How to Design Building Structures under Seismic Load Effects

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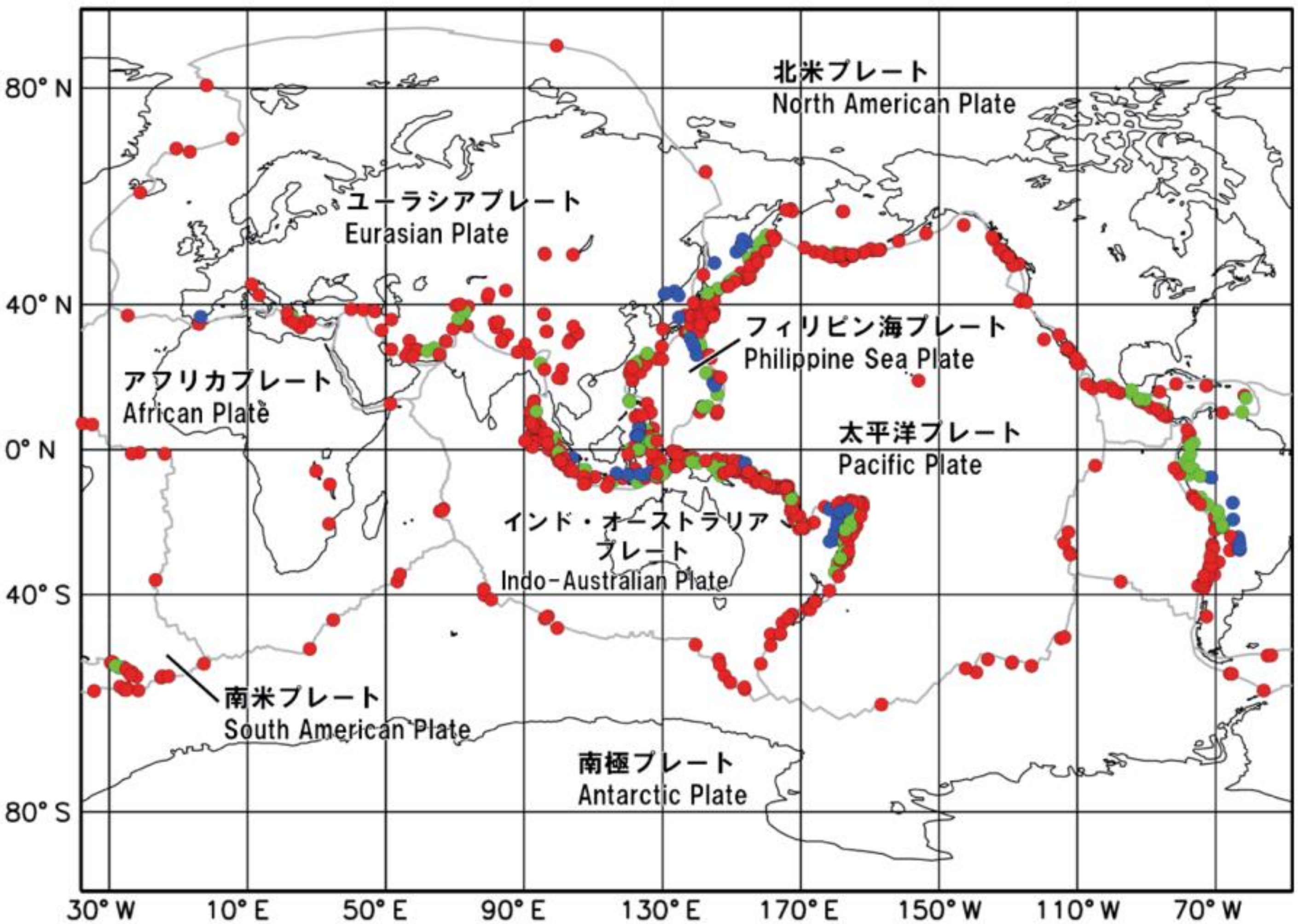
Seismic Design Procedure of Steel Structure in JAPAN

Distribution of Hypocenters



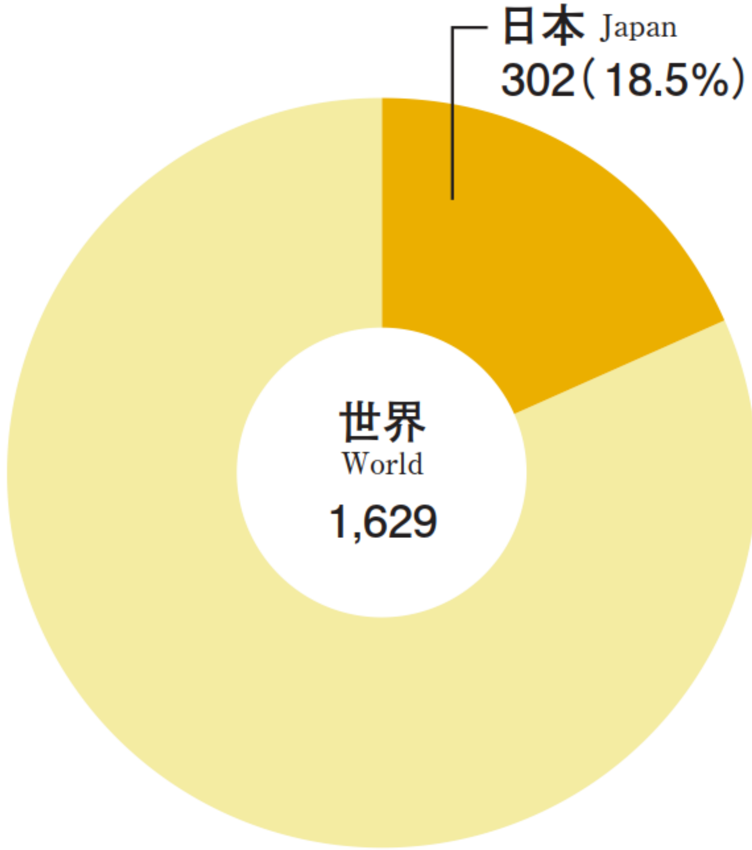
Depth

- ●: 0～ 60km
- ●: 60～300km
- ●: 300～700km

2004～2013, Magnitude ≧ 5.0

Reference: Disaster Management in Japan, Cabinet Office, Government of Japan

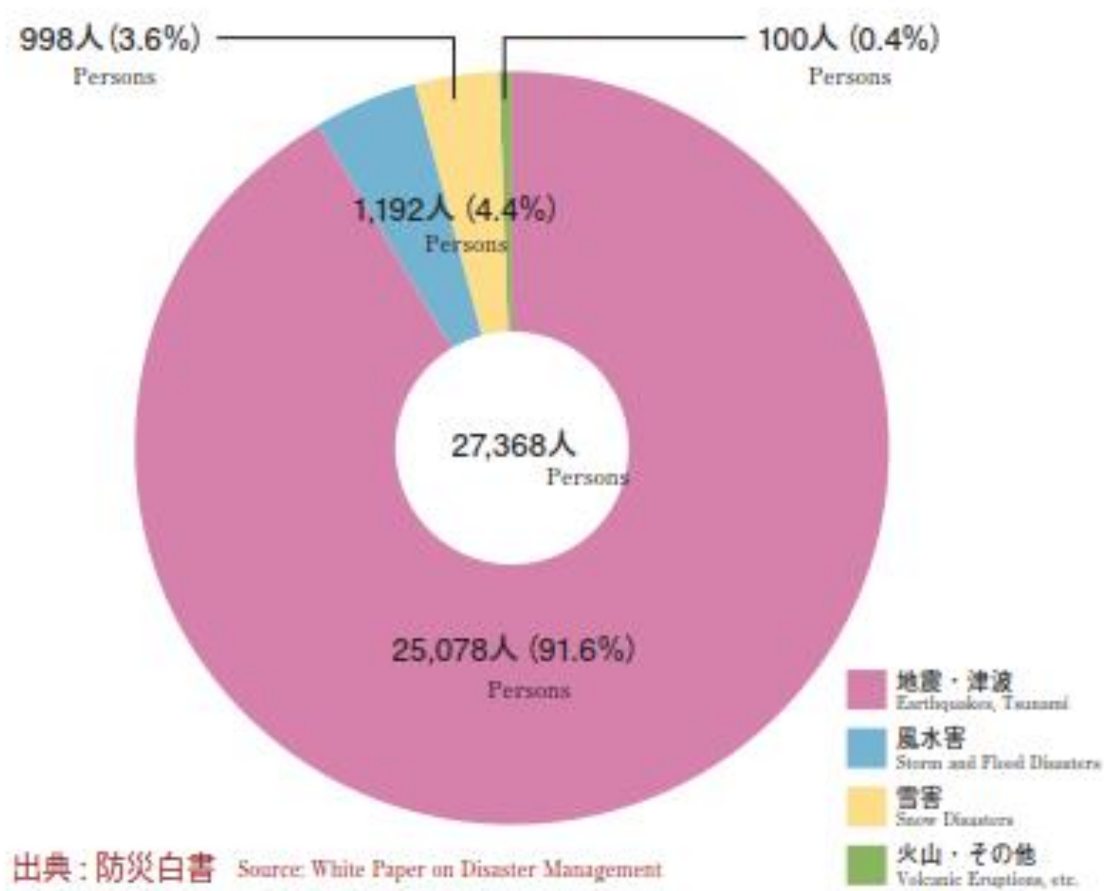
Number of Earthquake



2004～2013, Magnitude ≧ 6.0

Reference: Disaster Management in Japan, Cabinet Office, Government of Japan

Number of Deaths and Missing Persons



1994～2013 (Past 20 years)

Reference: Disaster Management in Japan, Cabinet Office, Government of Japan

History of Disasters and Codes

Year	Disaster or upgrade	Deaths and Missing
1923	**Great Kanto Earthquake(M7.9)**	**about 105 000**
1924	Upgrade in Rules	
	Seismic design became mandatory (0.1)	
1948	**Fukui Earthquake(M7.1)**	**3 769**
1950	Promulgation of the Building Standard of Law	
	Seismic load (0.2), Seismic design for timber structure	
1968	**Tokachi-oki Earthquake (M7.9)**	**52**
1971	Upgrade in Rules of BSL	
	Rules for RC structure became more strict	
1978	**Miyagi-ken-oki Earthquake (M7.4)**	**28**
1981	Upgrade in Rules of BSL	
	Equivalent lateral force procedure was introduced	

History of Disasters and Codes

Year	Disaster	Deaths and Missing
1995	**Great Hanshin-Awaji Earthquake (M7.3)**	**6437**
2000	Additional design procedure was included in BSL Promulgation of " The Calculation Method of Response and Limit Strength "	
2005	Additional design procedure was included in Notification Promulgation of "Energy Balance Based Seismic Resistance Design procedure "	

General (Structural Design)

Ministry of Land Infrastructure, Transport and Tourism (MLIT)

- **Building Standard of Law in JAPAN (BSL)**
  - **Notification** (similar to Law)

Architectural Institute of Japan (AIJ)

- Design Standard for Steel Structures -Based on Allowable Stress Concept-
- Recommendation for Limit State Design of Steel Structures
- Recommendations for the Plastic Design of Steel Structures
- Recommendation for Design of Connections in Steel Structures
- Recommendations for Stability Design of Steel Structures

General (Structural Design)

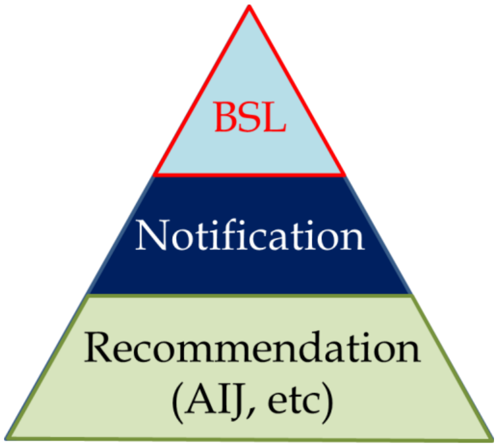
Ministry of Land Infrastructure, Transport and Tourism (MLIT)

- Building Standard of Law in JAPAN (BSL)
  - Notification (similar to Law)

-**Concept** of Design

-Load (Action)

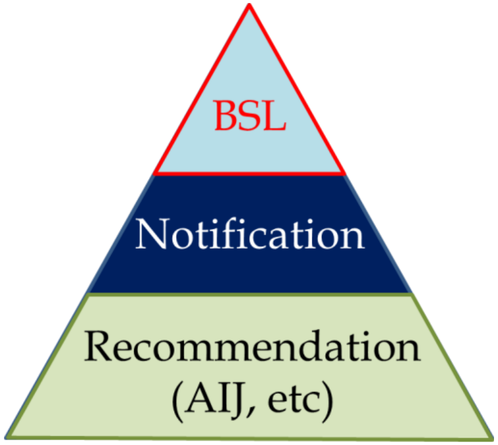
-Resistance (allowable stress)



If needed information are not provided in the Law or Notifications, structure designer will use the Recommendations published by AIJ.

AIJ Recommendations are often referred to compute the Resistance or Limitation for ULS.

Building Standard of Law (BSL)



Building Standard of Law in Japan (BSL)

- Building height greater than 60m

→ **Nonlinear dynamic response time-history analysis** should be conducted. Design process should get an endorsement from the scientific committee. (Peer review is needed)

- Height less than or equal to 60m

→ Standard Procedure can be used.

"Equivalent Lateral Force Procedure"

  - Validity was proved though Kobe Earthquake (1995) and Tohoku Earthquake (2011)

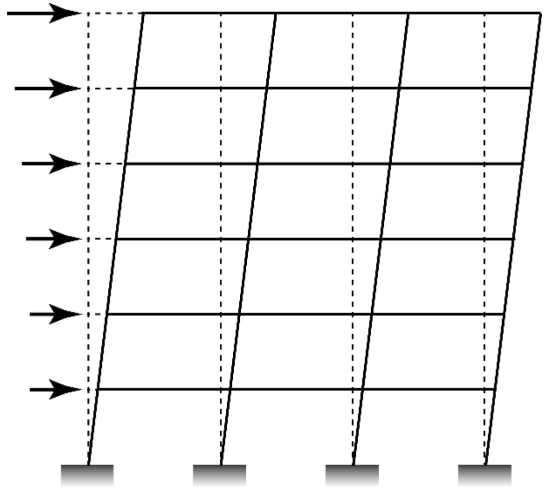
Seismic Design Procedures (BSL)

Equivalent Lateral Force procedure (1981)

The Calculation Method of Response and Limit Strength (2000)

Energy Balance Based Seismic Resistance Design procedure (2005)

Equivalent Lateral Force Procedure (1981)



Equivalent Lateral Force procedure (1981)

- Three types of design procedure, So called "Route" is stipulated in BSL.
  - Route 3, Route 2, and Route 1

Route 3: Sophisticated (Default)

Route 1: Simplified
- Height limitation;
- Size limitation;
- etc…

Design Procedure so called “**Route 3**”

- Can be applied to all size of structures. Building height greater than 31m and less than or equal to 60m should follow this procedure ($31 < H \leqq 60$m).
- Two phases of design should be conducted.
  - Phase 1 : **Allowable Stress Design**
    - Service and Damage Limitation requirements
  - Phase 2 : **Ultimate Strength Design**
    - No-collapse requirement

"Route 3" Phase 1 –Allowable Stress Design-

- Long term and short term should be checked

$$\sigma \leq f$$

- Return period of seismic event is about 50 years.

  (about 20% exceedance probability in 10 years)

Example of Allowable Stress (Steel)

Allowable stress	Long term	Short term
Tensile stress	$F/1.5$	1.5 × (long term values)
Shear stress	$F/(1.5\sqrt{3})$	

"Route 3" Phase 1 –Allowable Stress Design-

Load Combination

Duration of Force Long term	Condition Regular	Combination	
		Standard Region	Heavy Snow Region
Long term (SLS)	Regular	G+P	G+P
	Regular + Snow		G+P+0.7S
Short term (DLS)	Regular + Snow	G+P+S	G+P+S
	Regular + wind	G+P+W	G+P+W
			G+P+0.35S+W
	Regular + Earthquake	G+P+K	G+P+0.35S+K

G is Dead load effects, P is live load effects, S is Snow load effects, W is wind load effects, and K is seismic load effects

"Route 3" –Story Drift check-

- Return period of seismic event is about 50 years.

  (about 20% exceedance probability in 10 years)

Based on this seismic action, story drift ratio at

i story should be satisfied.

$$SDR_i \leq \frac{1}{200}$$

This value can be relaxed to 1/120 (0.0083) when the non-structural components are not affected.

