The 10th CTWWA/JWWA/WRF Water System Seismic Conference

Verification and Evaluation Method for the Seismic Performance of Potable Water Mains Lined with Cured-in-place Pipe (CIPP)

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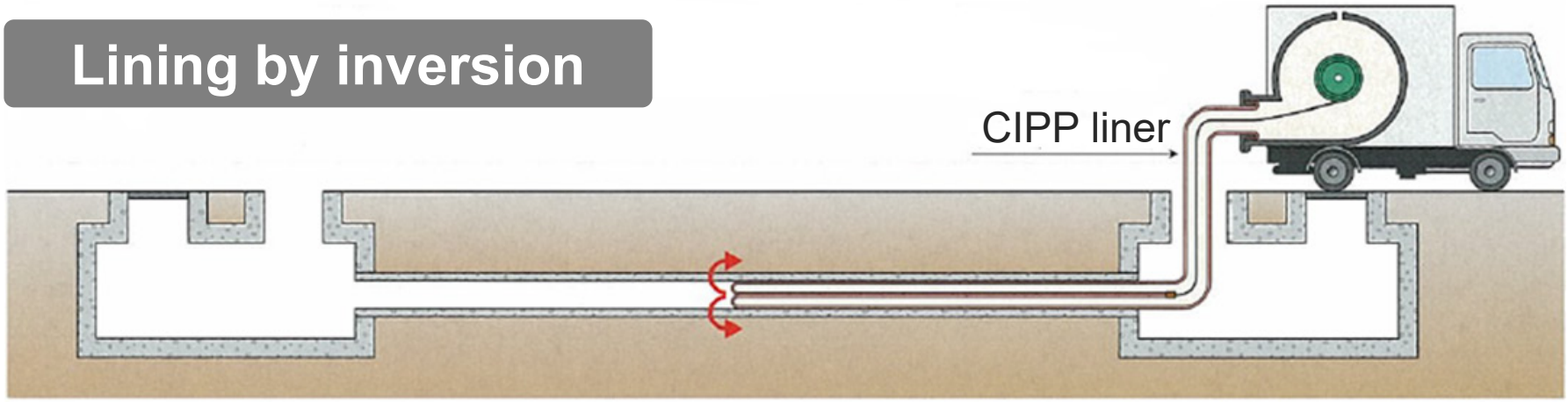
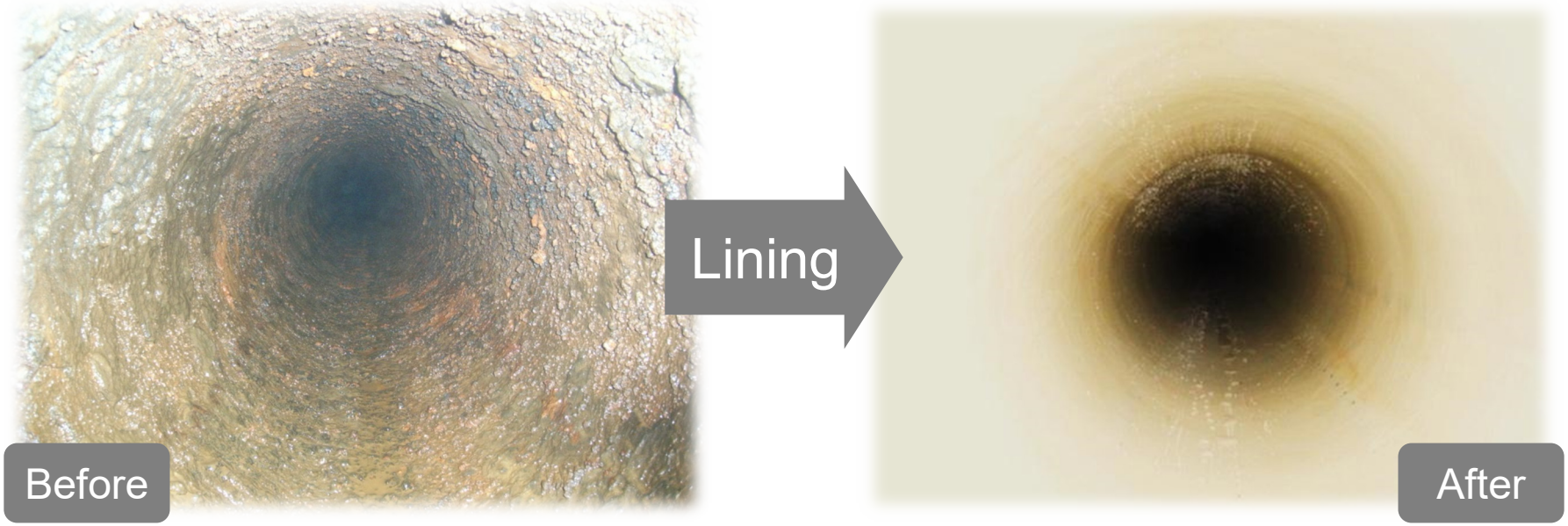
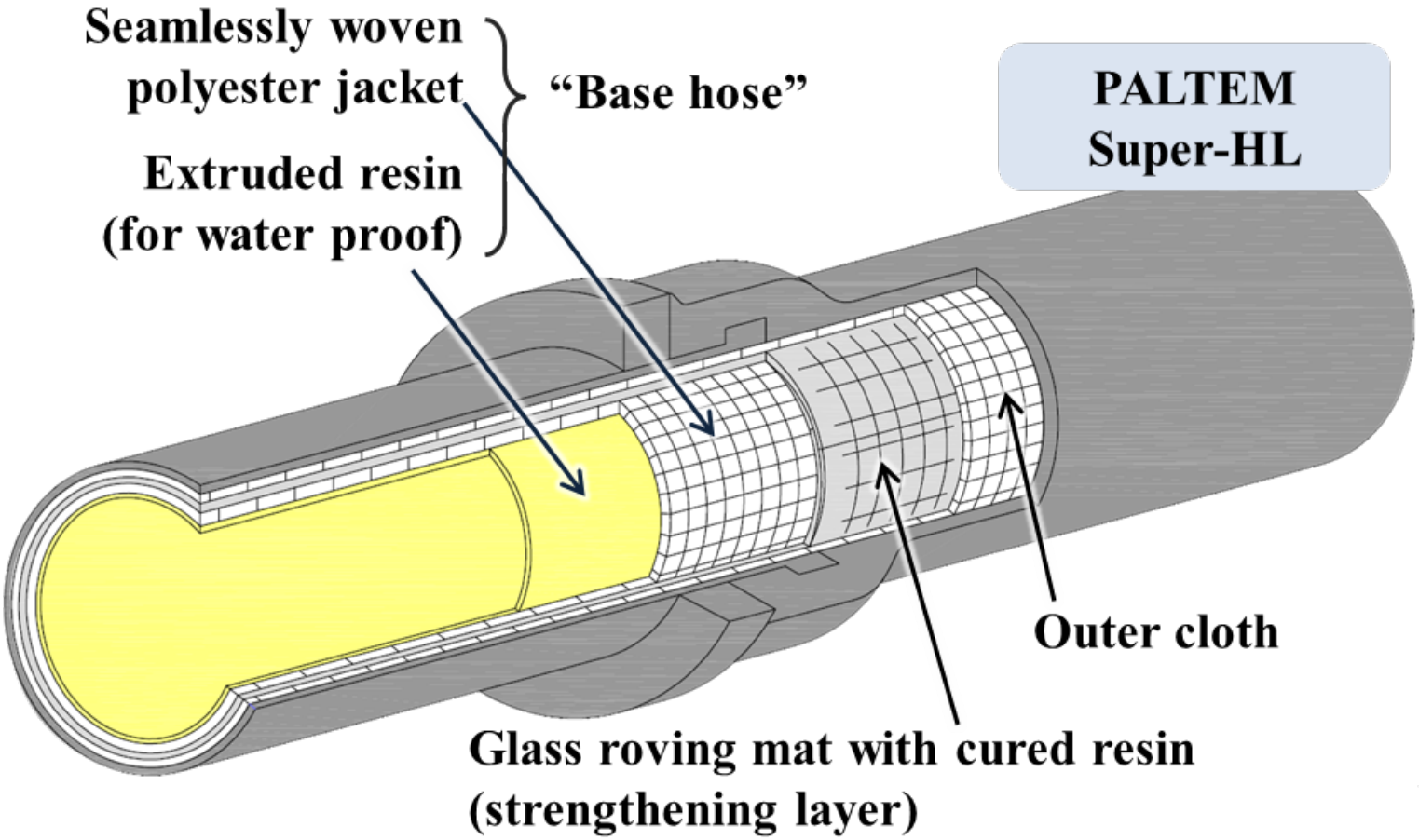
Why we do this? – CIPP (Cured-in-place pipe)

