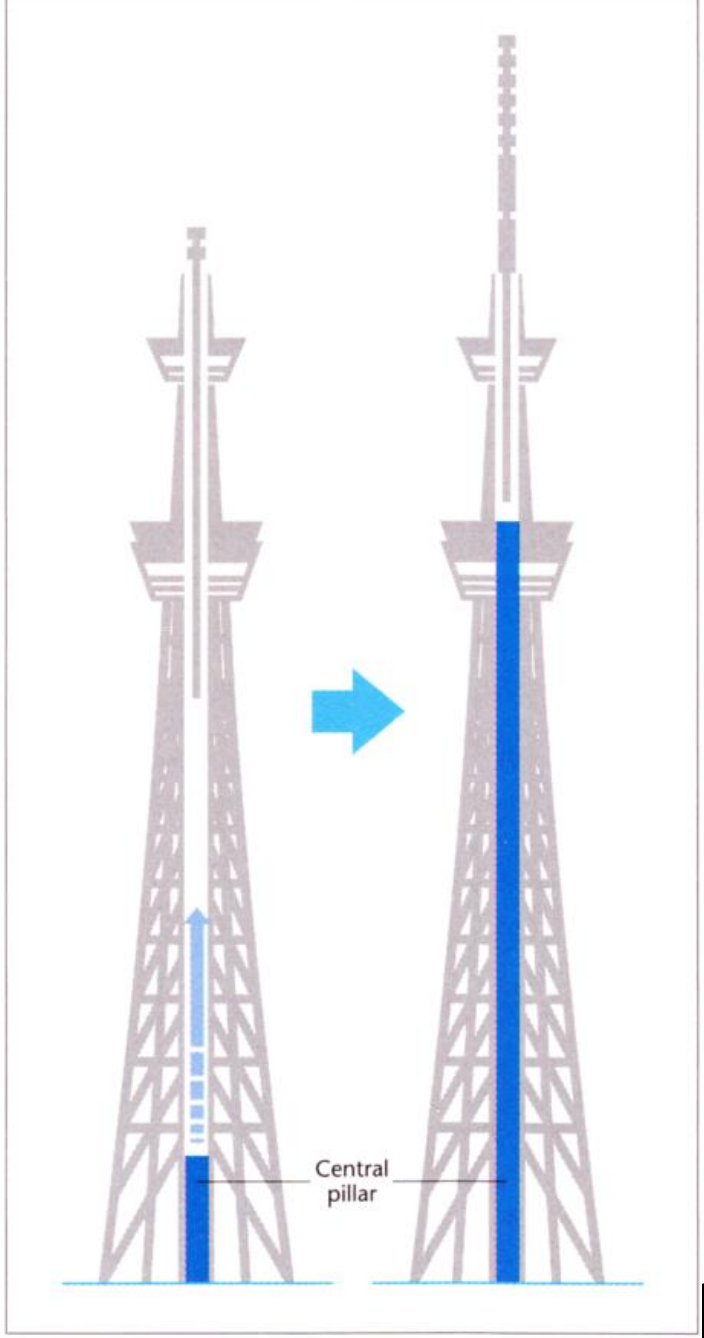
Feature 8 Slip form

1. The central tower was constructed in the void left after the antenna gain tower was raised.

2. The slip form method was adopted in which concrete was continuously placed while the form was slipped upward.

3. A concrete cylinder could be constructed in a short time.



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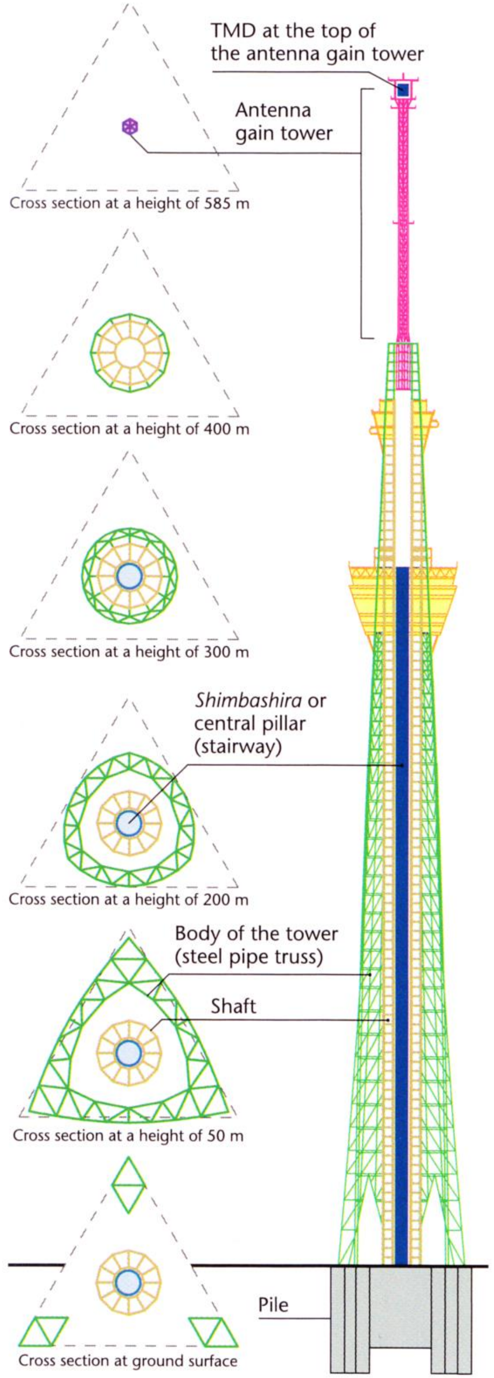
Feature 1 · Gain tower