"Route 3" Phase 2 –Ultimate Strength Design-

- Structural Safety should be confirmed.
- Return period of seismic event is about 500 years. (about 10% exceedance probability in 50 years)
- Horizontal load-carrying capacity should be greater than or equal to the required strength.

$$Q_{un,i} \leq Q_{u,i}$$

$Q_{u,i}$: Horizontal load-carrying capacity

$Q_{un,i}$: Required Horizontal load-carrying capacity (BSL)

"Route 3" Phase 2 –Ultimate Strength Design-

- Required horizontal load-carrying capacity, $Q_{un,i}$

$$Q_{un,i} = D_{s,i} \cdot F_{es,i} \cdot Q_{ud,i}$$

$Q_{ud,i}$: Load action determined by linear elastic response

$F_{es,i}$: Shape factor

$D_{s,i}$: Ductility Reduction Factor

- Strong Column Weak Beam Philosophy
  - for column steel grade BCR and BCP (at Floor Level)

$$\sum M_{pc} = \sum \min\left\{1.5M_{pb},\ 1.3M_{pp}\right\}$$

  - for column steel grade STKR (at All Joints)

$$\sum M_{pc} = 1.5\sum M_{pb}$$

"Route 3" Phase 2 –Ultimate Strength Design-

- Load action determined by linear elastic response, $Q_{ud,i}$

$$Q_{un,i} = D_{s,i} \cdot F_{es,i} \cdot \boxed{Q_{ud,i}}$$

$$Q_{ud,i} = C_i \cdot W_i$$

- W_i: Total weight supported at i story $= \sum_{j=i}^{n} w_i$
- C_i: Seismic story shear (force) coefficient at i story

$$C_i = Z \cdot R_t \cdot A_i \cdot C_0$$

- C_0: Intensity (≧1.0 for phase 2, ≧0.2 for phase 1)
- A_i: Lateral force distribution (≧1.0)
- R_t: Normalized elastic response acceleration (≦1.0)
- Z: Region coefficient (0.7 to 1.0)

"Route 3" Phase 2 –Ultimate Strength Design-

- Shape factor, $F_{es,i}$

$$Q_{un,i} = D_{s,i} \cdot \boxed{F_{es,i}} \cdot Q_{ud,i}$$

$$F_{es,i} = F_{e,i} \cdot F_{s,i}$$

$F_{s,i}$: Penalty factor to consider irregularity in elevation (1.0 to 2.0)

$F_{e,i}$: Penalty factor to consider irregularity in plan (1 to 1.5)

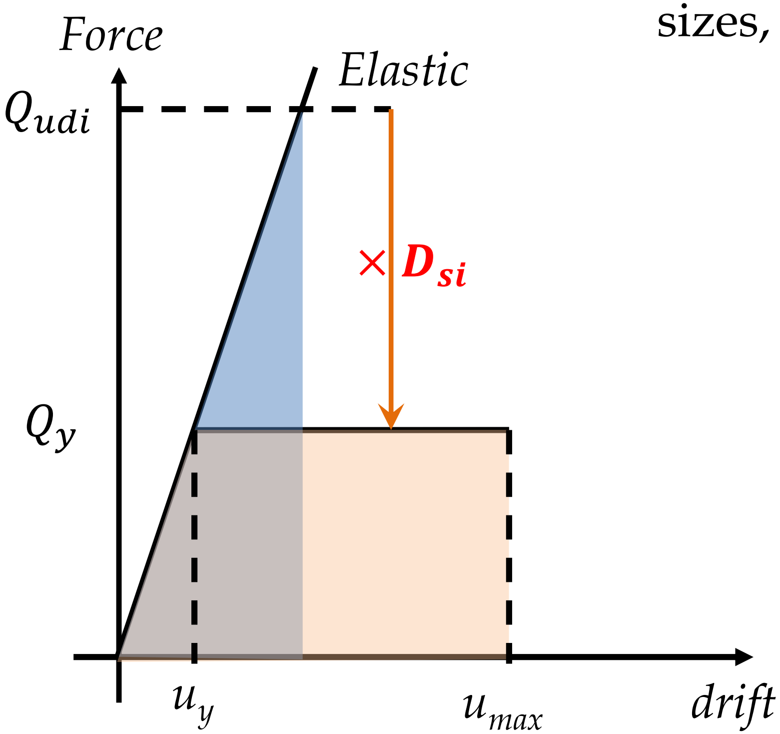
$F_{es,i}$: Shape factor will range from 1.0 to 3.0

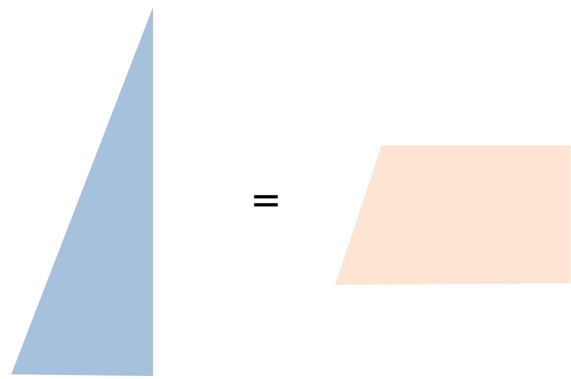
"Route 3" Phase 2 –Ultimate Strength Design-

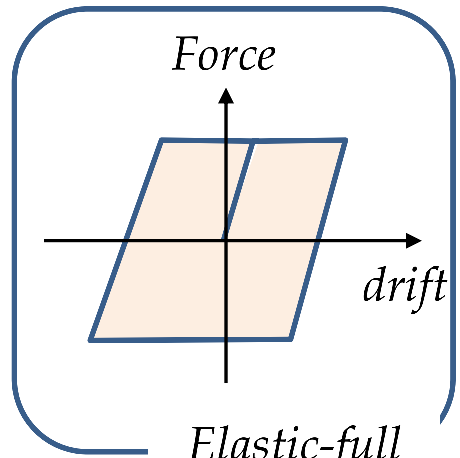
- Ductility Reduction Factor, $D_{s,i}$

$$Q_{un,i} = D_{s,i} \cdot F_{es,i} \cdot Q_{ud,i}$$

Basically, **Newmark Rule** is applied
This value is determined from the member sizes, i.e. compactness(0.25 to 0.50)







Elastic-full plastic Behaviour

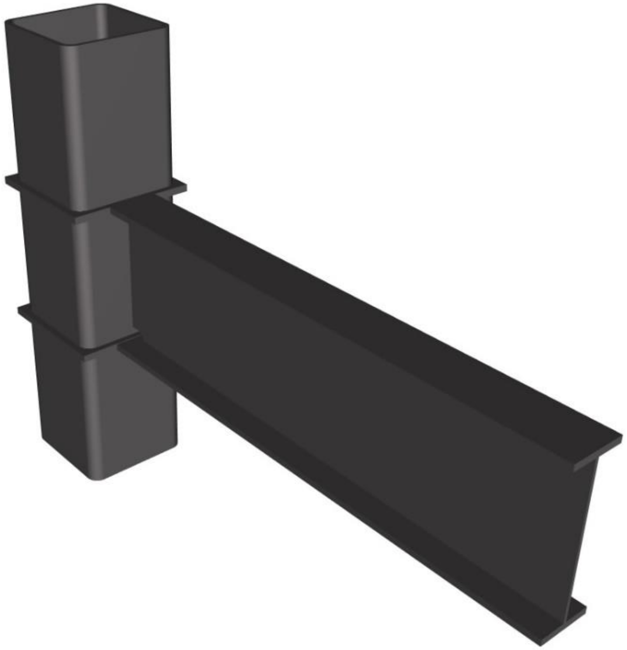
$$D_{s,i} = \frac{Q_y}{Q_{udi}} = \frac{1}{\sqrt{2\frac{u_{max}}{u_y} - 1}} = \frac{1}{\sqrt{2\mu - 1}}$$

"Route 3" Phase 2 –Ultimate Strength Design-

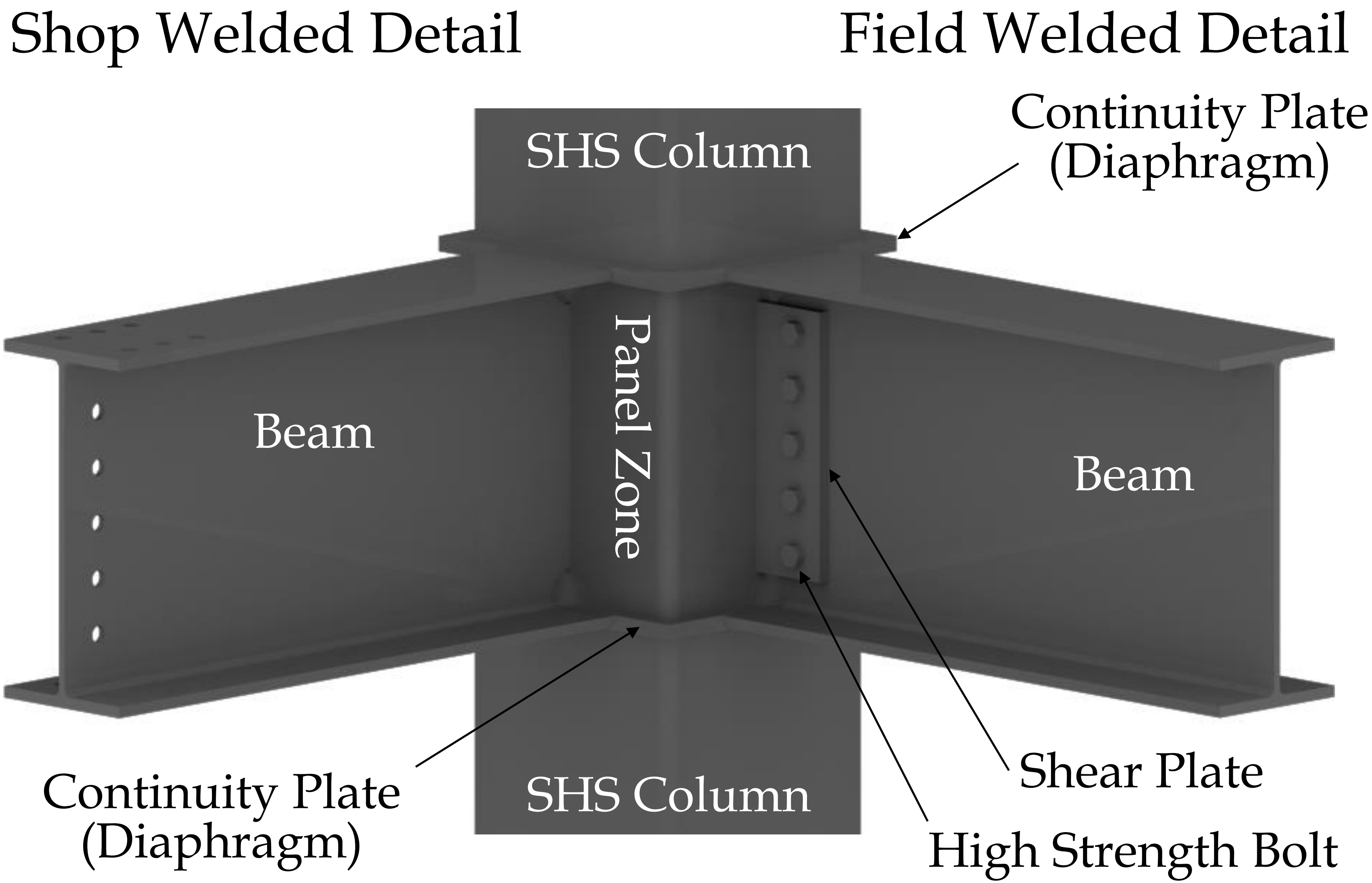
- Ductility Reduction Factor, $D_{s,i}$

Ds values			Classification of Group of Beam and Column			
A or bu = 0			A	B	C	D
Classification of Group of Braces	A or $\beta_u = 0$		0.25	0.3	0.35	0.4
	B	$\beta_u \leqq 0.3$	0.25	0.3	0.35	0.4
		$0.3 < \beta_u \leqq 0.7$	0.3	0.3	0.35	0.45
		$\beta_u > 0.7$	0.35	0.35	0.4	0.5
	C	$\beta_u \leqq 0.3$	0.3	0.3	0.35	0.4
		$0.3 < \beta_u \leqq 0.7$	0.35	0.35	0.4	0.45
		$\beta_u > 0.7$	0.4	0.4	0.45	0.5

Design of
Beam-to-Column Connection



Typical Beam-to-Column Connection



Typical Beam-to-Column Connection

Shop Welded Detail

- ✓ Column Tree
- ✓ CJP
- ✓ UT inspection

Ultrasonic Test Inspection

Typical Beam-to-Column Connection

Transport to Site

High strength bolts are used for Beam splice joints

Assemble Moment Frame

Beam-to-Column Connections

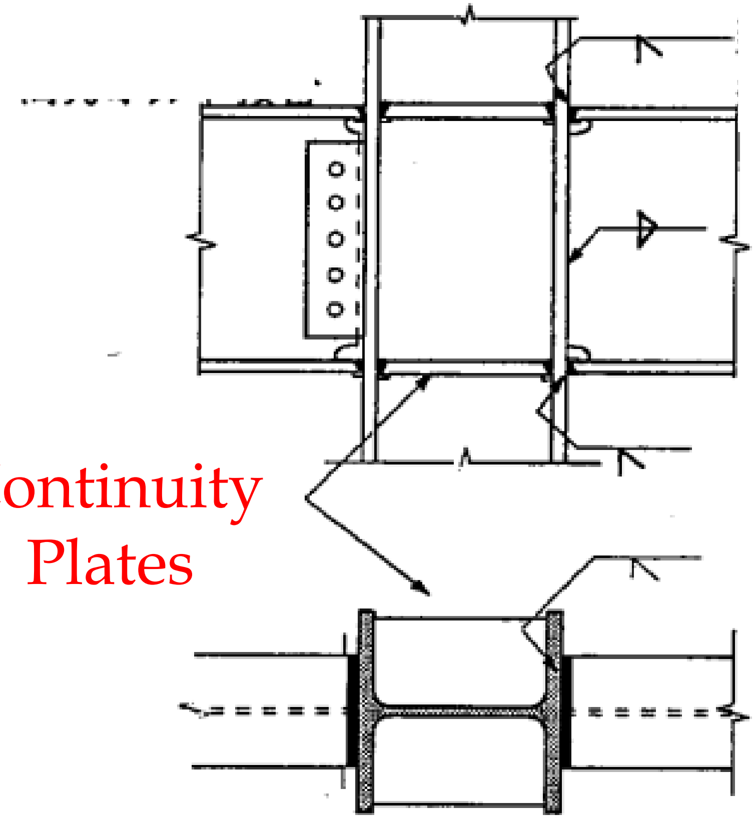
- Beam Joints
  - Assumed to be rigid and beam is expected to be the dissipative zones at Ultimate limit State (ULS).
    - → Consistent with BSL
  - Capacity design. Following should be satisfied.

$$\alpha \cdot {}_{b}M_{p} \leq {}_{j}M_{u}$$

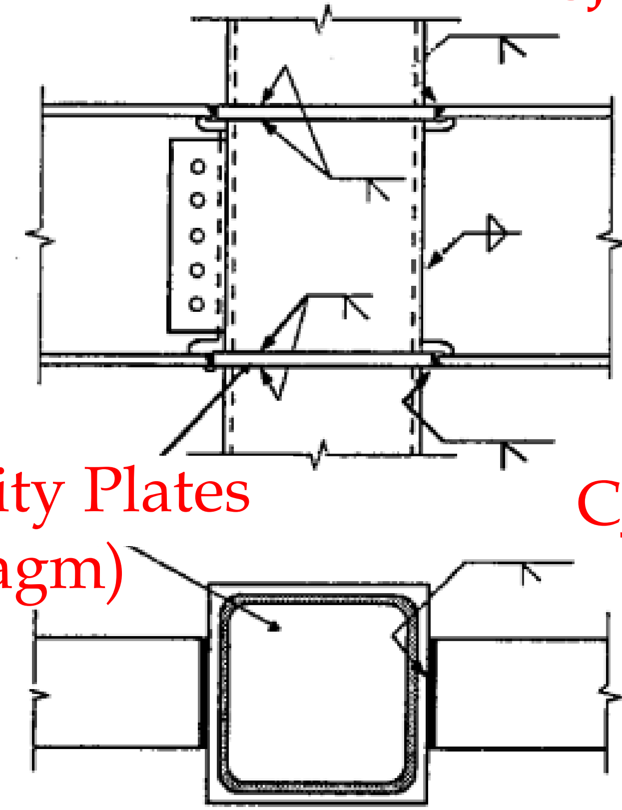
- ${}_{j}M_{u}$: Maximum Strength of the Beam Joint
- ${}_{b}M_{p}$: Full Plastic moment of the Beam
- α: Beam Joint Coefficient. Considering Hardening and Strength Randomness. Depending on Steel Grades.