Lining by inversion





Why we do this? – CIPP, example of PALTEM



Agenda

1. **Why we do this**
2. Past performance of CIPP in seismic areas
3. Loading test on pipe specimen with CIPP
4. Verification by calculation

Why we do this? – Industrial background

Seismic standards for trenchless pipe rehab

- Sewer

  Level 1 & 2 classification and performance criteria for CIPP

- Gas

  CIPP standardized for sealing purpose in earthquakes

- Potable water

  CIPP installation record not enough for standardization

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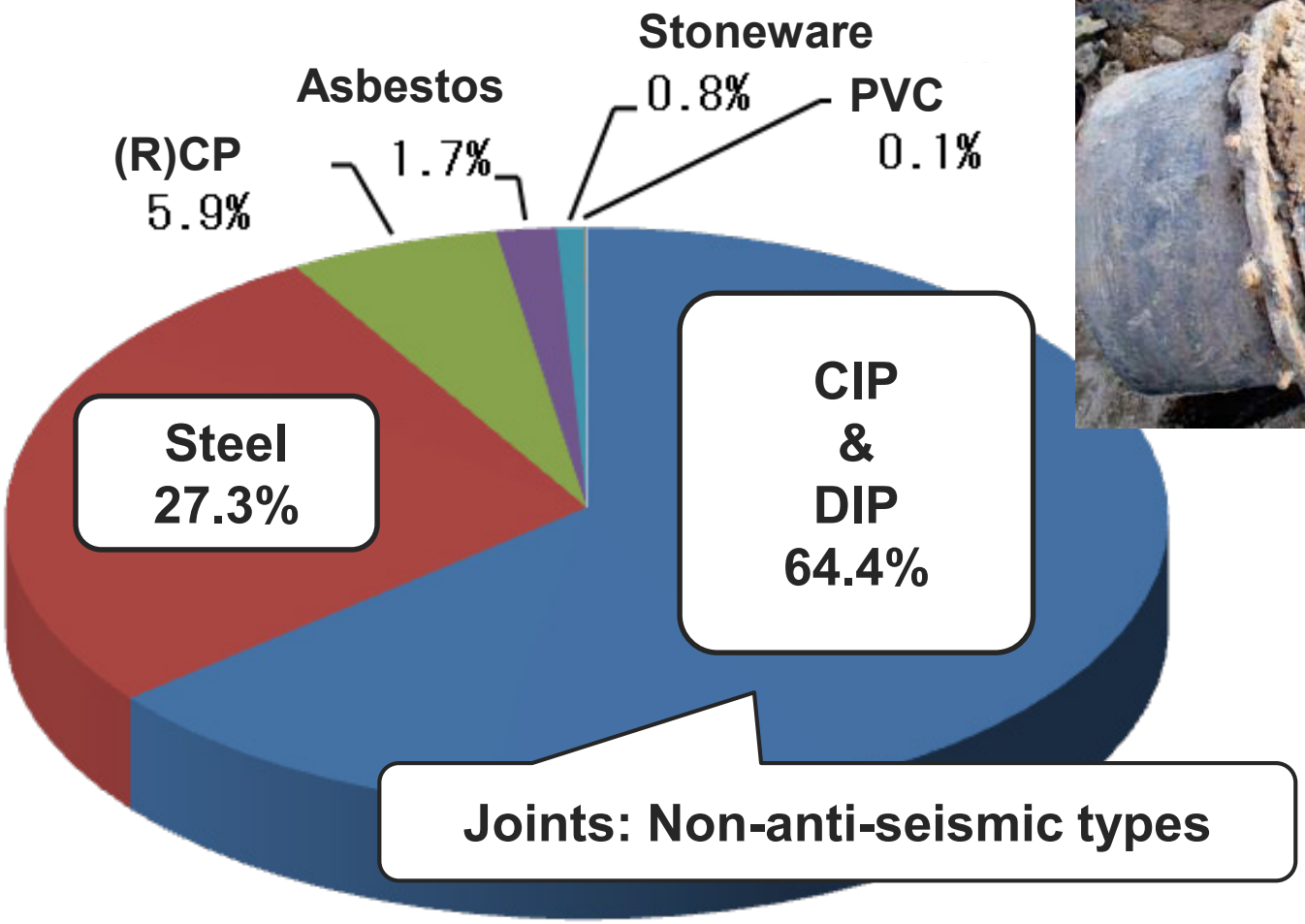
Past performance – no major troubles heard

370 km of our liners were used in...



Past performance – cross-checking

Year	Earthquakes	Max. intensity	Mw
Jan/17/1995	Great Hanshin	7	6.9
Oct/06/2000	West Tottori	6+	6.8
Oct/23/2004	Chuetsu	6+	6.6
Mar/25/2007	Noto	6+	6.7
Jul/16/2007	Chuetsu Offshore	6+	6.6
Mar/11/2011	Tohoku	7	9.0

PALTEM CIPPs installed in...

