Reinforced Concrete Buildings using High Strength Material in Japan

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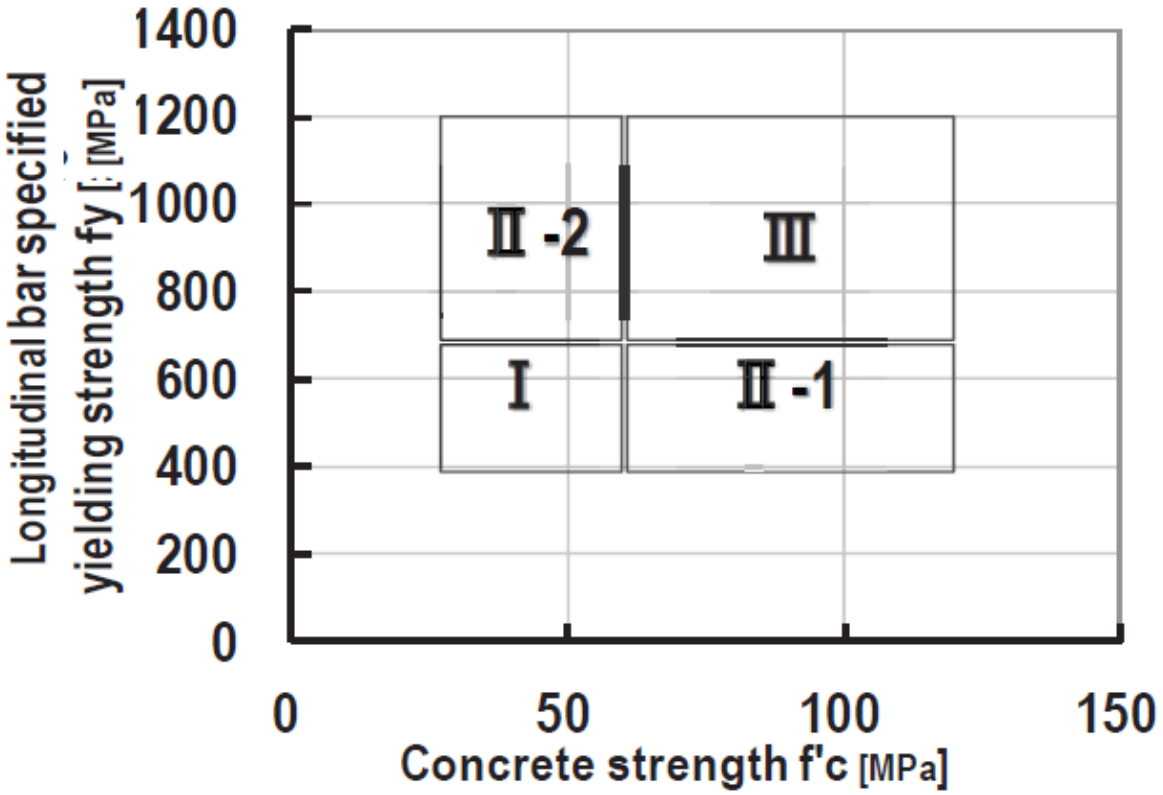
1. Introduction

Application of high strength materials to high-rise buildings in Japan.

Since the 1980's, the demand for high-rise buildings especially for residential use in urban areas has continued to increase, because of the increase in the population shift from suburbs to urban areas.

Affected by this demand,
high strength materials for reinforced concrete structures were developed.

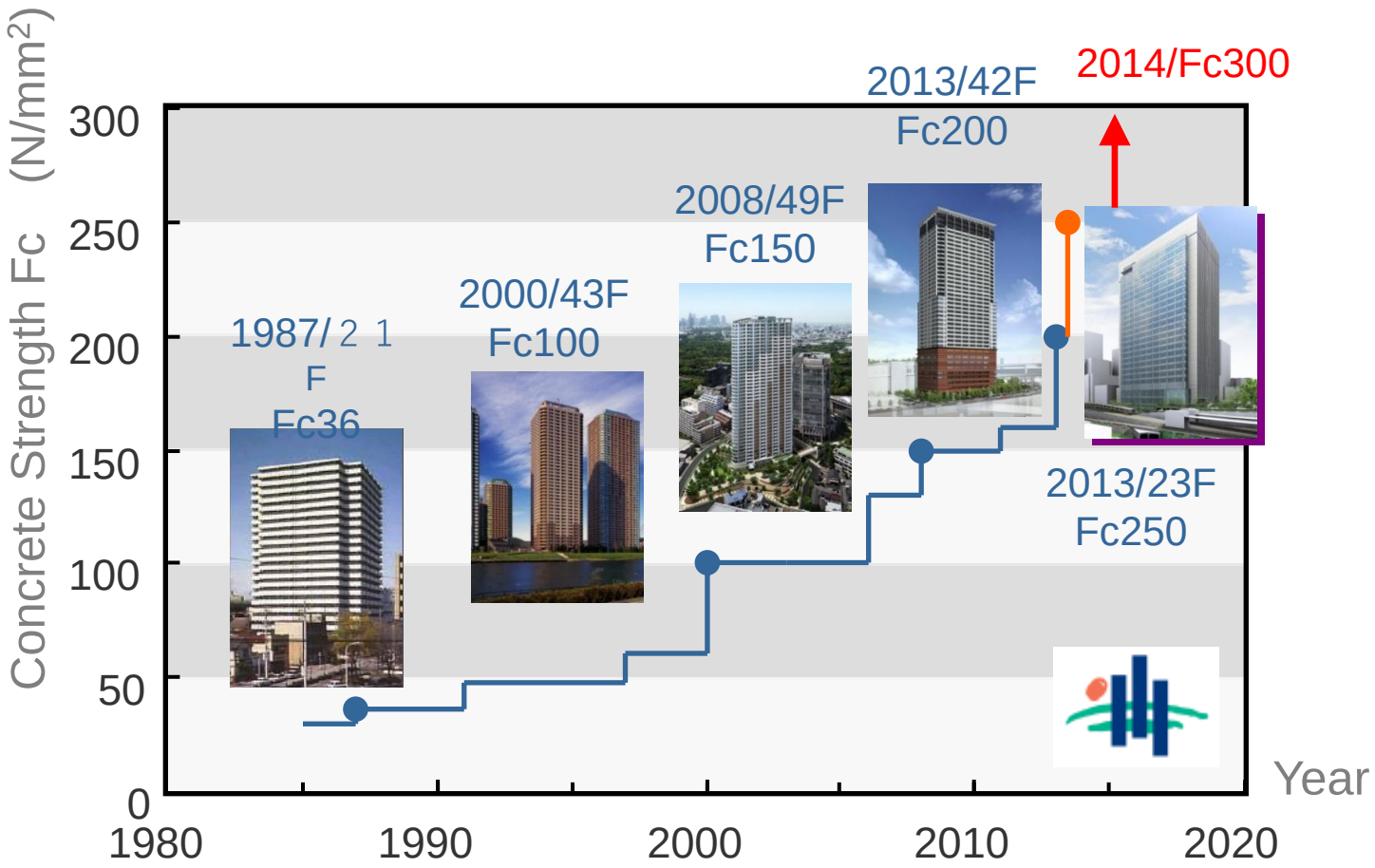
National Research Project(New RC), 1988-1993