α: SS400 1.40, SM490 1.35, SN400B 1.30, and SN490B 1.25

Rigid Joints (to be consistent with BSL)

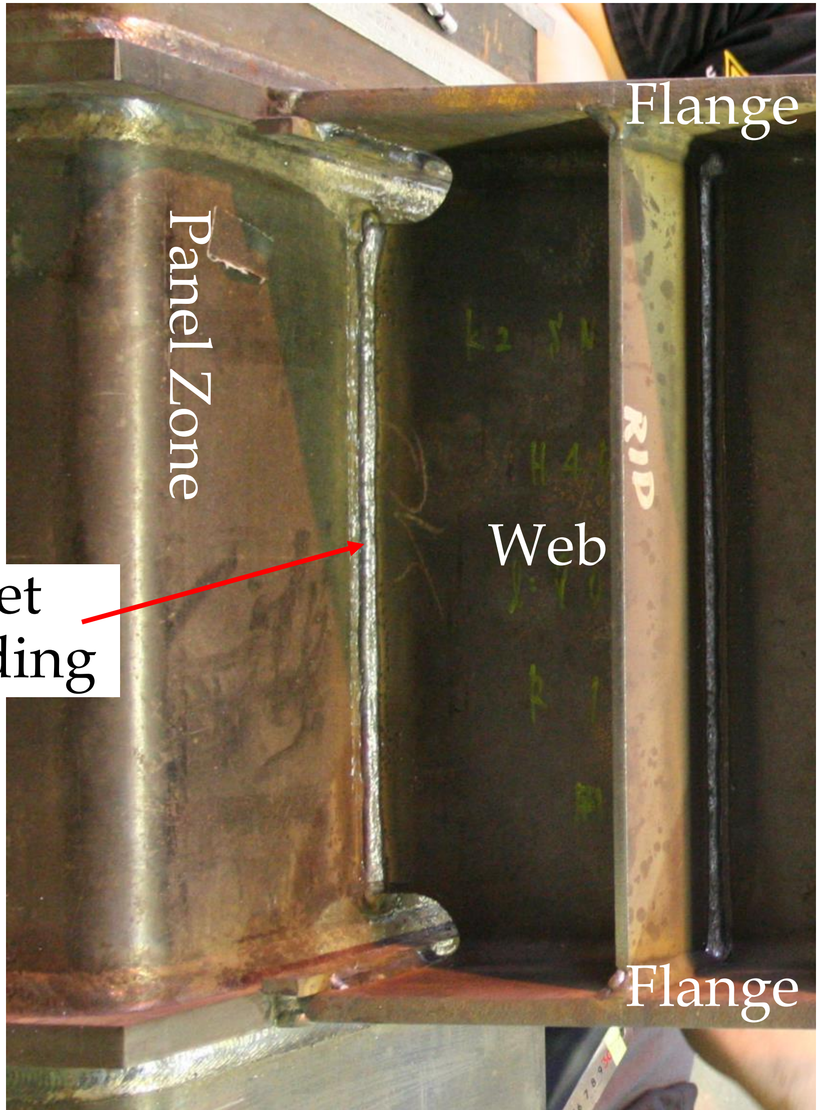


H section Column
<not common>

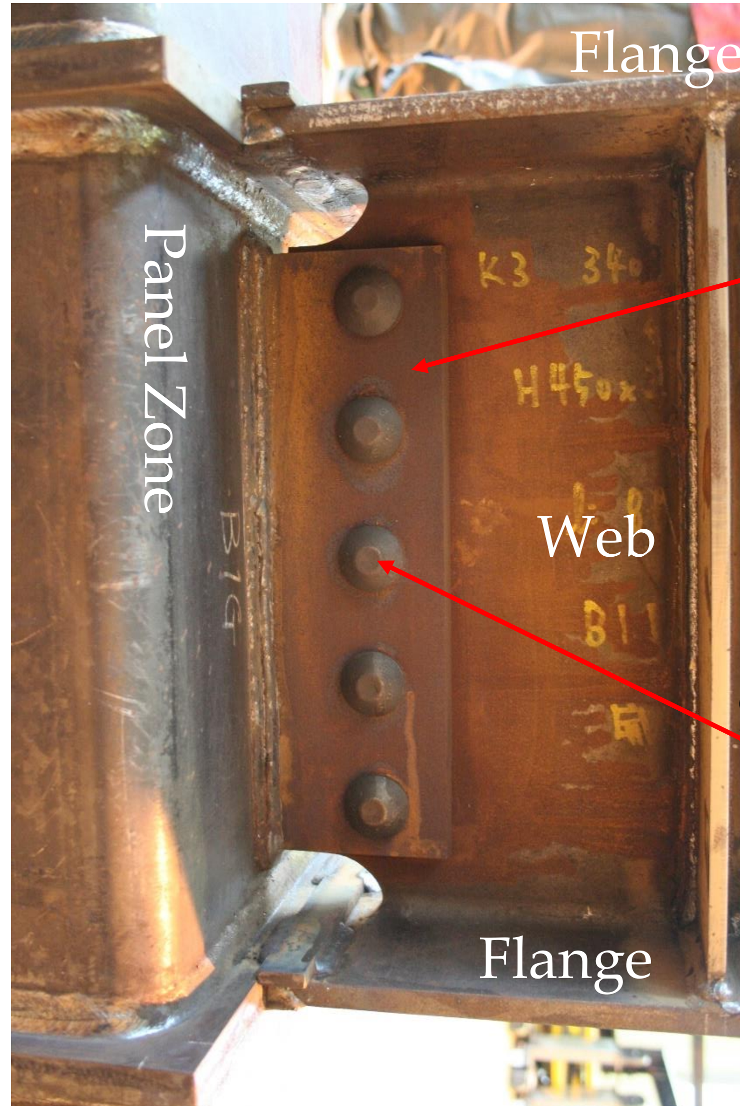


Hollow section Column
<Typical>

Difference Between Shop and Field



Shop Welding



Field Welding

Maximum Strength of the Beam Joint

- For Rigid Joints at ULS

$$\alpha \cdot {}_b M_p \leq {}_j M_u$$

<Beam>

$$\alpha \cdot {}_b M_p = \alpha \cdot Z_p \cdot F_{by}$$

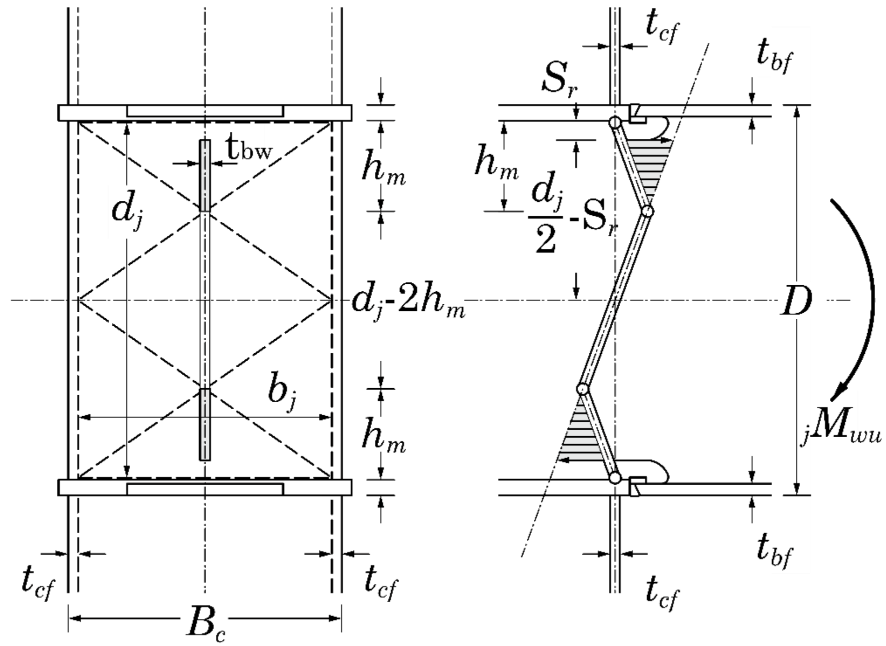
<Beam Joint Strength>

$${}_j M_u = {}_j M_{ju} + {}_j M_{wu}$$

<flange> $${}_j M_{fu} = A_f \cdot d_b \cdot F_{bu}$$

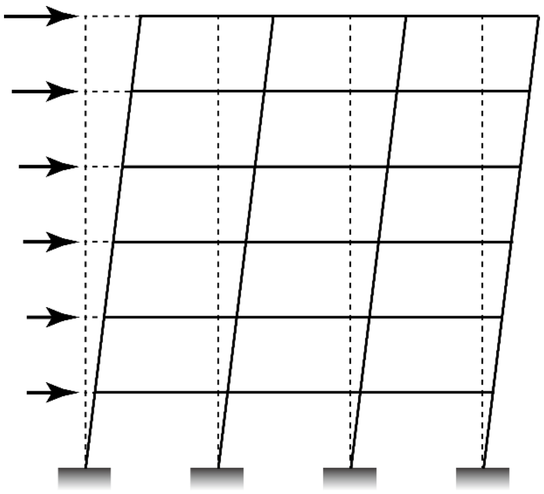
<web> $${}_j M_{wu} = m \cdot Z_{wpe} \cdot F_{by}$$

<web joint efficiency> $$m = \min\left\{1,\ 4\frac{t_{cf}}{d_j}\sqrt{\frac{b_j}{t_{bw}}\frac{F_{cy}}{F_{by}}}\right\}$$



<effective area of beam web>

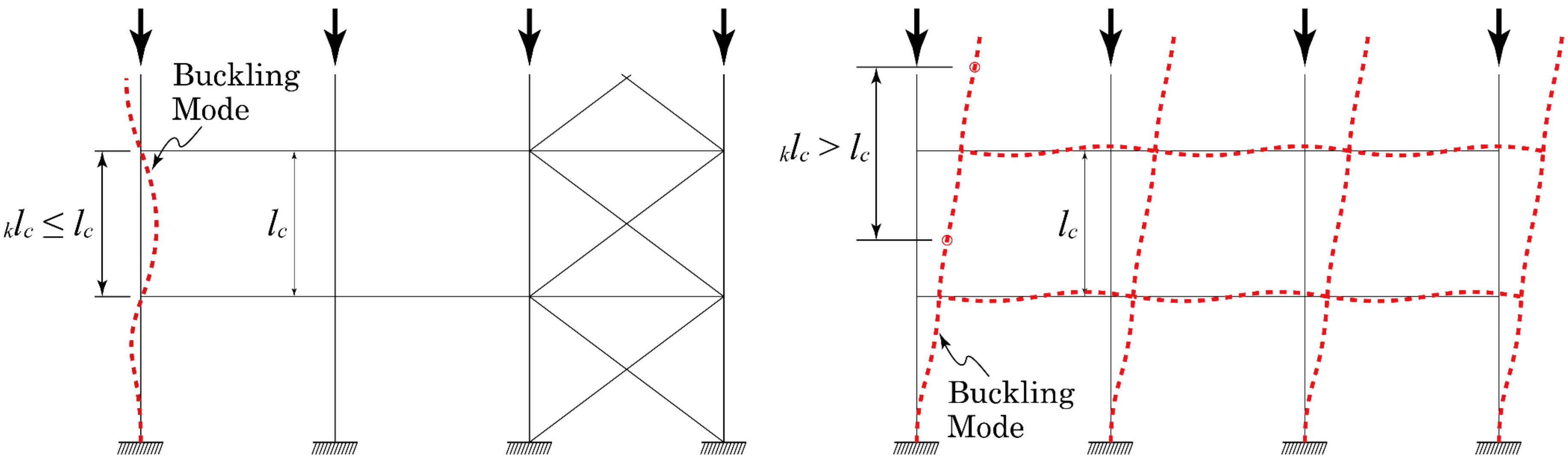
Design of Column



Flexural Buckling Length ${}_k l_c$

- Calculation Method base on relevant member stiffness

【Under **Gravity Load Condition**】



(a) Without Sway

(b) With Sway

$${}_k l_c \leq l_c \qquad\qquad {}_k l_c > l_c$$

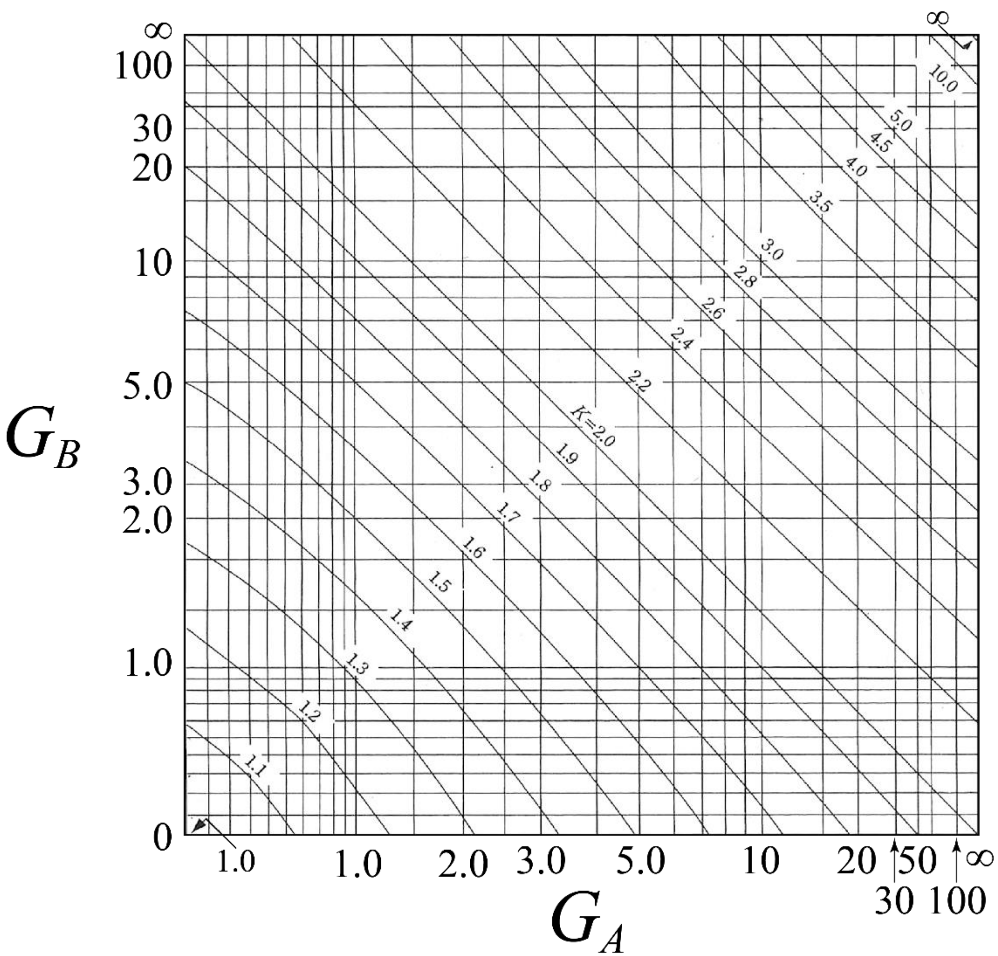
Column Length

【Flexural Buckling Length】 $${}_k l_c = k_c \cdot l_c$$

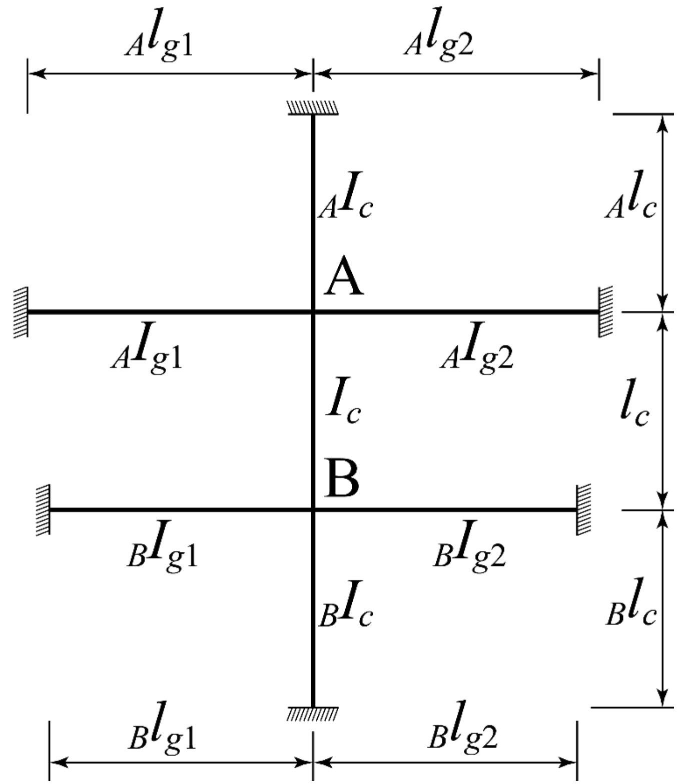
k_c : effective length factor

Flexural Buckling Length $_{k}l_c$

- Design Table (with sway)



Sway Buckling Mode



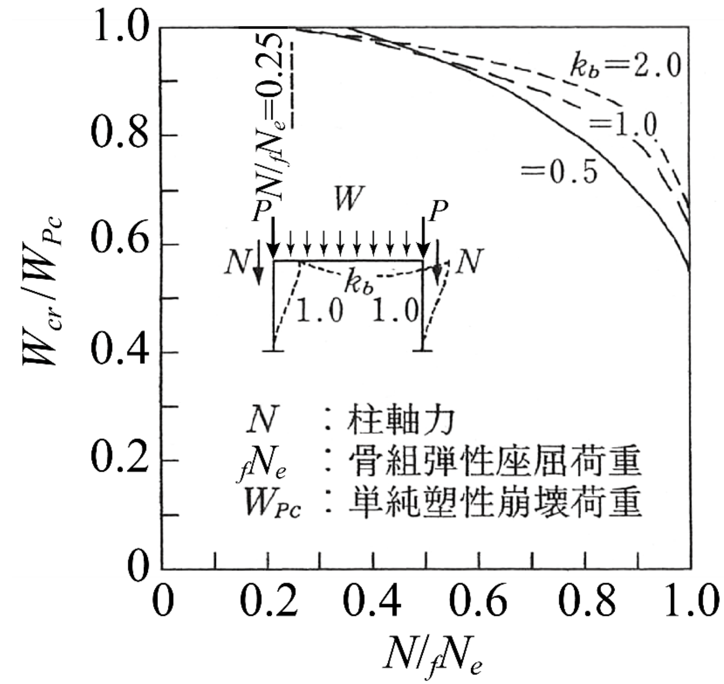
$$G_A = \frac{(I_c/l_c) + ({}_{A}I_c/{}_{A}l_c)}{({}_{A}I_{g1}/{}_{A}l_{g1}) + ({}_{A}I_{g2}/{}_{A}l_{g2})}$$

$$G_B = \frac{(I_c/l_c) + ({}_{B}I_c/{}_{B}l_c)}{({}_{B}I_{g1}/{}_{B}l_{g1}) + ({}_{B}I_{g2}/{}_{B}l_{g2})}$$

Frame Stability

（1）Combination of Compressive axial and slenderness

$$\left(\frac{N}{N_Y}\right)\cdot {}_f\lambda_c^{\,2} \le 0.25$$



（2）Maximum Compressive Axial force

$$\frac{N}{N_Y} \le 0.75$$

【Symbol】

In-plane non-dimensional slenderness ratio

$${}_f\lambda_c = \sqrt{N_Y / {}_fN_e}$$

In-plane elastic buckling strength

$${}_fN_e = \frac{\pi^2 \cdot E \cdot I}{{}_kl_c^{\,2}} = \frac{\pi^2 \cdot E \cdot I}{(k_c \cdot l_c)^2}$$

N : Compressive Axial force N_Y : Axial Yield Strength

Column Stability (class 1 cross-section)

Limitation for the column which will form Plastic Hinge

(1) Combination of Compressive axial and slenderness

(a) $-0.5 < \kappa \leq 1.0$

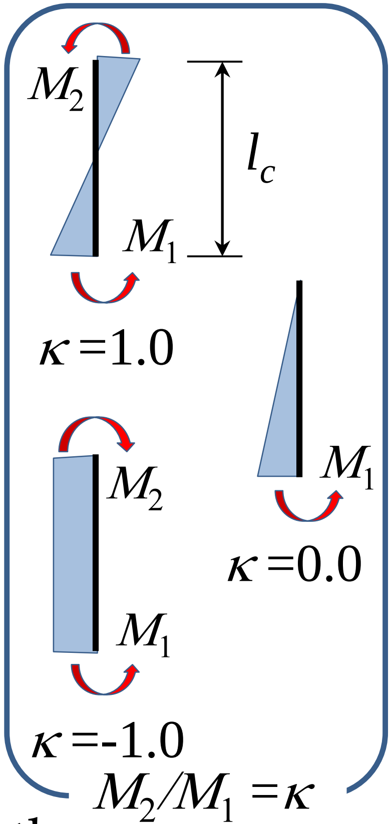
$$\left(\frac{N}{N_Y}\right) \cdot \lambda_{c0}{}^2 \leq 0.1 \cdot (1 + \kappa)$$

