

4th Latin American Trenchless Congress, Cartagena, Colombia, 2023/5/4

ON THE TRENCHLESS TECHNOLOGIES FOR UNDERGROUND PIPELINES

Keh-Jian Shou
**Chairman, International Society for
Trenchless Technology (ISTT)**

CONTENTS

- I. Introduction Trenchless Technologies
- II. The Trenchless Rehabilitation Method
---CIPP

I. Introduction Trenchless Technologies

I. Introduction Trenchless Technologies

1. About ISTT

The International Society for Trenchless Technology (ISTT) was established in September 1986 as a United Kingdom private limited company with the object "to advance the science and practice of trenchless technology for the public benefit..." and "to promote education, training, study and research in the said science and practice for the public benefit, and to publish the useful results of the same." In the years that followed, ISTT affiliated with regional trenchless societies located throughout the world to advance these objectives globally.

ISTT has 28 Affiliated Societies. All recorded members of an Affiliated Society are members of ISTT. In addition to Affiliated Society members, ISTT has a limited number of members who reside in regions where no Affiliate Society exists.

Affiliated Societies



<https://www.istt.com/index/>

2. Trenchless Technologies

What is Trenchless Technology (No-Dig)?

- A set of technologies for the remote installation, rehabilitation and repair of utilities, pipelines and small tunnels -- linked by their lack of need for digging a continuous trench for the installation of new pipes or the repair of old pipes

The Problem: Extensive and Deteriorating Networks



More than 11 million miles in U.S.
Existing investment in the trillions of dollars
Haphazard, poorly documented, neglected

Problems with Open Cut



- Traffic congestion growing
- Street pavement damage
- Cost of surface restoration
- Direct/indirect business loss
- CO₂ emission

Trenchless Technology provides modern solutions to underground utility problems



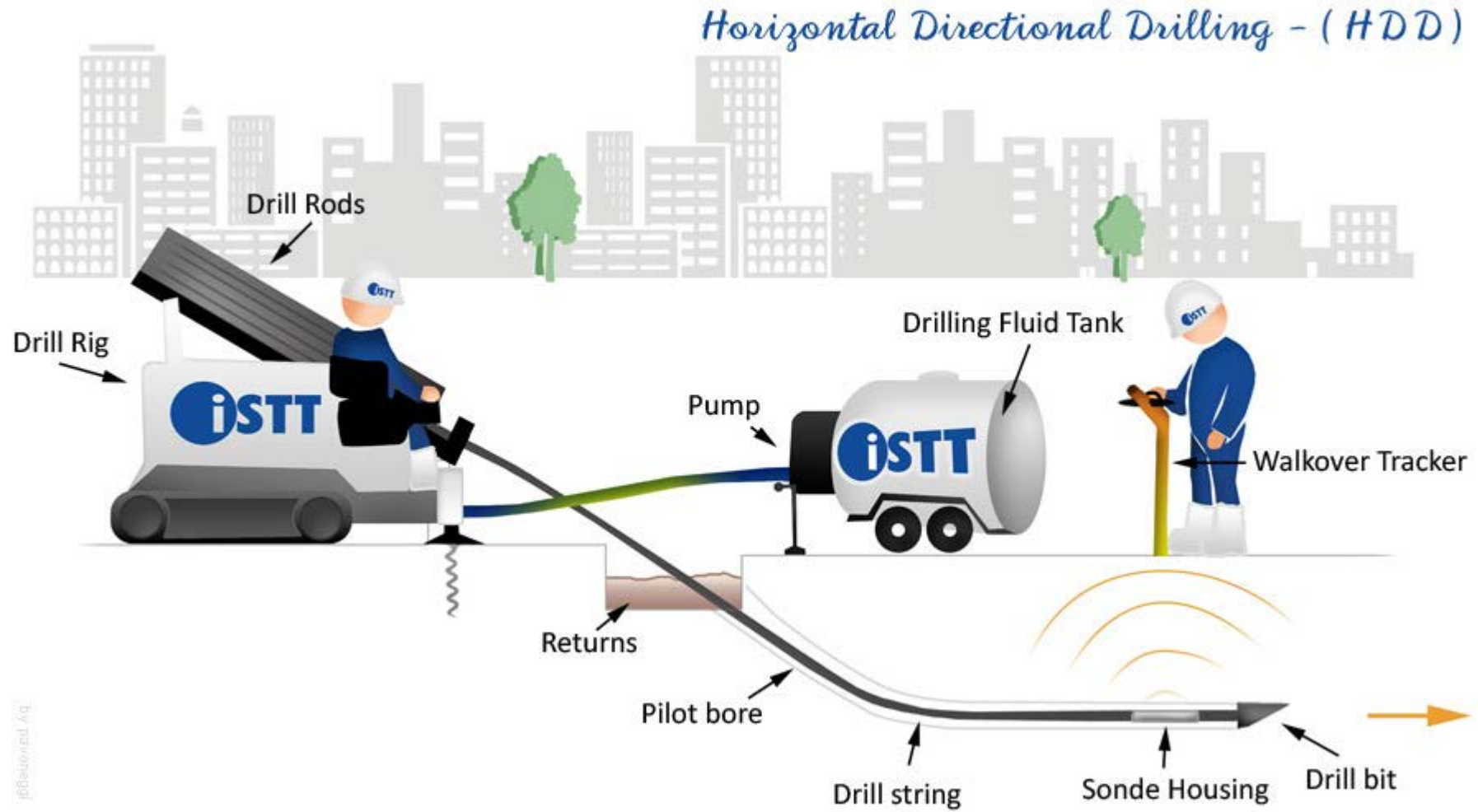
Underground Construction Techniques



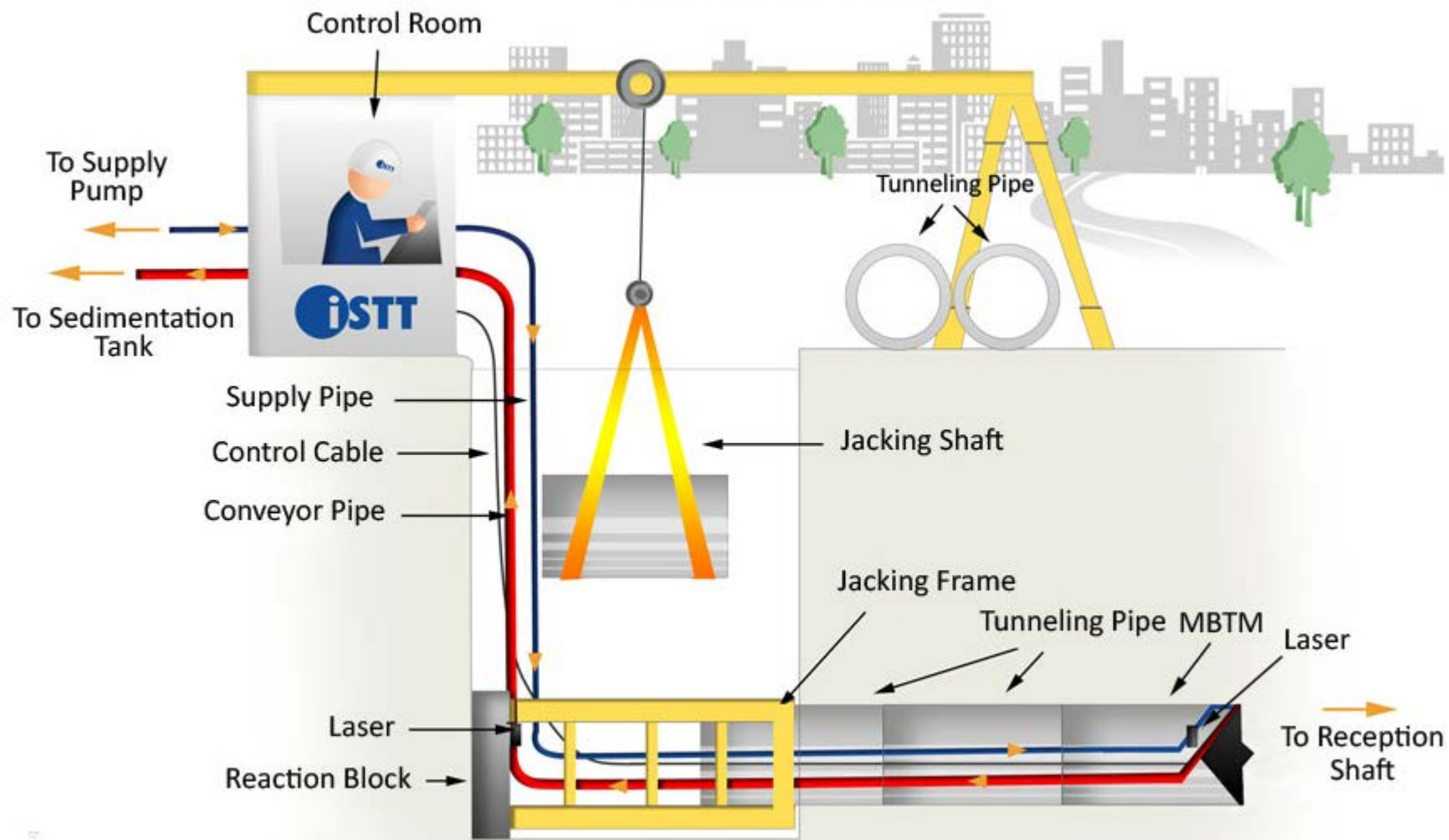
i. Condition Assessment

Common trenchless technologies for inspection and condition assessment include CCTV, laser, sonar, flow monitoring, gas monitoring and leak detection.

ii. New Installation



Microtunneling



by: csmw@egps

iii.Rehabilitation

Rehabilitation is divided into three sections;
renovation, replacement and repair.