Municipalities stricken by intensity 6+... 6,690 m

Areas in which liquefactions observed... 30,053 m

No failure reports

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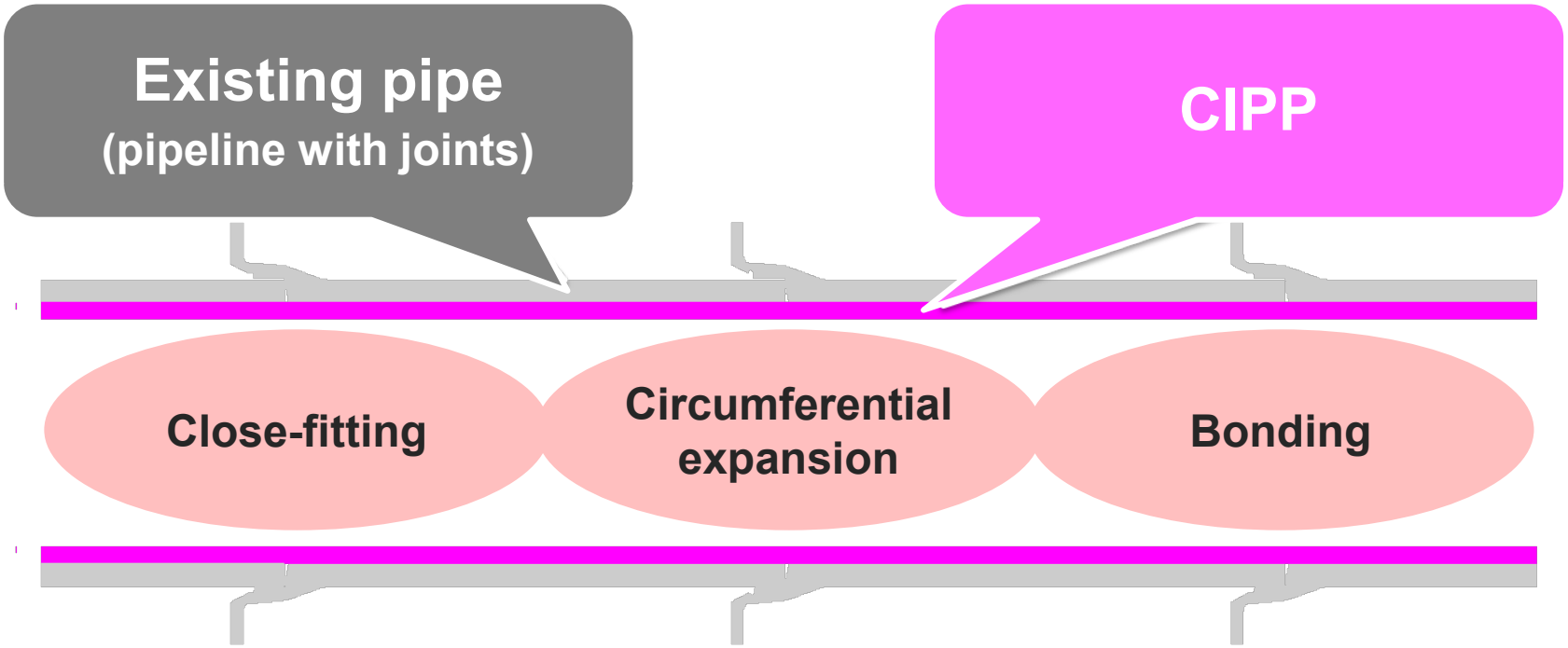
Before testing – understanding CIPP



Characteristics of CIPP suppress pullout phenomena of host pipe during earthquakes

Before testing – understanding joint pullout

$$R = \sigma_{2L} \times A = \frac{\pi \cdot D \cdot \tau \cdot L}{2A} \times A$$

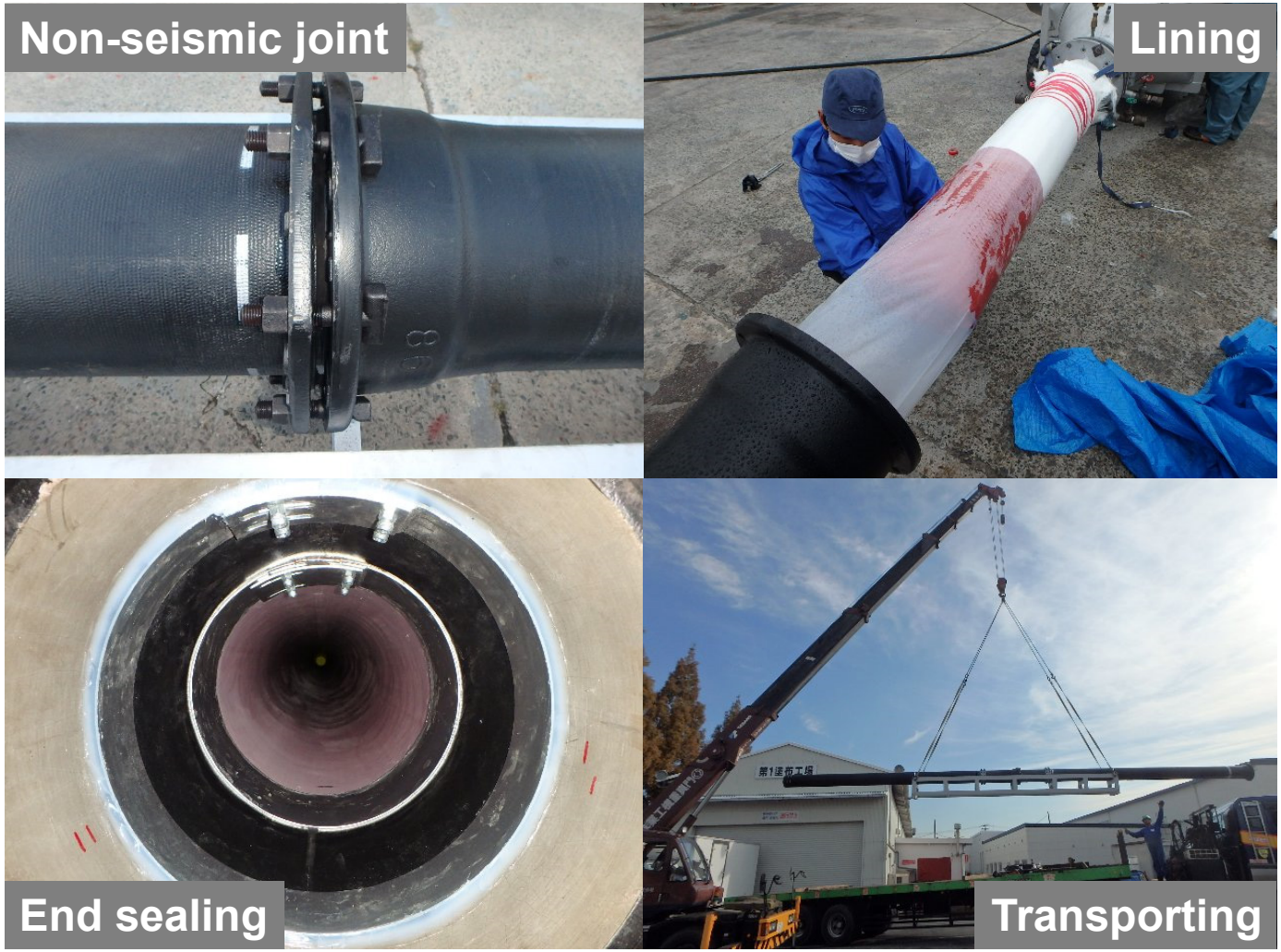
(JWWA)