(b) $-1.0 \leq \kappa \leq -0.5$

$$\left(\frac{N}{N_Y}\right) \cdot \lambda_{c0}{}^2 \leq 0.05$$

$\kappa = M_2 / M_1$

Positive for double curvature bending



【Symbol】

Non-dimensional slenderness ratio

$$\lambda_{c0} = \sqrt{N_Y / N_0}$$

Euler's buckling Strength

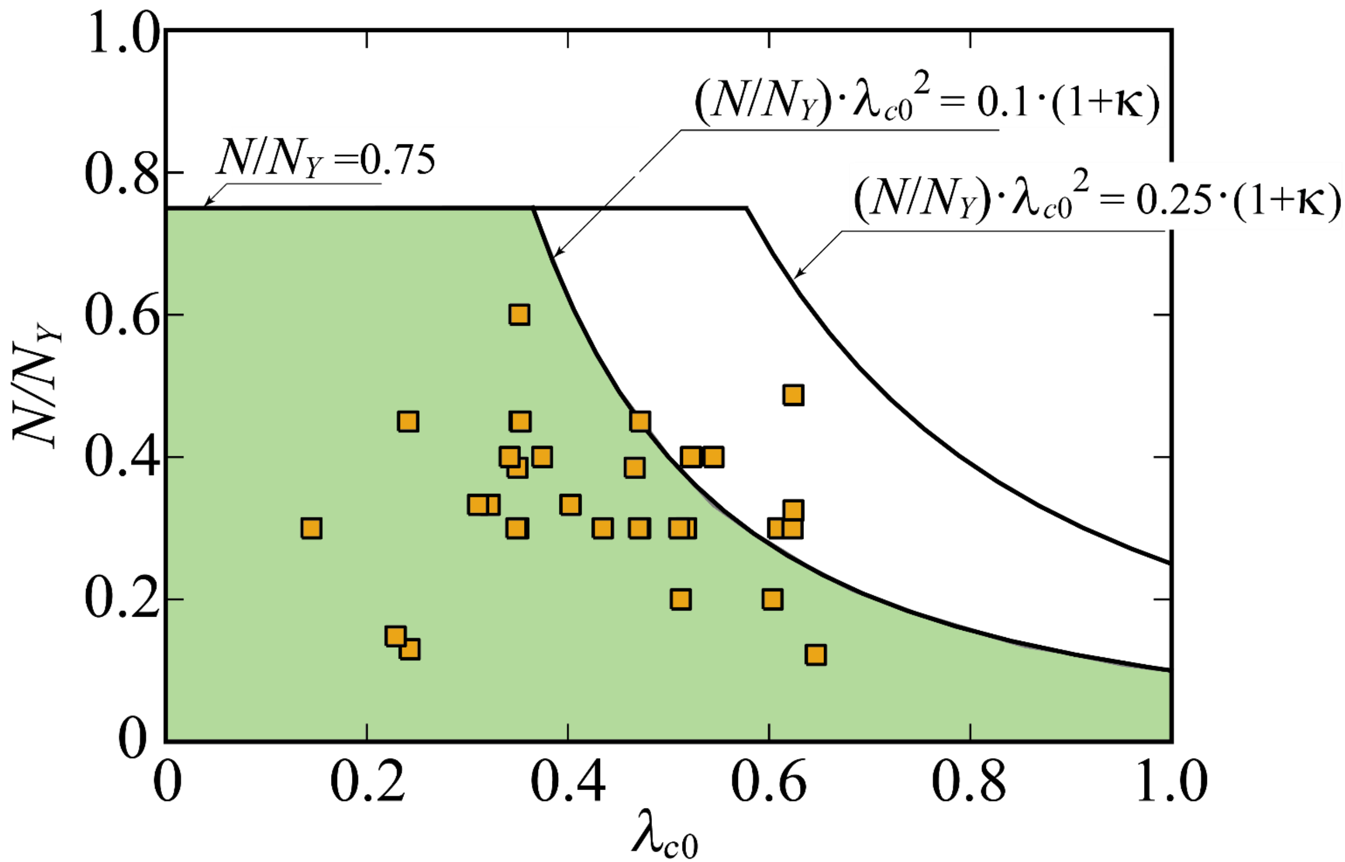
$$N_0 = \frac{\pi^2 \cdot E \cdot I}{l_c{}^2}$$

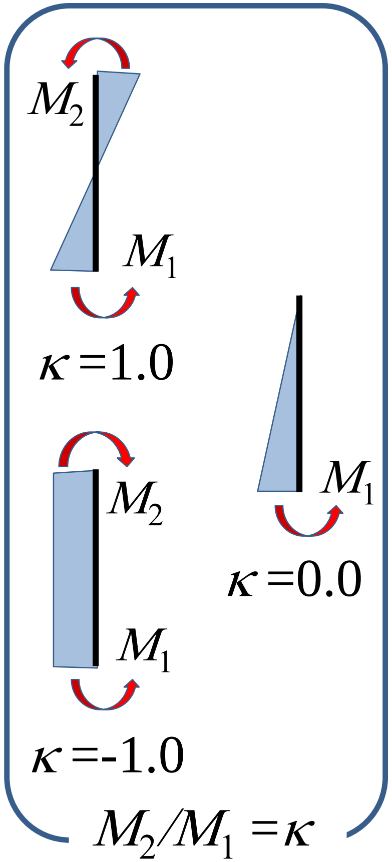
Column Length

Column Stability (class 1 cross-section)

Limitation for the column which will form Plastic Hinge

（1）Combination of Compressive axial and slenderness



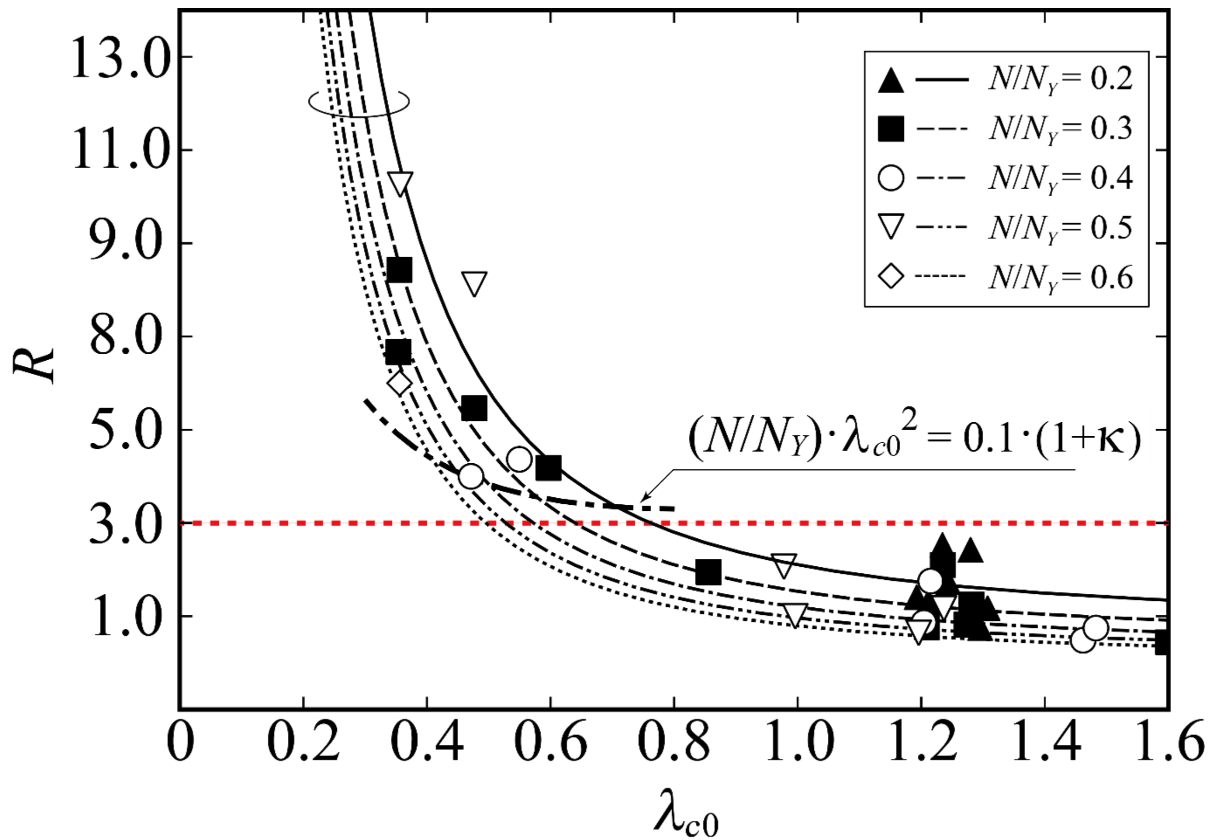


Comparison between test results and limitations (κ=0)

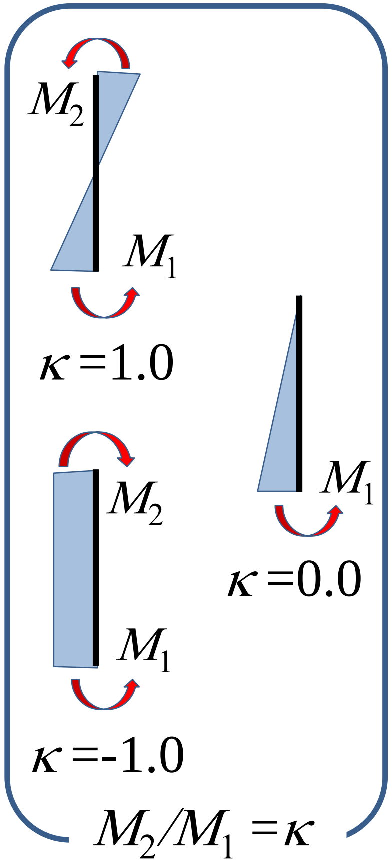
Column Stability (class 1 cross-section)

Limitation for the column which will form Plastic Hinge

(1) Combination of Compressive axial and slenderness



Deformation Capacity (κ=0)



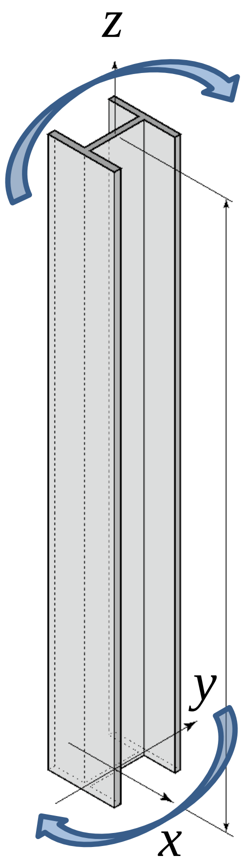
Column Stability (class 1 cross-section)

Limitation for the column which will form Plastic Hinge

(2) Wide Flange Section subjected to strong axis bending

Limitation of torsional-flexural non-dimensional slenderness ratio

$$\lambda_b \leq 0.75 \cdot {}_p\lambda_b$$



【Symbol】

λ_b: torsional-flexural non-dimensional slenderness ratio

$$\lambda_b = \sqrt{M_P / M_e}$$

$$M_e = C_b \sqrt{\frac{\pi^2 \cdot E \cdot I_y \cdot G \cdot J_T}{l_c^2} + \frac{\pi^4 \cdot E \cdot I_y \cdot G \cdot I_W}{{}_k l_c^2}}$$

$$C_b = 1.75 + 1.05 \cdot \kappa + 0.3 \cdot \kappa^2 \leq 2.3$$

${}_p\lambda_b$: Plastic Limit (plateau)

$$_p\lambda_b = 0.6 + 0.3 \cdot \kappa$$

$\kappa = M_2 / M_1$

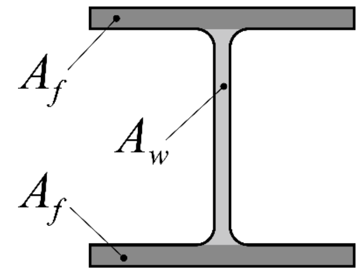
Positive for double curvature

Resistance

- Resistance of Column under combined loading

（1）Wide Flange Section

(a) Under Strong Axis bending



i) Fulfill **Column Stability**→Full Strength (M_{Pc})

$$\frac{N}{N_Y}+\frac{4\cdot A_f+A_w}{2\cdot A}\cdot\frac{M}{M_P}=1.0$$

ii) $\lambda_b \leq {}_p\lambda_b$ (in-plane)

$$\frac{N}{N_{cr}}+\varphi\cdot\frac{4\cdot A_f+A_w}{2\cdot A}\cdot\frac{M}{M_P}=1.0 \quad , \quad \frac{M}{M_{Pc}}\leq 1.0$$

iii) $\lambda_b \geq {}_p\lambda_b$ (out-of-plane)

$$\frac{N}{N_{cr,y}}+\frac{4\cdot A_f+A_w}{2\cdot A}\cdot\frac{M}{M_{cr}}=1.0 \quad , \quad \frac{M}{M_{cr}}\leq 1.0$$

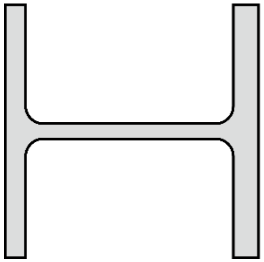
Resistance

- Resistance of Column under combined loading

（1）Wide Flange Section (cont.)

(a) Under Weak Axis bending

i) Fulfill **Column Stability**→Full Strength (M_{Pc})



$$\left(\frac{N - N_{wY}}{N_Y - N_{wY}}\right)^2 + \frac{M}{M_P} = 1.0$$

ii) others

$$\left(\frac{N - N_{wY}}{N_Y - N_{wY}}\right)^2 + \varphi \cdot \frac{M}{M_P} = 1.0 \,, \qquad \frac{N}{N_{cr}} \leq 1.0$$

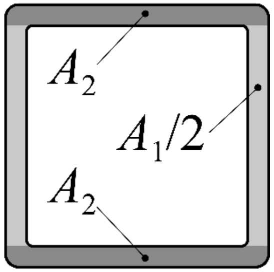
【Symbol】

φ: Coefficient to evaluate $P\delta$ effects (Second order effects)

N_{wY}: Yield strength of web

Resistance

(2) Rectangular (Square) Hollow Section



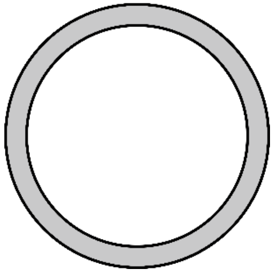
i) Fulfill **Column Stability**→Full Strength (M_{Pc})

$$\frac{N}{N_Y} + \frac{4 \cdot A_2 + A_1}{2 \cdot A} \cdot \frac{M}{M_P} = 1.0$$

ii) others

$$\frac{N}{N_{cr}} + \varphi \cdot \frac{4 \cdot A_2 + A_1}{2 \cdot A} \cdot \frac{M}{M_P} = 1.0 \quad , \quad \frac{M}{M_{Pc}} \le 1.0$$

(3) Circular Hollow Section



i) Fulfill **Column Stability**→Full Strength (M_{Pc})

$$\frac{N}{N_Y} + 0.80 \cdot \frac{M}{M_P} = 1.0$$

ii) others

$$\frac{N}{N_{cr}} + \varphi \cdot 0.80 \cdot \frac{M}{M_P} = 1.0 \quad , \quad \frac{M}{M_{Pc}} \le 1.0$$

Resistance

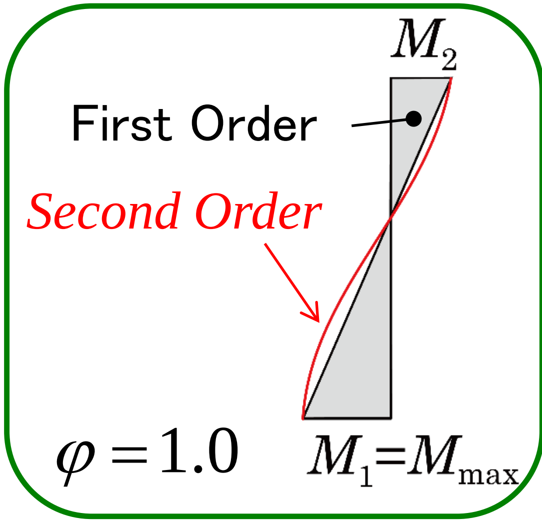
- Coefficient to evaluate $P\delta$ effects (Second order effects) φ