1. The vibration should be avoided because of the digital terrestrial broadcasting antenna.

2. A tuned mass damper (TMD) has been installed at the top of the antenna gain tower to control the vibration of the entire antenna gain tower.

3. The mass is tuned to dampen the vibration of the entire peak tower.



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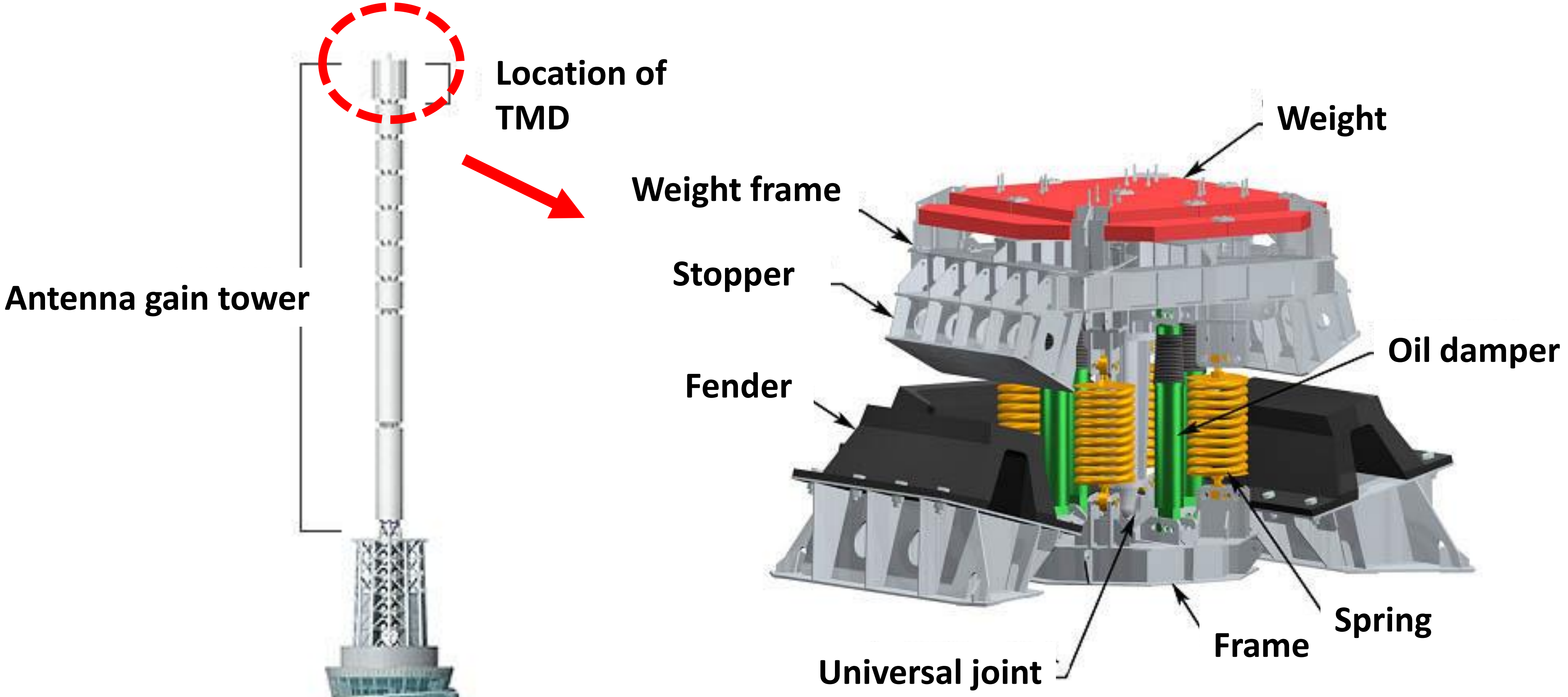
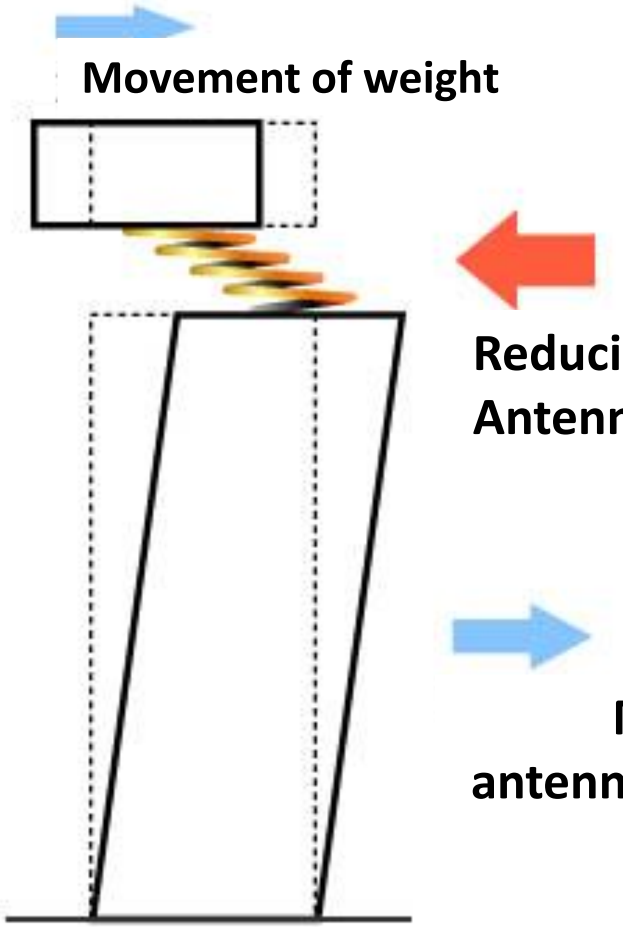
Tuned mass damper (TMD)

