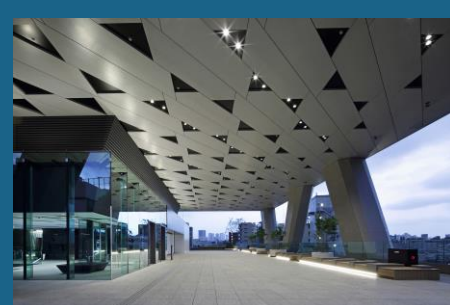


DaiyaGate Ikebukuro

Mid-story Isolation Building Straddling over Railroad Track

Yuichi Koitabashi, Seiya Kimura, Daiki Nakamizo



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EXPERIENCE, INTEGRATED

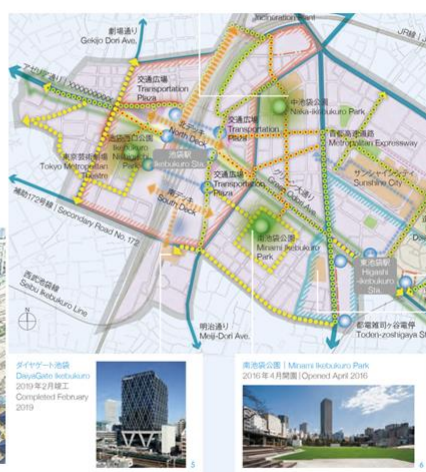
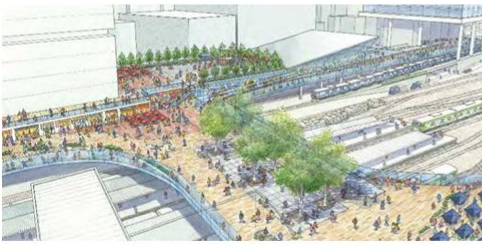


1 Architectural Scheme of the building project

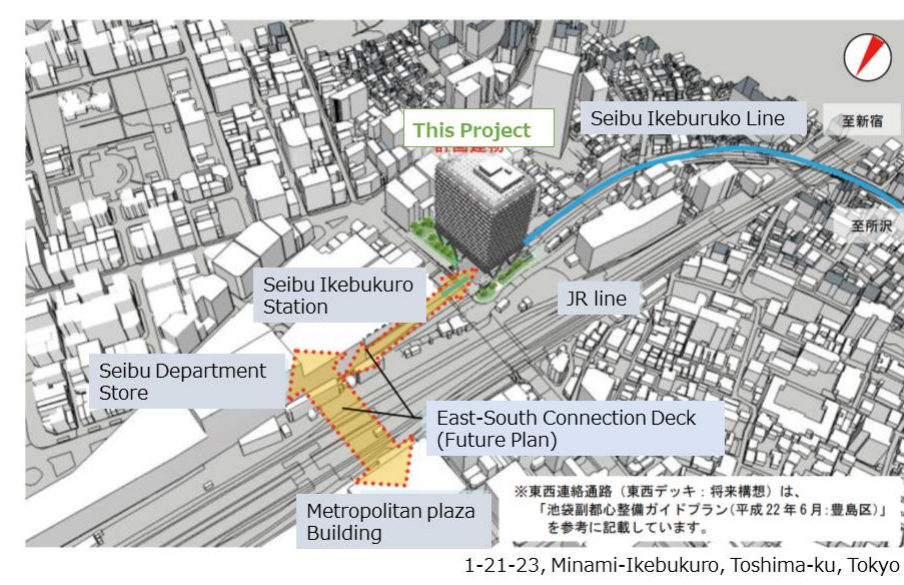
Transit Oriented Development

A deck equipped to serve as a temporary disaster shelter

Making it possible to connect to the (planned) pedestrian deck that would bridge the east and west sides of the station.



Location



In recent years, Transit-Oriented Development (TOD) is garnering attention and popularity for urban development projects. In particular, the popularity of over-track buildings is beginning to increase. The building was built over railroad track adjacent to Ikebukuro station. Because the railroad is owned by Seibu group, the headquarter building was planned as built over the tracks due to the effective use for the airspaces.

