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Experimental Study on the Ultimate Behavior of Concrete Filled Tubular Columns Using Spiral Welded Pipes under High Fluctuating Axial Force



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Integrated Columns by Multiple Steel Pipes

4 CFT Columns + Shear Panels
(Spiral Welded Pipes ¹⁾)

Damage Control ²⁾

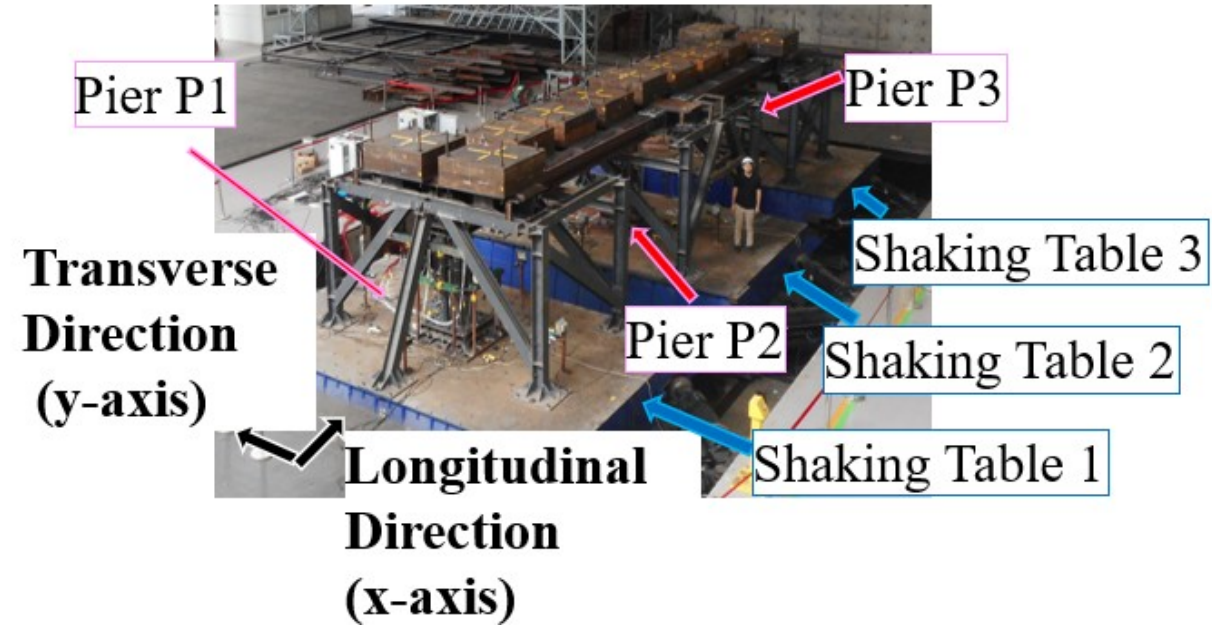
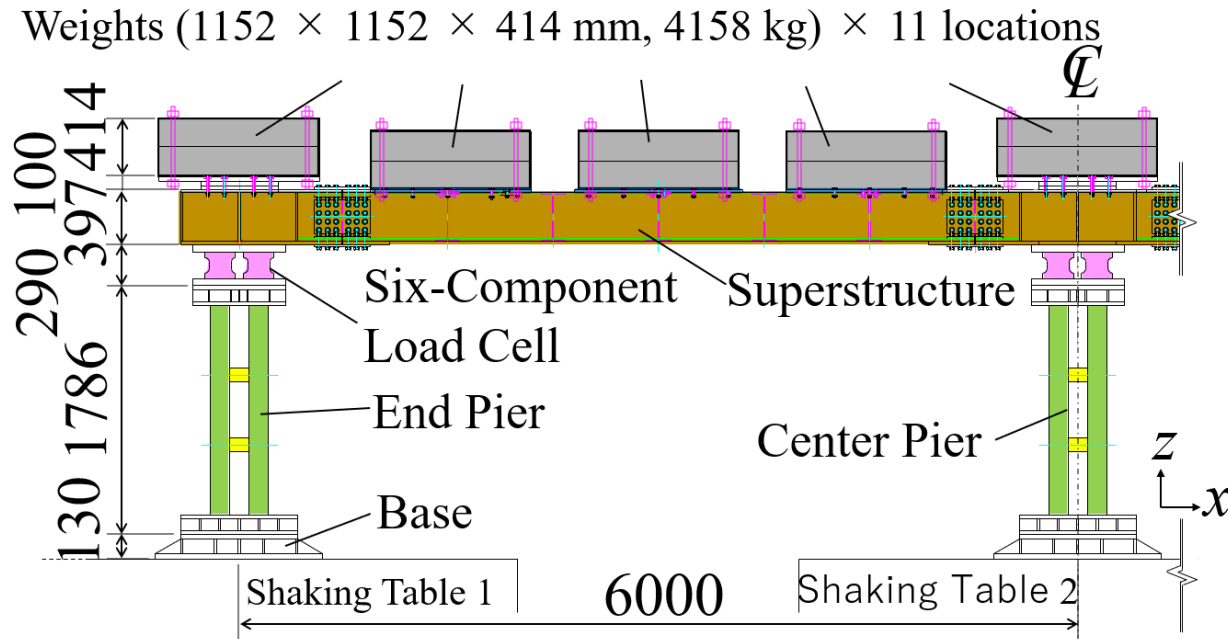
- Shear Panels : Concentrated Damage
- Columns : Stay Elastic

Safety	Elastic Columns
Repairability	Early Traffic Reopening
Economy	Cost-Effective Spiral Pipes
Constructability	Anchor-Free Design



1) Ono, K., Akiyama, M., Shirato, M. and Okada, S. : “Elasto-Plastic Behavior and Seismic Evaluation Method of Concrete-Filled Spiral Steel Pipe Piers”, Proc. of 30th U. S.-Japan Bridge Engineering Workshop, 2014.

2) Shinohara, M., Kanaji, H., Kosaka, T. and Imai, T. : “Design and Construction of Highway Viaduct Supported by New Steel Pipe Integrated Pier with Shear Link”, Proc. of 9th German-Japanese Bridge Symposium, 2012.



1/10 Scaled Model

(2-span continuous elevated bridge supported by integrated columns by multiple steel pipes)

* **Electric Resistance Welded (ERW) Steel Pipes** used as a substitute for spiral pipes
(Table capacity & small-diameter availability)

3) Goto, Y., Ebisawa, T., Nonaka, T., Xu, Y., Kanaji, H., Okagami, M., Ando, T. and Hattori, M. : "Seismic Behavior of Multi-CFT Column Bridge Piers with Shear Dampers in Two-Span Elevated-Girder Bridges Tested by Shake-Table Excitations", Journal of JSCE, Vol. 77, No. 1, pp. 199-218 (in Japanese), 2021.