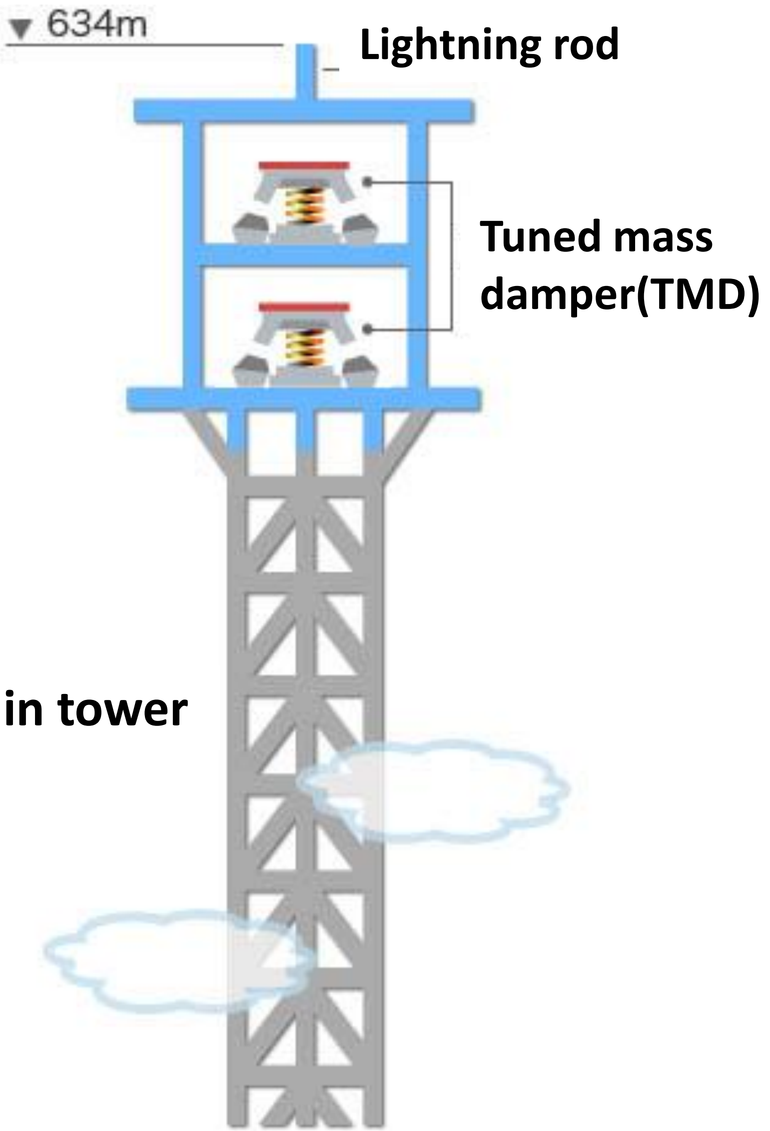


http://www.obayashi.co.jp/news/skytreedetail10_20101125_1

Tuned mass damper (TMD)

Time lag of movement between weight and antenna gain tower