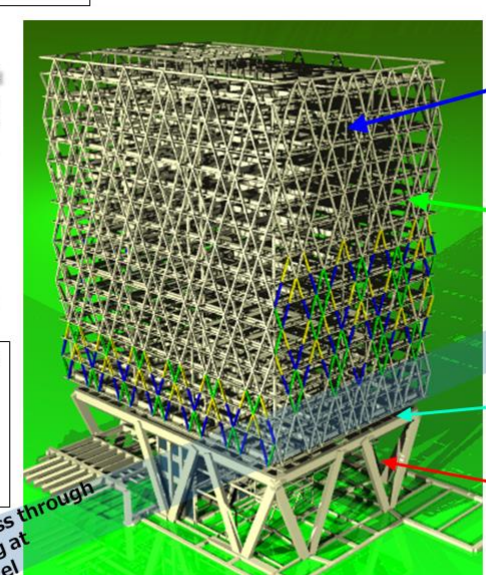
2 Implemented schemes for Innovative Use of SI Technologies due to the Achieved High Seismic Performance

The building – being an over-track structure – is the first of its kind to employ mid-story isolation (an increasingly popular tall building solution in Japan). The decision to adopt this system was taken in order to reduce vibration effects due to train operation, and also to decouple the relative displacement between the lower stories and above office floors. The isolation system grants significant response reduction and absorbs almost all of the seismic energy, since the drift of the other layer is small. The building is designed to have sufficient toughness to mitigate train vibration effects, and sufficient redundancy in accidental scenarios where the trains derail and impact the structure.

Structural System

The outer braces and V-shaped transfer columns have very high stiffness and lateral capacity. As such, in large earthquakes, only the isolation layer experiences strong horizontal displacement. Story drift angles above the isolation layer are less than 1/4000, whilst those below are less than 1/800. Almost all seismic energy is absorbed by the isolation system.

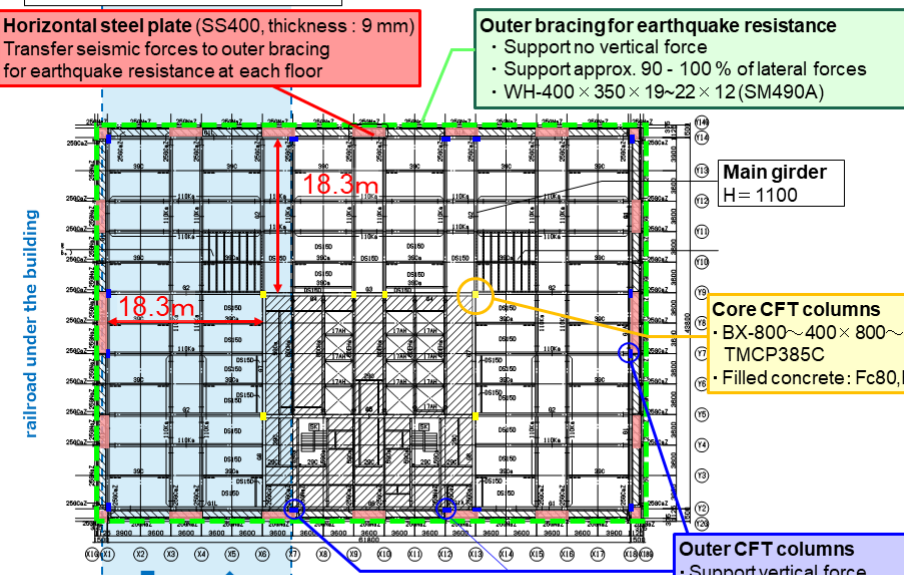
Aspect ratio of the building (short direction)
Whole structure
H/W=100/45=2.2
Above isolation layer
H/W=80/45=1.8



Perimeter columns
Outer bracing for earthquake resistance
Mid-story isolation layer
V-shaped transfer columns

1

Structural floor plan



Horizontal steel plate (SS400, thickness 9 mm)
Transfer seismic forces to outer bracing for earthquake resistance at each floor

Outer bracing for earthquake resistance
Supporting vertical force
Support approx. 90~100% of lateral forces
W/H=400×360×19-22 (12SM490A)

Main girder
H=1100

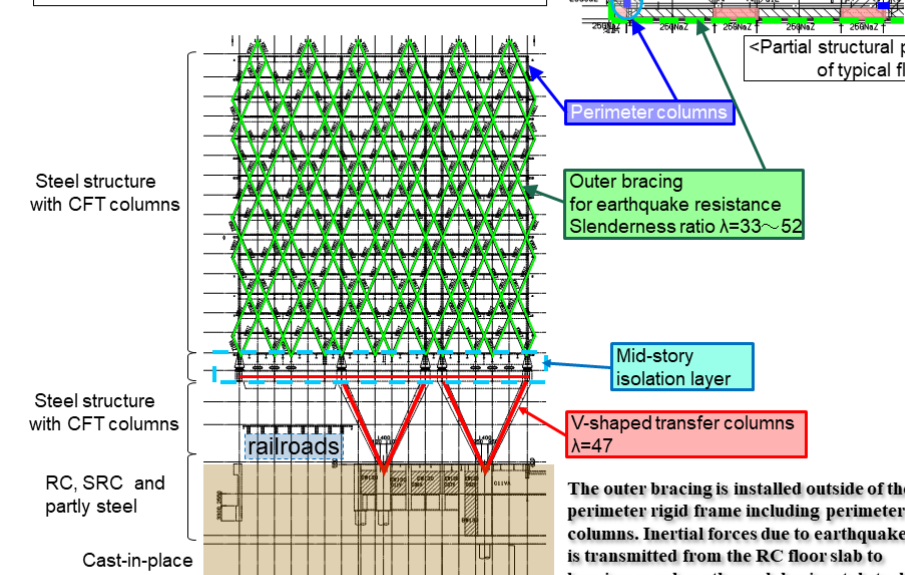
Core CFT columns
BX-800×400×800-400
TMCP385C
Filled concrete: Fc80, Fc80