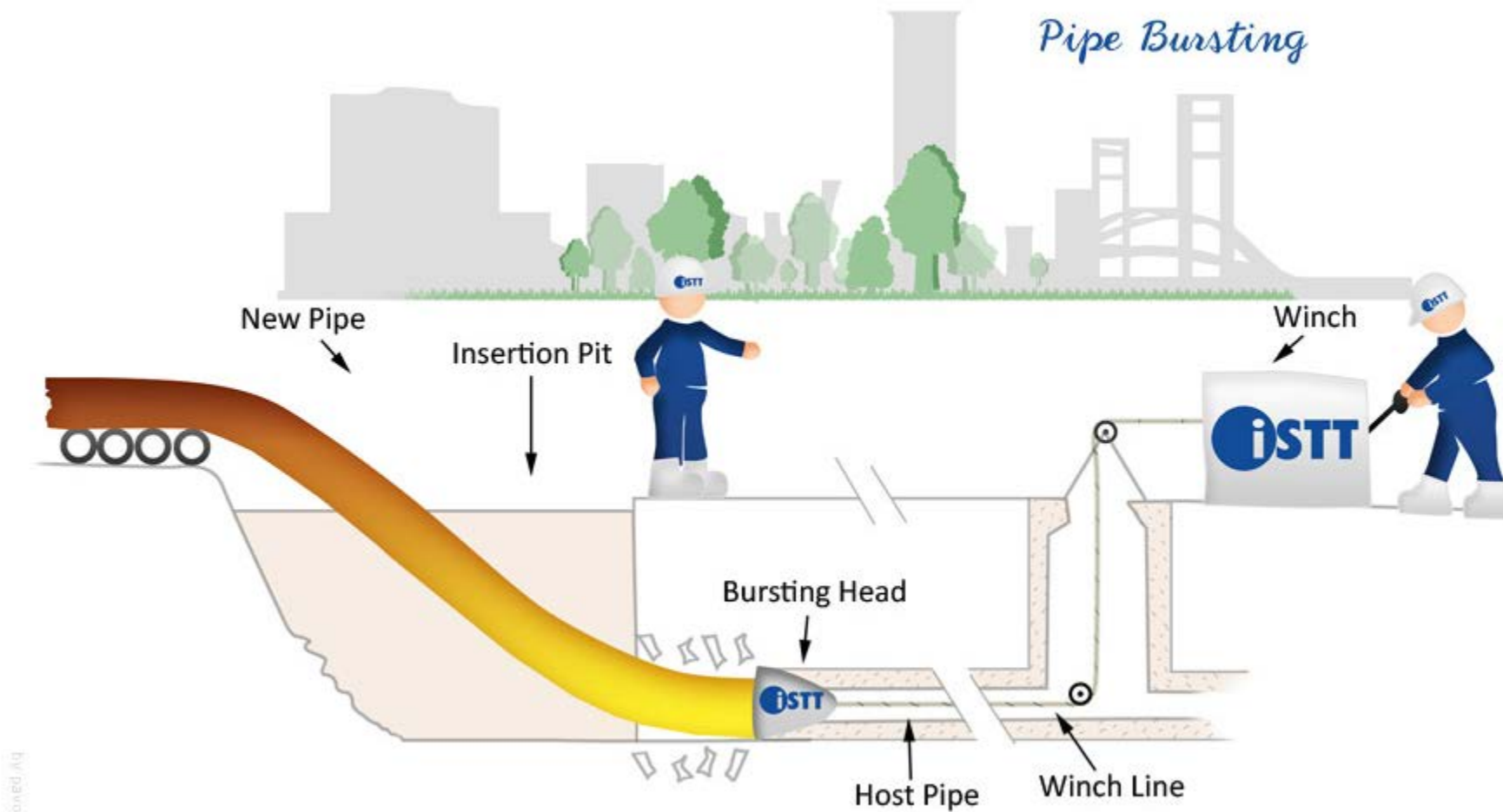
Ageing infrastructure and increasing populations have resulted in the development of pipe rehabilitation as a fundamental concern in the maintenance of essential underground services. This category encompasses methods of restoring integrity to defective pipelines and underground structures and extending their operational life.

Renovation is a method in which all or part of the original fabric of a pipeline is incorporated and its current performance improved. Replacement is the rehabilitation of an existing pipeline system by the installation of a new system, either on or off the existing line without incorporating the original fabric. Repair entails the rectification of local damage.

iii.Rehabilitation

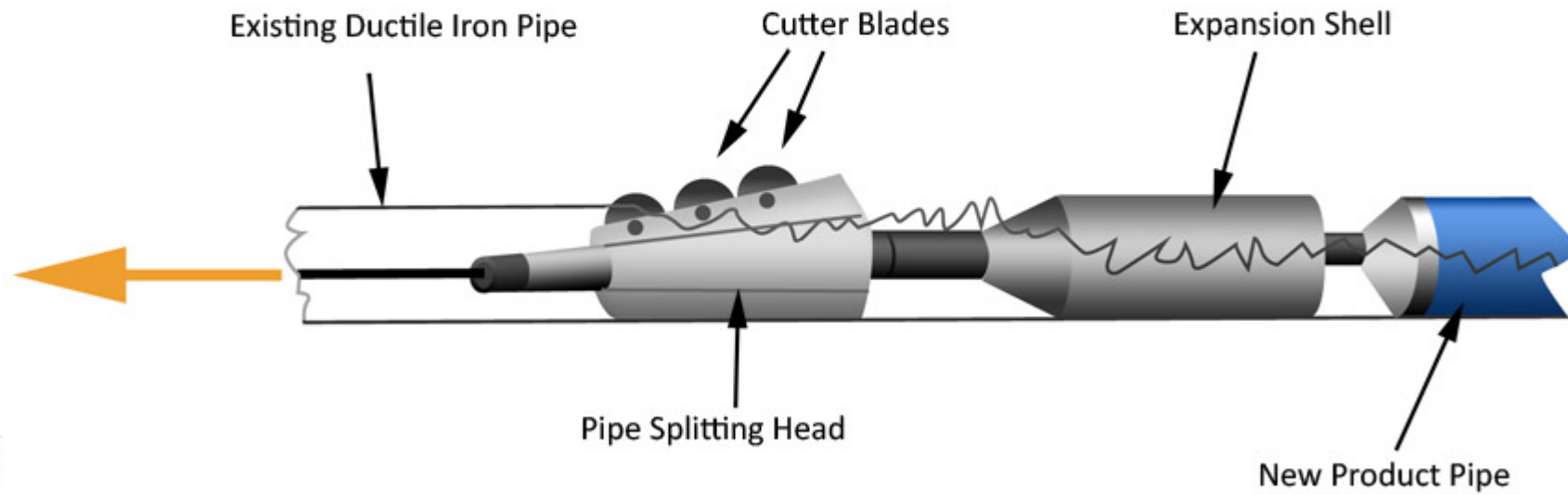
is divided into three sections; renovation, replacement and repair.