http://www.obayashi.co.jp/news/skytreedetail10_20101125_1

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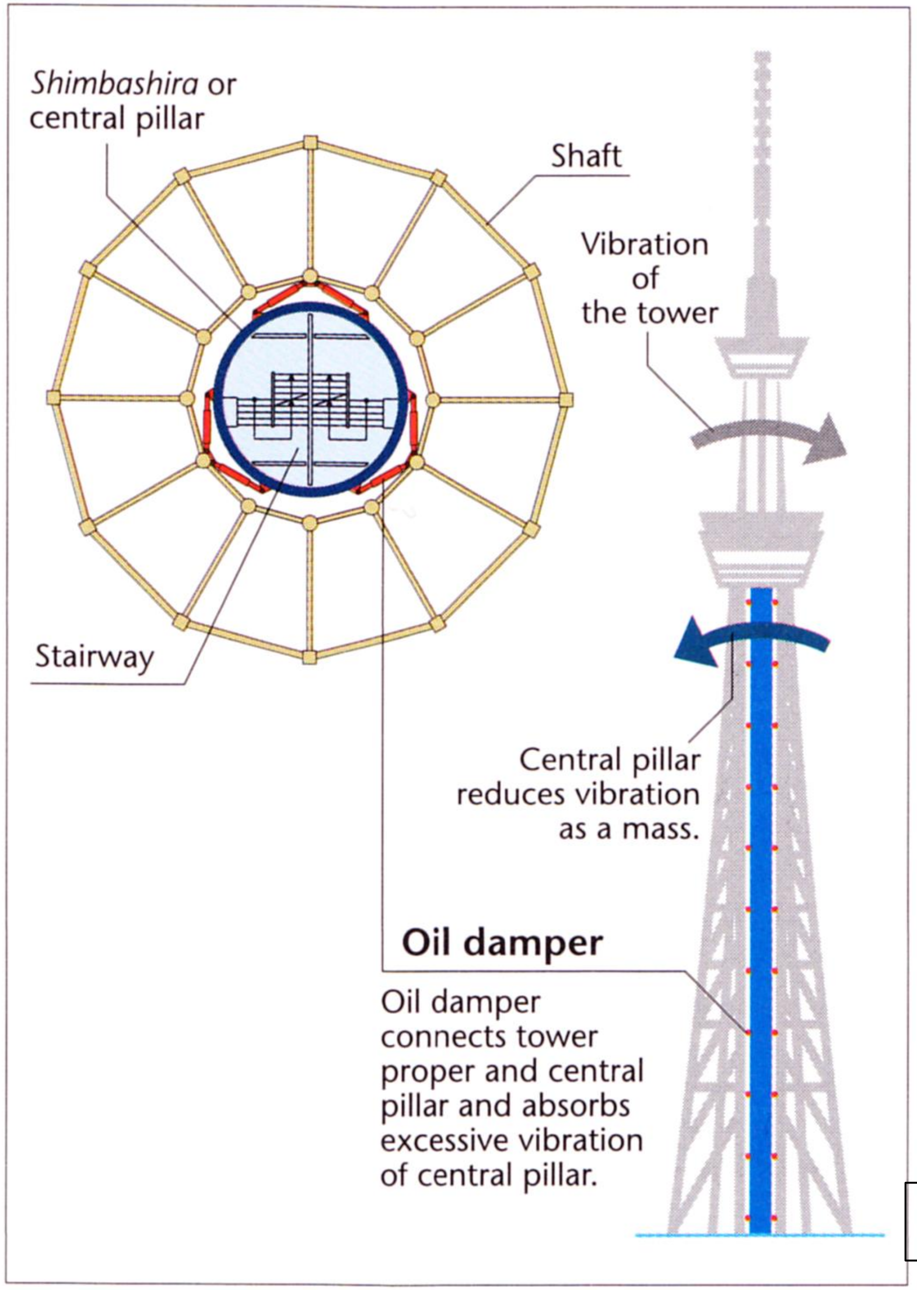
Feature 3 **Piller**