Design Validation

Damage Control

Elastic Columns

Shear panels yielded first

Strain remained within $\approx 2\epsilon_y$

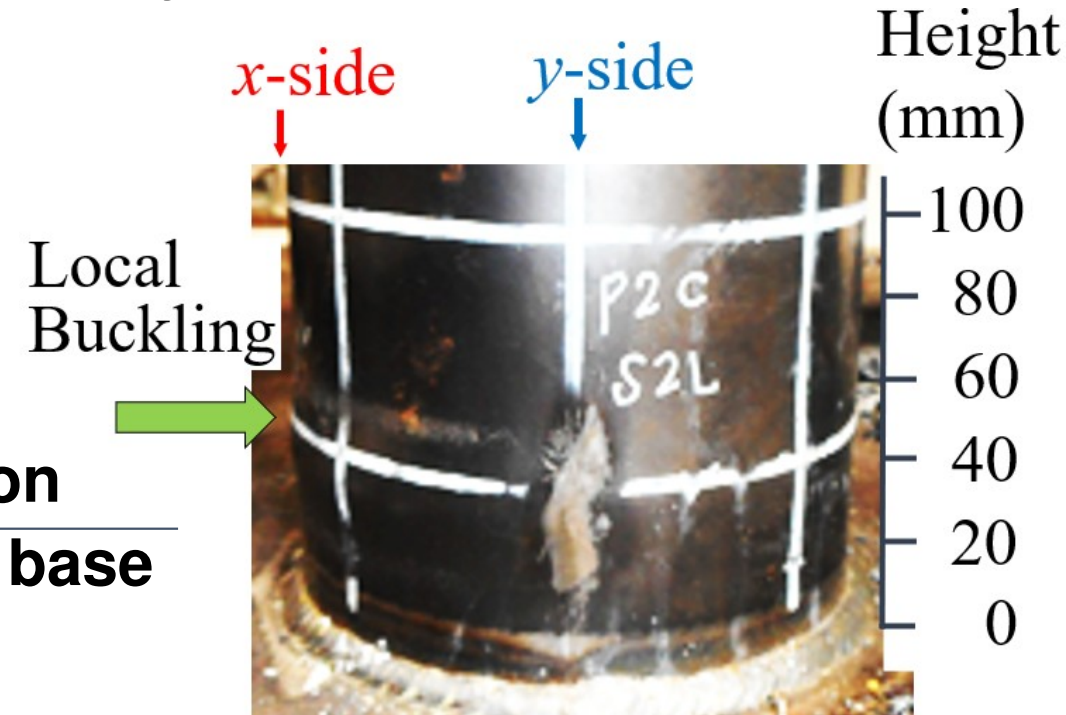
Ultimate State

Up to 3x Design Accel

At 4x Design Accel

No strength degradation

Local buckling at pipe base





Spiral welded pipe



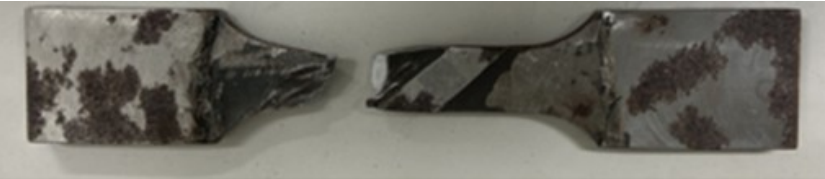
ERW pipe

Key Differences : Manufacturing Process & Weld Seam

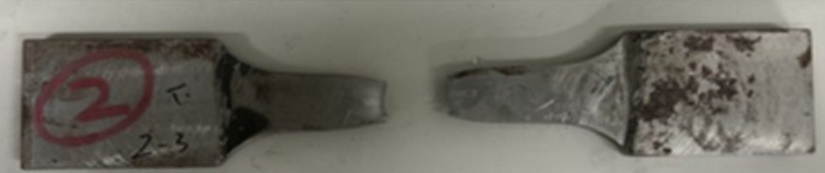
How does the spiral weld affect ultimate behavior?

Purpose

To evaluate the influence of the difference between spiral welded pipes and ERW pipes on the ultimate state of the columns



C1. Welding part of spiral pipe (Original)



C2. Non-welding part of spiral pipe(Original)



C3. Welding part of spiral pipe (Milled)



C4. Non-welding part of spiral pipe (Milled)

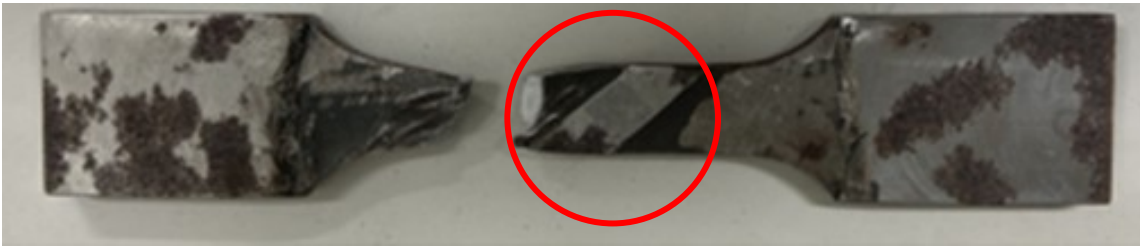


C5. ERW

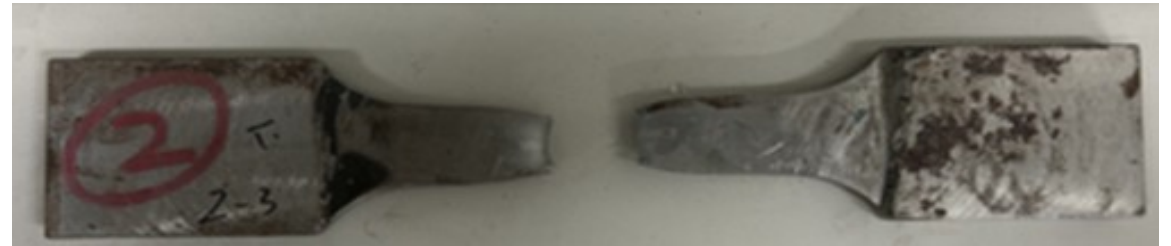
Objective

Evaluate effects of weld seam & pipe type

Pipe	No.	Welding part	Thickness
Spiral	C1	Yes	8.0mm (Original)
	C2	No	8.0mm (Original)
	C3	Yes	4.0mm (Milled)
	C4	No	4.0mm (Milled)
ERW	C5	No	7.9mm (Original)



C1. Welding part of spiral pipe (Original)



C2. Non-welding part of spiral pipe (Original)



C3. Welding part of spiral pipe (Milled)



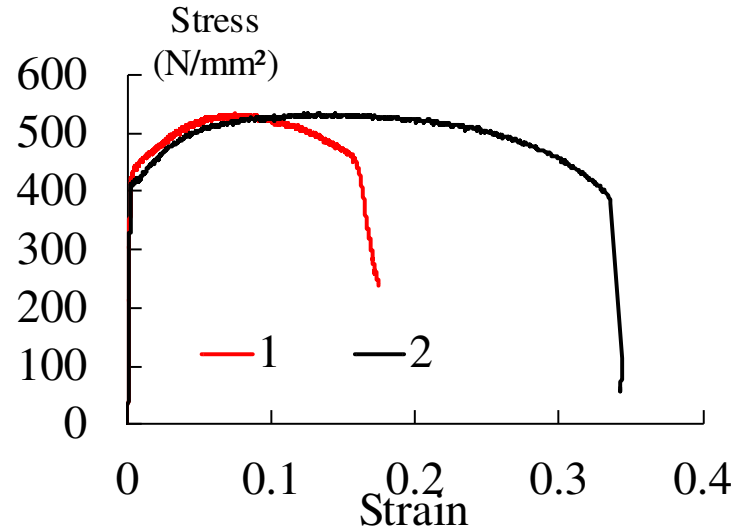
C4. Non-welding part of spiral pipe (Milled)