Outer CFT columns
Support vertical force
BX-400×400 TMCP385C
Filled concrete: Fc80, Fc80

Typical structural floor plan above isolation layer

2

Structural System <Outer Frame>



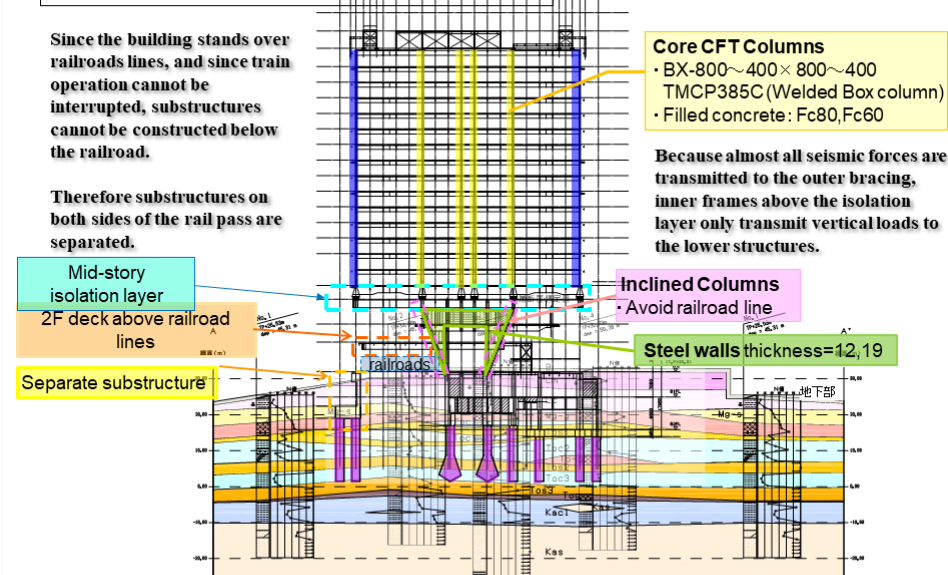
Steel structure with CFT columns
Steel structure with CFT columns
RC, SRC and party steel
Cast-in-place concrete piles

Partial structural plan of typical floor
Outer bracing for earthquake resistance
Slenderness ratio λ=33~52
Mid-story isolation layer
V-shaped transfer columns
H=47

The outer bracing is installed outside of the perimeter rigid frame including perimeter columns. Inertial force due to earthquakes is transmitted from the RC floor slab to bracing members through horizontal steel plates installed between the braces and perimeter rigid frame.

3

Structural System <Inner Frame>



Since the building stands over railroad lines, and there train operation cannot be interrupted, substructures cannot be constructed below the railroad.

Therefore substructures on both sides of the railroad are separated.

Mid-story isolation layer
2F deck above railroad lines
Separate substructure

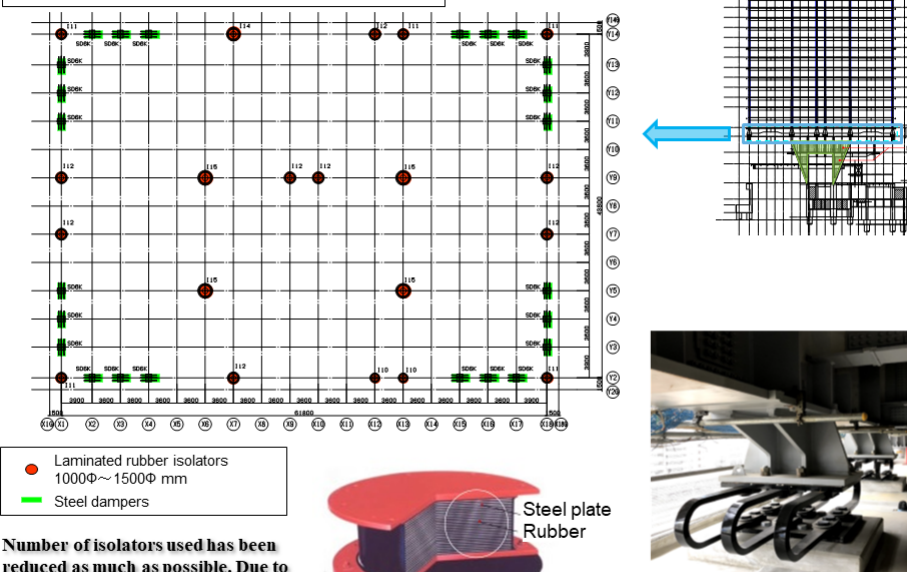
Core CFT Columns
BX-800×400×800-400
TMCP385C (Welded Box column)
Filled concrete: Fc80, Fc80