replacement



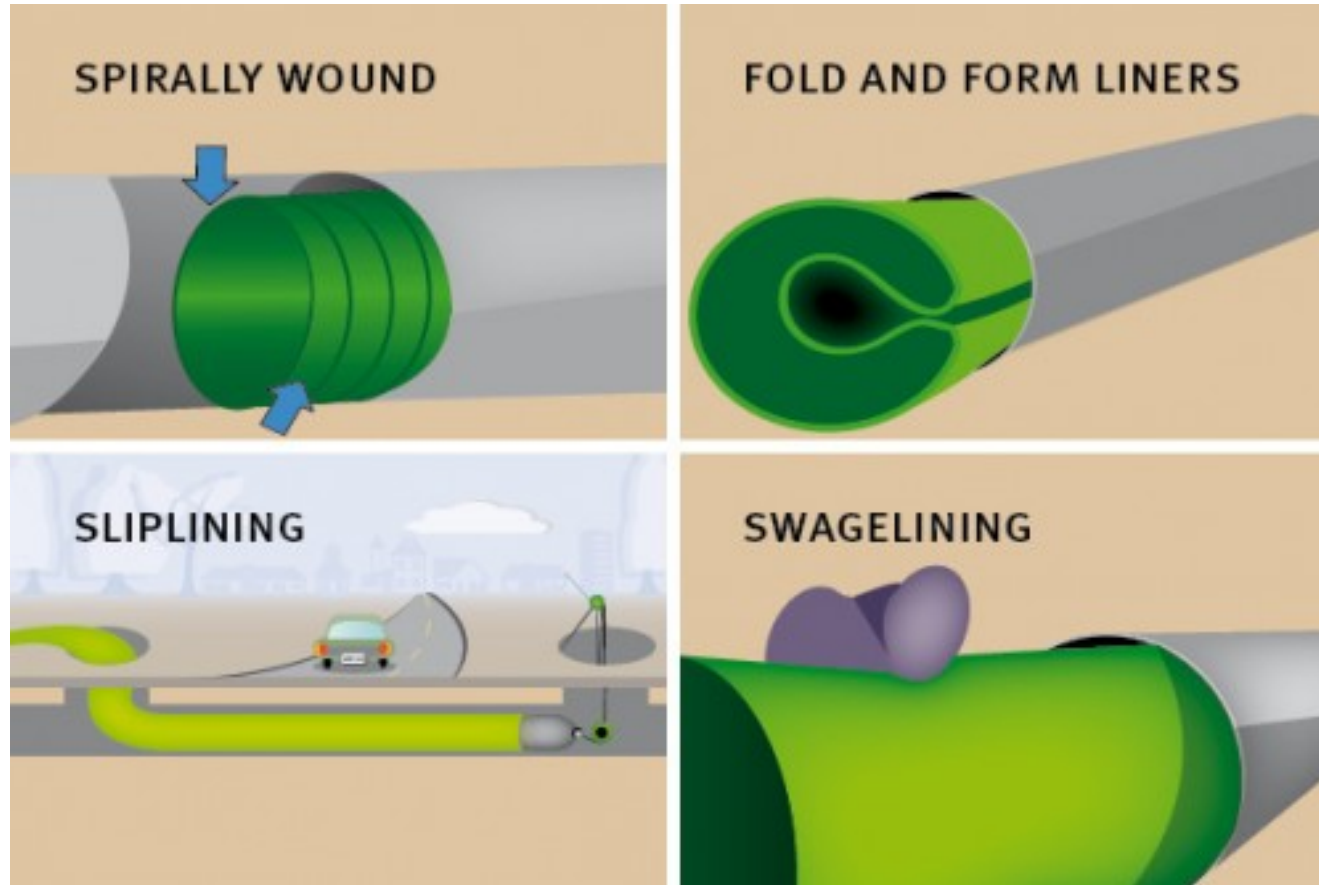
Pipe Splitting

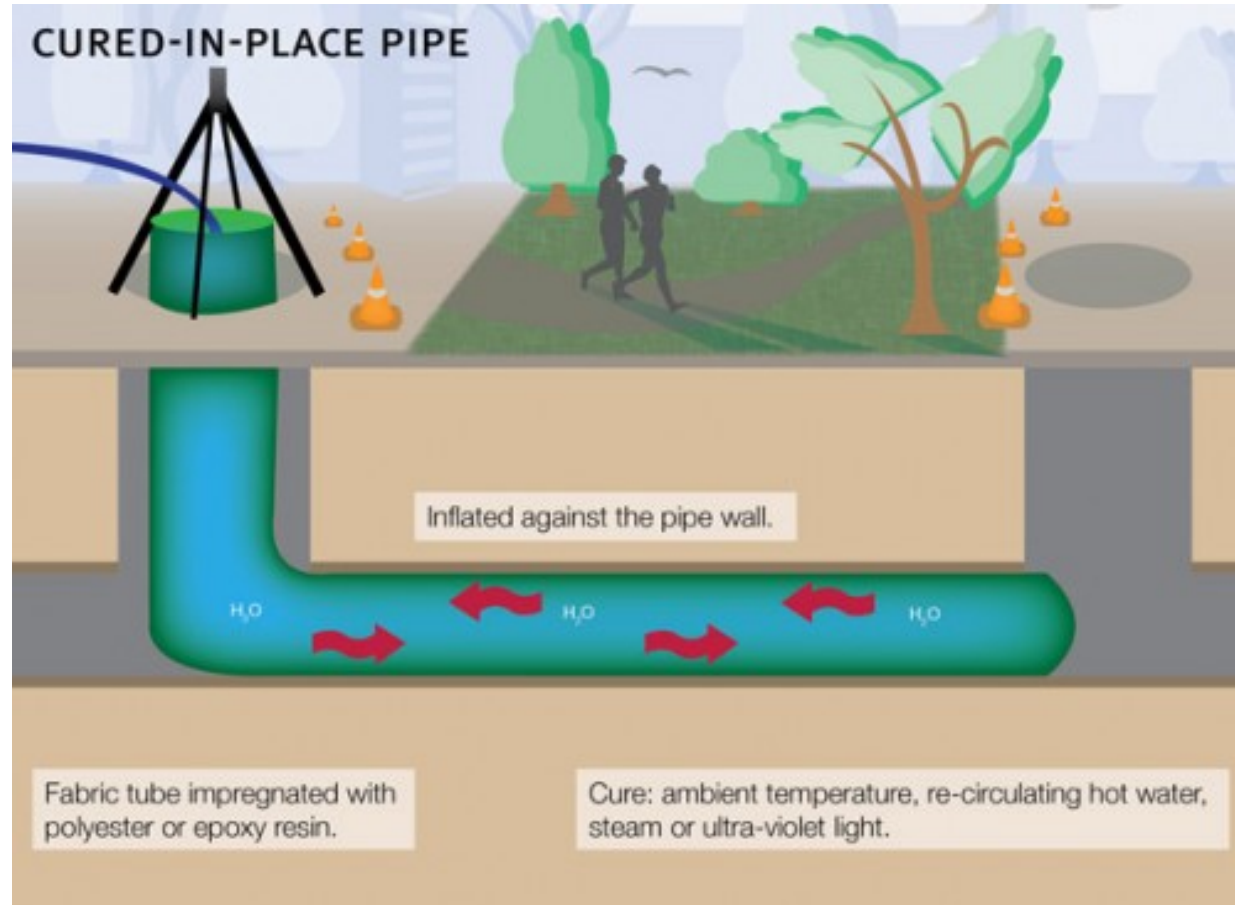
PREV



by pavonaggi

renovation





3. ISTT Technical Guidelines



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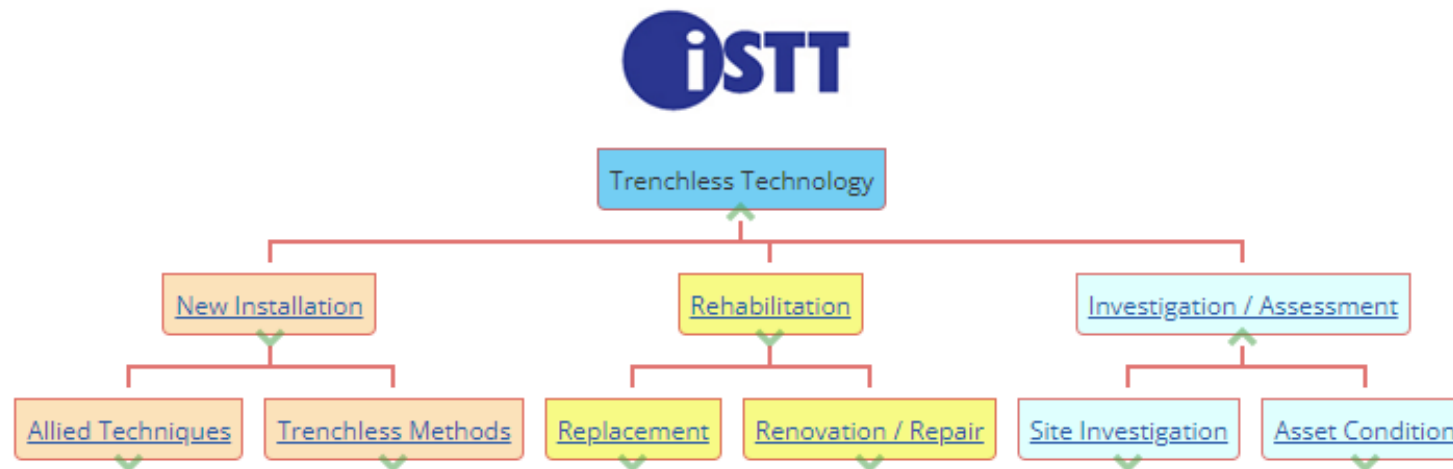
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chart as a ZIP file