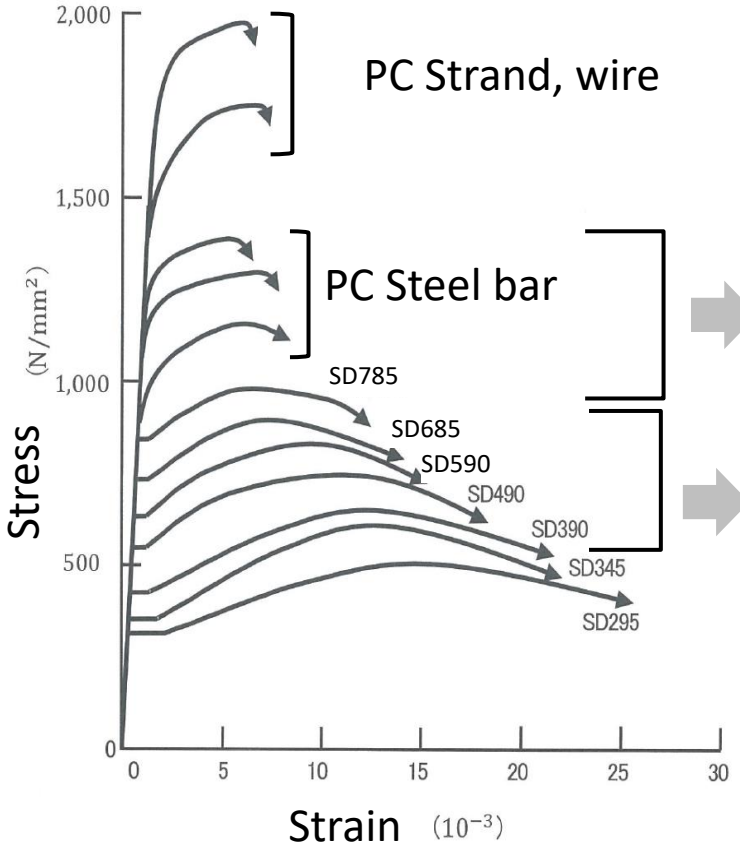
New RC project had promoted the design and construction of high-rise RC buildings with high strength materials.

Research Material Target

High Strength Concrete



High Strength Steel



Lateral Reinforcement

Main Re-bar

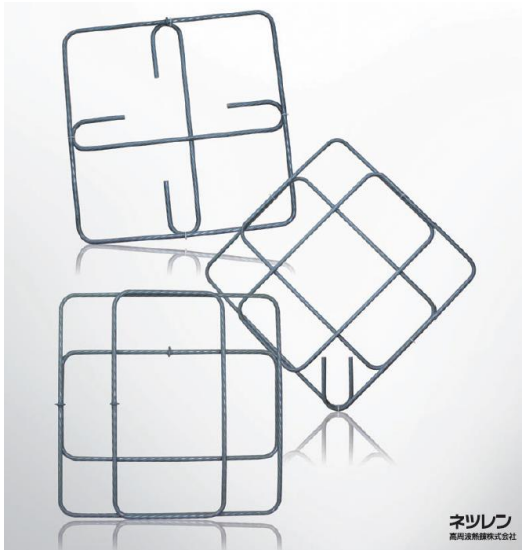


Photo from Neturen

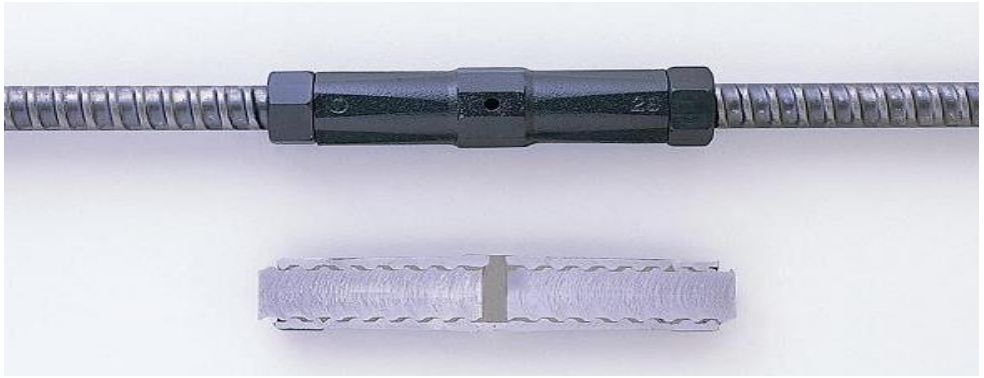
Large diameter re-bars

Photo from Tokyo Tekko Co., Ltd.

Mechanical Joint

Threaded-rebar joint

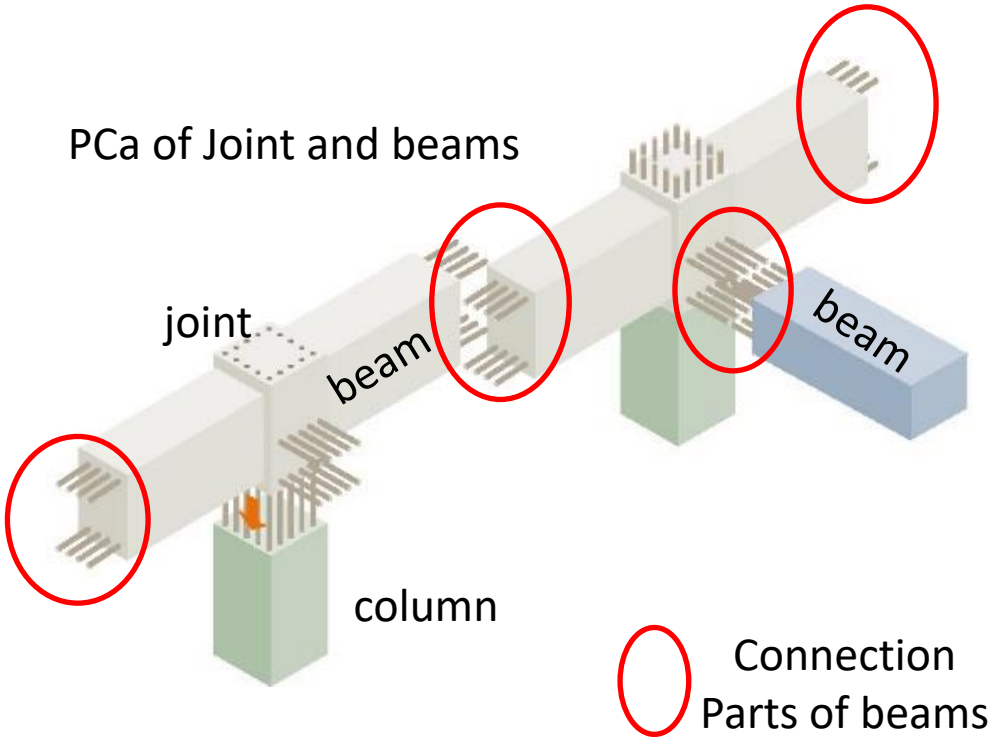
Sleeve joint



Cross-sectional view of threaded-rebar joint

Photo from Tokyo Tekko Co., Ltd.