Because almost all seismic forces are transmitted to the outer bracing, inner frames above the isolation layer only transmit vertical loads to the lower structures.

Inclined Columns
Avoid railroad line
Steel walls thickness=42, 19

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Isolation layer above 4th floor

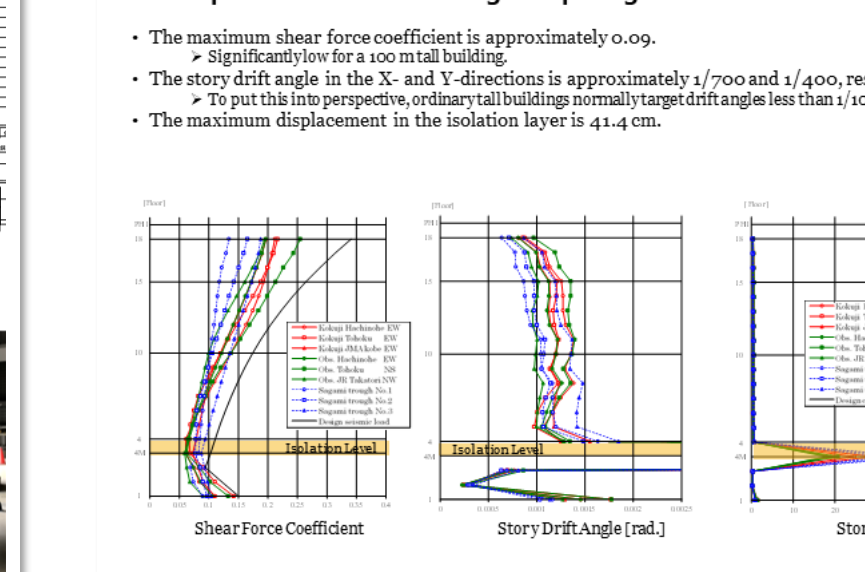


Laminated rubber isolators
10000~15000 mm
Steel dampers

Steel plate
Rubber
Laminated rubber isolator
Steel damper

Number of isolators used has been reduced as much as possible. Due to the chosen arrangement, the building fundamental period is longer and the seismic response is reduced.

Responses of the design input ground motions

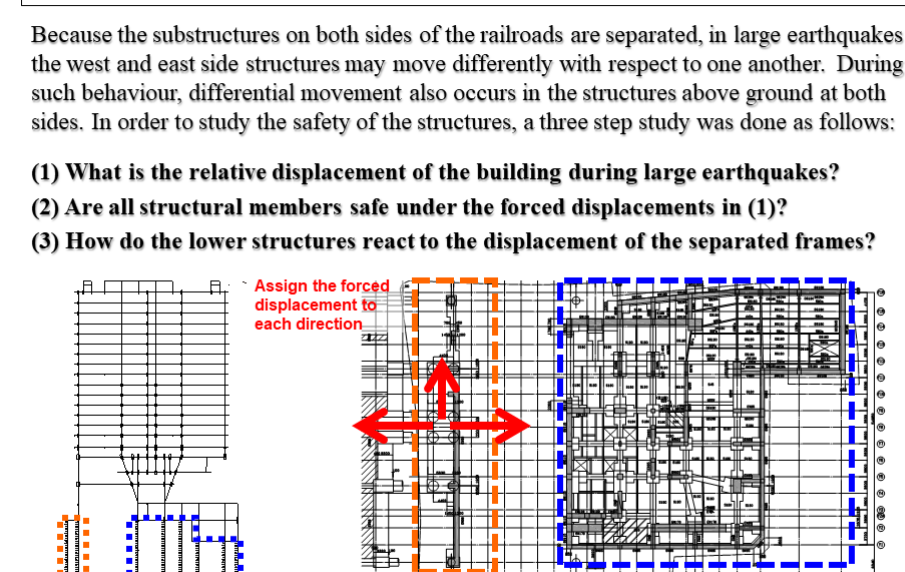


The maximum shear force coefficient is approximately 0.09.
→ Significantly low for a 100m tall building.
The story drift angle in the X- and Y-directions is approximately 1/700 and 1/400, respectively.
→ Put this into perspective, ordinary tall buildings normally target drift angles less than 1/100.
The maximum displacement in the isolation layer is 41.4 cm.