Trenchless Methods - Chart and Descriptions

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Trenchless Technology

New Installation

Allied Techniques

Trenchless Methods

Reduced Surface Disturbance

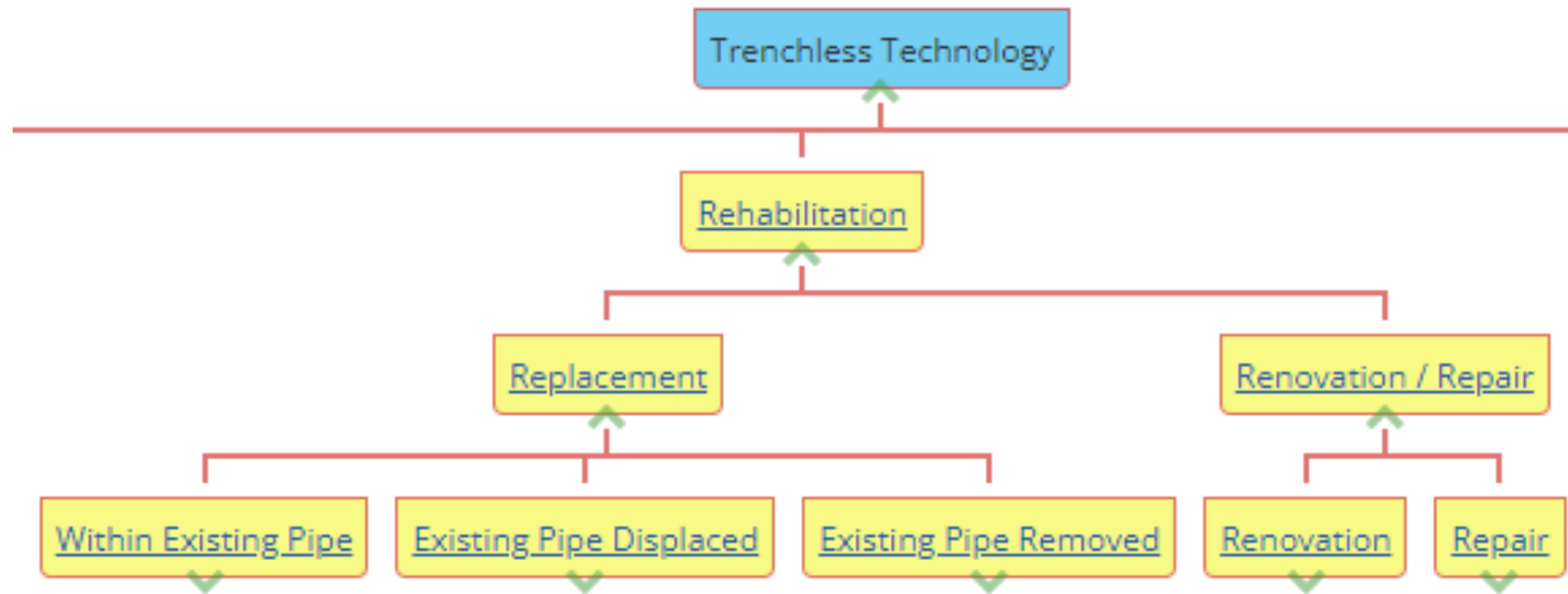
Conventional Tunneling

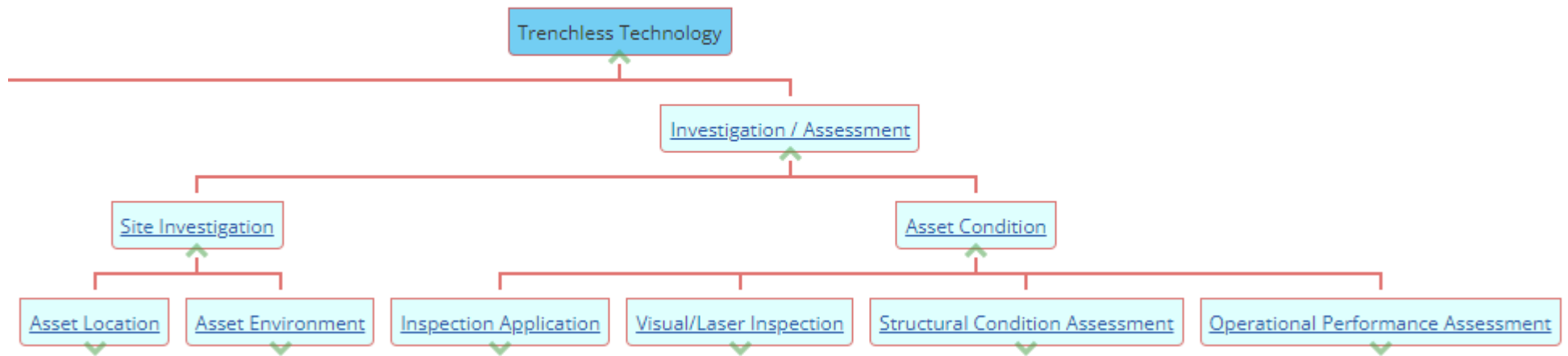
Horizontal Directional Drilling (HDD)

Pipe Jacking / Microtunnelling

Ramming / Impact

Hybrid Methods







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WHAT'S NEW

- Extended to 1st June - Call for Abstracts for No-Dig Mexico
- New dates (17-18 Oct) and the hotel for No-Dig Mexico
- Trenchless Works (magazine) - Free translation/Article submission form

TRENCHLESSWORKS 200th

Webinar — 2023-05-12

Hazard Resilient Infrastructure and Lessons from the Turkey-Syria Earthquake

Category: Analytical models for the soil-structure interaction



Presenter: Tom O'Rourke

Date: 12 May 2023

Organization: Cornell University

Time: 10:00 am EST US (16:00 CEST) Duration: 1 hour

Non-Members can join our webinars (no fee required) but recorded videos and Presentation files are for ISTT members only (after member login). No certificates...

The International Society for Trenchless Technology



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NASTT 2023 No-Dig Show

Start Date: **Apr 30, 2023**
End Date: **May 4, 2023**

Type: **Conference,Exhibition**

Geographical Area: **North America and South America**
Country: **United States**



Venue: **Oregon Convention Center**
[Link to Map \(opens new tab\)](#)

Contact: NASTT office
info@nastt.org

Website: [\(opens new tab\)](#)

Hosted/Endorsed by: **NASTT**



4th TRENCHLESS LATIN AMERICAN CONFERENCE AND EXHIBITION

Start Date: **May 3, 2023**
End Date: **May 5, 2023**

Type: **Conference,Exhibition**

Geographical Area: **North America and South America**
Country: **Colombia**



Venue: **CARTAGENA DE INDIAS CONVENTION CENTER**
[Link to Map \(opens new tab\)](#)

Contact: ARLEX TORO
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Website: [\(opens new tab\)](#)

Hosted/Endorsed by: **LAMSTT**



Trenchless Asia

Start Date: **May 17, 2023**
End Date: **May 18, 2023**

Type: **Conference,Exhibition**

Geographical Area: **Asia**
Country: **Malaysia**



Venue: **The Kuala Lumpur Convention Centre**
[Link to Map \(opens new tab\)](#)

Contact: Paul Harwood
trenchless@westrade.co.uk

Website: [\(opens new tab\)](#)

Hosted/Endorsed by: **Westrade**



Next International No-Dig Conference and Exhibition



International No-Dig Mexico 2023
Expo Santa Fe Mexico

Start Date: Oct 17, 2023

End Date: Oct 18, 2023



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Website: [\(opens new tab\)](#)

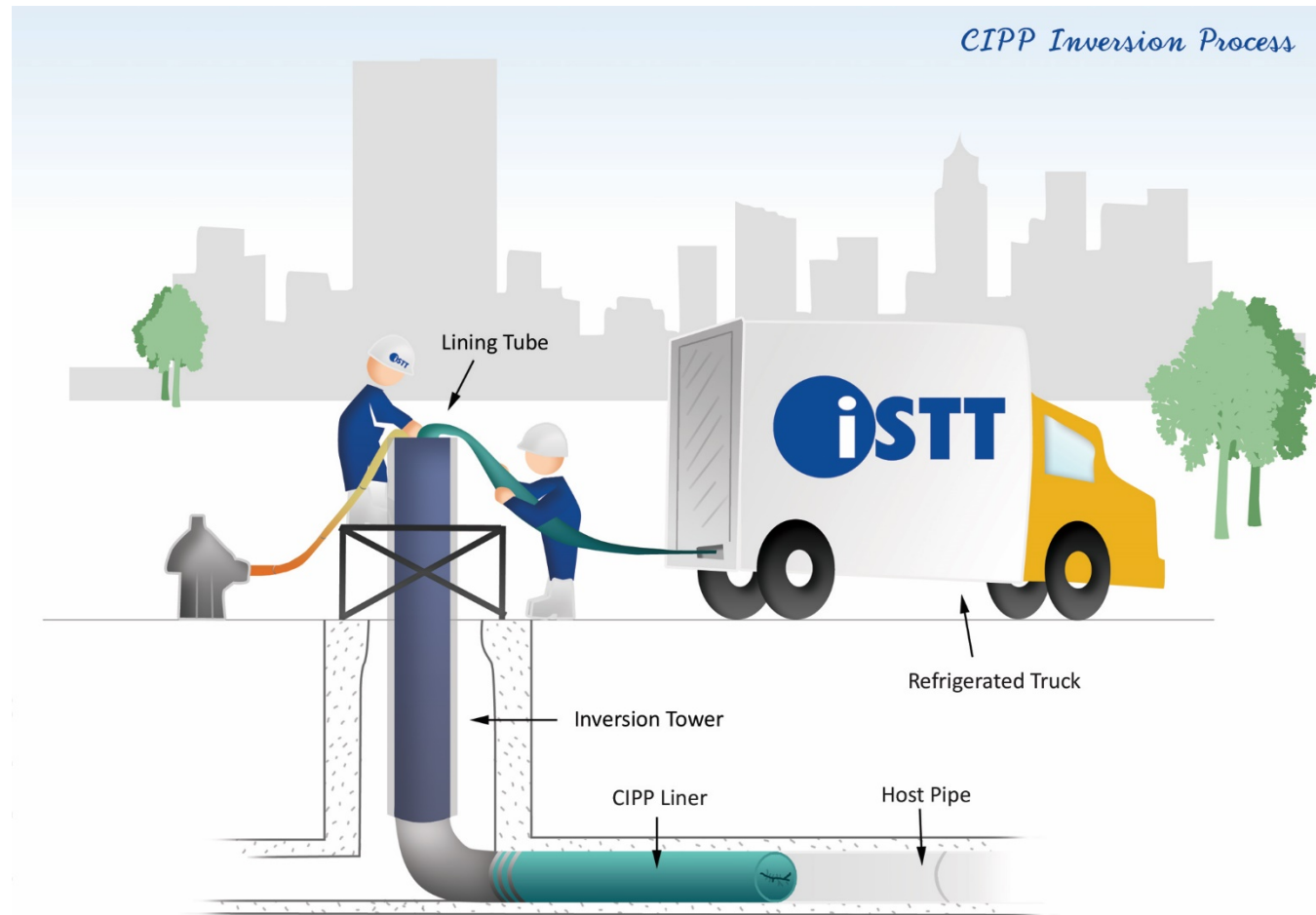
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pharwood@westrade.co.uk