R : Pullout force at joint
A : Sectional area
D : Outside diameter of pipe
τ : Friction between pipe and ground (=0.0098 N/mm^2)
L : Length of pipe

No joint pullout should occur when friction forces are…

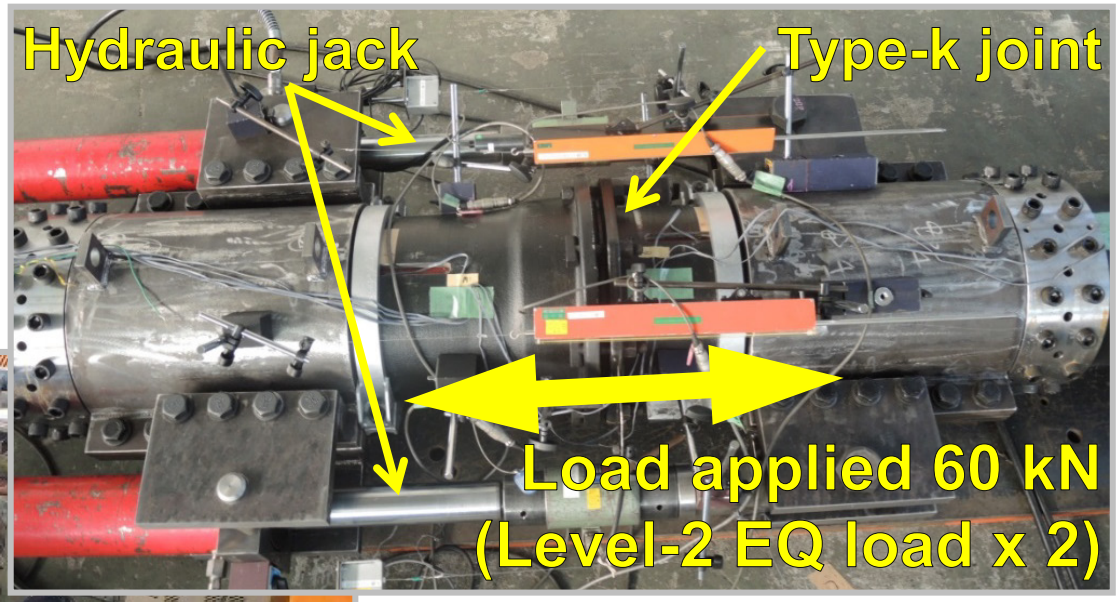
Ground and existing pipe (approx. 0.01 N/mm^2) **≤** **Existing pipe and CIPP** (0.025 ~ 1.000 N/mm^2)