C5. ERW

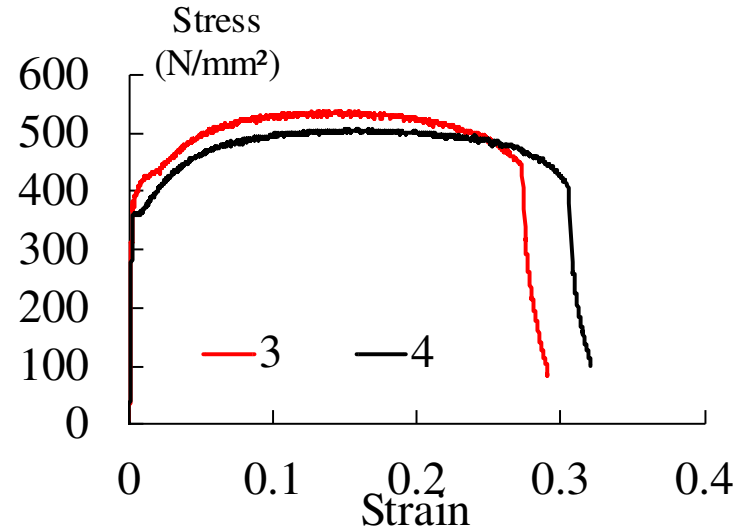
- C1 (Original): Fracture occurred at a location offset from the weld center
- C3 (Milled): Fracture occurred at the exact center of the weld region
- C5 (ERW): Fracture mode was similar to that of C2

C1 (With Weld) / C2 (No Weld)



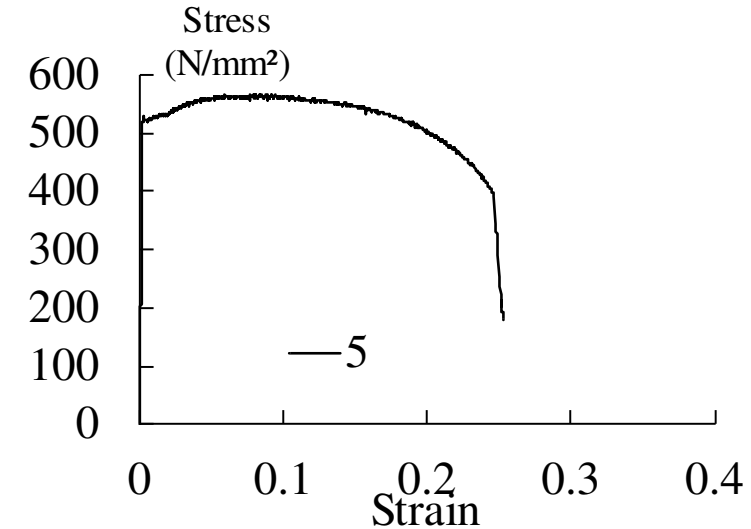
C1 (With Weld) showed significantly lower elongation than C2.

C3 (Milled Weld) / C4 (No Weld)



By milling the weld seam (C3), elongation recovered to a level similar to C4.

C5. ERW



ERW (C5) exhibited higher yield strength

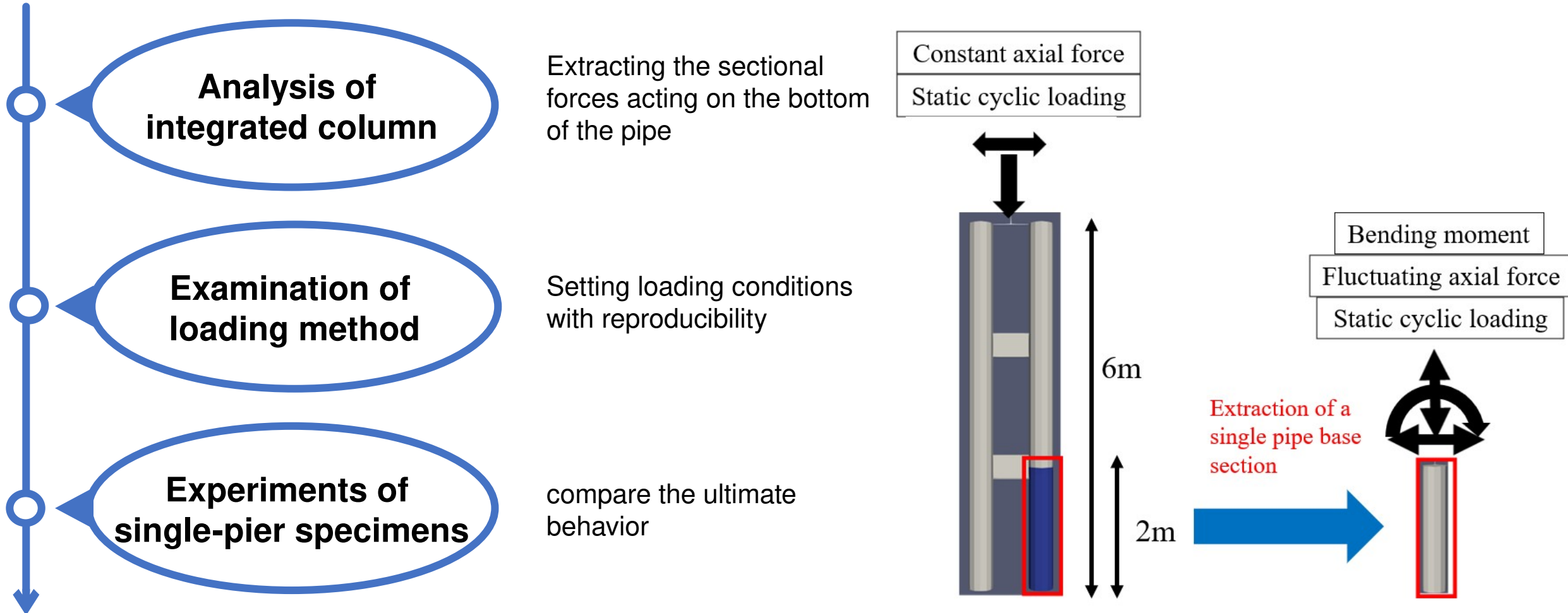
The influence of the pipe type on the ultimate behavior of CFT members is considered to be limited