II. The Trenchless Rehabilitation Method ---CIPP

- 1. What is CIPP**
- 2. The applications of CIPP**
- 3. The design analysis of CIPP**
- 4. Further development and consideration**

1. What is Cured In Place Pipe (CIPP)

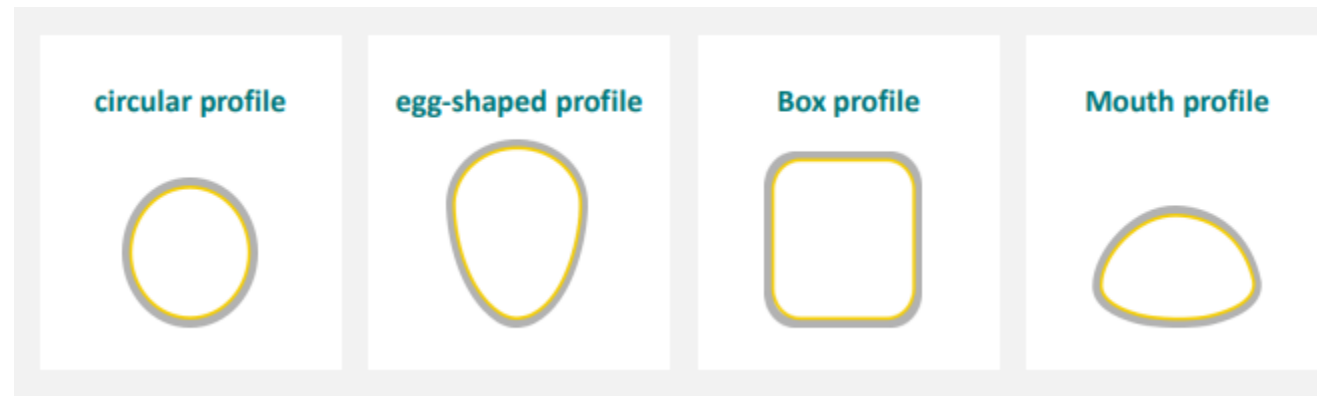


<https://www.bing.com/videos/search?q=CIPP+youtube&&view=detail&mid=A886325371BD0F22C2E3A886325371BD0F22C2E3&&FORM=VRDGAR&ru=%2Fvideos%2Fsearch%3Fq%3DCIPP%2520youtube%26%26FORM%3DQVXX>



ISTT Educational Webinar 2022

- Cured in Place pipe (CIPP) can be used to rehabilitate sanitary sewers, storm drains and pressure pipelines for water, gas and process effluents.
- **Circular** pipe from 100-2,700mm and a variety of **noncircular** pipe such as egg shapes, ovoids, and box culverts can be lined.



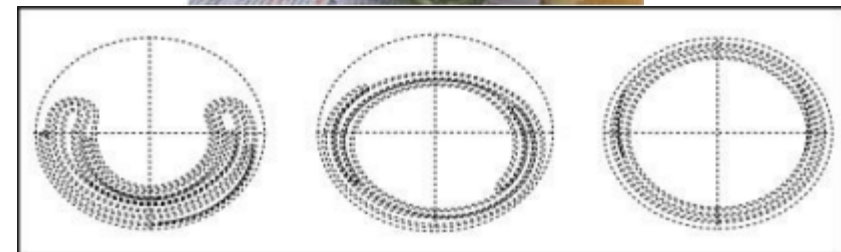
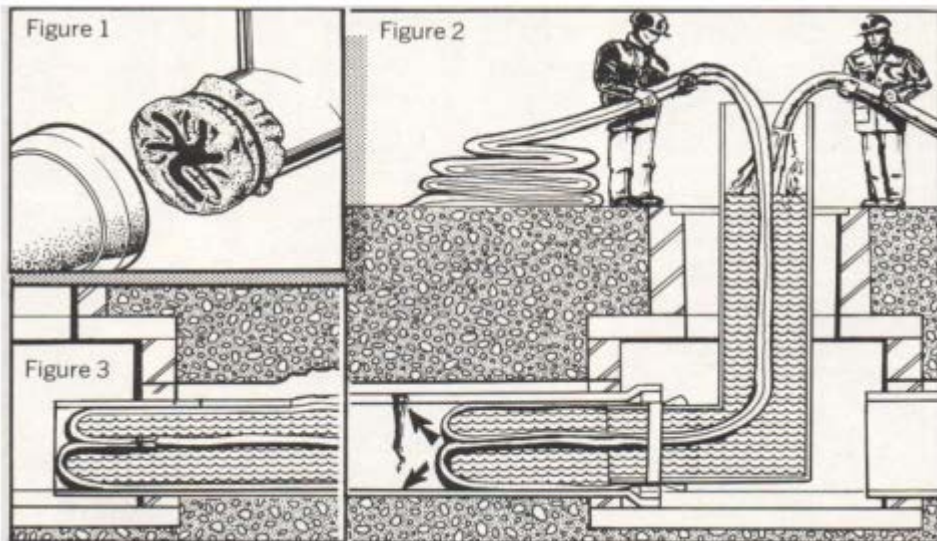
- Lining with CIPP **removes the pipe from service** for the duration of the installation and reinstatement process so overpumping or provision of an alternate source of supply may be necessary.
- Prior to lining, the pipe must be cleaned by jetting to remove corrosion debris and detritus.
- Protruding **lateral connections** also must be removed.
- **Local repairs** may be required where the existing pipe is substantially deformed or damaged.
- Lined water mains must be disinfected before returning to service.

- CIPP liners of **non-woven polyester felt** or **fibre reinforced fabric** are manufactured to fit the host pipe.
- The liners are impregnated with a polymer resin, which when **cured (by heat or light)** will form a close fitting liner pipe within the host pipe.
- The liner may be **designed with sufficient thickness** when cured to sustain the loads imposed by external groundwater and internal service pressure, and soil and traffic over the pipe.



- The liner is **thoroughly saturated with polyester, vinyl ester epoxy or silicate resin** using vacuum, gravity or other applied pressure. **The resin includes a chemical catalyst or hardener to facilitate curing.**
- The **outermost layer** of the liner tube is coated with a polymer film to protect the liner during handling and installation. The impregnated liner may be chilled for transportation to maintain stability until installed.