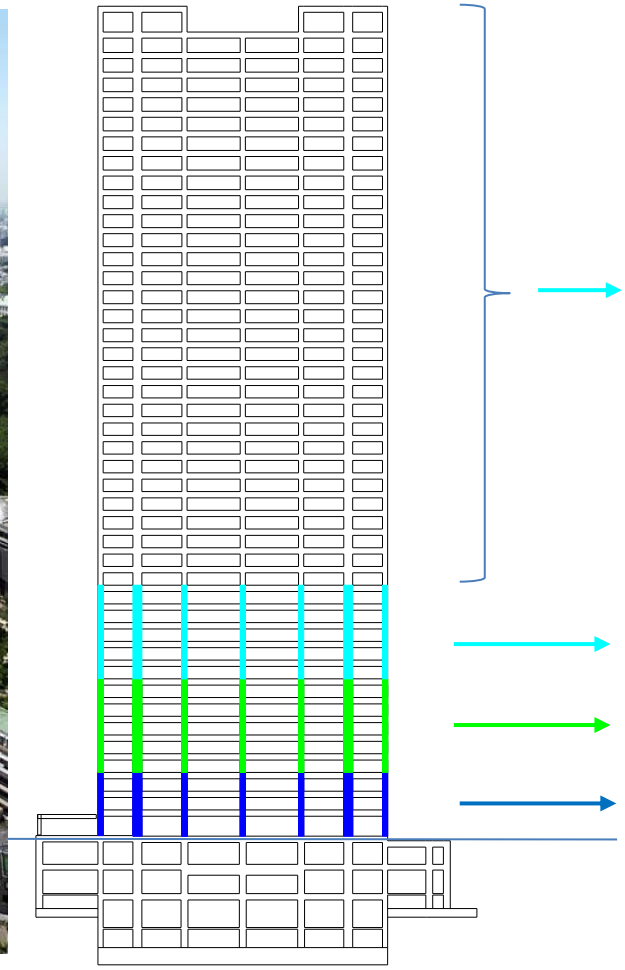
PCa System



Re-bar arrangement in the beam-column joint is congested and high strength concrete is used for the joint, so in this case the joint parts are precast.
To make the connection parts cast in site fewer, a joint and beams are integrated into one PCa member.

2. Application

43 story Residential Project



Maximum Strength of Concrete used : Fc150 (MPa)

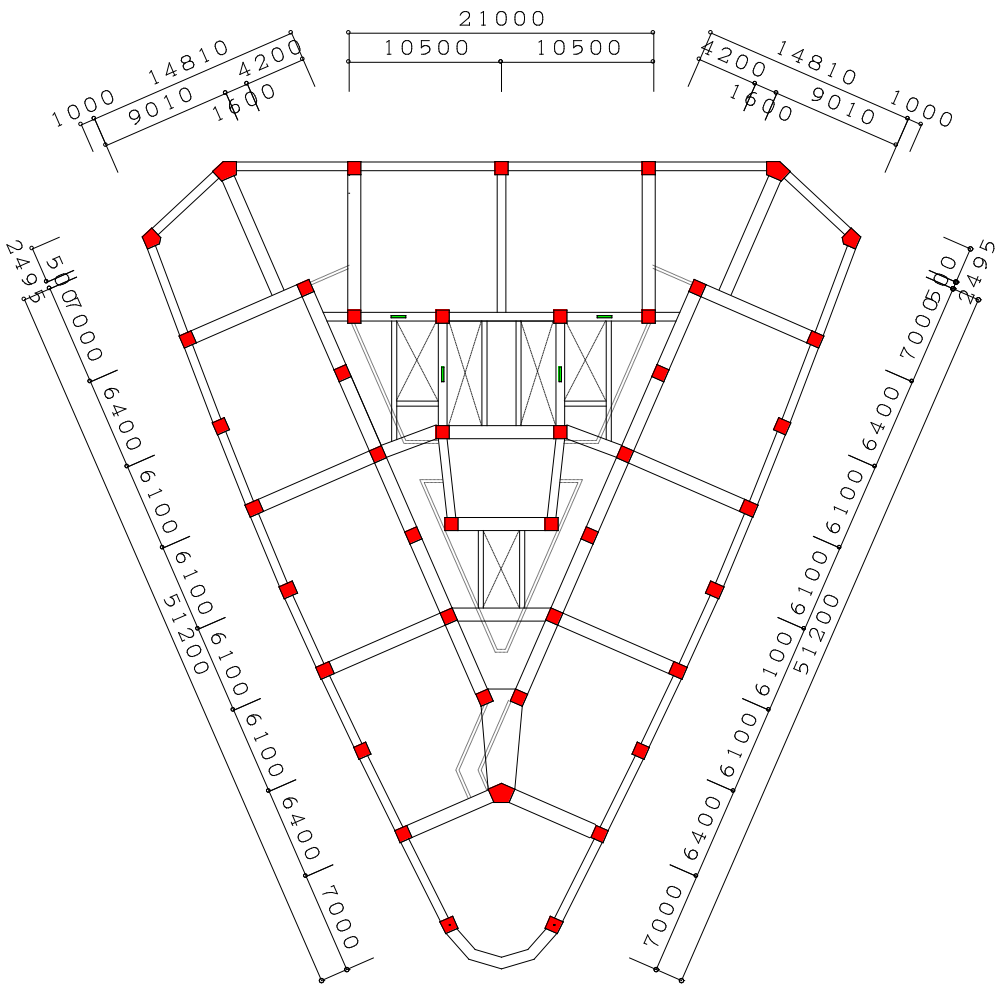
Fc=30~80 MPa
(Column of 10～43 story)

Fc=100 MPa
(Column of 9～13 story)

Fc=130 MPa
(Column of 4～8 story)

Fc=150 MPa
(Column of 1～3 story)