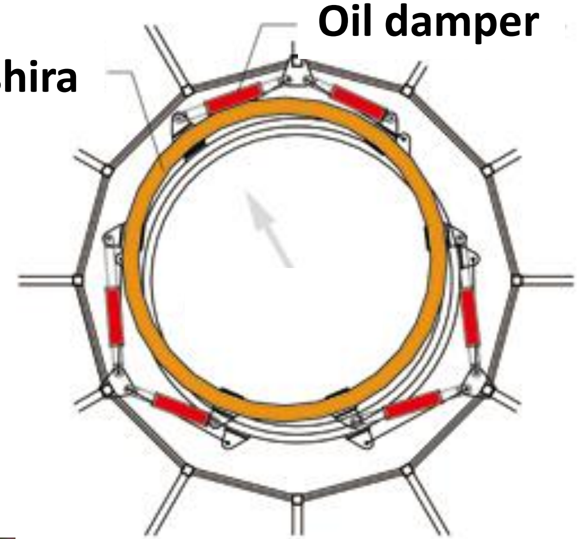
1. **The central concrete cylindrical center pillar was installed at the center of the tower.**

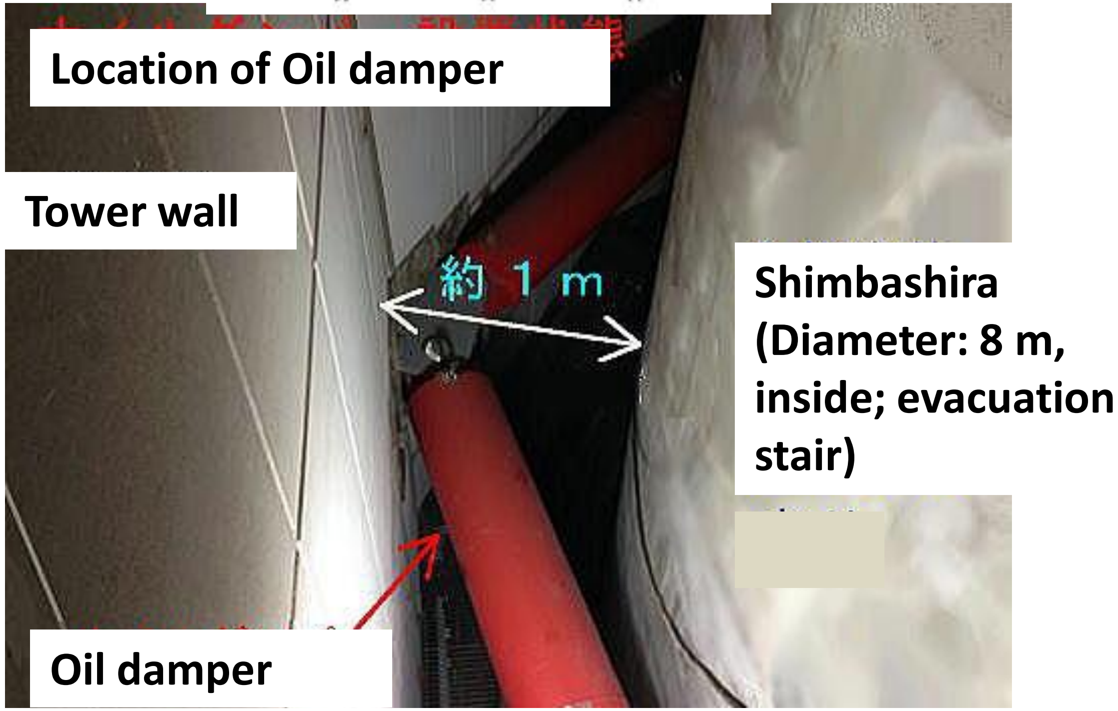
2. **It reduces the seismic vibration of the entire tower.**