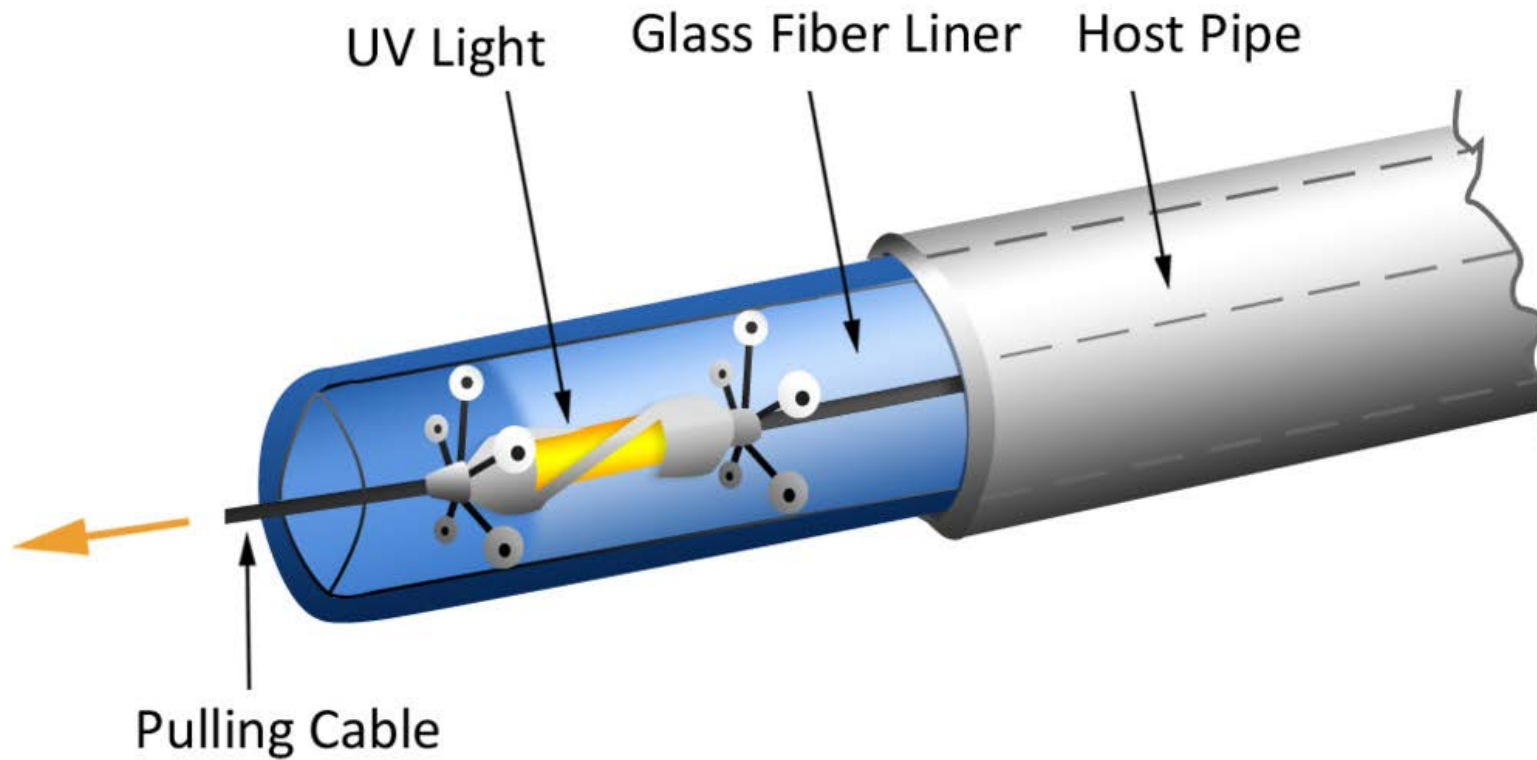
- CIPP liners may be installed using the **inversion** method as shown above. The inversion method employs a scaffold tower or pressure vessel to apply air or water pressure to turn the liner inside out and push it along the host pipe.
- CIPP liners also may be installed by winching into place through a manhole or specially prepared access point and **inflated** to come into close contact with the circumference of the existing pipe. The liner is restrained in any intermediate manhole.
- CIPP liners may be inflated or inverted with air or water pressure.



- Lengths installed may vary from short sections over a joint or defect, to full length linings **typically 30-150m**. Lengths of **up to 900m** have been installed in a single shot.
- The resin impregnated liner may cure at ambient temperature but the cure is more usually accelerated by application of **heat** by circulation of inversion water through a boiler, blending steam with inflation air or by pulling through a **UV light** train.
- A **sample of the CIPP** may be taken from pipe ends or from a mould cured under the conditions of manufacture **for testing and verification** that the liner met performance specifications.



UV Cured Liner



2. Applications of CIPP

- Deformation
- Corrosion
- Crack
- Breakage
- Joint Separation
- The Consequences of Void, Soil Penetration, Water Inflow, etc.

Deformation - flexible pipe



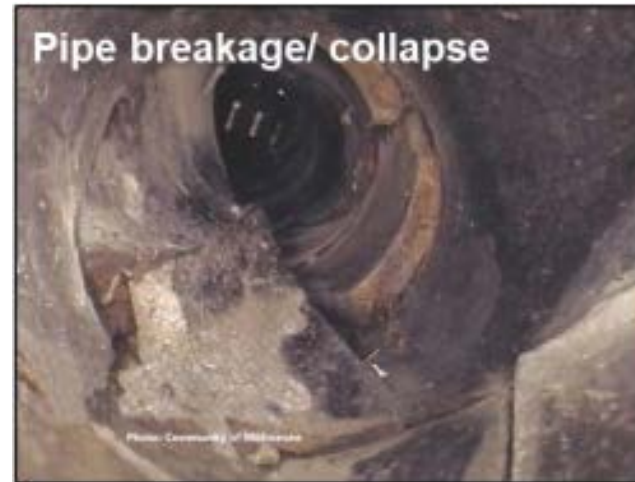
Deformation – rigid pipe



Crack formation

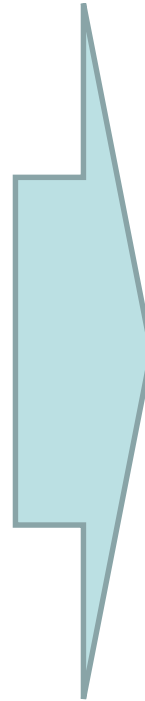


Pipe breakage/ collapse



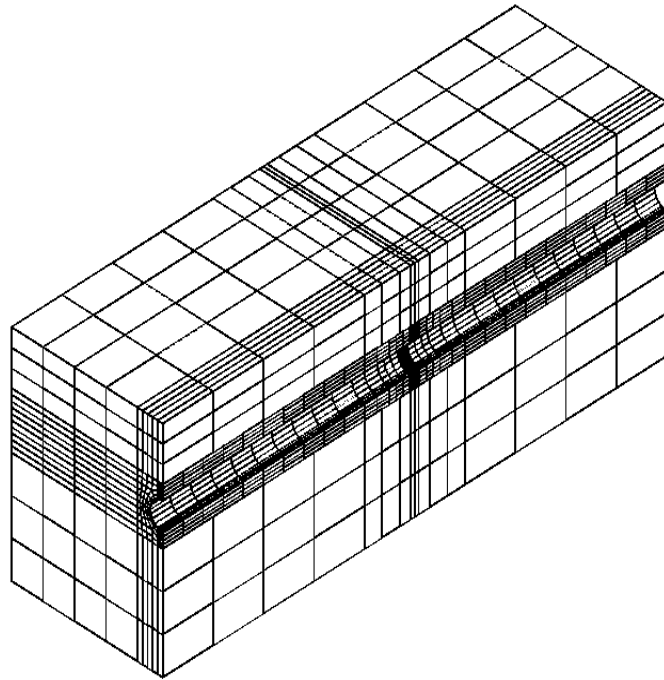




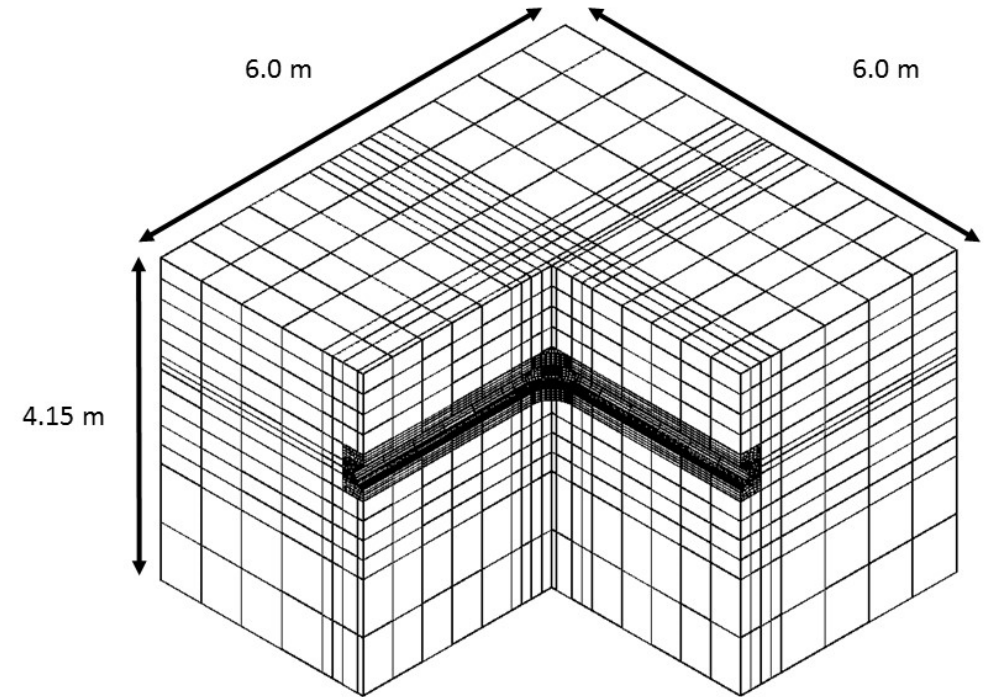
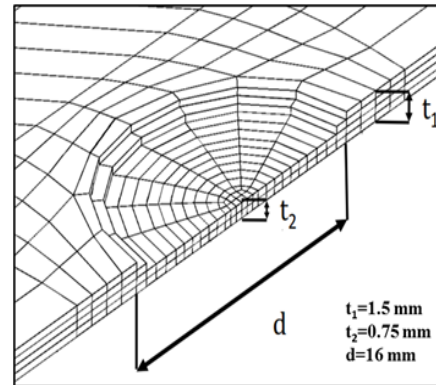


3. Design Analysis

- Numerical analysis such as FEA can be used to simulate different geometries of underground pipelines, i.e. straight line and curved pipeline, damaged by corrosion and the performance of the Cured-In-Place-Pipe (CIPP).
- The analysis results can be used to confirm that CIPP can reinforce the damaged pipe by reducing the stress concentration and reducing the differential displacement.
- The design of the CIPP liner could be further optimized in terms of its design, i.e., thickness and material properties.