Frame Planning



Column

B × D = 900mm × 900mm

Outside Beam

B × D = 620mm × 1100mm

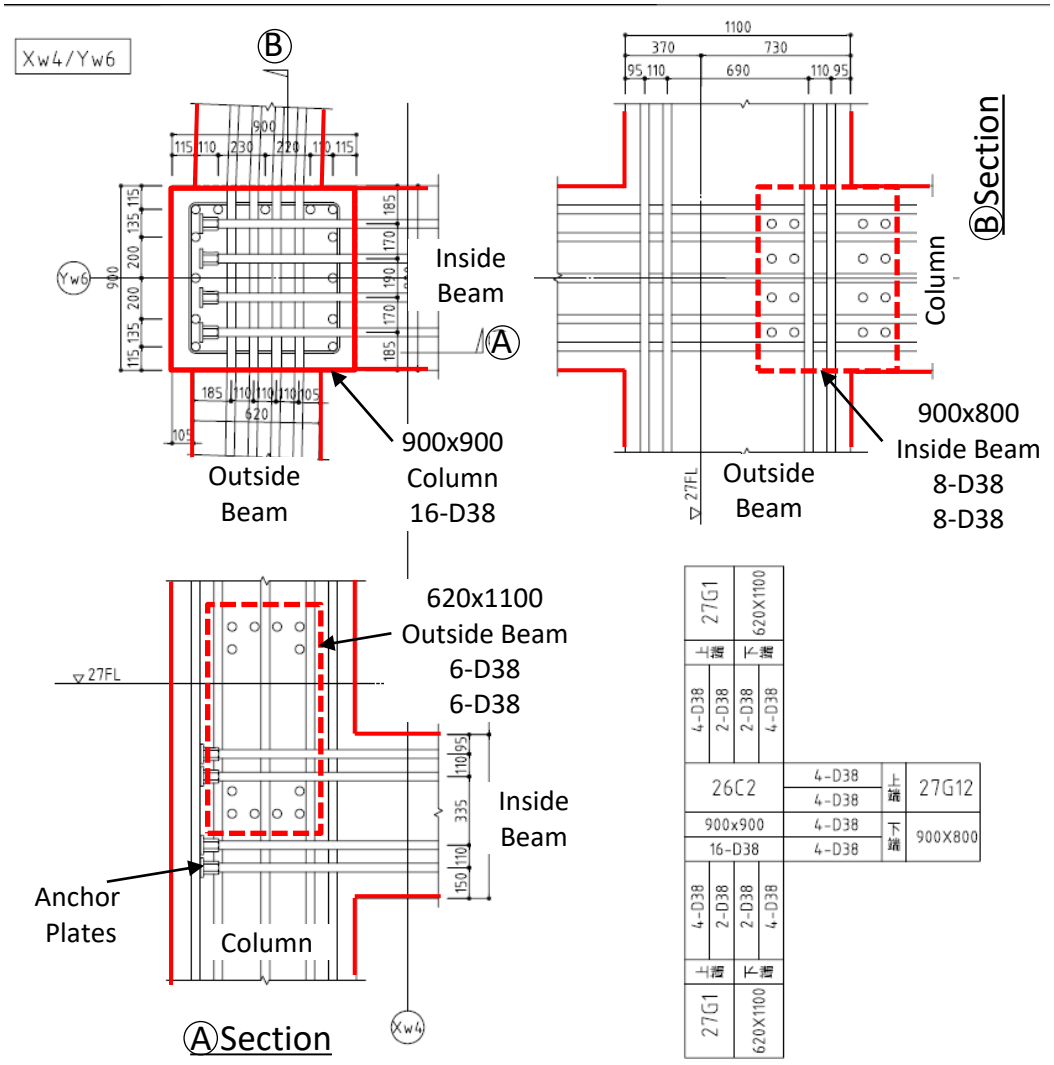
Inside Beam

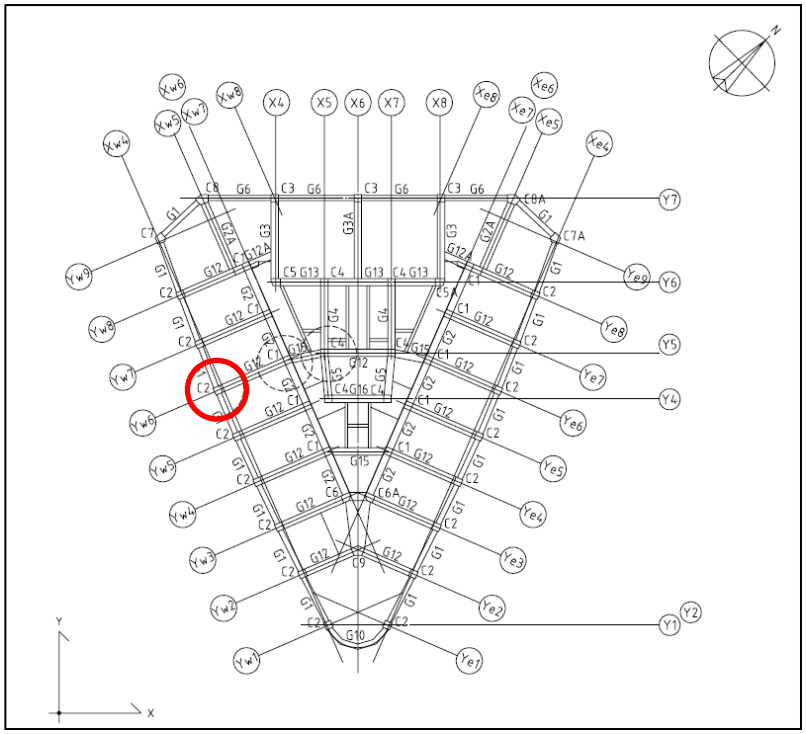
B × D = 900mm × 800mm

Slab thickness

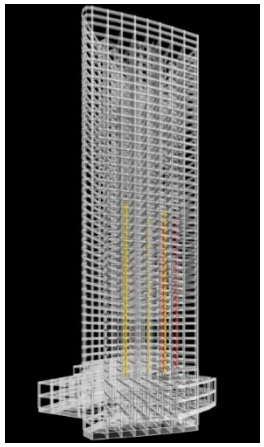
t=370mm,350mm,250mm

Detail of Beam-Column Joint



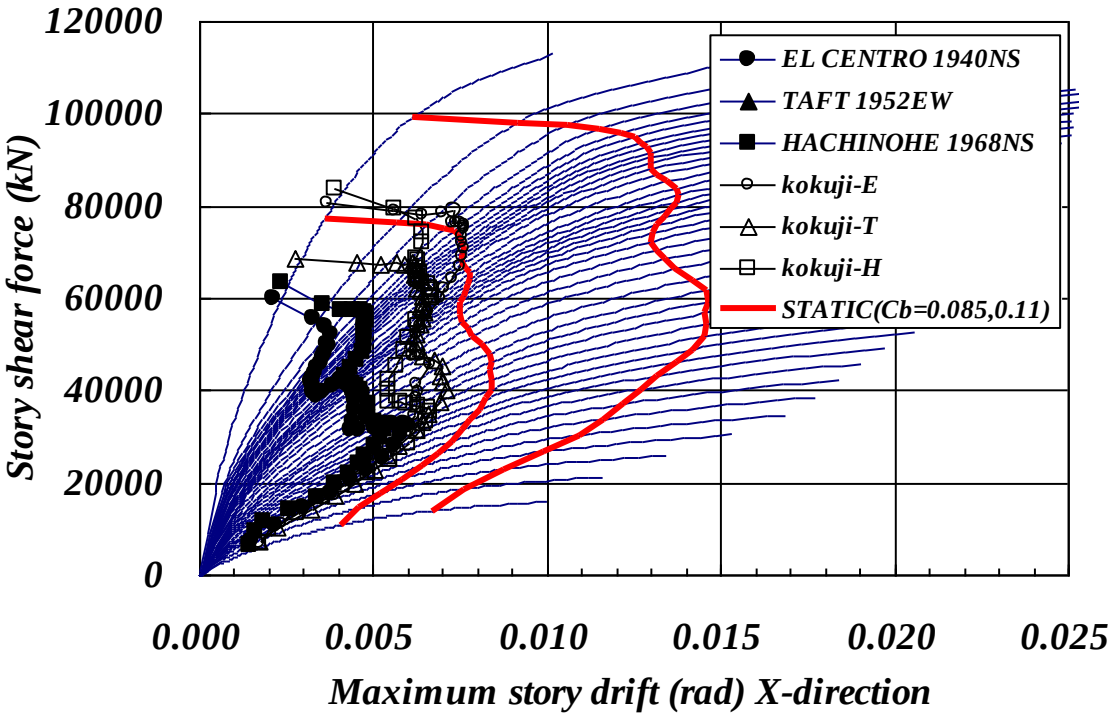


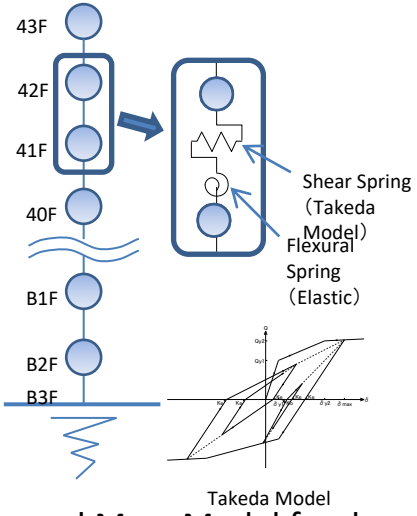
SEISMIC DESIGN



3D Frame Model for pushover analysis

Performance based seismic design
using Pushover Analysis (Static Non-liner) and Dynamic Analysis