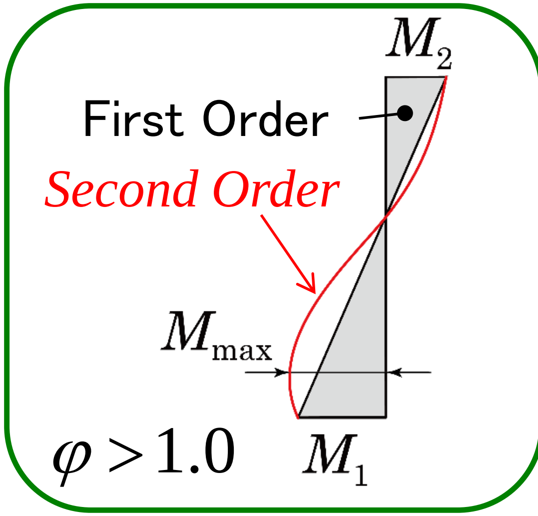
$$\left(N/N_Y\right)\cdot\lambda_{c0}^{\ 2}\le 0.25(1+\kappa)$$

$$\varphi=1.0 \qquad (6.3.6.a)$$

$$\left(N/N_Y\right)\cdot\lambda_{c0}^{\ 2}> 0.25(1+\kappa)$$

$$\varphi=\frac{1-0.5(1+\kappa)\sqrt{N/N_0}}{1-N/N_0}\ge 1.0 \qquad (6.3.6.b)$$





【Symbol】

Non-dimensional slenderness ratio

$$\lambda_{c0}=\sqrt{N_Y/N_0}$$

Euler's buckling Strength

$$N_0=\frac{\pi^2\cdot E\cdot I}{l_c^{\ 2}}$$

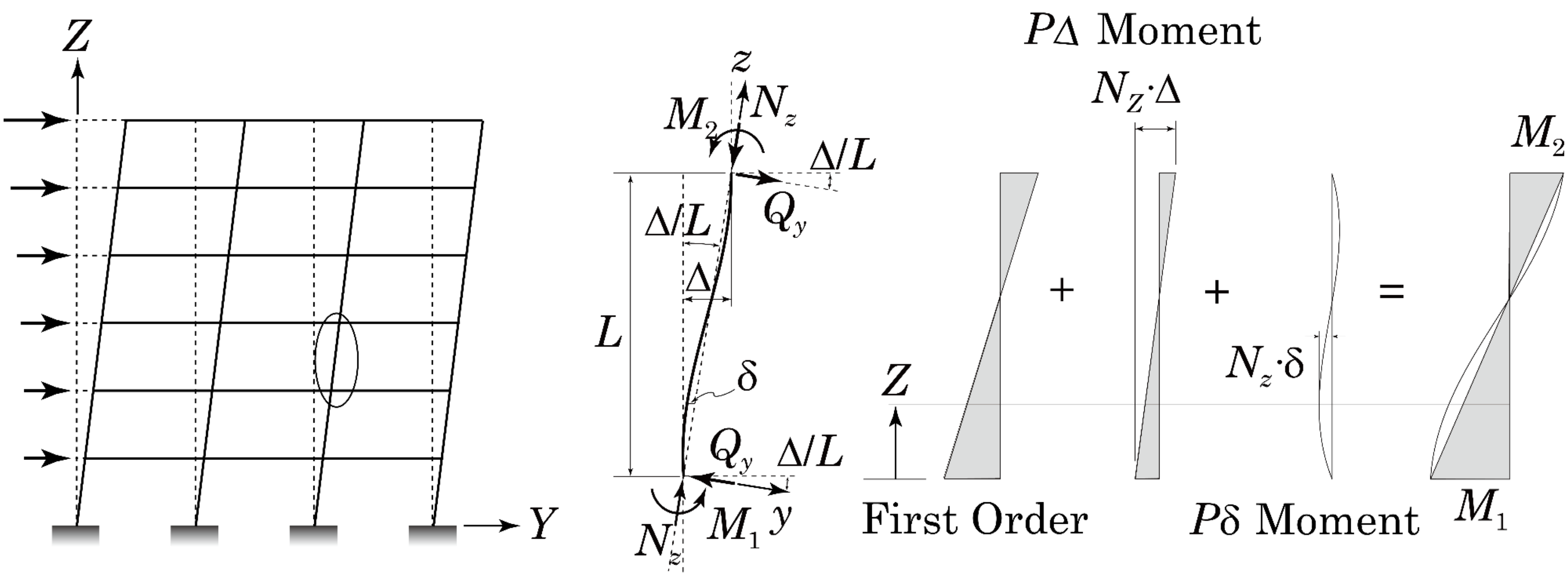
$\kappa = M_2/ M_1$

Positive for Double Curvature bending

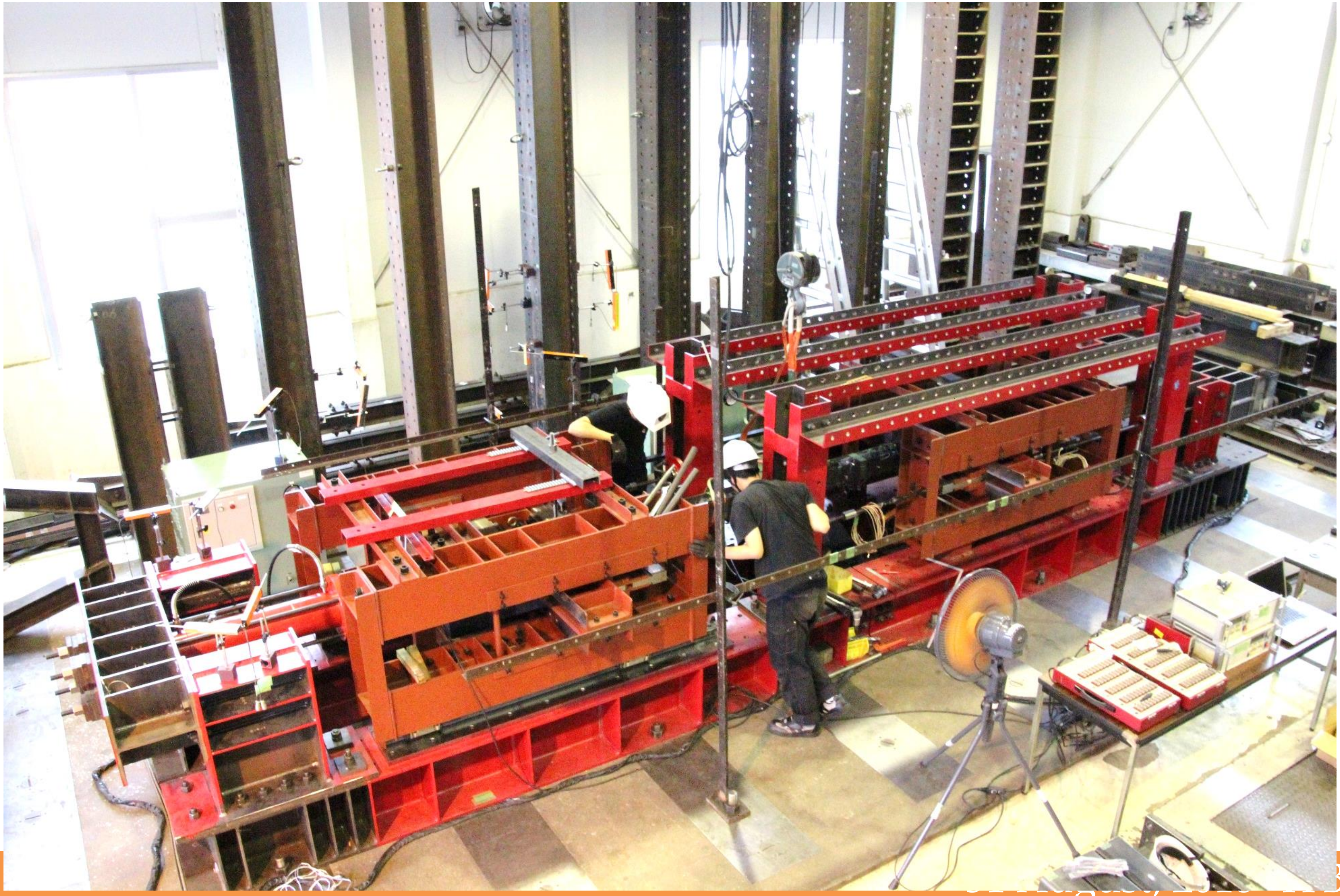
Column
in Steel Structure

Column

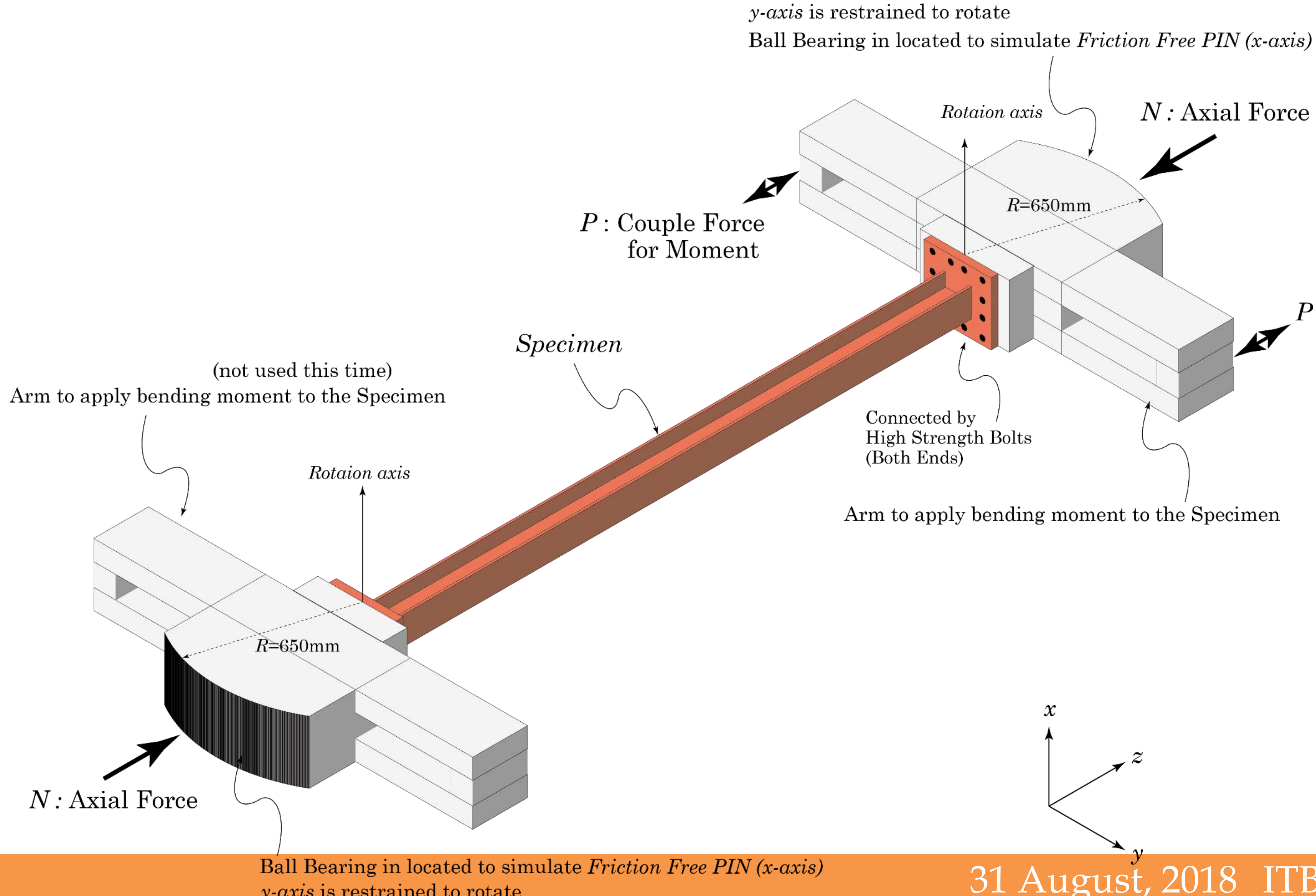
- It will support gravity load (**Axial Force ,*N***).
- **Bending Moment** (***M***) will get larger once horizontal force is applied.
- Capacity for Combined Loading (**Axial Force** with **Bending Moment**) is important in a large story drift.



Test Setup (NITech 2015)

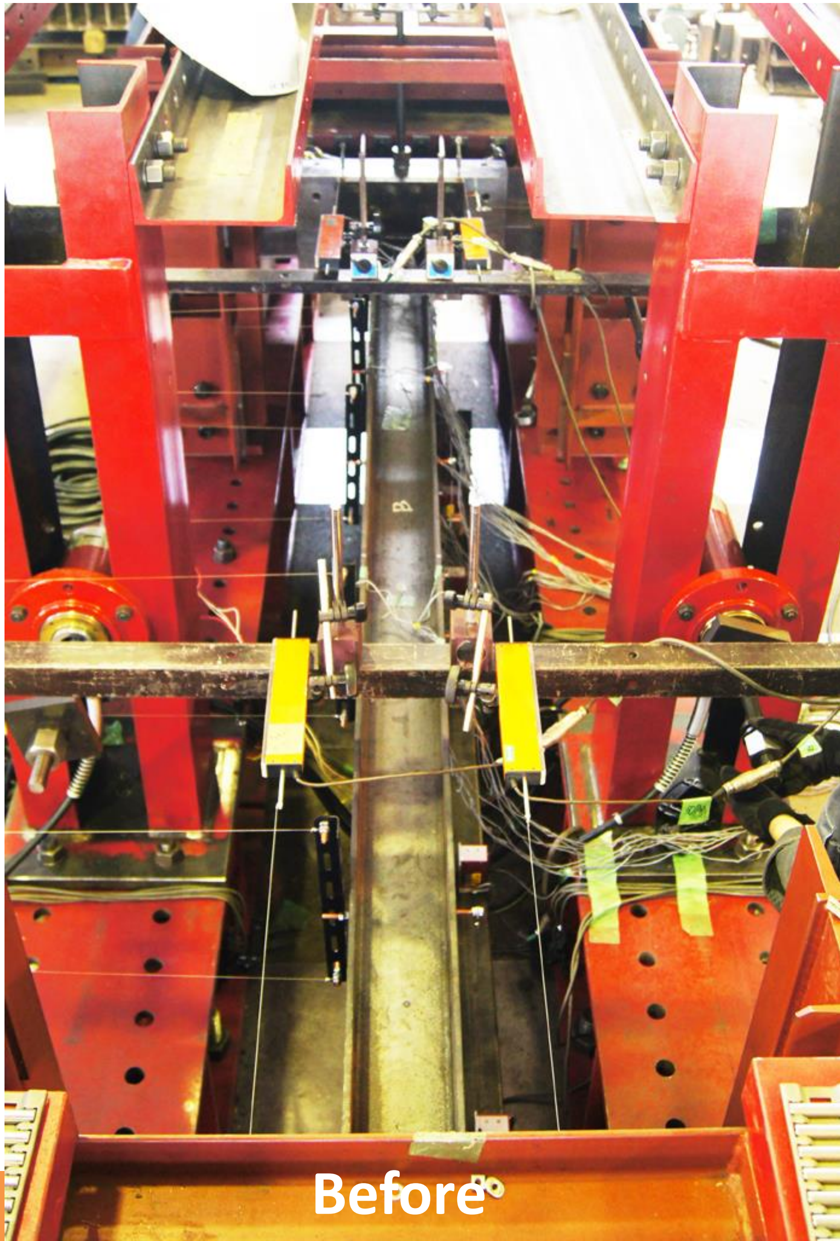


Test Setup

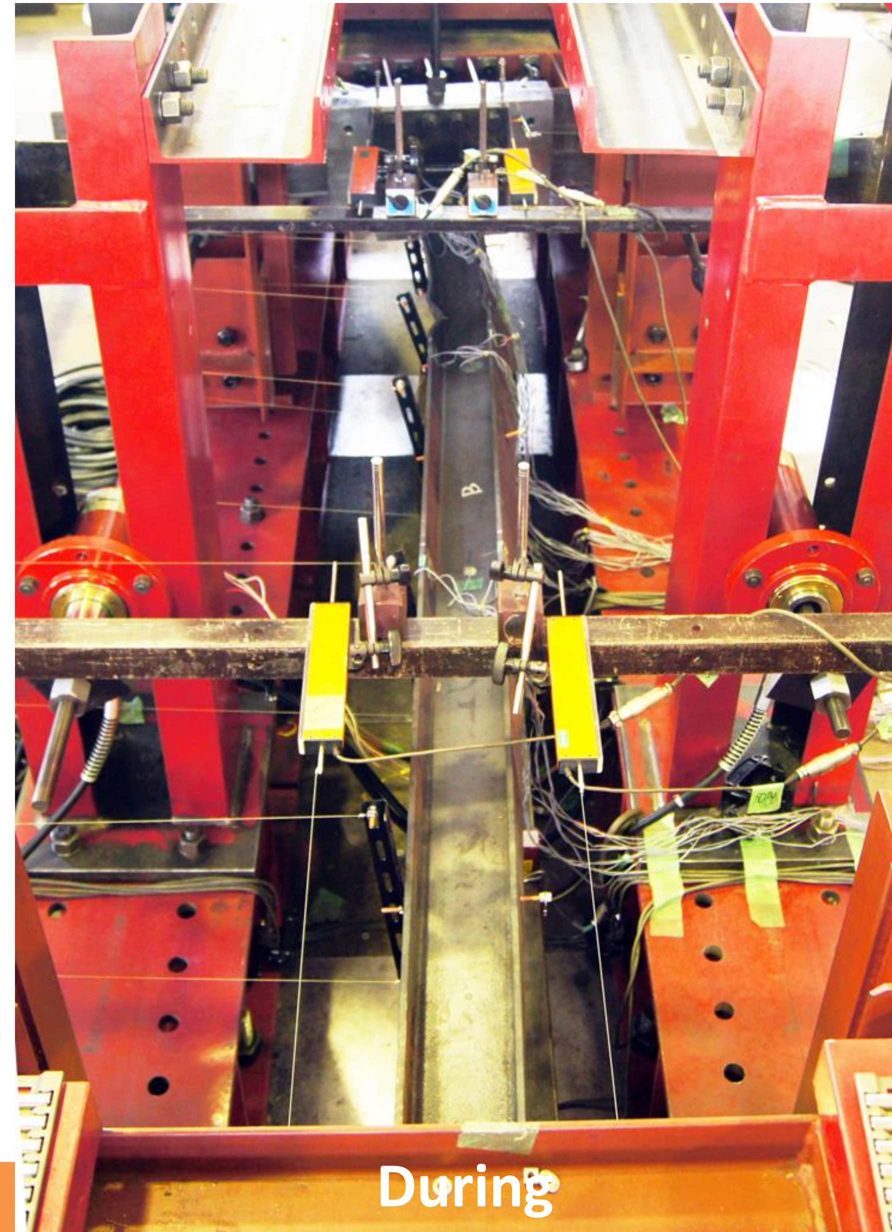


y-axis is restrained to rotate
Ball Bearing in located to simulate *Friction Free PIN (x-axis)*
Rotaion axis
N : Axial Force
R=650mm
P : Couple Force
for Moment
P
Specimen
(not used this time)
Arm to apply bending moment to the Specimen
Connected by
High Strength Bolts
(Both Ends)
Arm to apply bending moment to the Specimen
Rotaion axis
R=650mm
N : Axial Force
x
z
y
Ball Bearing in located to simulate *Friction Free PIN (x-axis)*
y-axis is restrained to rotate