Shear Force Coefficient
Story Drift Angle [rad.]
Story Drift [cm]

5

Safety study in regard to differential movement between separated substructures



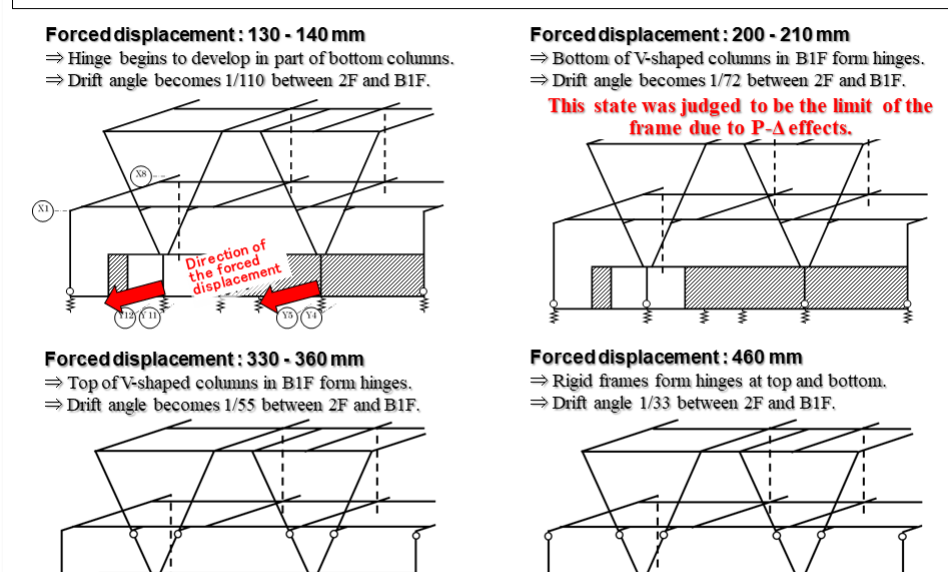
Because the substructures on both sides of the railroads are separated, in large earthquakes the west and east structures may move differently with respect to one another. During such behaviour, differential movement also occurs in the structures above ground at both sides. In order to study the safety of the structures, a three step study was done as follows:

- What is the relative displacement of the building during large earthquakes?
- Are all structural members safe under the forced displacements in (1)?
- How do the lower structures react to the displacement of the separated frames?

3-Dimensional Analysis Model
Structures on west side
Structures on east side

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(3) How do the lower structures react to the displacement of the separated frames?



Forced displacement: 130~140 mm
⇒ Hinge begins to develop in part of bottom columns.
⇒ Deft angle becomes 1/110 between 2F and B1F.

Forced displacement: 200~210 mm
⇒ Bottom of V-shaped columns in B1F form hinges.
⇒ Deft angle becomes 1/72 between 2F and B1F.
This state was judged to be the limit of the frame due to P-Δ effects.

Forced displacement: 330~360 mm
⇒ Hinge develops in B1F form hinges.
⇒ Deft angle becomes 1/55 between 2F and B1F.

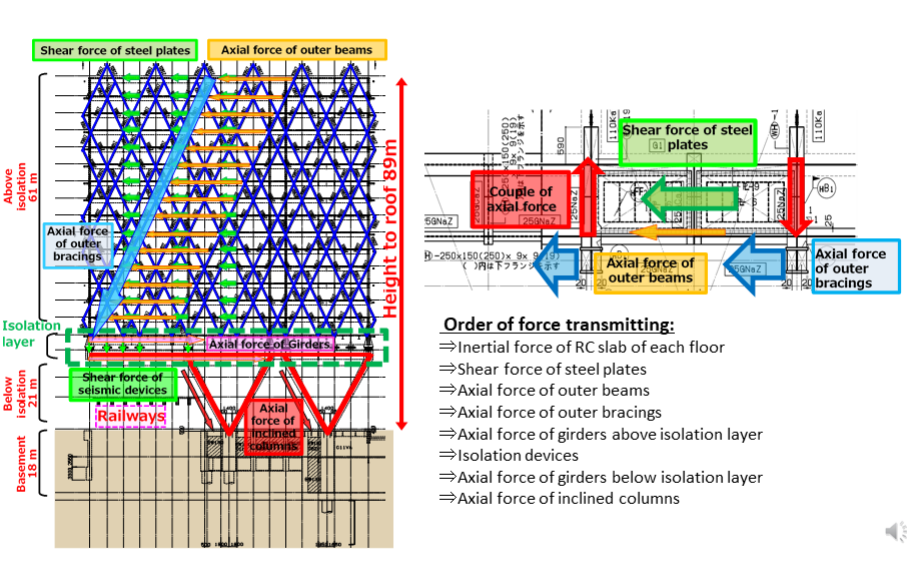
Forced displacement: 460 mm
⇒ Top of V-shaped columns in B1F form hinges.
⇒ Deft angle 1/33 between 2F and B1F.