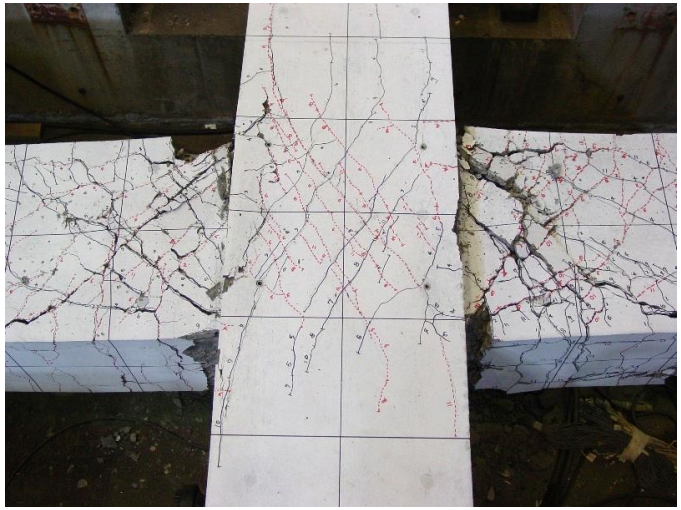


Lumped Mass Model for dynamic analysis

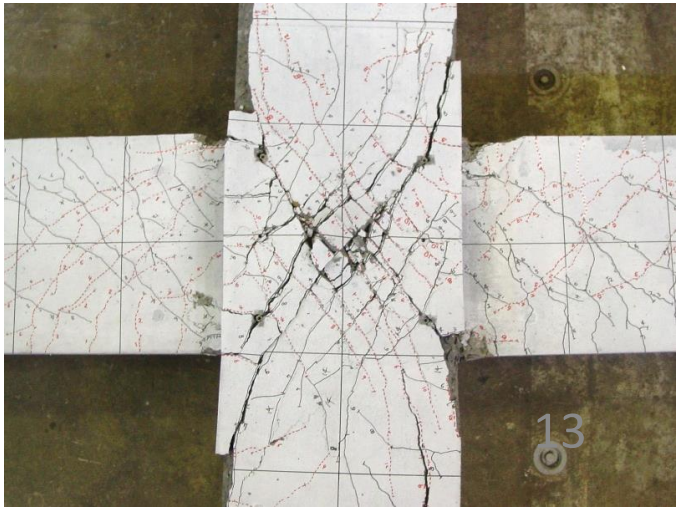
3. Recent Innovative Research and Application

Research of Beam-Column Joint

If the column is not enough stronger than the beam,
the joint will be damaged before the strength of the frame attains.



Plastic Hinge of Beam end

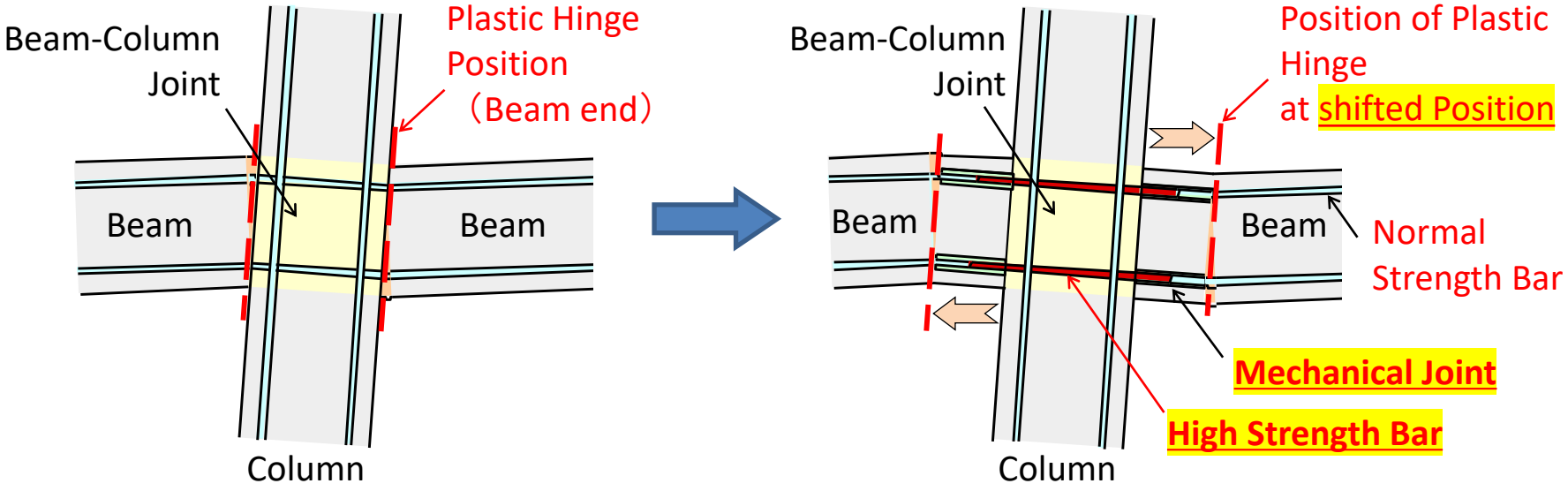


Damaged Joint

To avoid this damage,
the columns should be well stronger than the beams,
but the dimensions of the columns become larger.

Hinge Relocation System

To avoid the damage of the beam-column joint rationally, the hinge relocation system is introduced, where the plastic hinges are designed at the relocated positions of the beams.