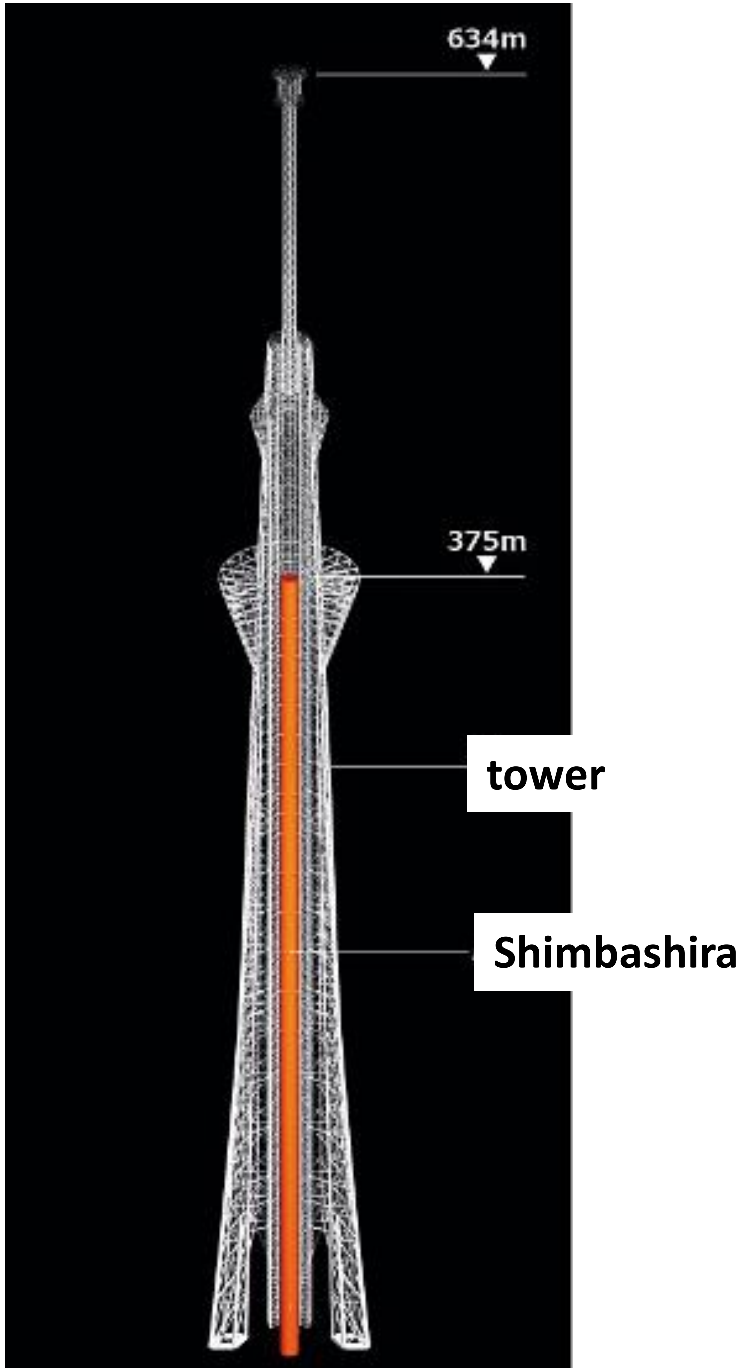
3. **It referred as the system for controlling seismic response with shimbashira at the center of pagoda, a traditional Japanese architecture.**