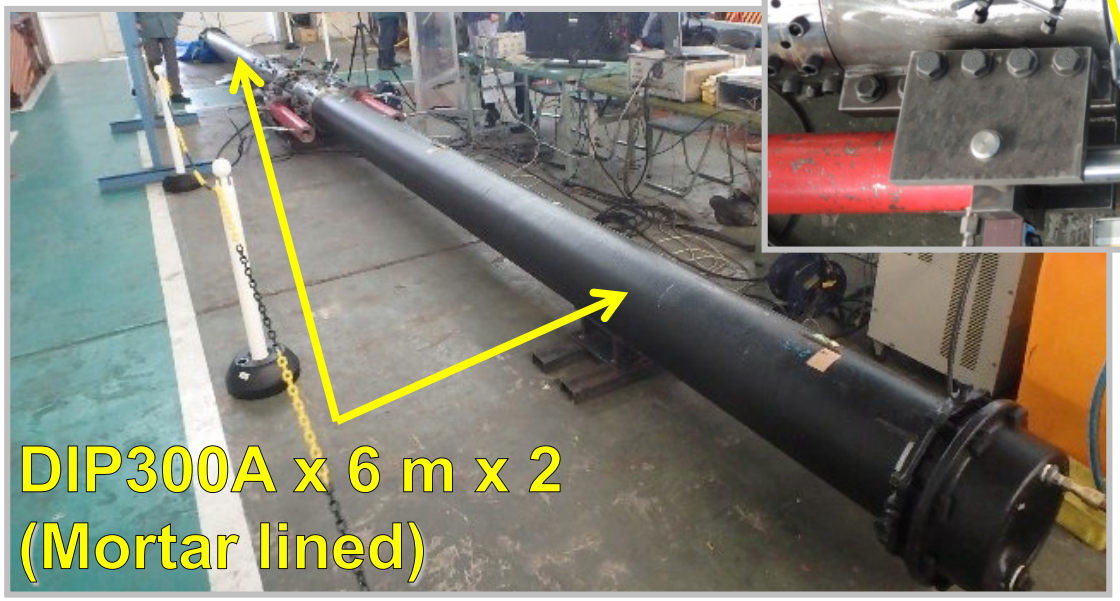
Testing – loading test, preparation



Testing – loading test, execution

60 kN
pullout load





Internal water pressure
0.75 MPa

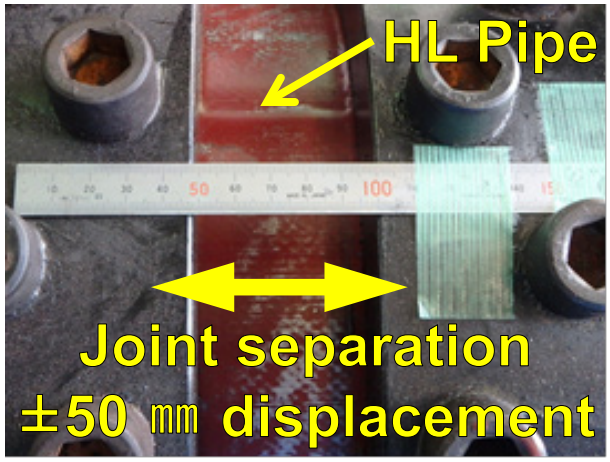
Testing – loading test result, no joint pullout

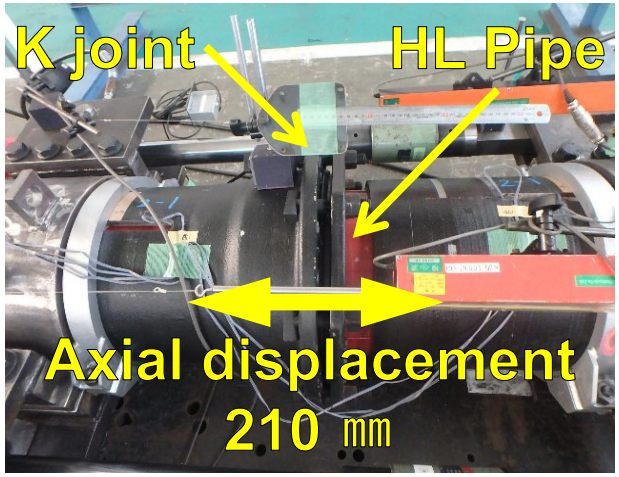
CIPP		“Super-HL” Φ300, t=4.0 ㎜		
Host pipe		DIP, Φ300 ㎜, L=6,000 ㎜ x 2		
Specimen		No.1	No.2	No.3
CIPP’s properties	Close-fitting	✓	✓	✓
	Expansion	✓	✓	✓
	Adhesion	-	-	-
Load applied		60 kN (Estimated seismic load[1)] w/ s.f. 2)		

1) JWWA

No joint displacement, leak or damage under 60 kN

Testing – forcing joint pullout





Testing – forcing joint pullout

	Test Ⅰ (SP, 4 m)		Test Ⅱ(DIP, 12 m)
Direction of displacement	Comp.	Tensile	Tensile
Max. displacement (㎜)	50	58	210
A) Max. load applied（kN）	165		427
B) Estimated seismic load (kN) [1)]	9.23		27.69
A／B	**approx. 18x**		**approx. 15x**

1) JWWA

- **15 times the estimated seismic load was needed to generate joint displacement**
- **No leaks or damages resulted from displacement**

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4. **Verification by calculation**