Test Results (H-125x125x6.5x9)

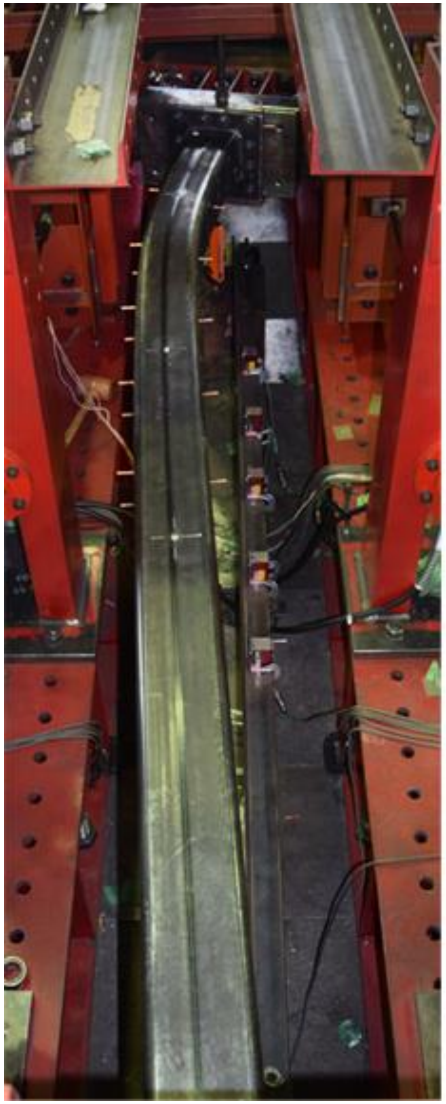


Before



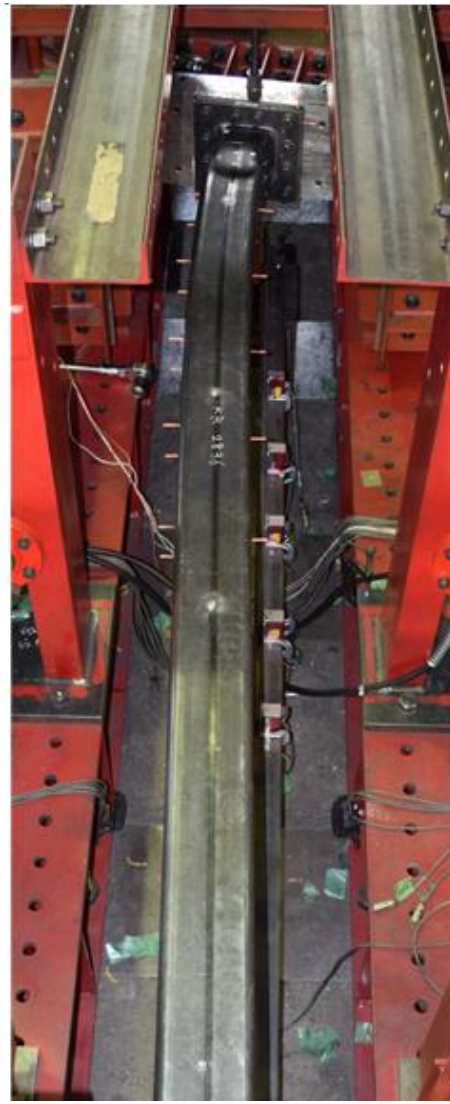
During

Deformed Shape (SHS Column)



n_y=0.2, Mono
STKR400

n_y=0.3, Mono
STKR400

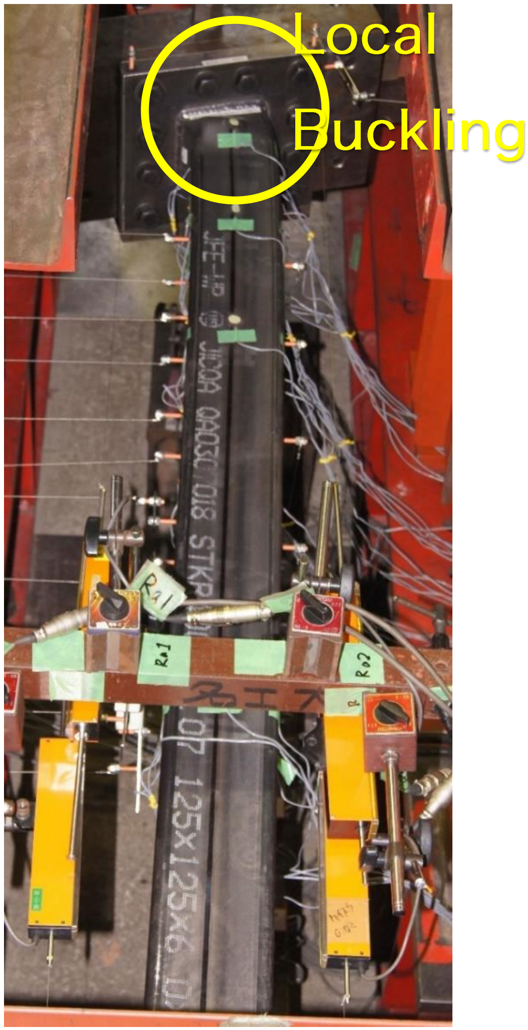


n_y=0.3, **Cyc.**
STKR400

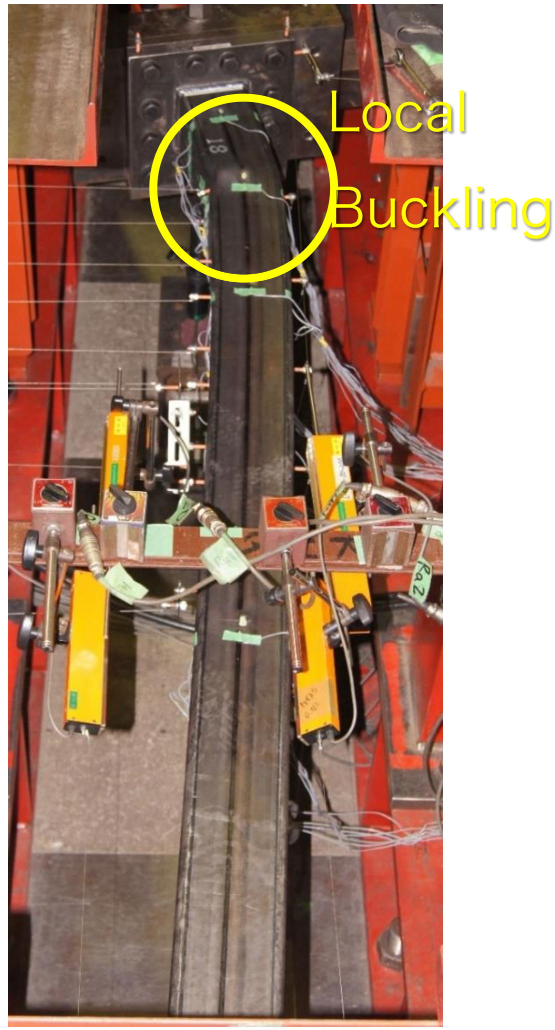
n_y=0.3, Mono
BCR295

Deformed Shape (under one end moment)

Three types of failure mode were observed

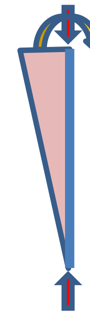


C.M.:L

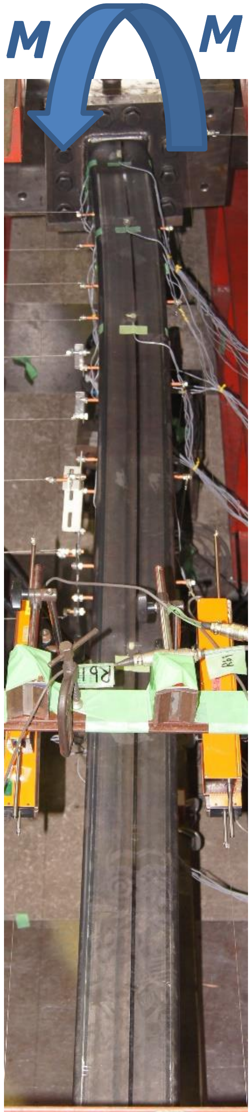


C.M.: $P\delta$ +L

C.M.:$P\delta$

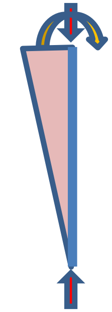


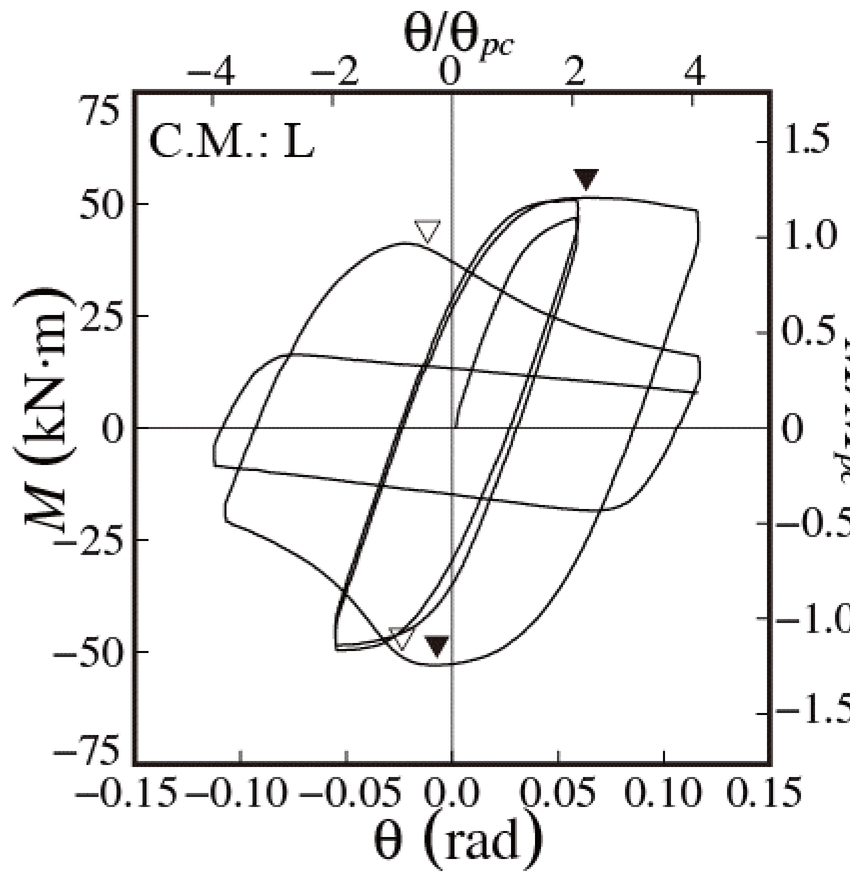
Under Cyclic Loading (one end moment)



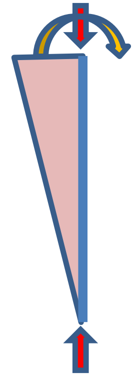
C.M.:L

C.M.: $P\delta$ +L





Test Results (One End Moment)



Strength

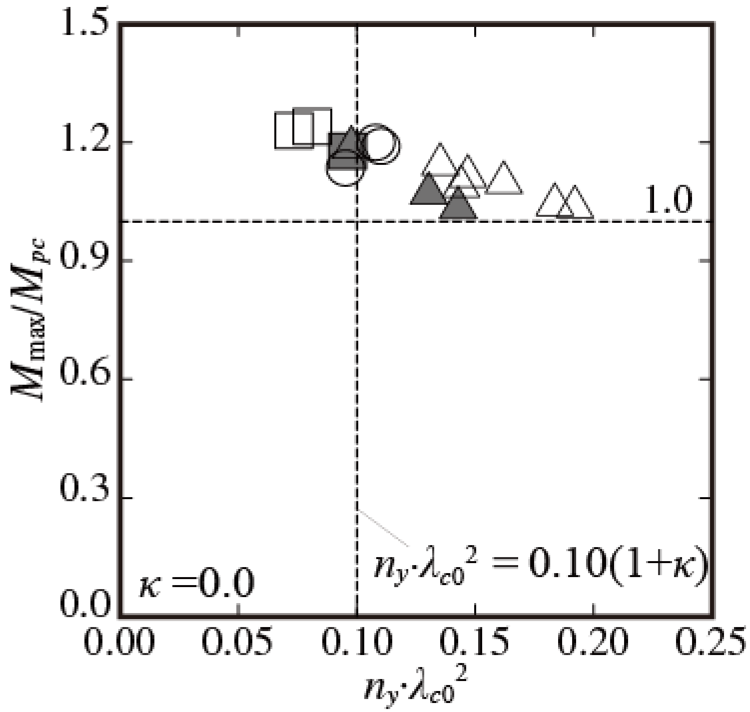


Fig. 2.15 Relationship between M_{max}/M_{pc} and $n_y \cdot \lambda_{c0}^2$

Deformation Capacity

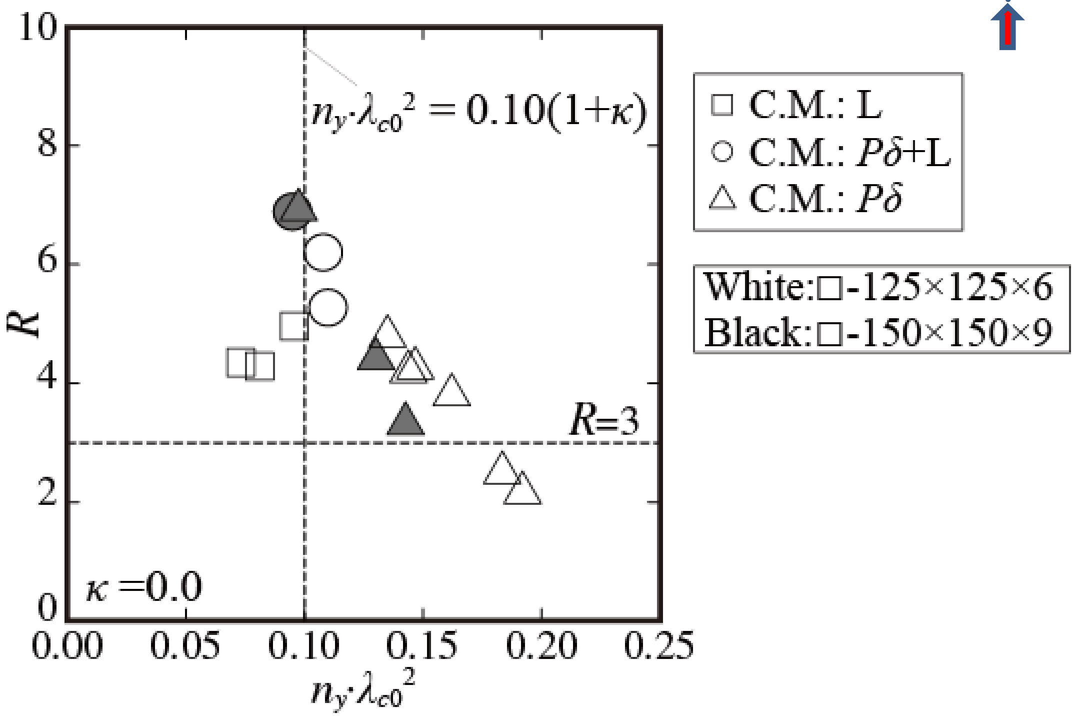
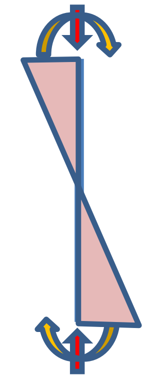


Fig. 2.16 Relationship between R and $n_y \cdot \lambda_{c0}^2$

Test Results (Antisymmetric Bending Moment)