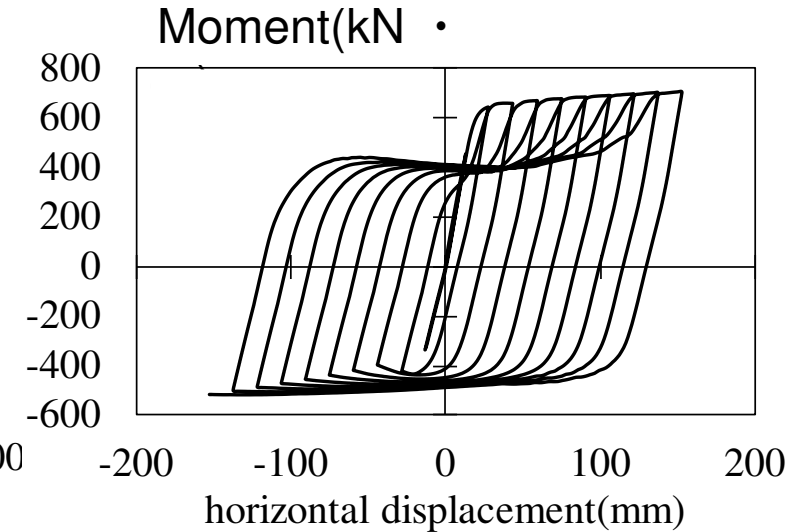
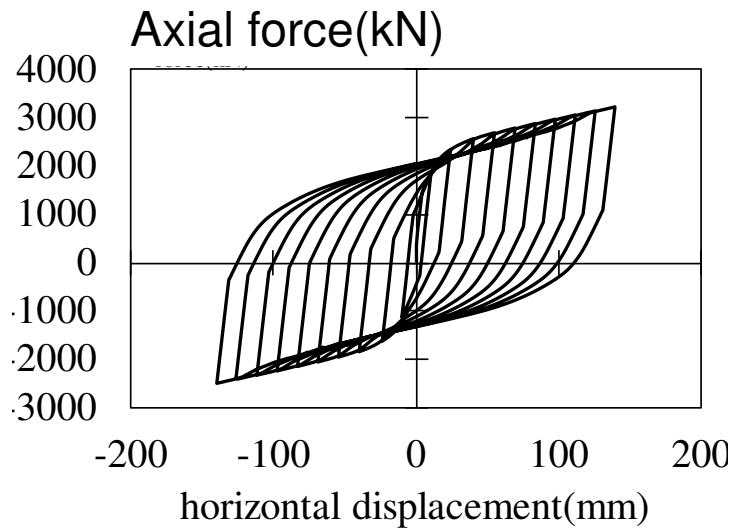
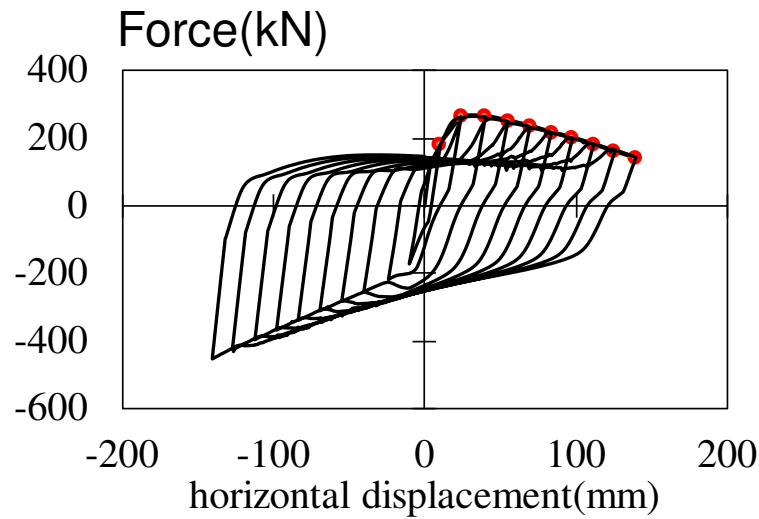
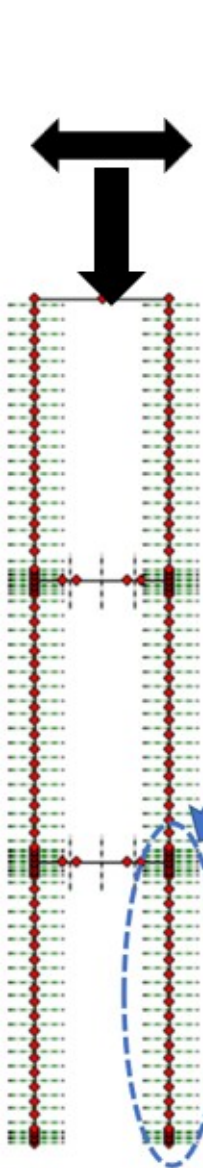
Problem

Min. diameter of Spiral Pipes is 400 mm ► **Full-scale bridge testing is not feasible**

Solution

Single-pier specimens focusing on the pier base





The sectional forces at point A

Point A

Steel Pipe
 $\Phi 400 \times t 8$
 (SKK490)
 Shear Panel
 $a 370 \times t 8 \times b 370$
 (LY225)

At Point A

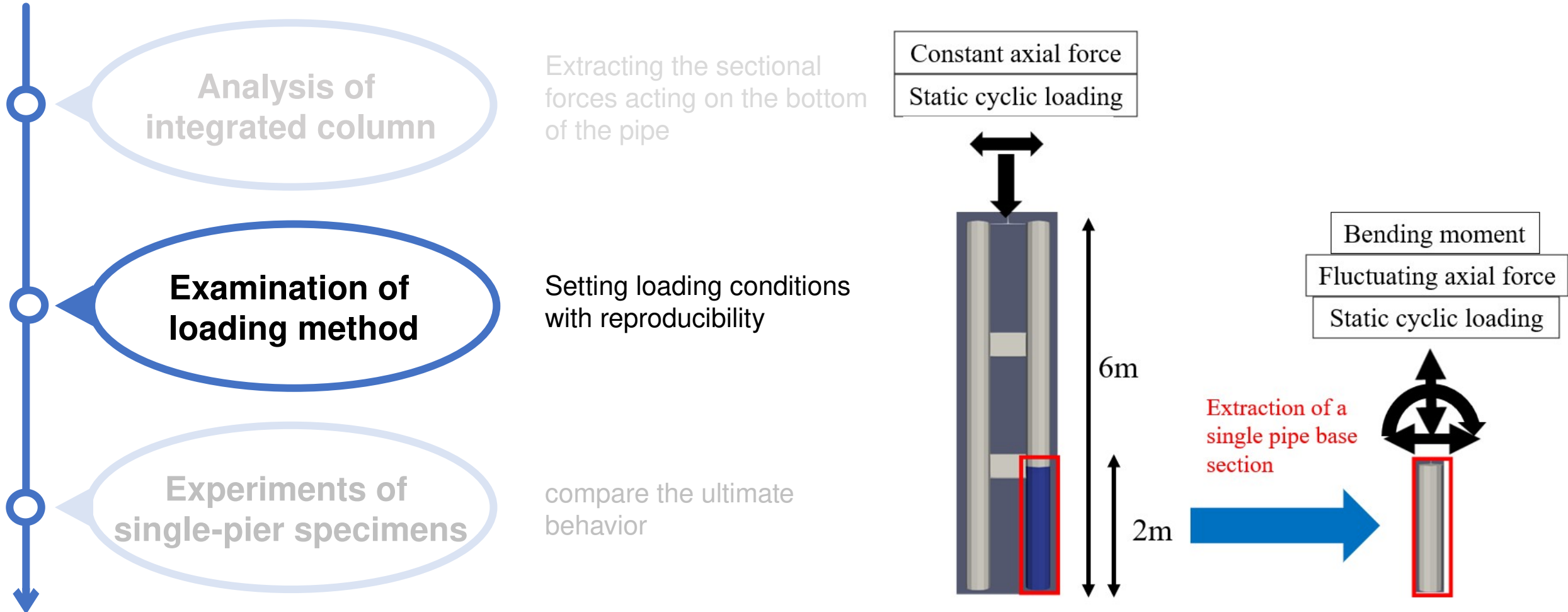
- **High fluctuating axial forces (couple)**
- **Bending moments**

Problem

Min. diameter of Spiral Pipes is 400 mm ► **Full-scale bridge testing is not feasible**