Straight-line case



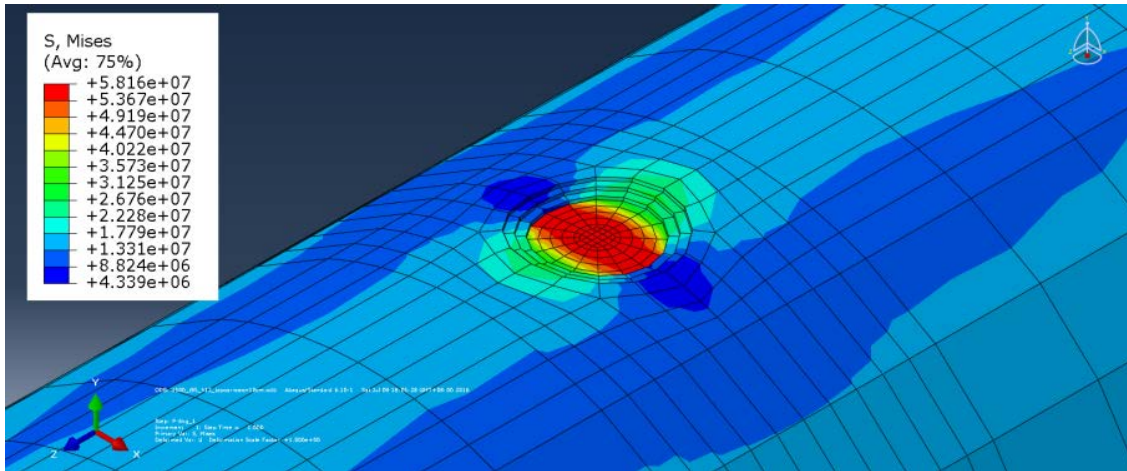
Curved case

Parameter	Sandy soil	Gravelly soil	Aluminum Pipe	Carbon Steel Pipe	Rehab. Liner
γ_t (kN/m ³)	16.7	21.6	26.9	77.0	18.5
ϕ (°)	38.3	40	---	---	---
ψ (°)	8.3	10	---	---	---
c (MPa)	0.0137	0.015	---	---	---
K_o	1	0.398	---	---	---
ν	0.3	0.3	0.330	0.286	0.385
E (MPa)	1.90	300	68000	205700	13000

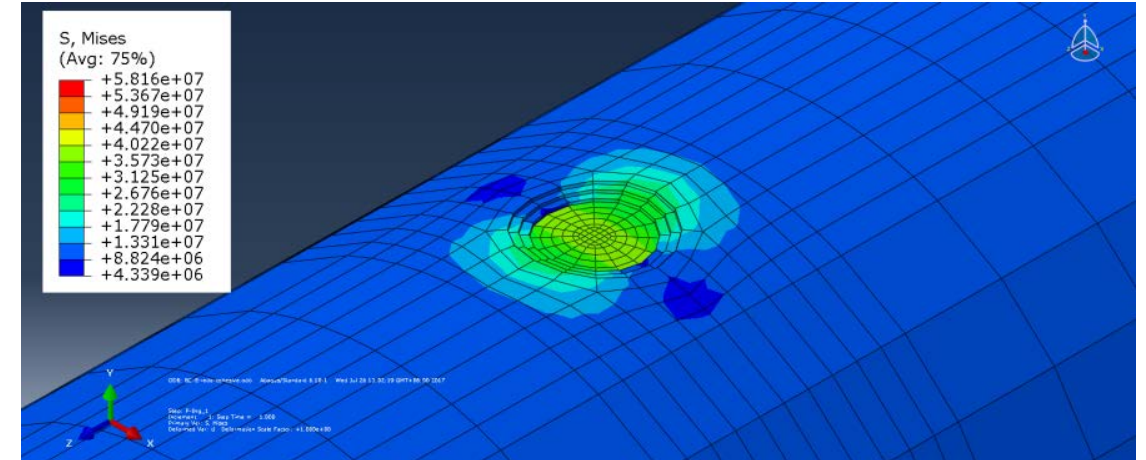
The soil parameters were based on rational assumptions from the aforementioned studies. The properties of the rehabilitation liner were from Ashimori Industry Co (2016).

- Typical pipe diameters were chosen based on Chinese National Standard (CNS) 4626 G3111 of Taiwan (2012), that defines the specifications of carbon steel pipes for operation under pressure.
- The size of the modeled soil mass differed according to the size of the pipes. The distances from the left and right boundaries of the soil mass to the center of the pipe were about six times the diameter of the pipe. The distances from the bottom boundary of the soil mass to the center of the pipe were about five times the diameter of the pipe. Both the soil and the pipe were 10m in length.
- Detailed dimensions of the models are listed in Table 2.

Case	Shape of pipe	Area of Damage (mm ²)	Location of Damage
1	Straight-line	2826	Top
	Curved	15133	Inner and outer side
2	Straight-line	7850	Top
	Curved	55296	Inner and outer side
	Curved-small	18432	Inner side

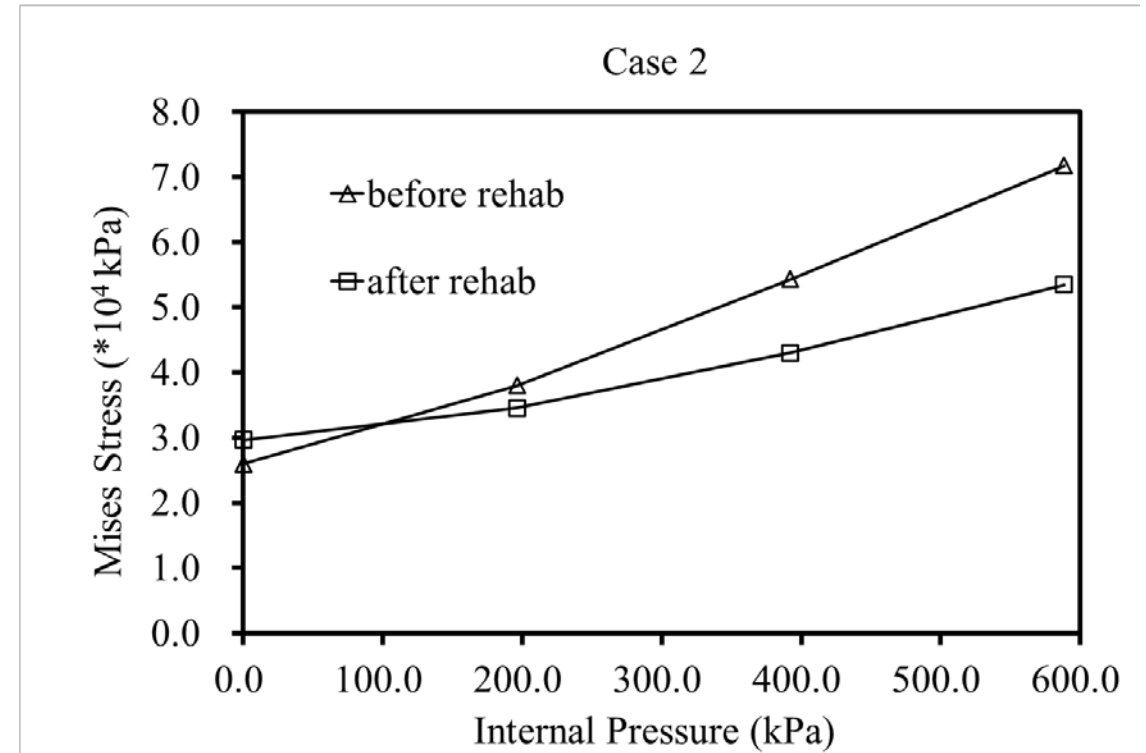
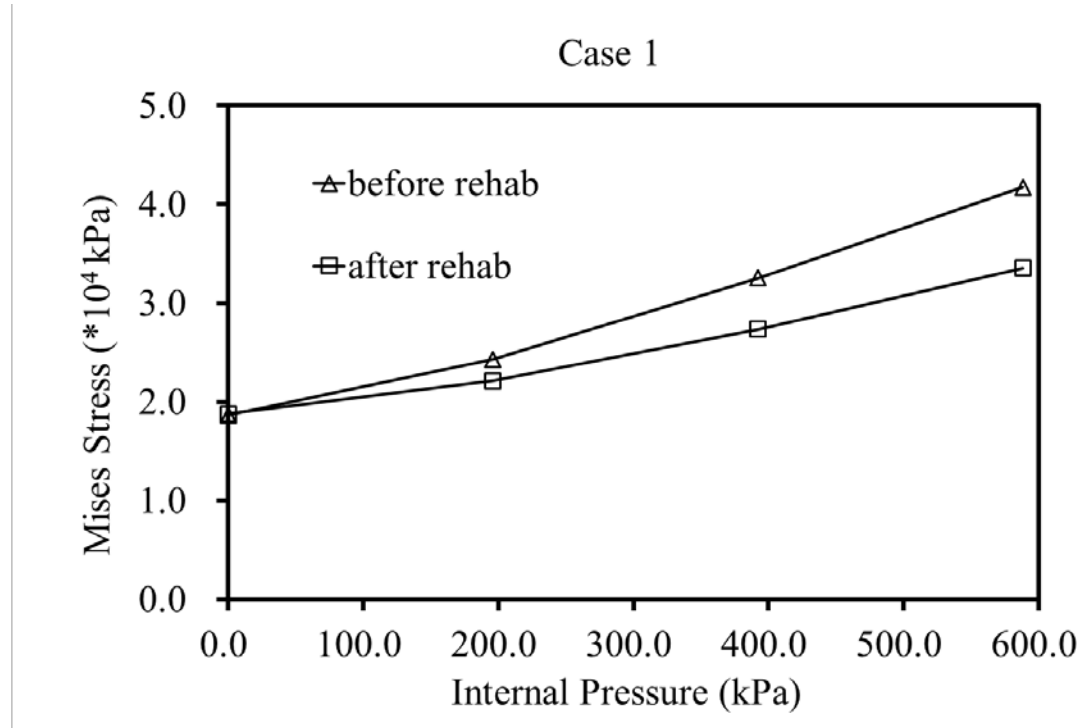