Verification – selecting calculation conditions

Based on observation, CIPP within jointed pipeline is

Continuous pipe

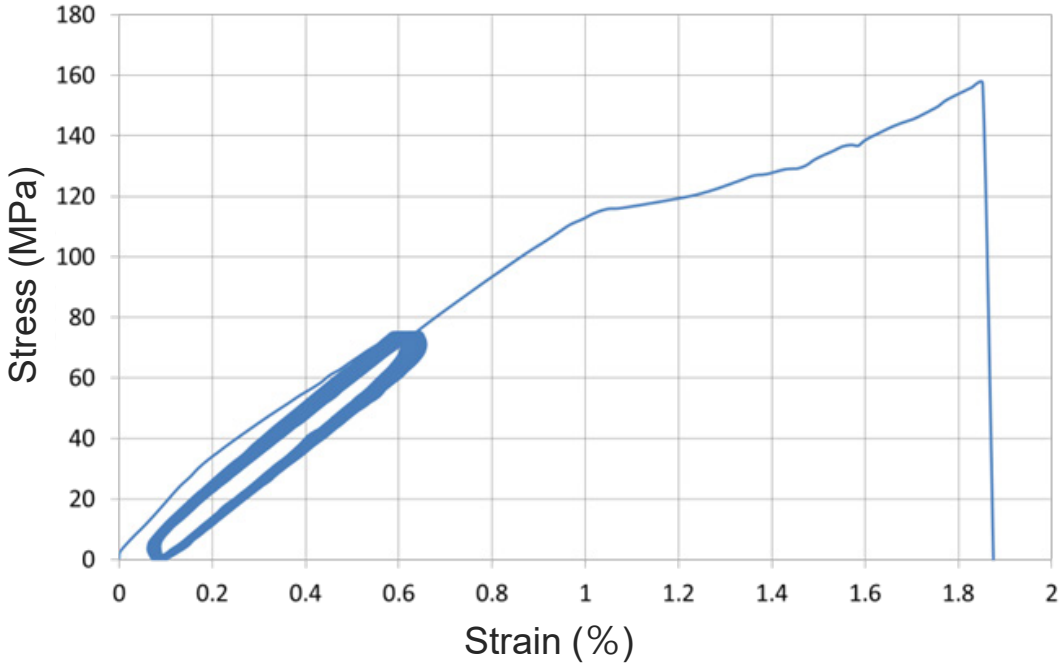
Calculation conditions for CIPP within host pipeline

	CIPP	SP
Structural classification	Continuous pipe	
Joint	Ignored	No joint
Slippage between host pipe and ground	Ignored	Considered
Tensile elastic modulus	CIPP	SP
Allowable strain setting	CIPP	SP

Verification – allowable strain for Level-1 EQ

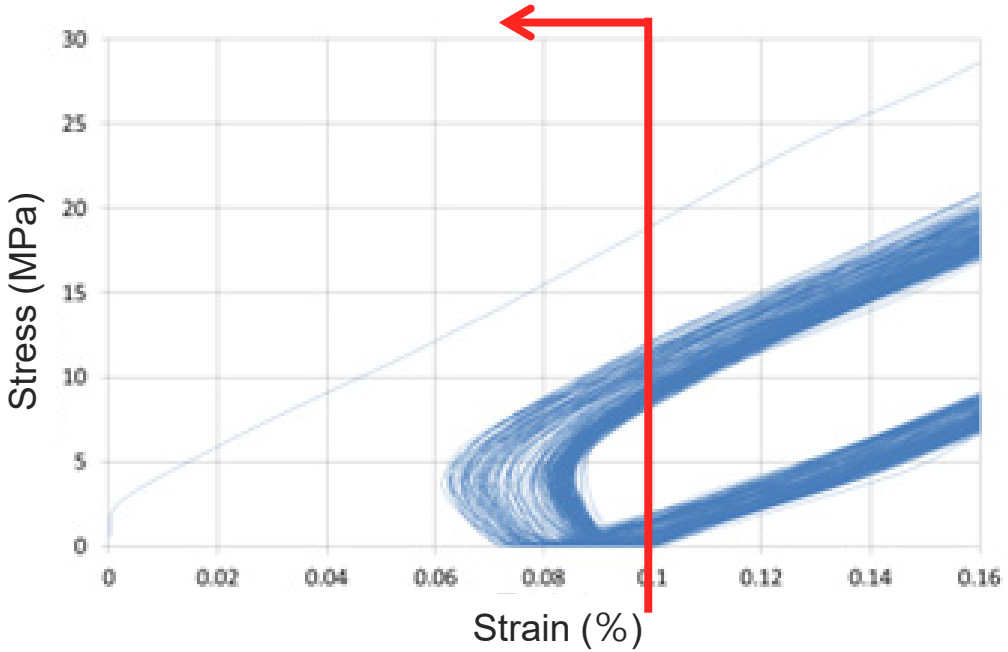
Dynamic property ≤ Elastic range

0.6% strain (equivalent to Level-1 seismic motion) cyclically applied for 300 times at the speed of 5 mm/min



Verification – allowable strain for Level-1 EQ

Determined to be 0.6%



Input strain1	Speci-men	Residual strain after test (%)	Tensile strength after test (MPa)
0.6%	1	0.07	160.6
	2	0.09	157.4
	3	0.07	163.2
n/a	4	-	159