OCAJI





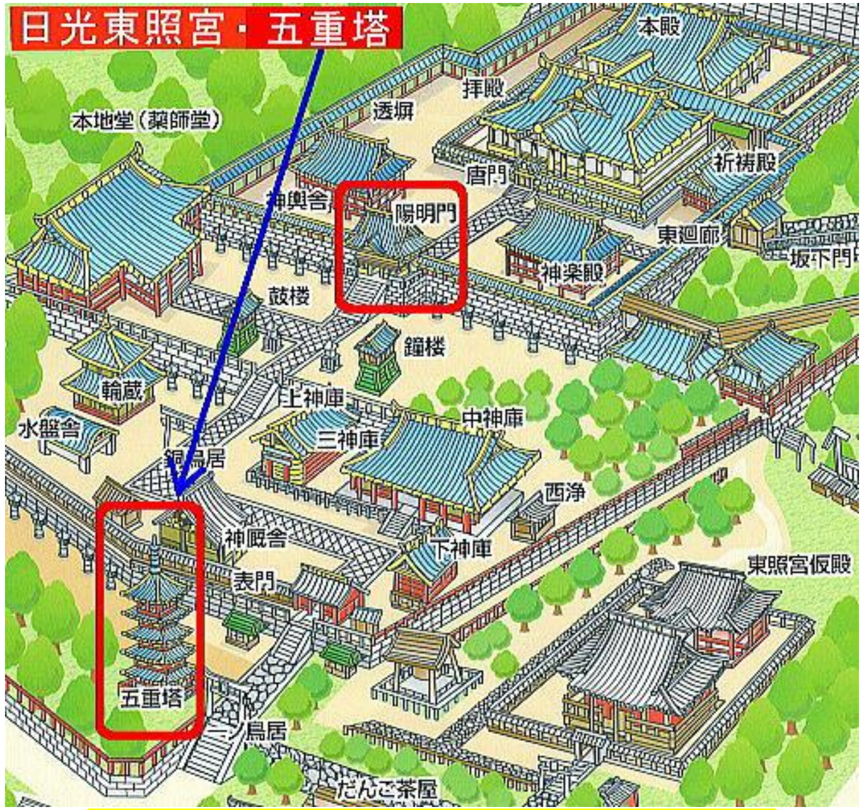


http://www.nikken.jp/ja/archives/history/12_03.html

Nikko Toshogu shrine, Japan

1999 World heritage

Five stories Pagoda

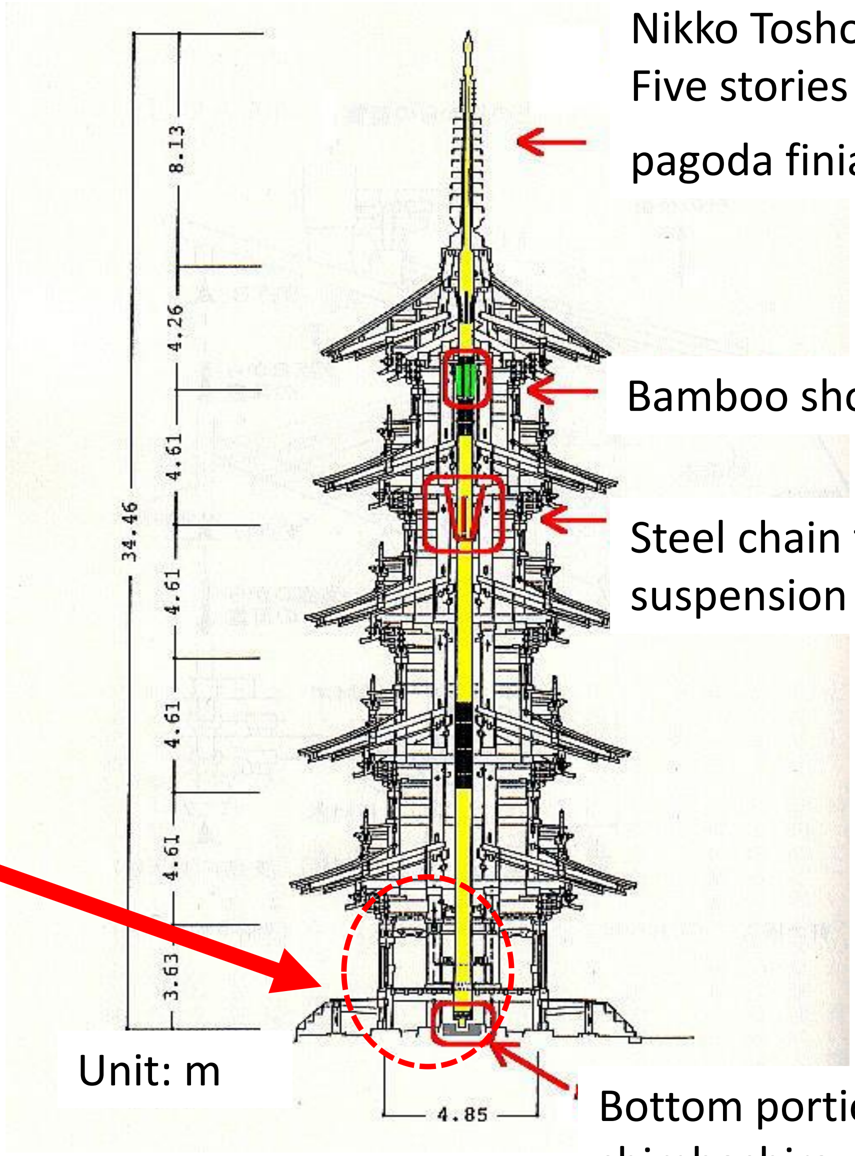


Precinct of Nikko Toshogu shrine

http://musen.server-shared.com/SINBASIRA-Midasi.html

Structure of shimbashira

http://musen.de-blog.jp/jbfblog/2012/08/post_8ebc.html