Strength

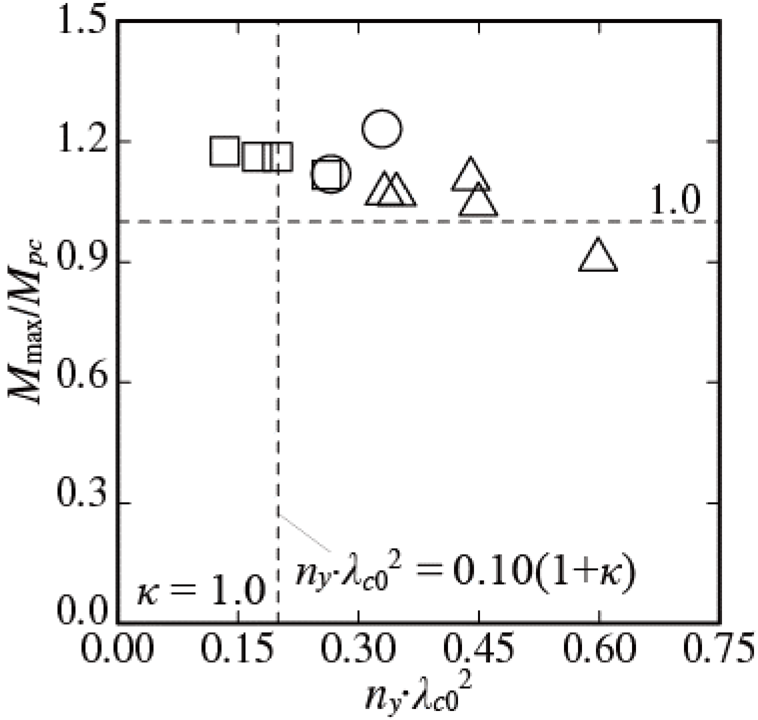


Fig. 4.15 Relationship between M_{max}/M_{pc} and $n_y \cdot \lambda_{c0}^2$

Deformation Capacity

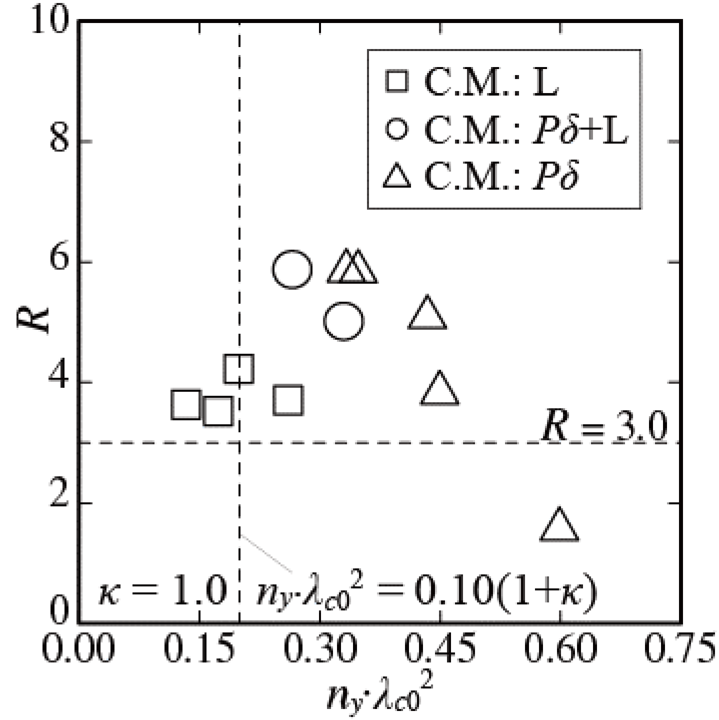
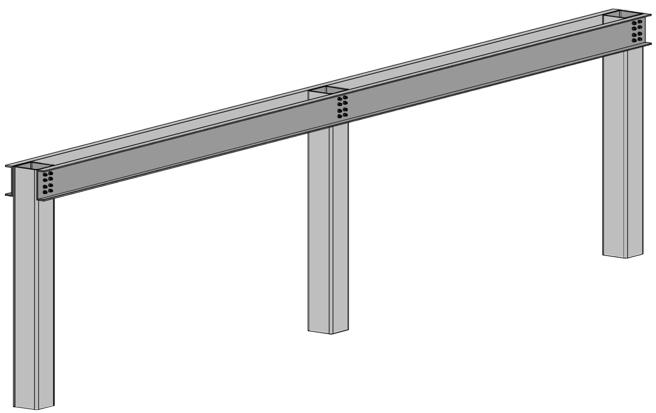


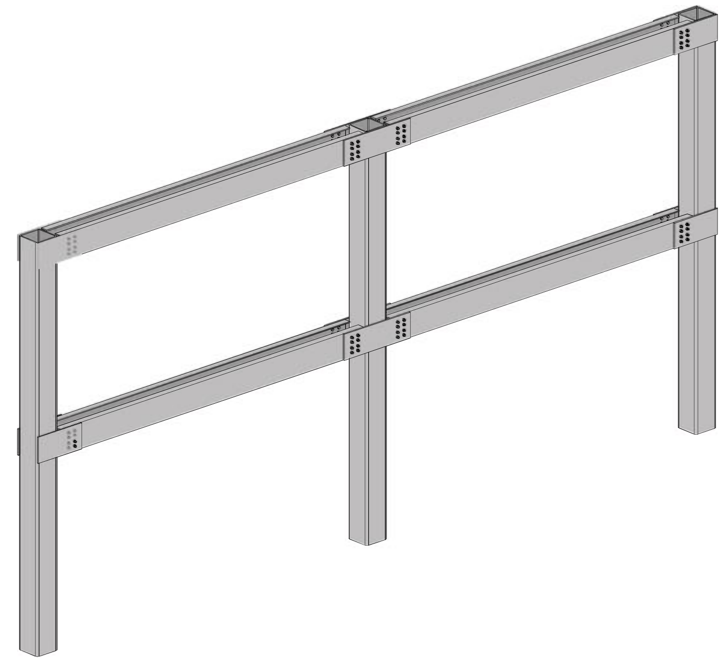
Fig. 4.16 Relationship between R and $n_y \cdot \lambda_{c0}^2$

Special Bolted Moment Frame (SBMF) System
US Project

Special Bolted Moment Frame System



Ordinary Detail for One-Story Building

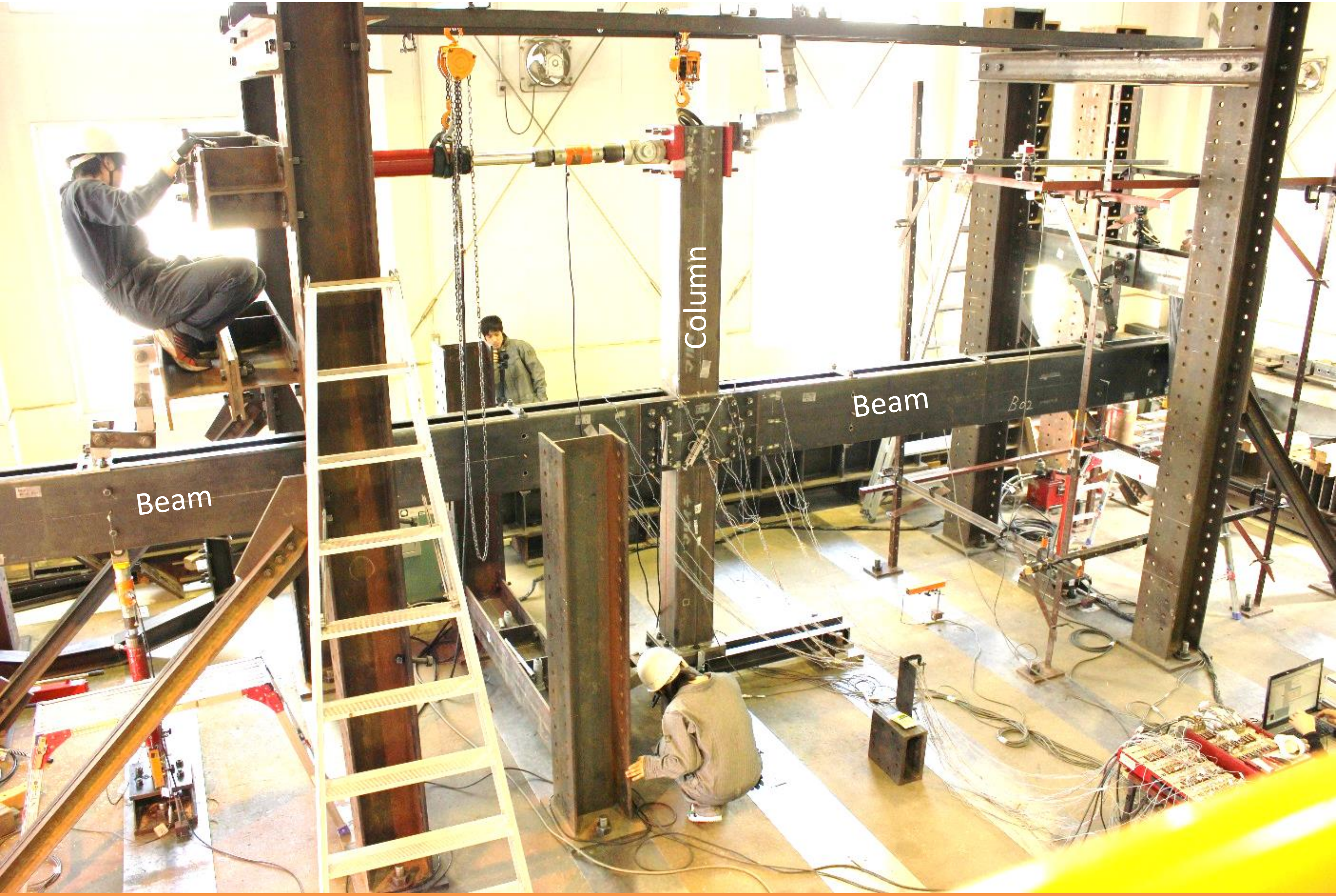


Proposed Detail for Multi-Story Building

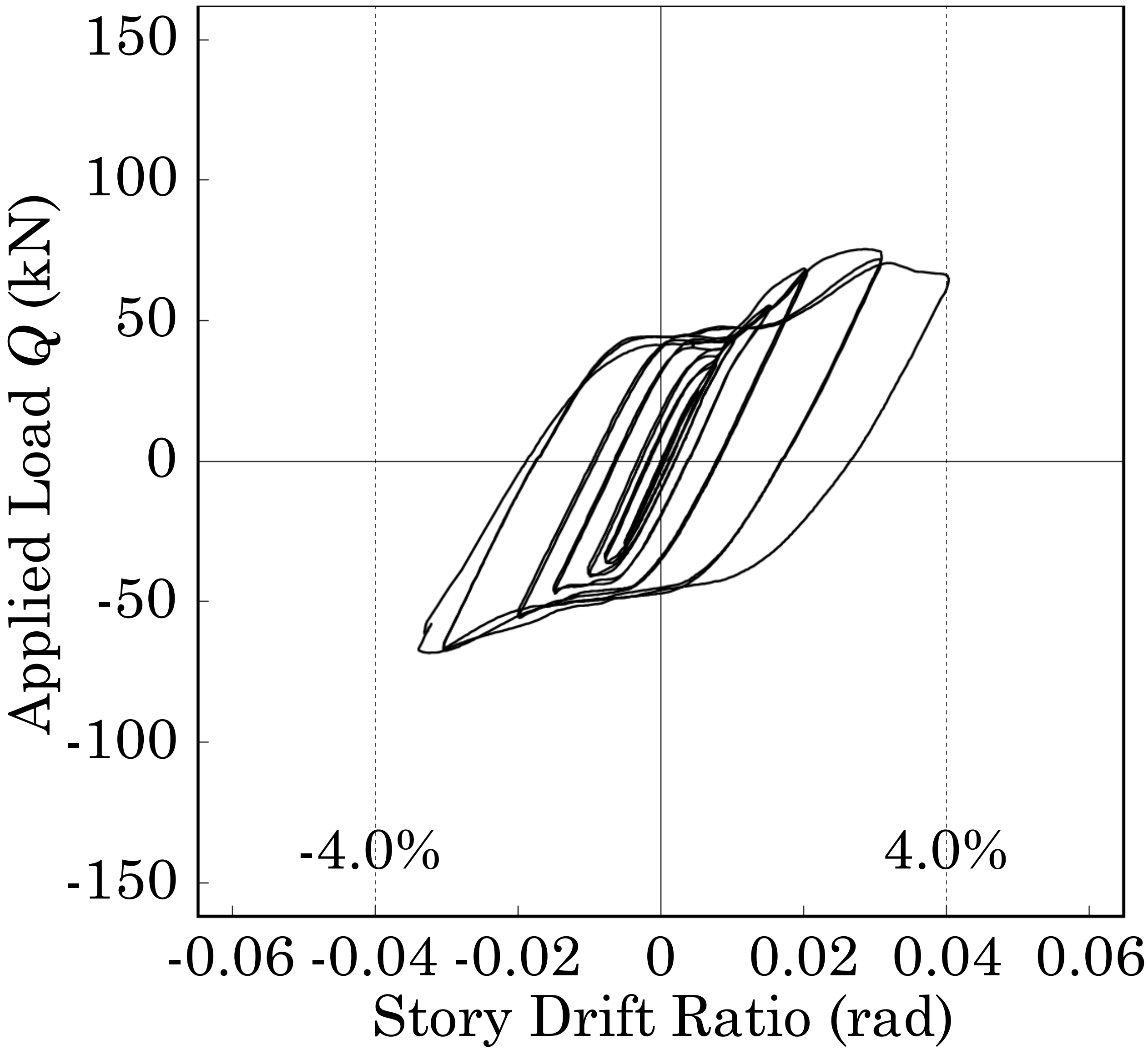
Establish Design Procedure of Multi-Story Moment-Frame using the proposed bolted connection design method


Column
Beam
Beam

Special Bolted Moment Frame (SBMF)



Sample Test Result



Failure mode observed in Special Bolted Moment Frame (SBMF)

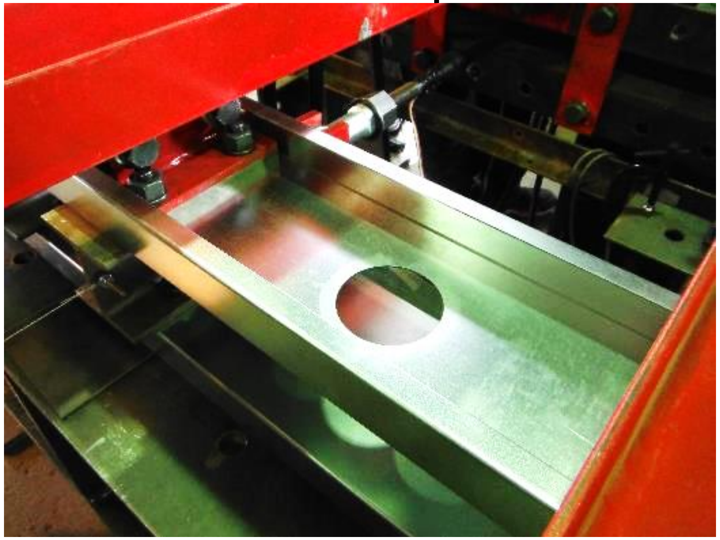
Buckling Strength of Light-Gauge Members with Large Openings