Solution

Single-pier specimens focusing on the pier base

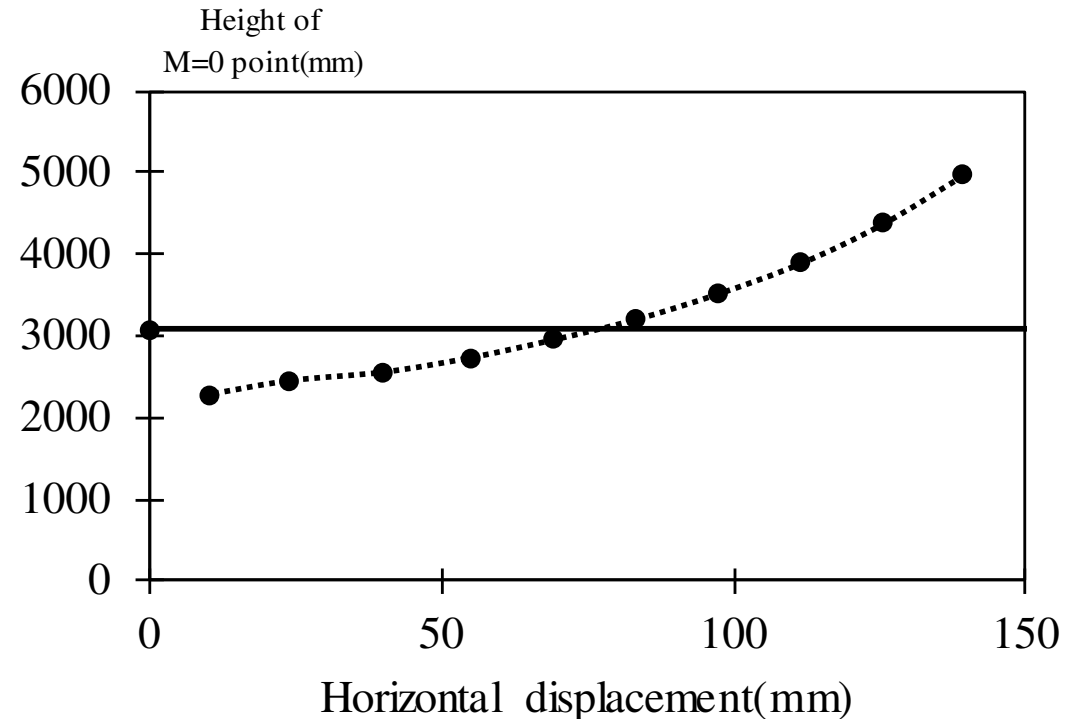
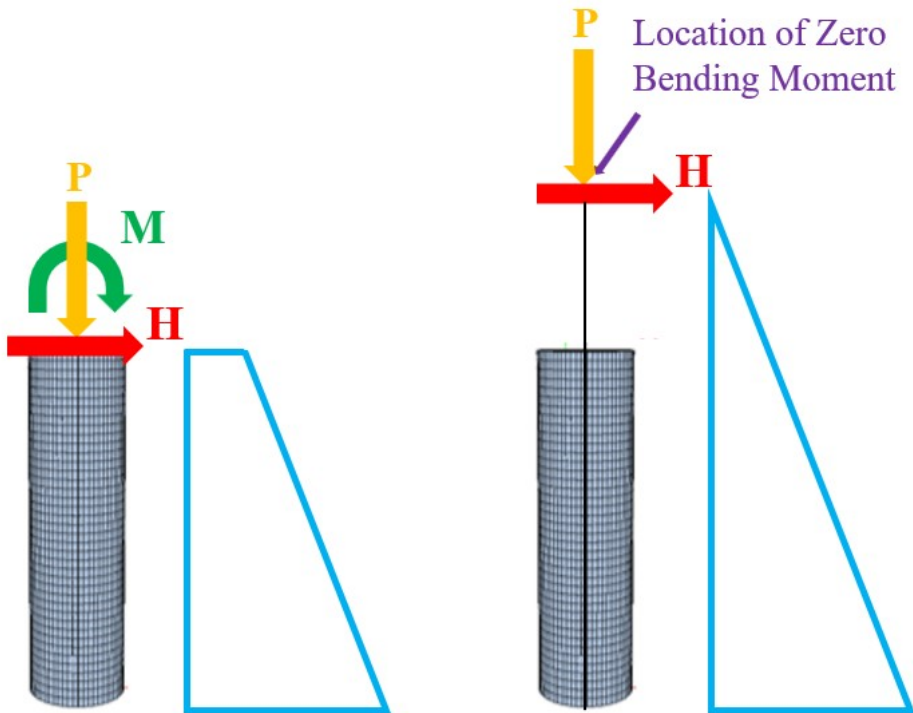


It is difficult to directly apply a moment using multiple actuators



Elevated loading point to reproduce bending moment via horizontal load

Loading Height: 3100 mm (Inflection point of a fixed-end elastic beam)



Axial Force

Initial State: Dead load only ($0.1P_0$)

Maximum Compression (+)

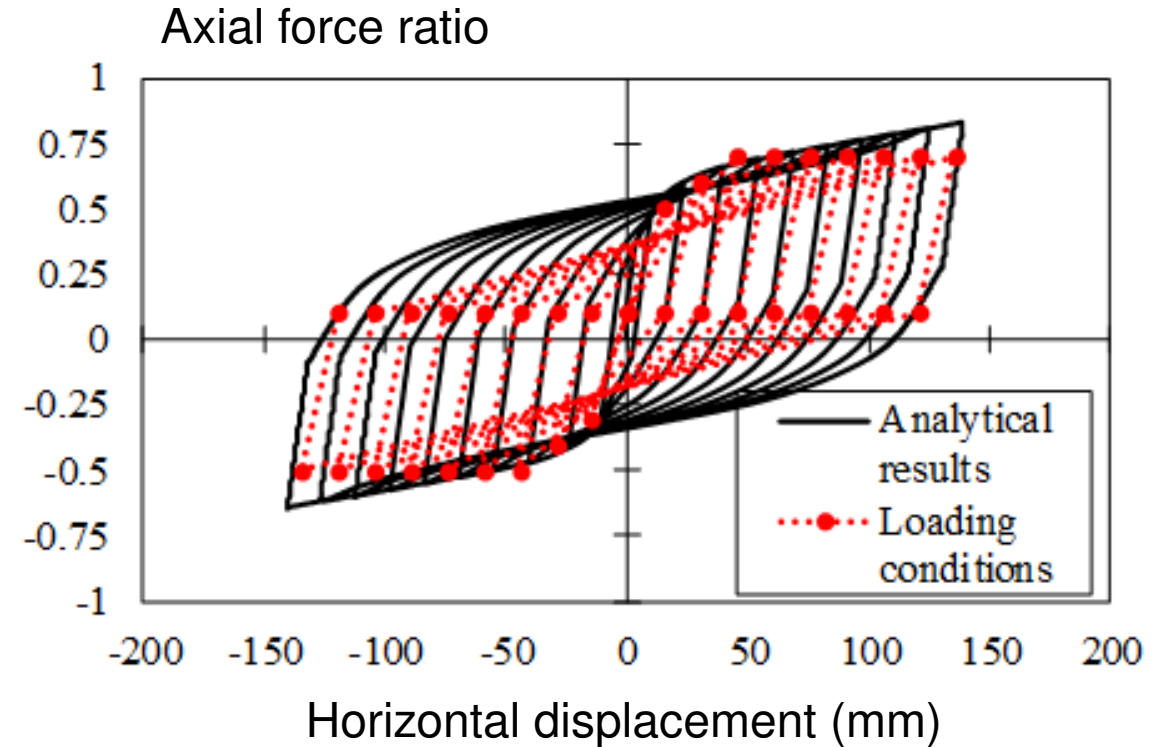
Incremented up to $0.7P_0$

Maximum Tension (-)