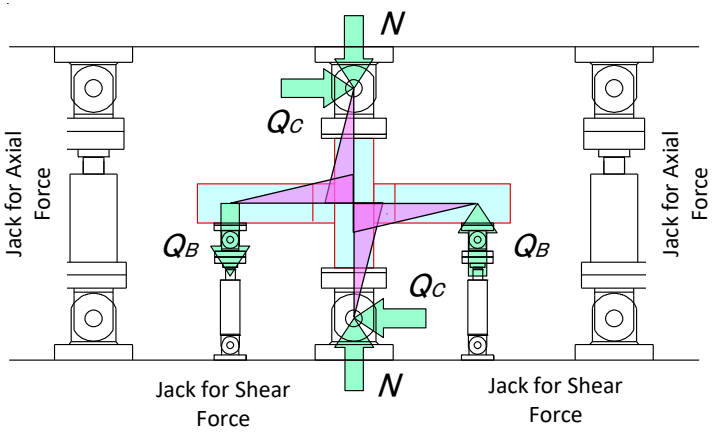


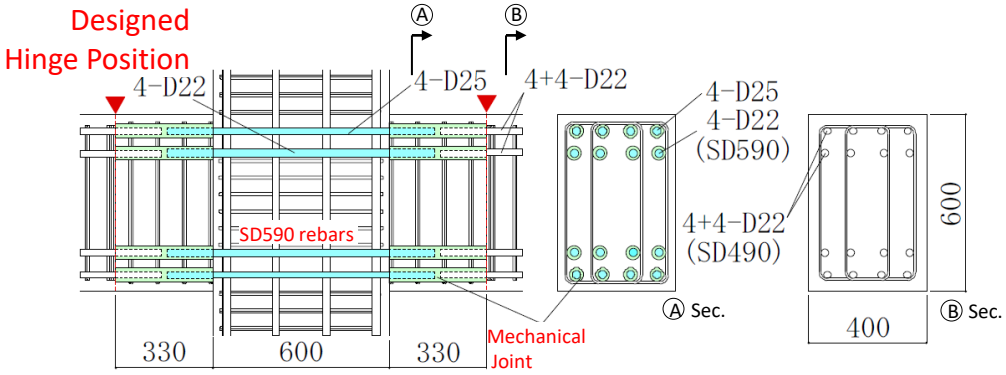
(1) Conventional

(2) Hinge Relocation System

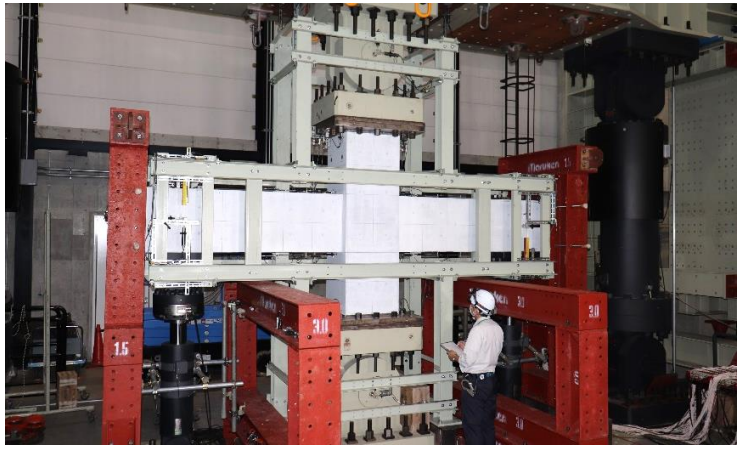
Comparison of Deformation around Joint

Structural Experiment

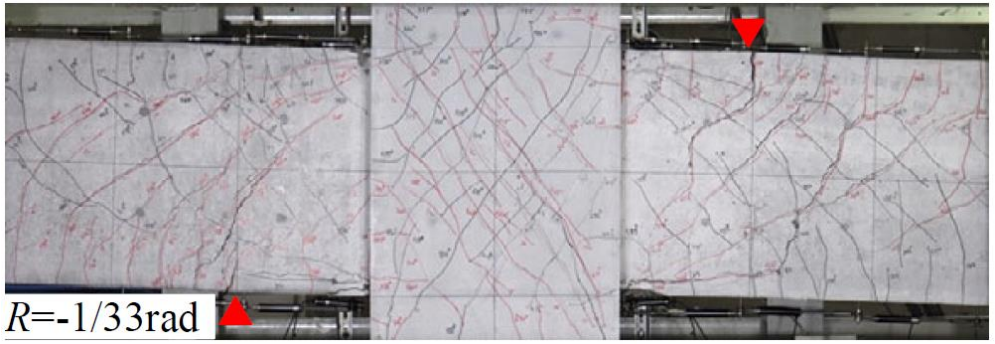




Detail of Reinforcement



Hinge Position



Hinge Position

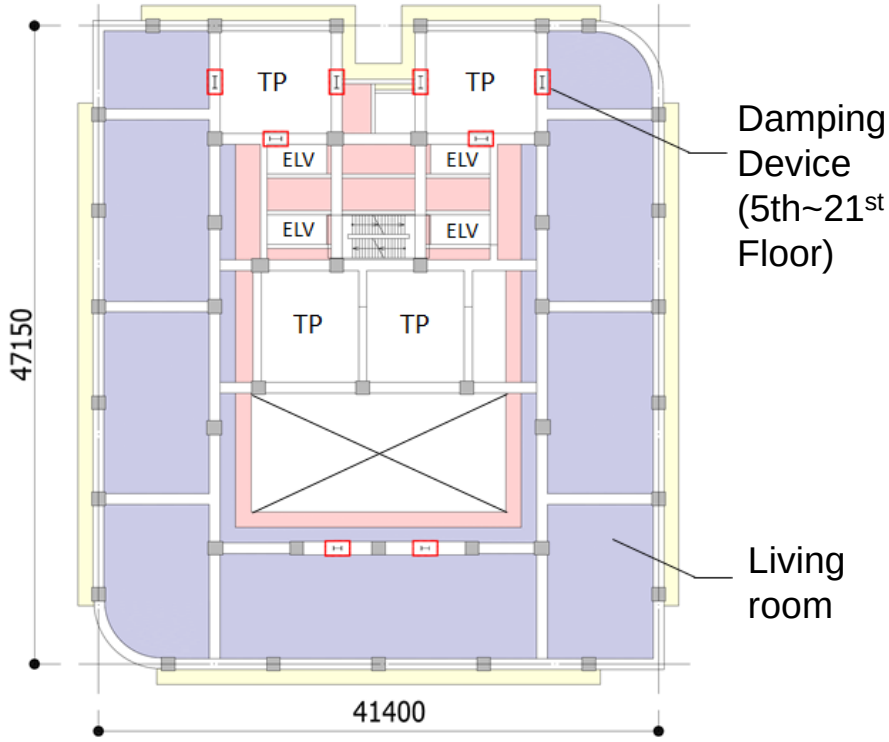
Crack Condition after Large Deformation

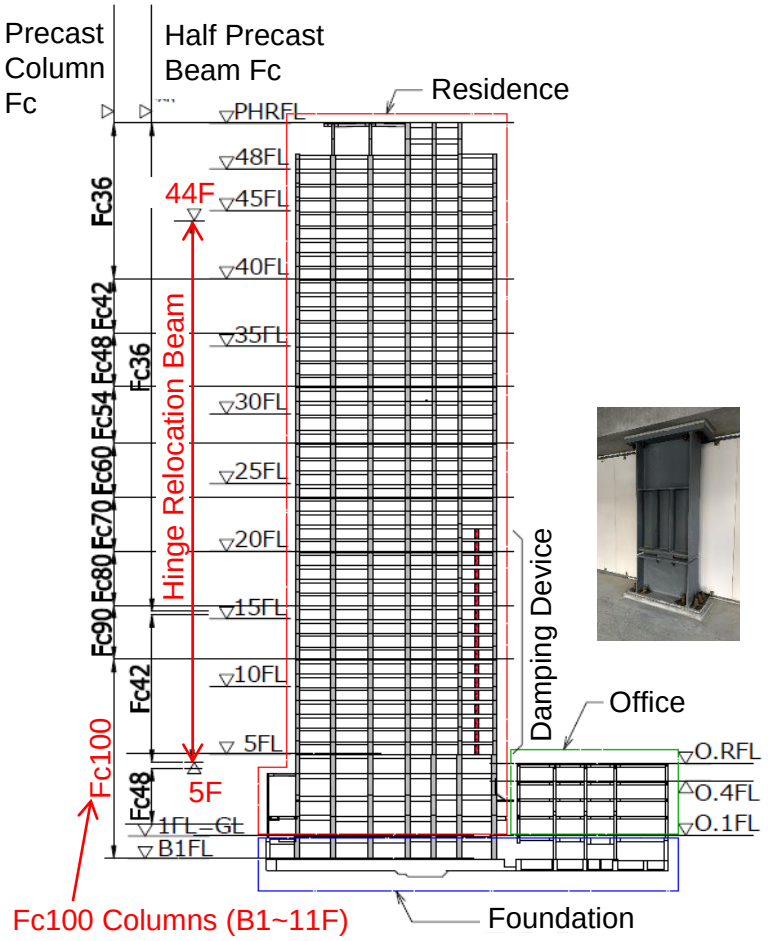
Application of Hinge Relocation System

- Site : Sapporo City, Japan
- Usage : Residence