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3 Structural Schemes Including Innovative Use of SI to Facilitate Architectural Form and Expression Exceeding Conventional Structural Design

The outer bracing (installed above the isolation layer) and V-shaped columns (below the isolation layer) complement the building façade and aesthetic. These structural members are engaged during large earthquakes to reduce story drift, and are inspired by train schedule diagrams. Such structural arrangements represent symbolic and memorable meanings for the owners, Seibu Group... and are all the more significant since the building will serve as their headquarters in close vicinity to the Seibu-Ikebukuro line. The bracings are considered from a multi viewpoint not only structural load transmission and full-scale loading test but also aesthetic of the part of the bolted joint, paintings for anti-rust, snow accumulation and ponding of rainwater, etc.

Structural system of outer bracing

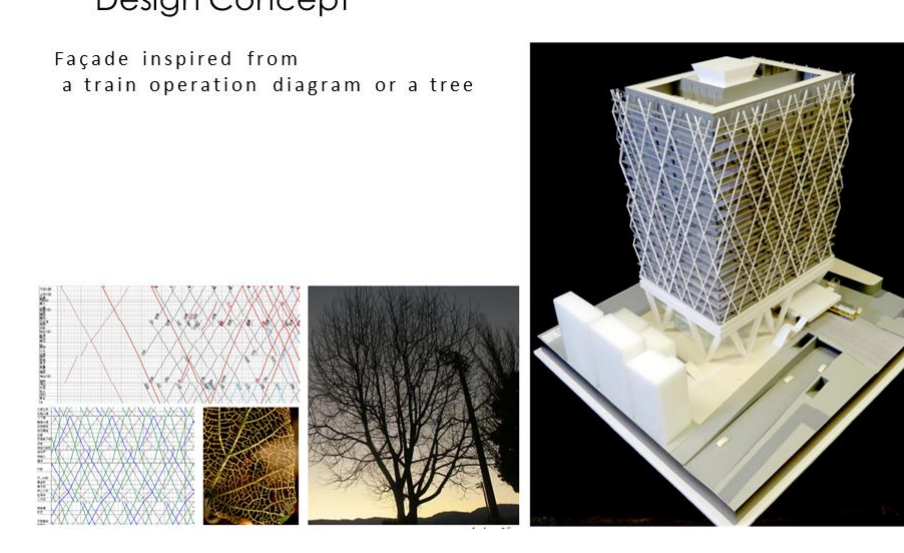


Shear force of steel plates
Axial force of outer beams
Order of force transmitting:
⇒ Inertial force of RC slab of each floor
⇒ Shear force of steel plates
⇒ Axial force of outer beams
⇒ Axial force of outer bracings
⇒ Axial force of girders above isolation layer
⇒ Isolation devices
⇒ Axial force of girders below isolation layer
⇒ Axial force of inclined columns

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"Giant Tree" and "Timetable" Design Concept