Incremented down to $-0.5P_0$

Unloading

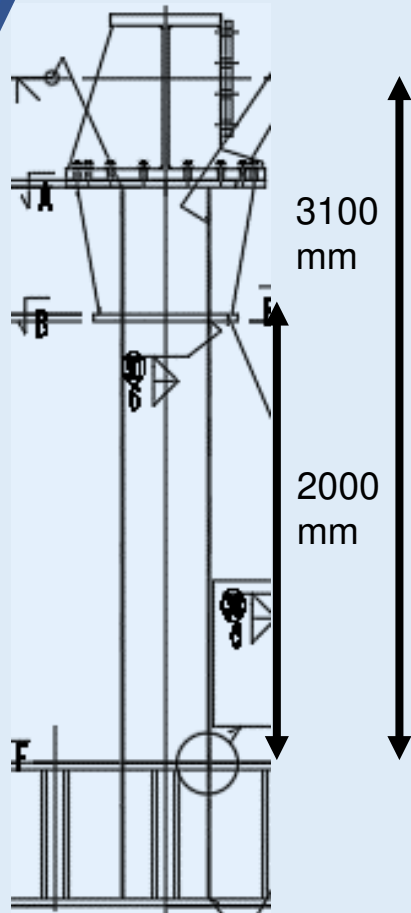
Controlled to return to dead load in each cycle



Horizontal Displacement

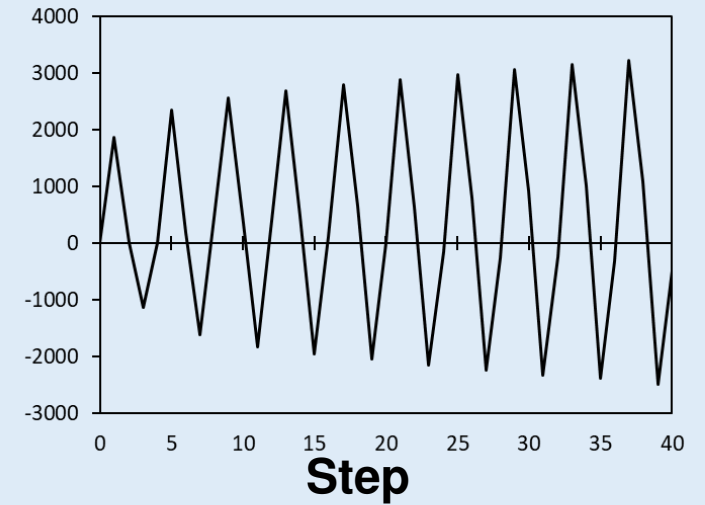
Incremental cyclic loading with $1\delta_y$ steps ($\delta_y = 25.5$ mm via pushover analysis)

Experimental Setup

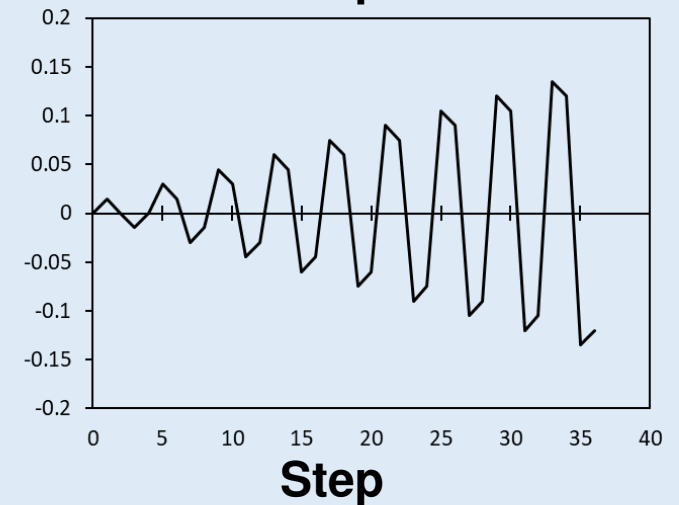


Loading Pattern

Axial force (kN)



Horizontal displacement (m)