- Floor Area : 98,600m^2
- Stories : 48
- Total height : 175m
- Concrete : 100MPa
- Features
  - Hinge relocation design method
    (Improvement of seismic performance)
  - Separated precast columns & beams
    (speedy construction)
- Construction period: July 2020 to Dec. 2023

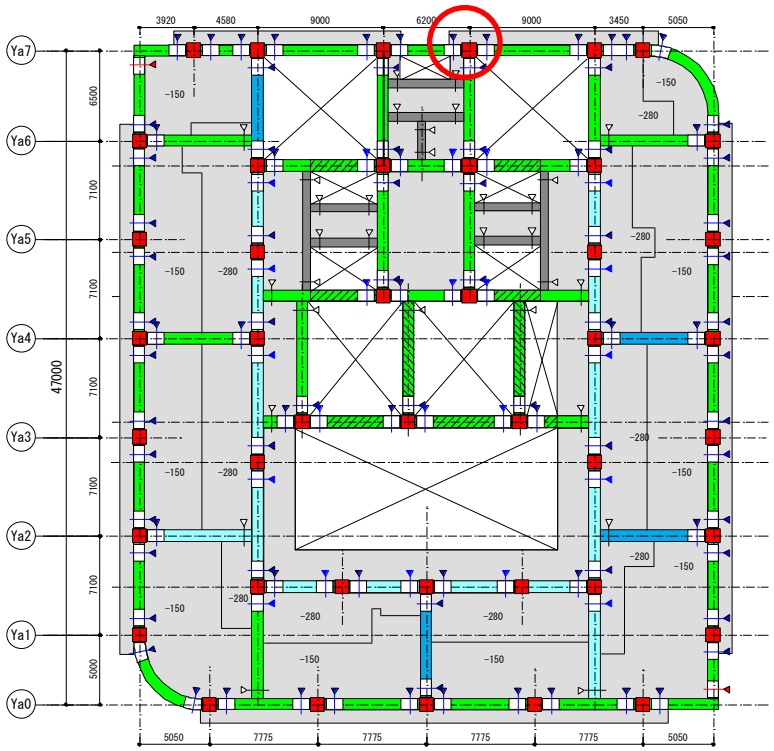
Application

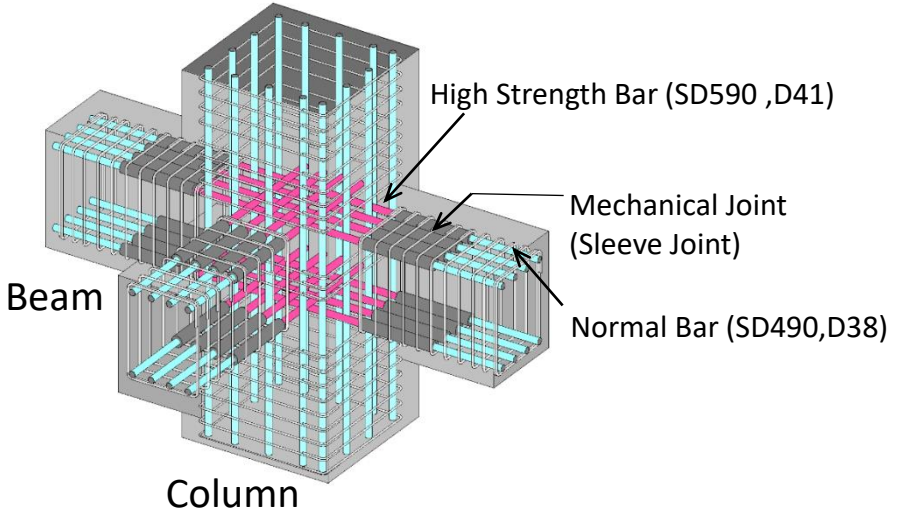
- HSC (100MPa) is used for columns on the 11th floor and below
- Newly developed hinge relocation method is applied for the beam-column joints of from 5th to 44th floors.