INTRODUCTION

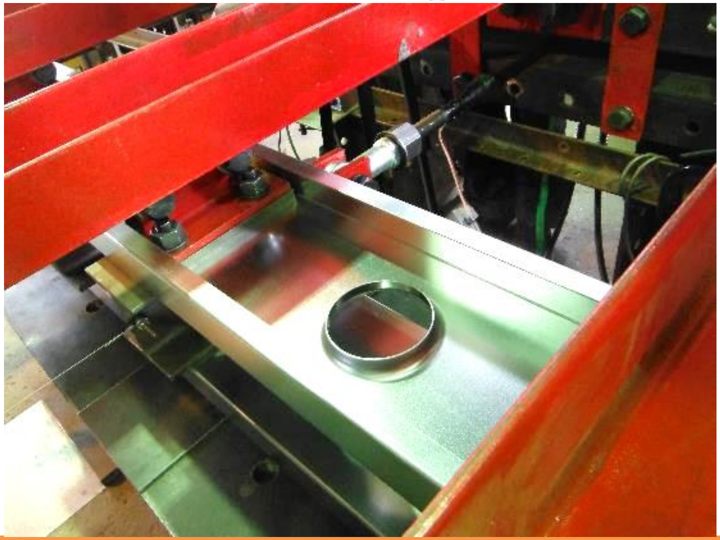
http://www.rewardwalls.com/

TEST RESULTS

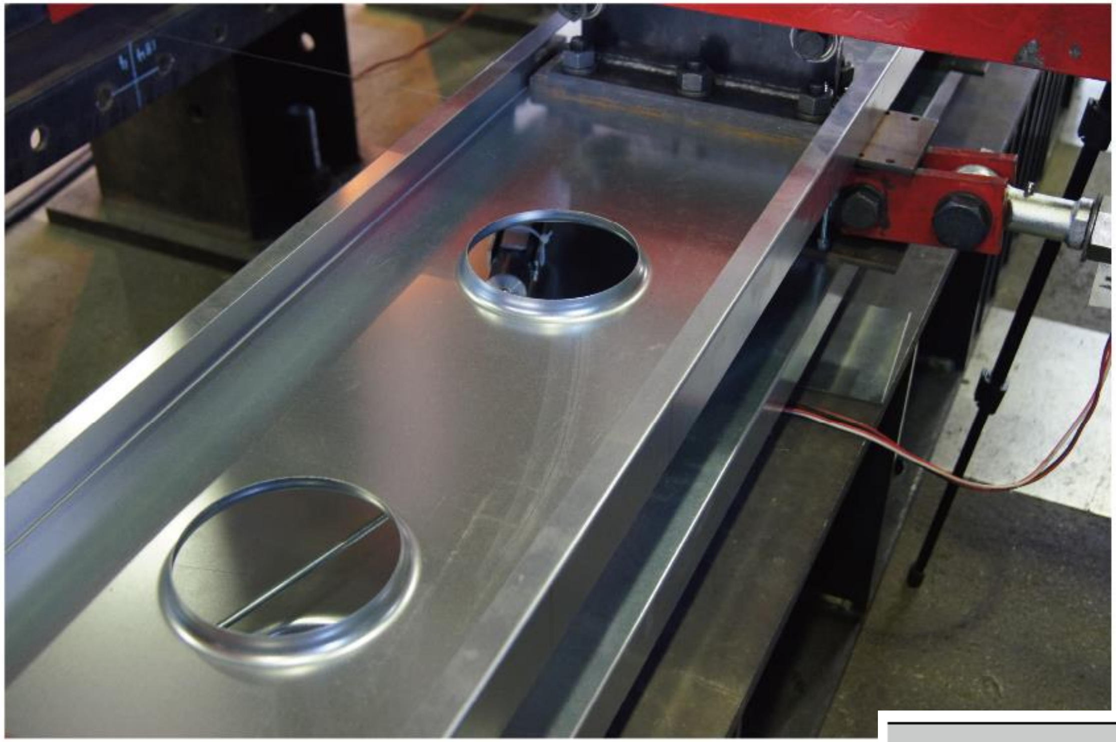
- Deformed Shape **-SIMPLE OPENING-**

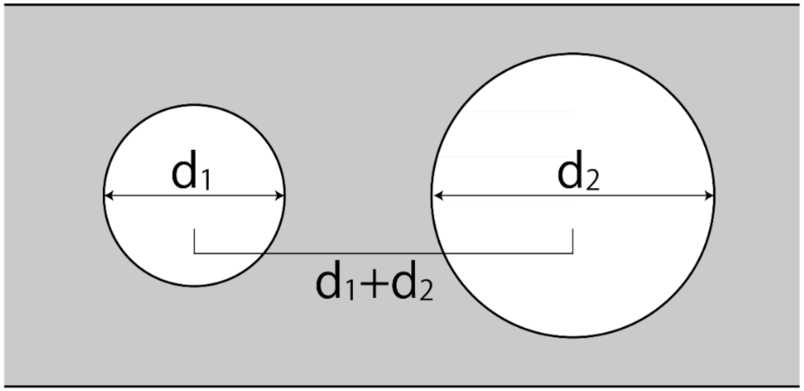


- Deformed Shape **-Burring OPENING-**

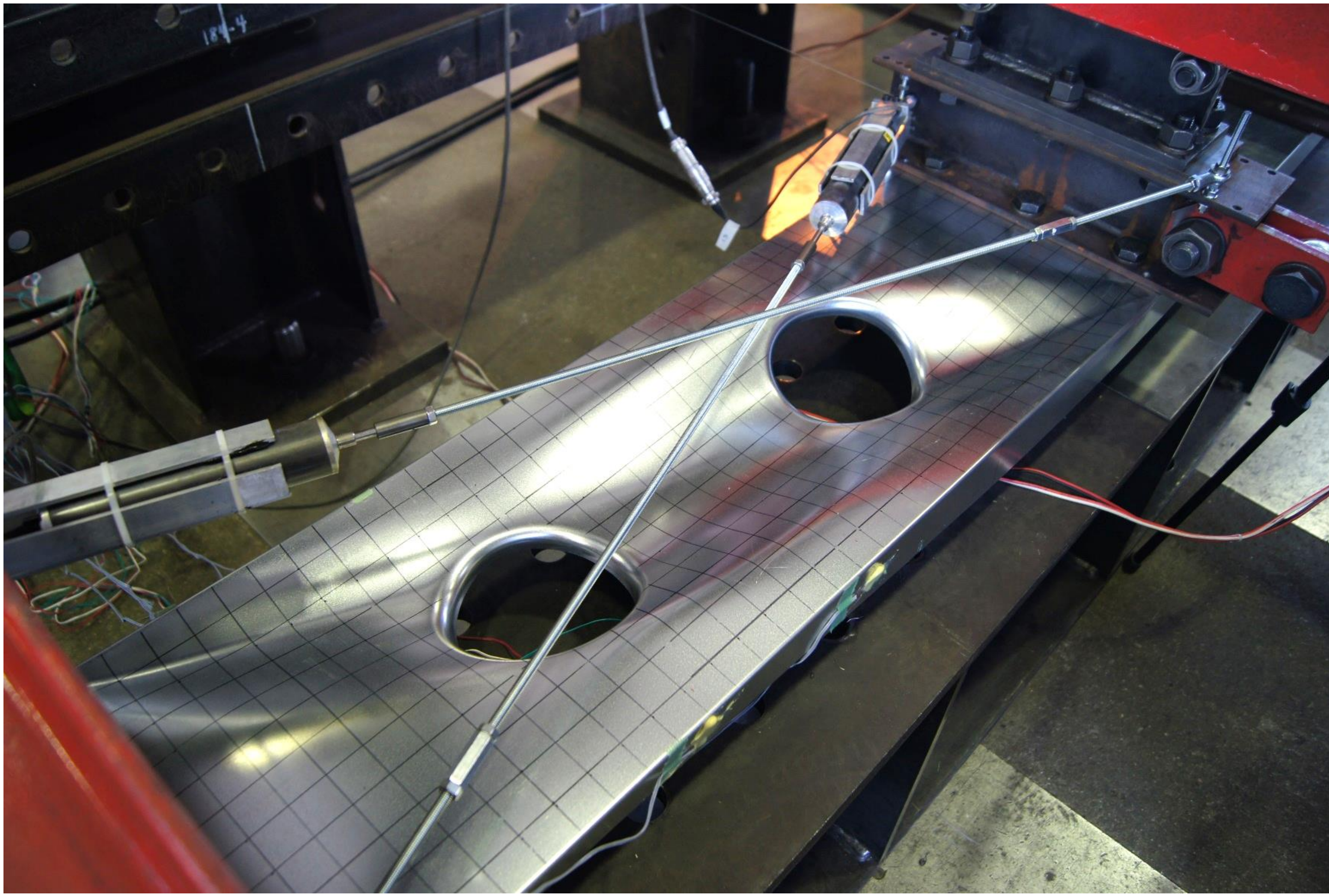


Aligned Burring Openings (Burring)

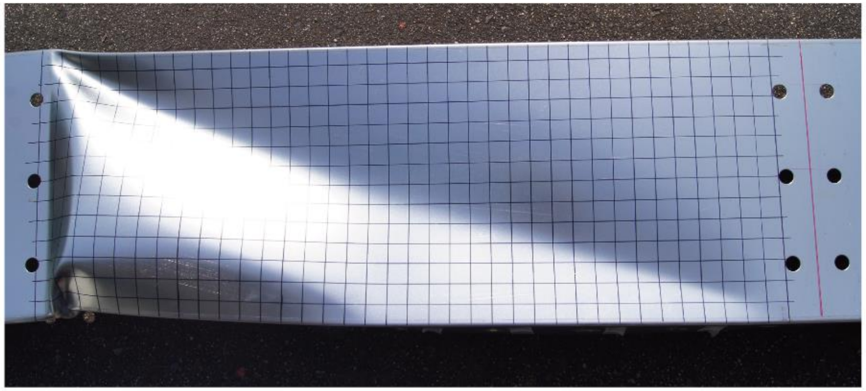




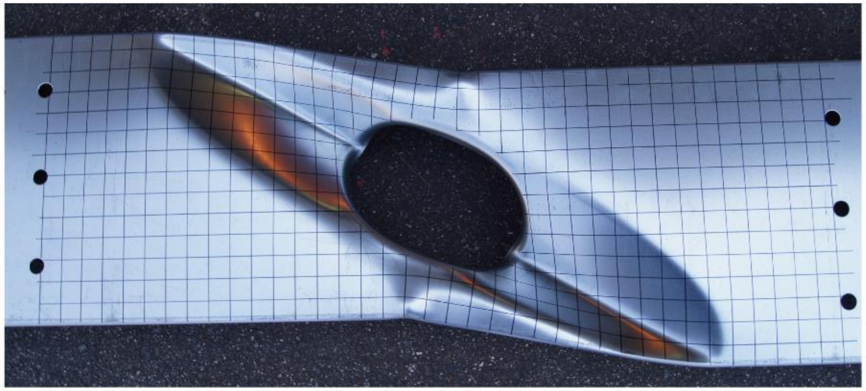
Aligned Burring Openings (Burring)



Aligned Burring Openings (Burring)

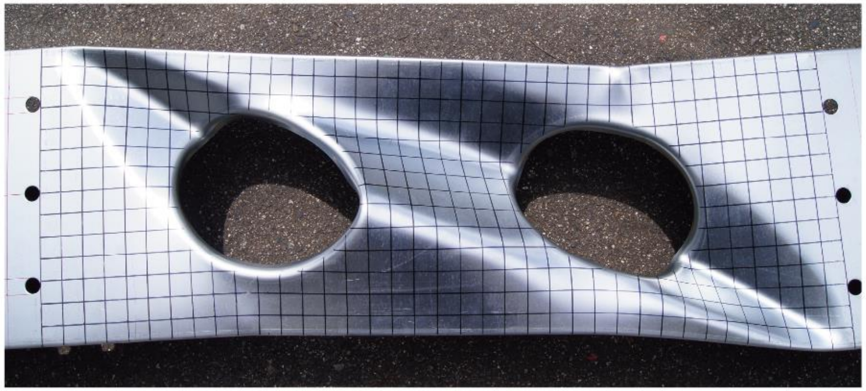


Full Web



Single Opening

Aligned Opening with Different size



Aligned Opening with Same size

Burring Shear Wall System in Real Practice

Burring Shear Wall System in Real Practice

Burring Shear Wall System in Real Practice

After Kobe Earthquake (after 1995)

BSL is a minimum requirement; protection of the human life is the main objective.

- Damage is allowed in Ultimate Limit State, and after a severe seismic action it should be demolished and do a reconstruction.

↓

However, in current social system does not allow this concept. Level of damage due to severe earthquake should be controlled by the designer.

↓

Performance Based Design became a high demand

Not only protecting the human life but also maintain the function of the buildings

Seismic Design Procedures (BSL)

Equivalent Lateral Force procedure (1981)

The Calculation Method of Response and Limit Strength (2000)

Energy Balance Based Seismic Resistance Design procedure (2005)

Installation of Damper (Oil Damper)

- Example

Reference: KYB https://www.kyb-ksm.co.jp/products/

Installation of Damper (Steel Damper)

- Examples

Reference: NSENGI https://www.nsec-steelstructures.jp/

Recommendation from AIJ

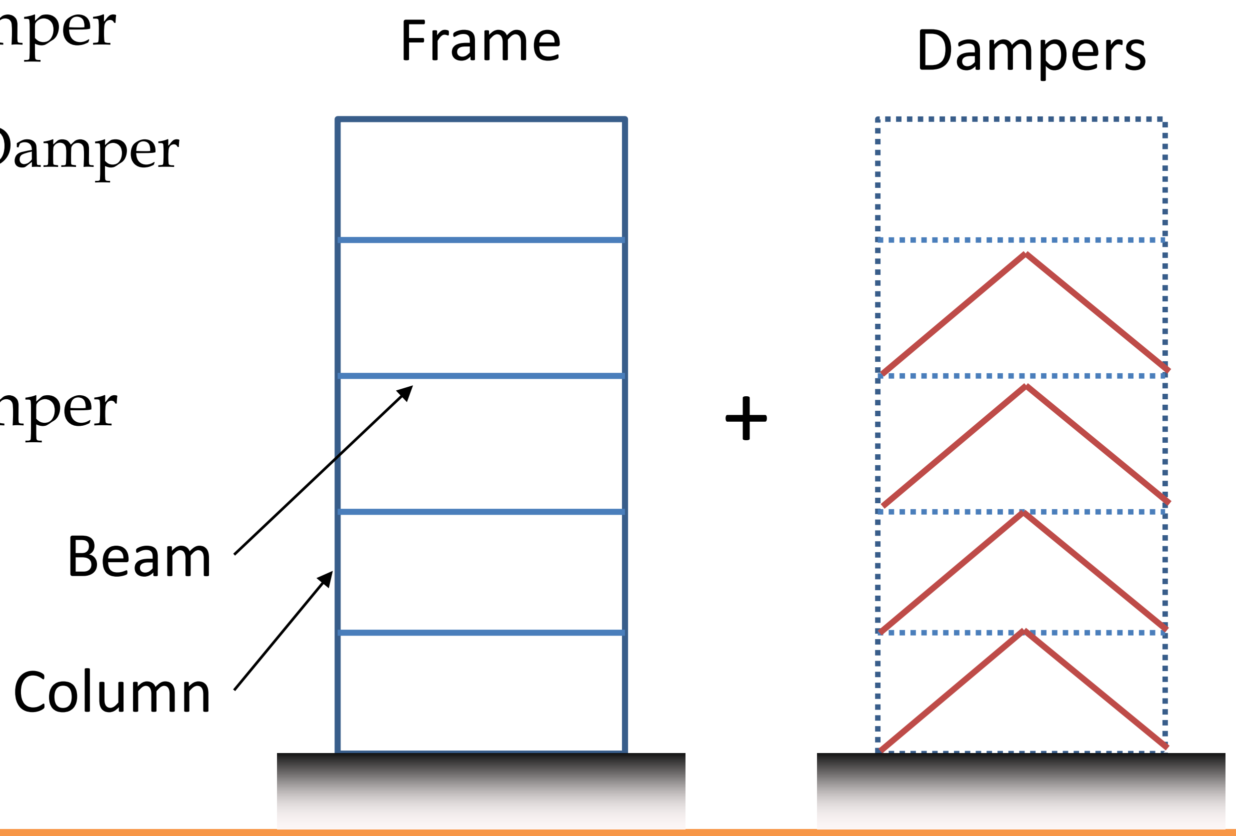
- Recommended Provisions for Seismic Damping Systems applied to Steel Structures (2014)

Recommendation from JSSI

- Design of Passive Damping (2005, 2013)

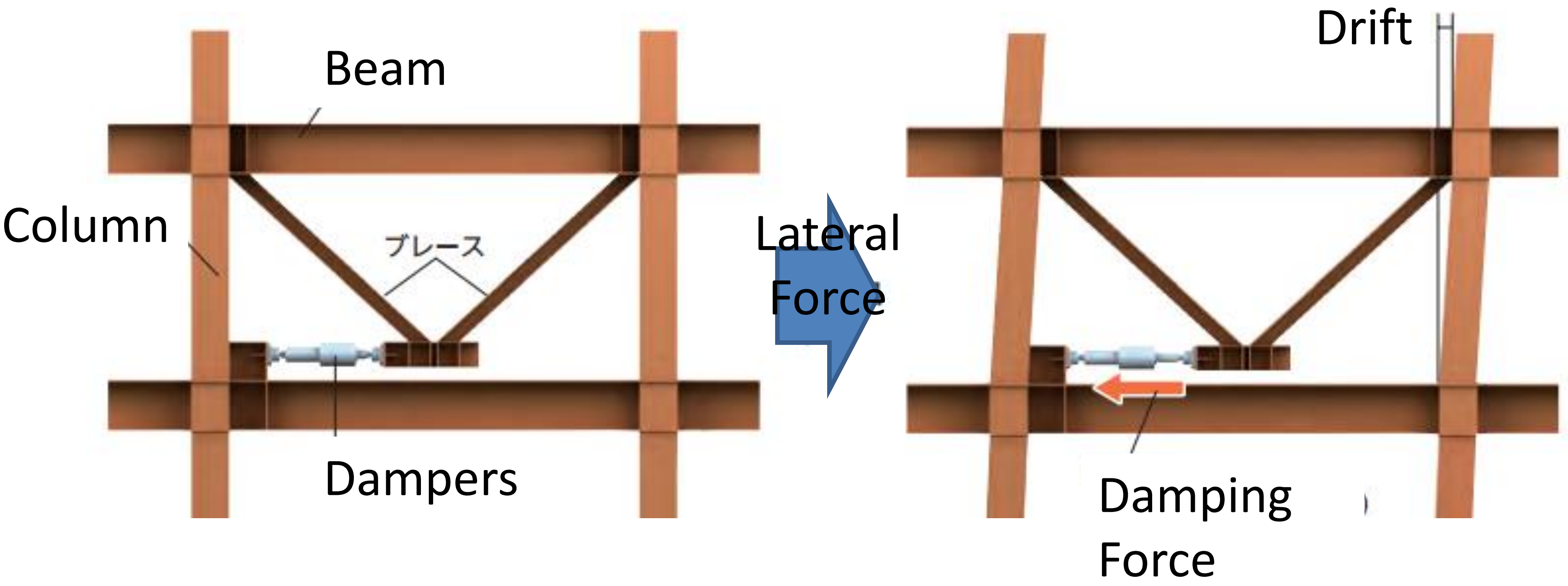
  Design Procure for following dampers are shown.

  - Steel Damper
  - Friction Damper
  - Viscoelastic Damper
  - Oil Damper
  - Viscous Damper



Installation of Damper (Oil Damper)

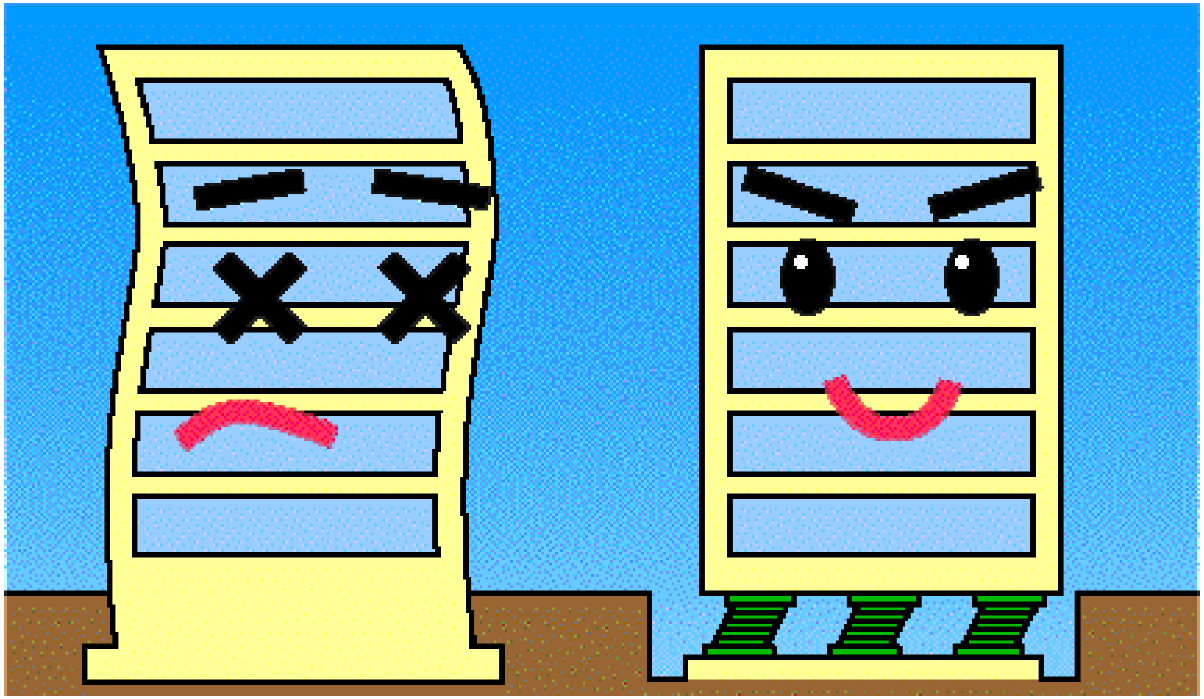
- Example



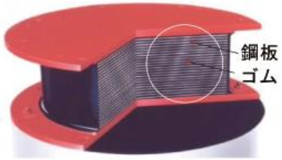
Reference: SENQCIA https://www.senqcia.co.jp/products/kz/damper/

Base Isolated Structure

- Concept of this structure



Force Resisting Structure Base Isolated Structure



Isolator

Steel Damper

Oil Damper

Reference: JSSI http://www.jssi.or.jp/menshin/m_kenchiku.html

Base Isolated Structure

- Examples




Reference: NSENGI https://www.nsec-steelstructures.jp/