TENSION



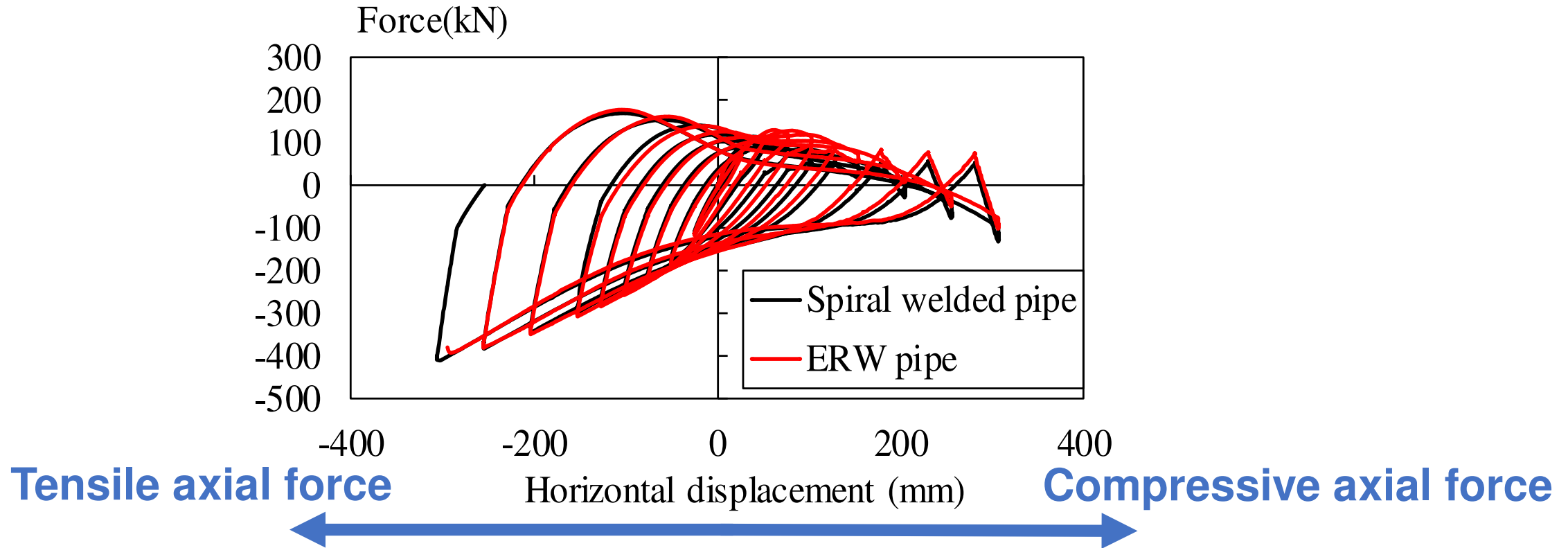
COMPRESSION



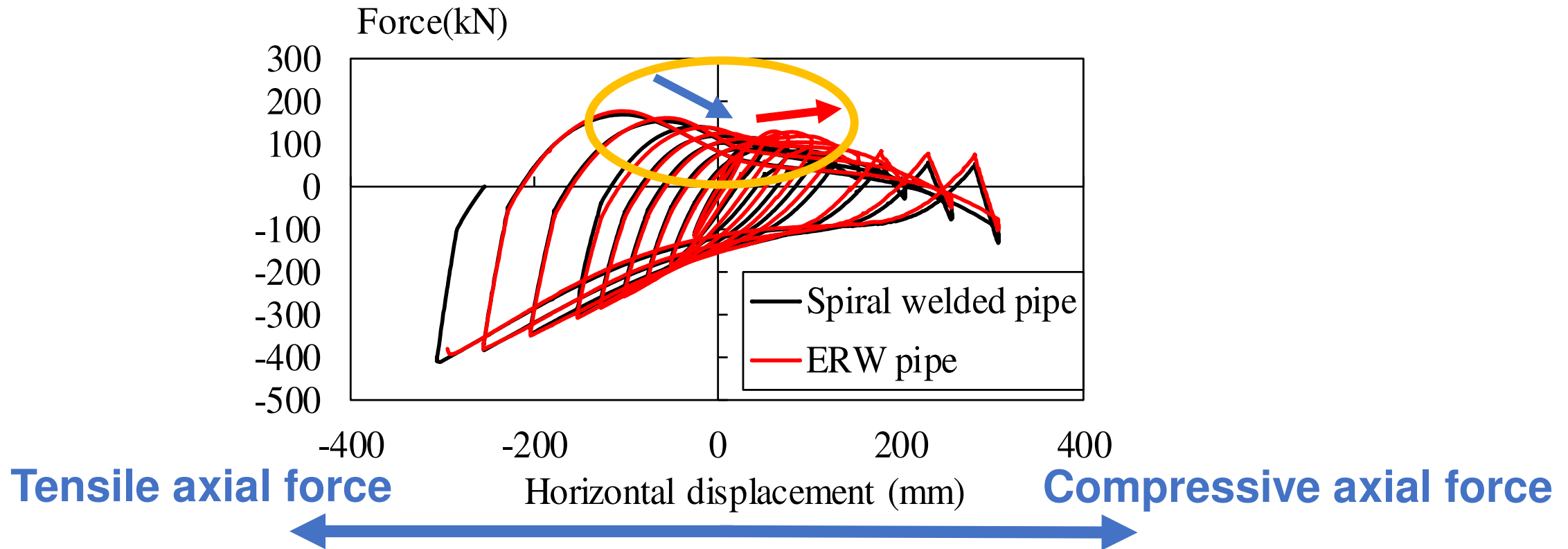
-X



+X

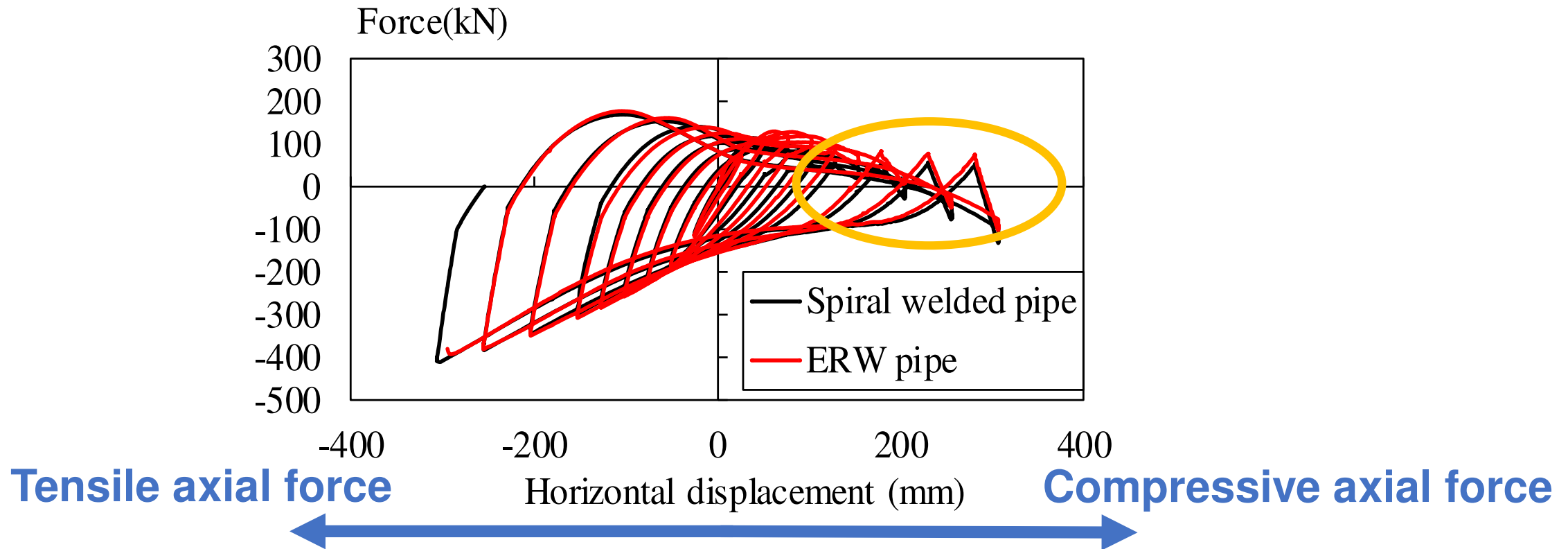


Spiral welded pipe and ERW pipe exhibit similar fundamental seismic performance



Occurs when the previously tensioned steel pipe shifts into compression

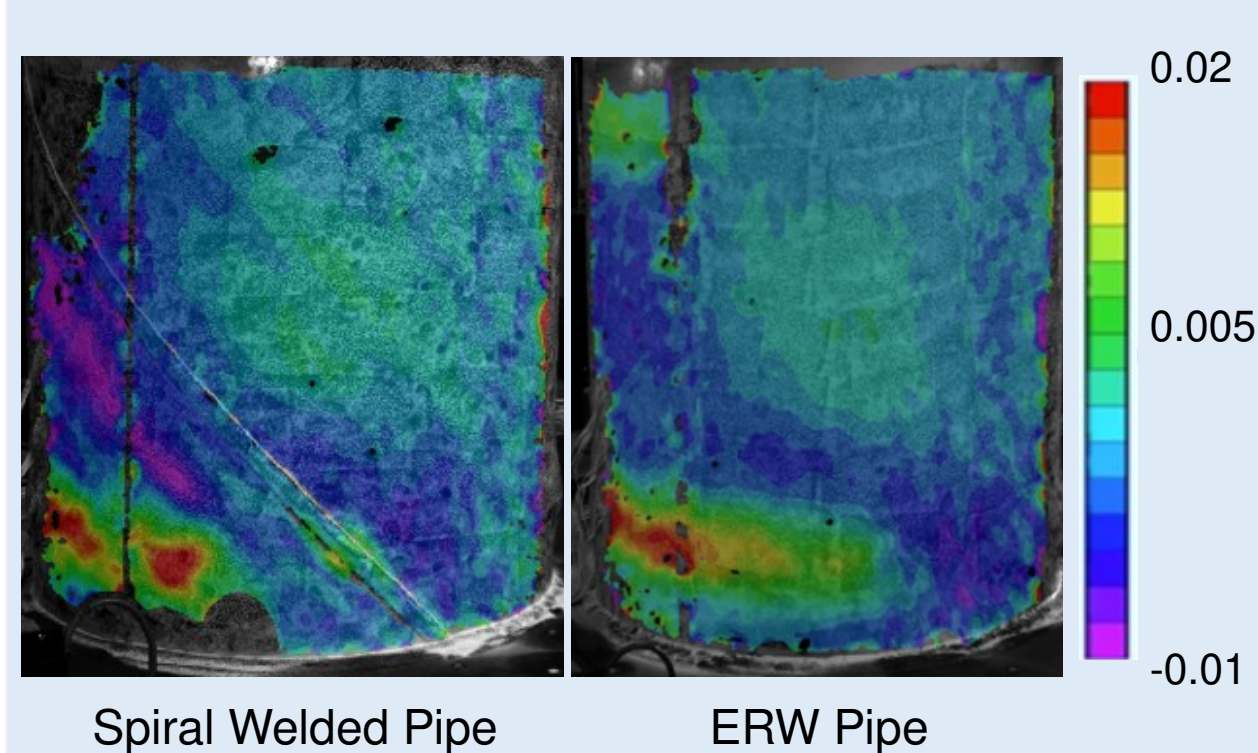
Triggered by re-contact with the in-filled concrete at the compression edge, redistributing the load