Nikko Toshogu shrine
Five stories pagoda

pagoda finial

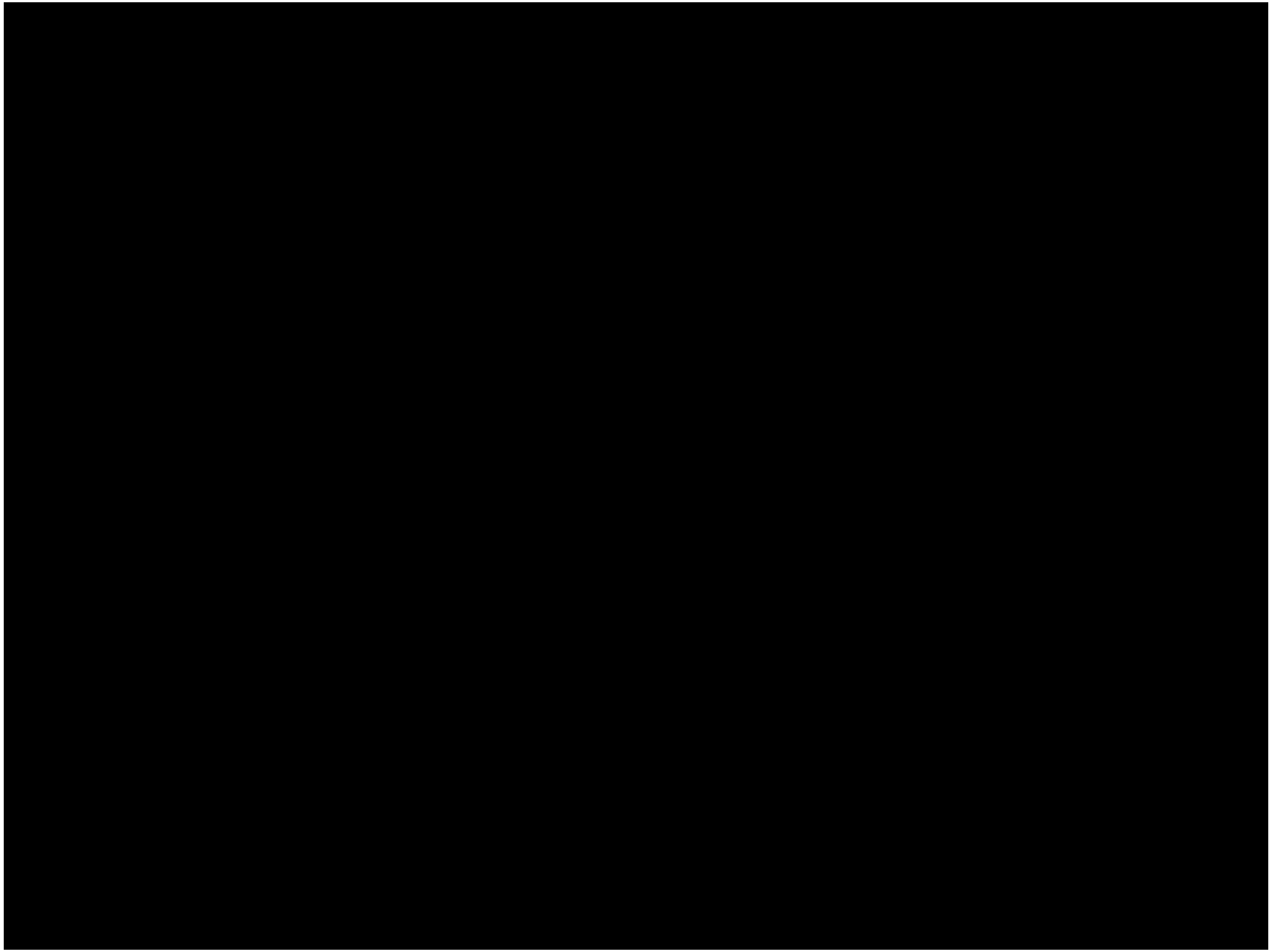
Bamboo shock absorber

Steel chain for suspension

Unit: m

Bottom portion of shimbashira

Skytree Construction work (Video)



Conclusion

Japan is still challenging the innovative construction technologies for safety, sustainability, and labor-saving.

Thank you for your attention!