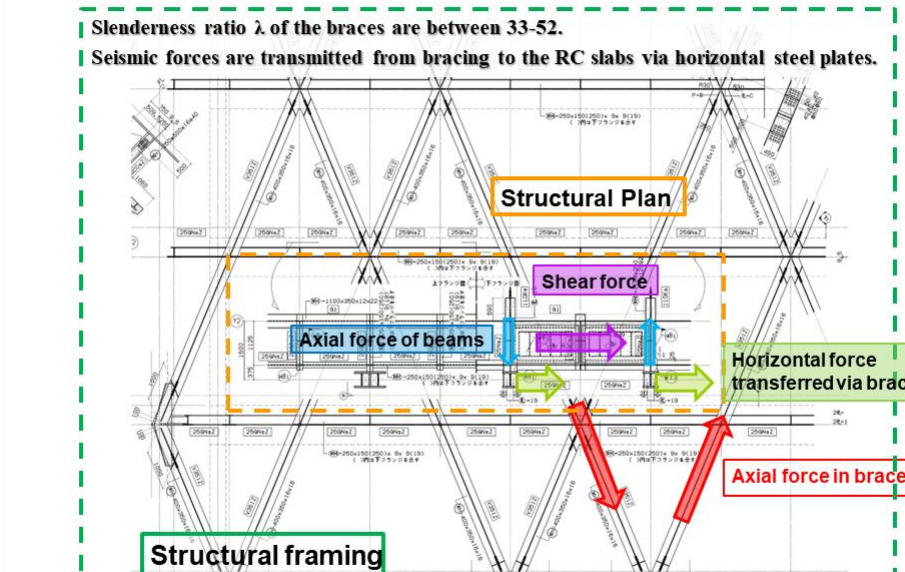


Facade inspired from a train operation diagram or a tree

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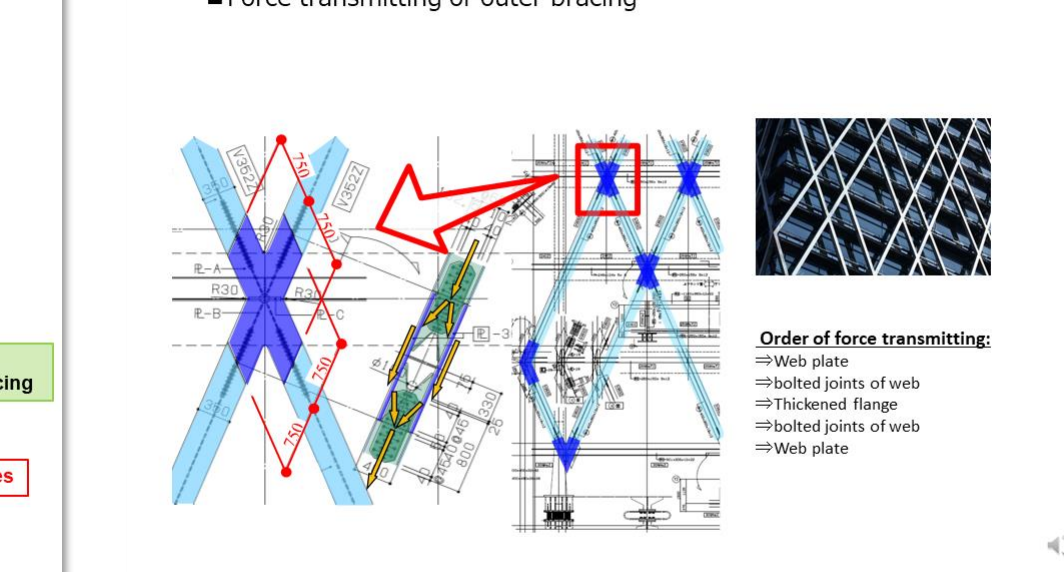
Design rules of outer bracing for earthquake resistance



Slenderness ratio λ of the braces are between 33-52.
Seismic forces are transmitted from bracing to the RC slabs via horizontal steel plates.

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Force transmitting of outer bracing

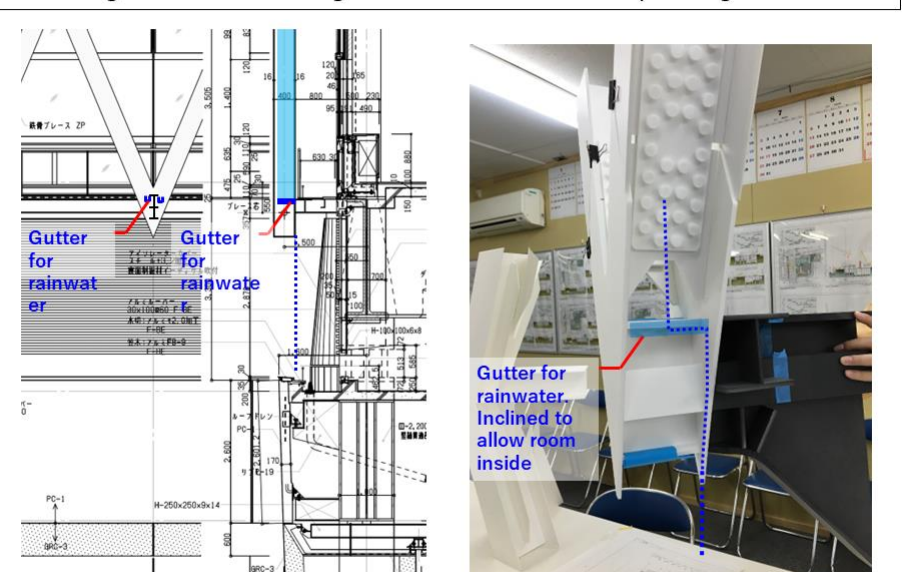


Order of force transmitting:
⇒ Web plate
⇒ Bolted joints of web
⇒ Thickened flange
⇒ Bolted joints of web
⇒ Web plate

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Bracing details considering snow accumulation and ponding of rainwater



Gutter for rainwater
Inclined to allow rain inside

The webs of bracing members include small openings in order to avoid significant snow accumulation. In addition, a rainwater gutter is attached to the end of the braces.