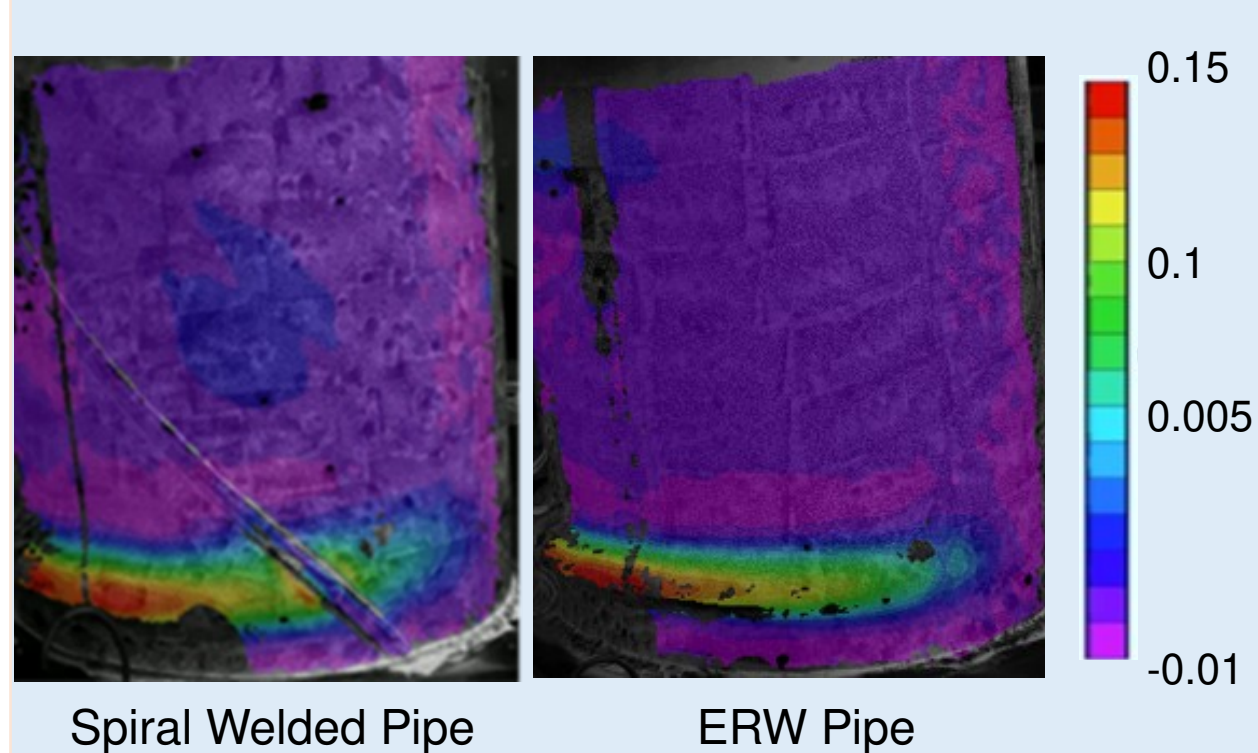
Beyond $+10\delta_y$: Strength dropped due to concrete crushing & local buckling of the steel pipe

Final Stage : Horizontal load became negative, indicating a complete loss of load-carrying capacity

Hoop Strain Distribution at 10 δy



Hoop Strain at 12 δy



- Low Strain Level: Localization along the spiral weld seam
- Ultimate State: Buckling across the seam (ignoring the seam line)

Behavior matches ERW pipes; weld seam influence is limited

+X (Compression Side)



Spiral Welded Pipe



ERW Pipe

-X (Tension Side)



Spiral Welded Pipe



ERW Pipe

- **Local Buckling:** Occurred at 70 mm from the base in both pipe types

- **Cracks**

Upper / Lower Ends: Propagated from the outer surface (at $-12\delta_y$)

Buckling Crown: Initiated from the inner surface

- **Weld Seam Effect:** No localized damage along the weld line

+X (Compression Side)



Spiral Welded Pipe



ERW Pipe

-X (Tension Side)



Spiral Welded Pipe



ERW Pipe

Concrete Crushing: Severe crushing observed at the base local buckling region

Equivalent seismic performance between Spiral and ERW CFTs

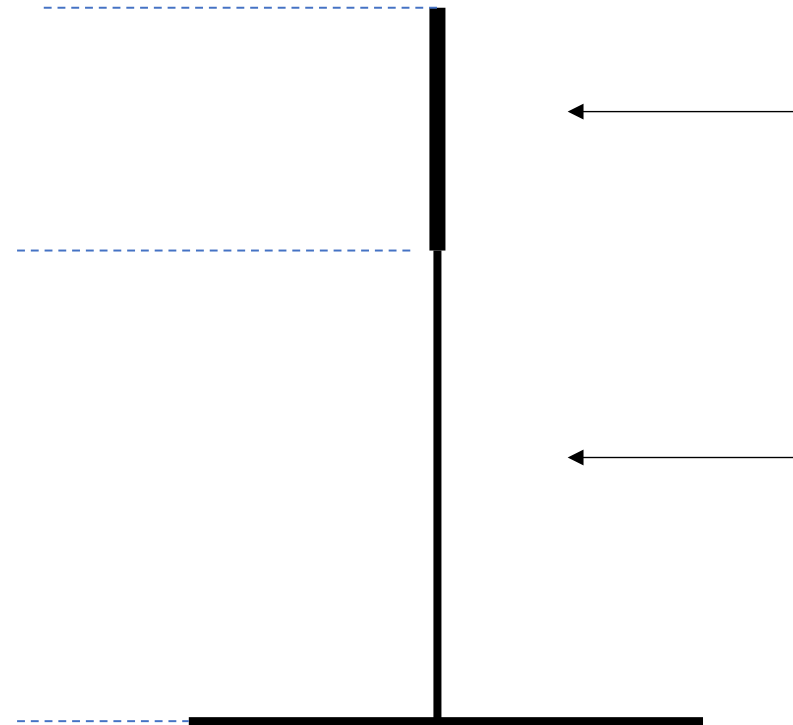
Material Level (Coupon Tests)

- Weld seams localized deformation and reduced elongation
- Without weld reinforcement, behavior was comparable to ERW pipes

Member Level (Single-Pier Tests)

- Hysteresis and buckling trends were similar for both pipe types
- Early strain concentration along the spiral weld disappeared with deformation
- Concrete cracking and crushing patterns were identical

Spiral welded pipes exhibit ultimate performance comparable to ERW pipes



single-pier
specimens