Application

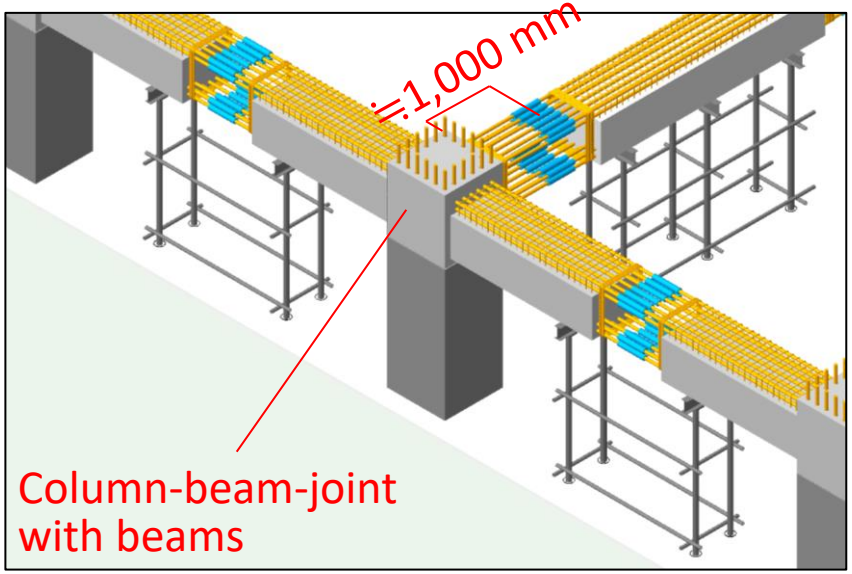




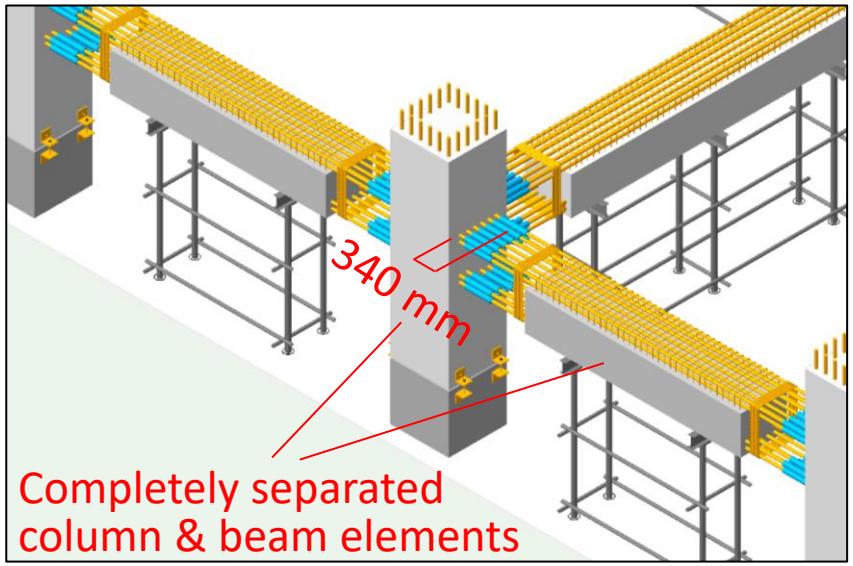
Large-diameter re-bars of SD590 are used for the main bars of the beam-ends and they are connected to SD490 re-bars by using mechanical joints

Precast construction

Conventional Precast Construction



Hinge Relocation Method



Hinge Relocation Method has great advantages
not only in structural design, but also in manufacturing,
transportation and construction.

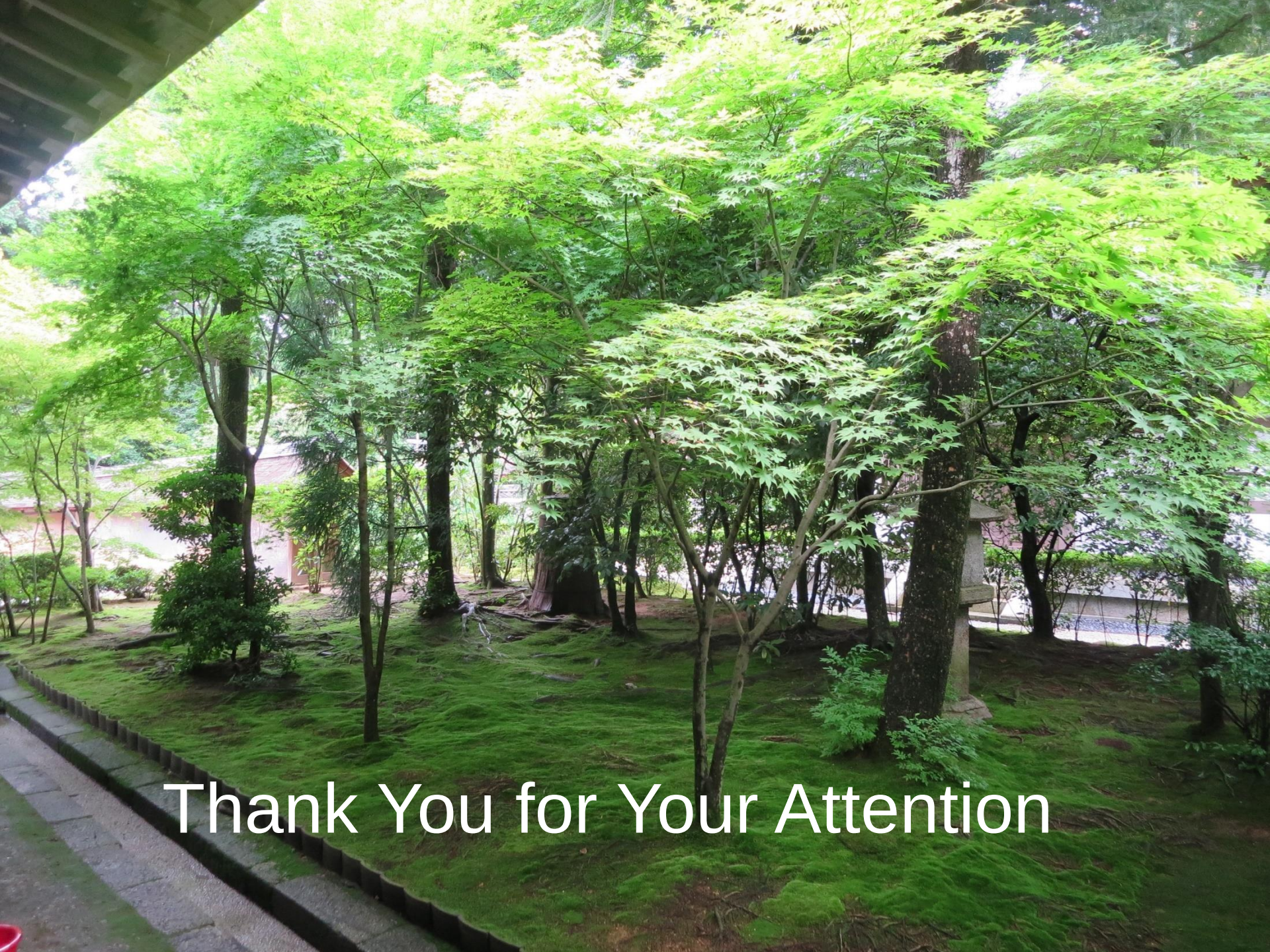
Precast construction

Precast construction

Summary

Recent application of high strength materials to high-rise buildings in Japan are discussed.

In order to make structural seismic performance higher, hinge relocation system had been developed and applied to a high-rise building.


Thank You for Your Attention

High Strength Steel (SD490,590,685) Code and Usage in Japan

【Buildings】

JIS (Japanese Industrial Standard) :Material

SD490, SD590A, SD590B, SD685A, SD685B, SD685R[a)] , SD785R[a)] are added to new JIS in 2020.

a) Use only for lateral reinforcement

Y/T ration is not exceeding 80% (that is 1.25 of T/Y) for SD490, SD590B, SD685B and 85% (that is 1.18 of T/Y) for SD590A, SD685A.

AIJ(Architectural Institute of JAPAN) :Design for buildings

Only SD490 can be used, according to AIJ Standard.

BSL(Building Standard Law in JAPAN) :Design and Construction for buildings

Only SD490 can be used, according to Standard Manual.

As for SD490, it can be used for any buildings, according to the AIJ and BSL.
As for SD685,590, certification of Ministry of Land, Infrastructure, Transport and Tourism (MLIT) is necessary for each project, so performance based design is required.

Explanations above are not official, just for the understanding the state of usage of high strength re-bars in Japan

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1989.3 Graduate : Kyoto University

1989.4 Taisei Corporation, Design Division,
Structural design

2012.1 Taisei Corporation, Advanced Center of Technology

2007 Ph.Eng. Kyoto University

Compressive Performance of RC Column Using Ultra High Strength Concrete

Buildings designed

Taisei Sapporo Building

8 Stories, RC,
Response Control System
Complete in 2006

Ochanomizu Sola City

23 Stories, Steel(CFT),
Base Isolation System
Competed in 2013

Ootemachi Tower

38 Stories, Steel(CFT),
Response Control System
Competed in 2014