Factory production of bracing joints

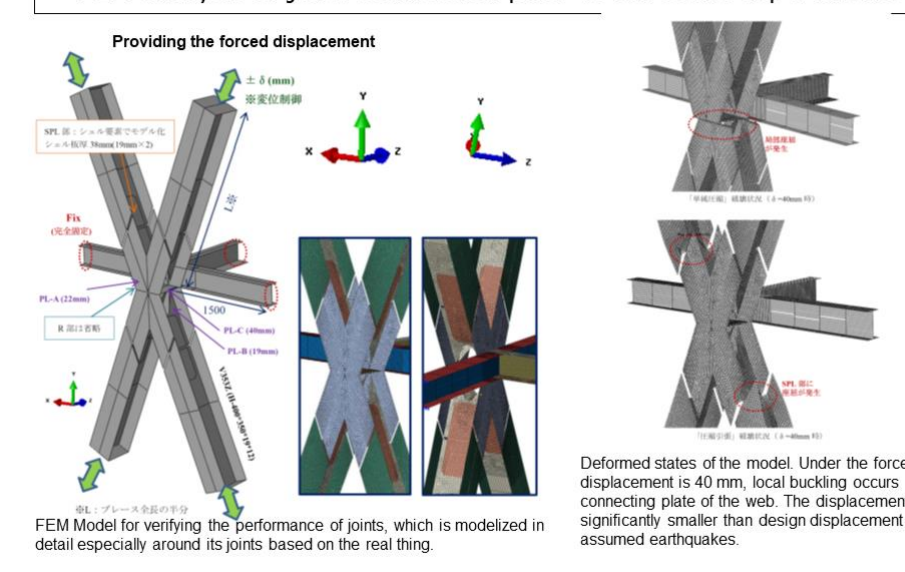


All parts of the braces are bolted. There are some patterns of the joint parts of the braces. Because each pattern is designed with consideration of 3-Dimensional transmitted force, the joints are composed of many plates. When in the procedure of bolted bracings, we paid attention so that the parts are well-galvanized.

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FEM analysis of joint-connection prior to full-scale experiments



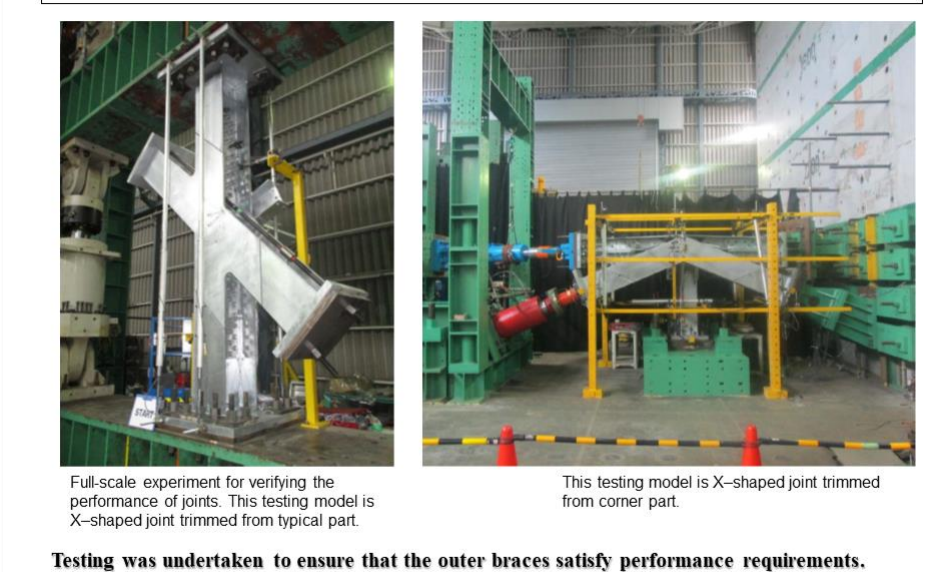
Providing the forced displacement
Deformed states of the model. Under the force displacement is 40 mm, local buckling occurs connecting plate on the web. The displacement significantly smaller than design displacement in assumed earthquakes.

Because axial forces in the bracing are transmitted only through their webs, the details of the bolted joints are very important. Based on the results of the analyses, it is verified that the approved joints make stress concentration easier to disperse.

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Full scale experiments



Full-scale experiment for verifying the performance of joints. This testing model is X-shaped joint trimmed from corner part.
Testing was undertaken to ensure that the outer braces satisfy performance requirements. The applicants verified that the results of these experiment model is harmonic to that of FEM models.

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