Verification – allowable strain for Level-2 EQ

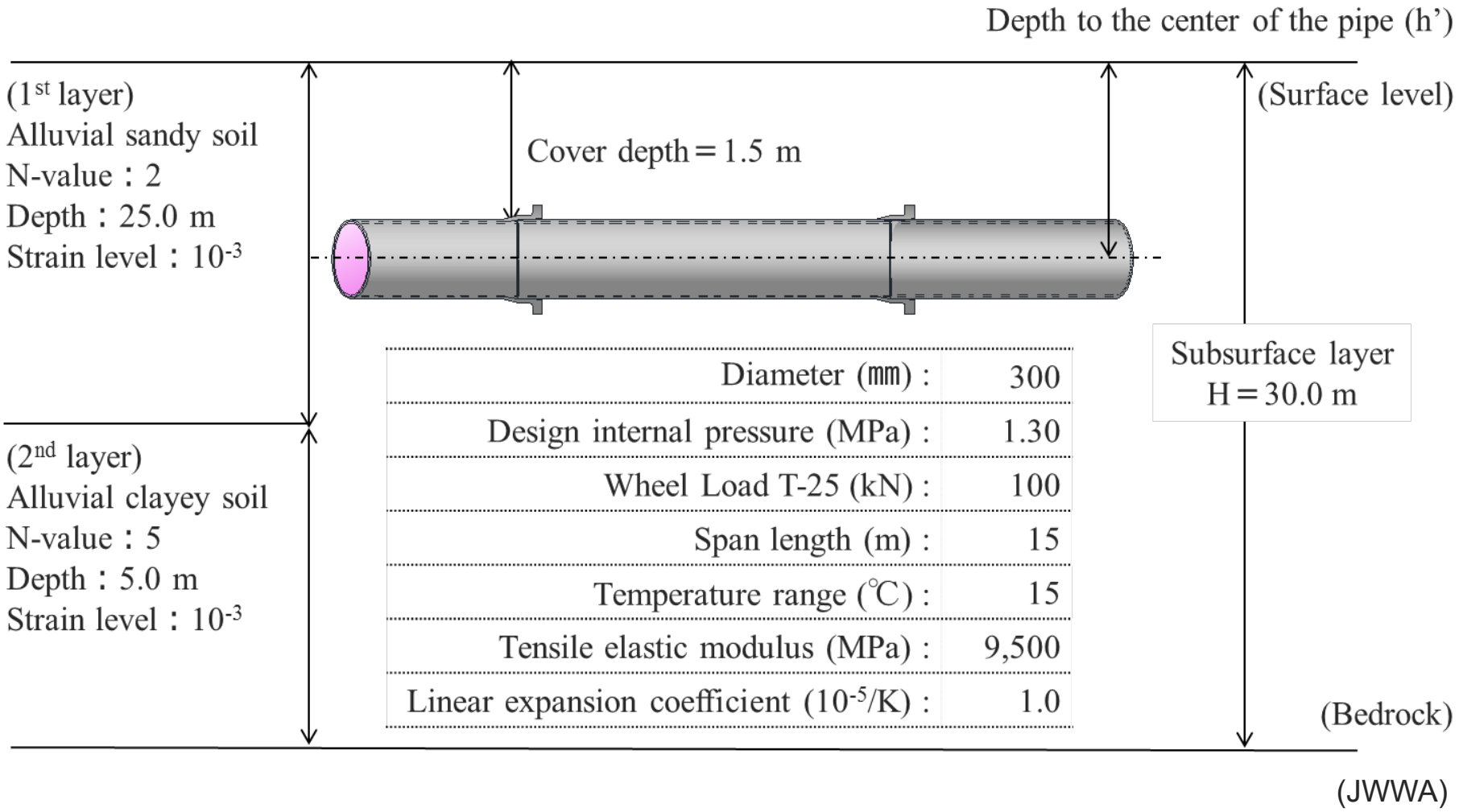
Water-tightness to be maintained under plasticization

1.2% strain (Level-2 equivalent) cyclically applied for 100 times on 5 Hz frequency.

Input strain	Specimen	Specimen status after testing	Tensile strength after testing (MPa)
1.2%	1	No damage	Avg. 137 ↓ No strength deterioration
	2		
	3		
-	4	-	140

For Level-2, 1.2%

Verification – in a model ground condition



Diameter (mm) :	300
Design internal pressure (MPa) :	1.30
Wheel Load T-25 (kN) :	100
Span length (m) :	15
Temperature range (℃) :	15
Tensile elastic modulus (MPa) :	9,500
Linear expansion coefficient (10^{-5}/K) :	1.0

Verification – in a model ground condition

		Level-1	Level-2
Normal load	Design internal pressure	0.152%	
	Vehicle load	0.046%	
	Temperature change	0.015%	
	Unbalanced subsidence	0.010%	
Seismic load		0.060%	0.502%
Total strain in axial direction		0.283%	0.725%
Allowable strain		0.600%	1.200%
Result of verification		**Within Allowable strain**	**Within Allowable strain**

Conclusion

Test proved past performance

Pipe with CIPP behaves like continuous pipe

Calculation method selected for CIPP

Q&A

Future challenge still remains

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