Before liner installation

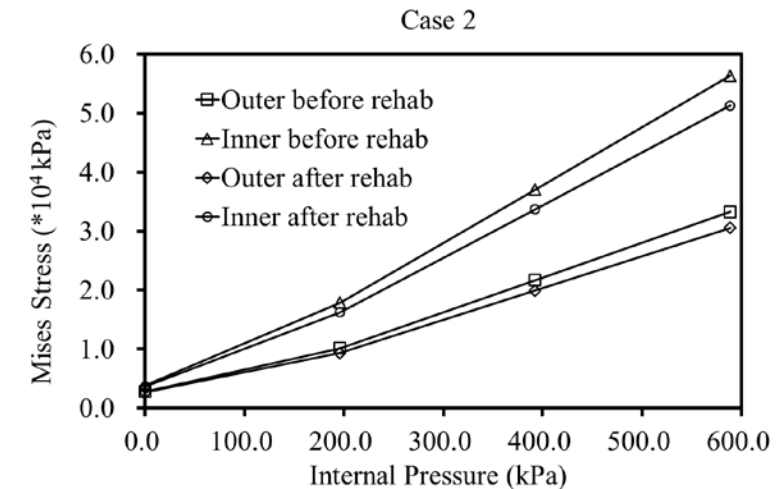
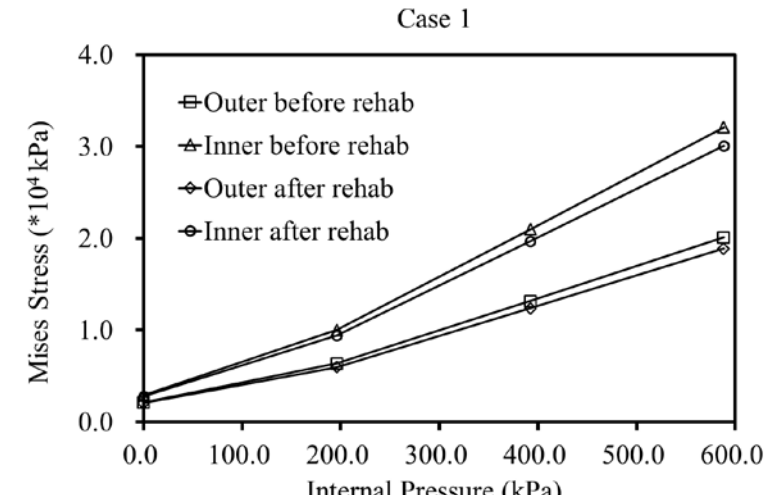
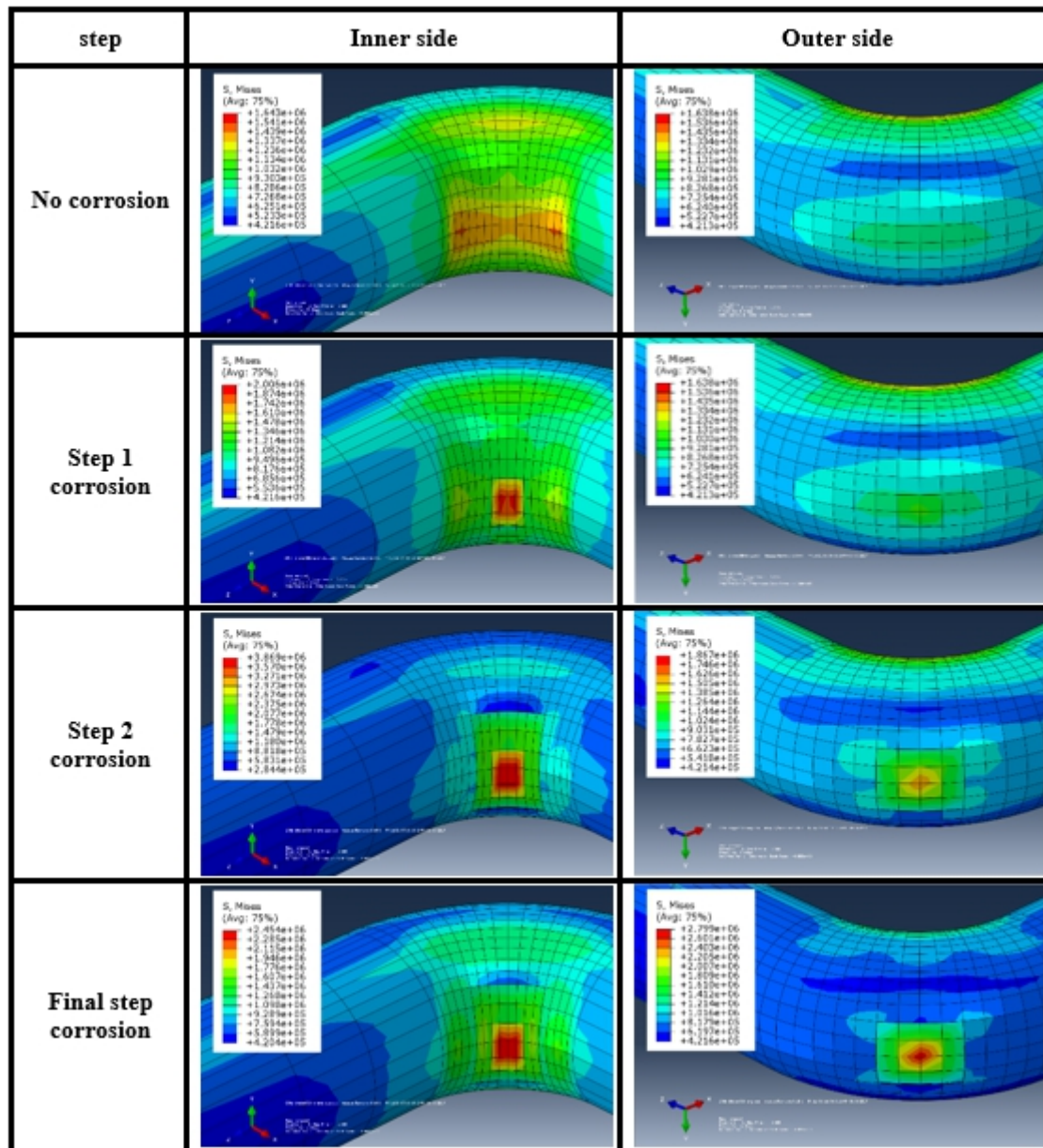


After liner installation

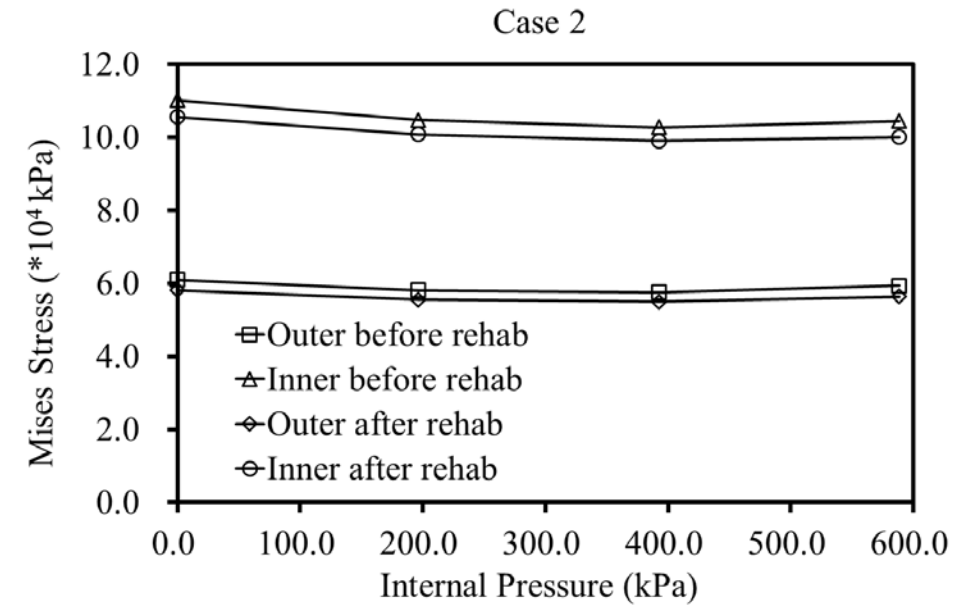
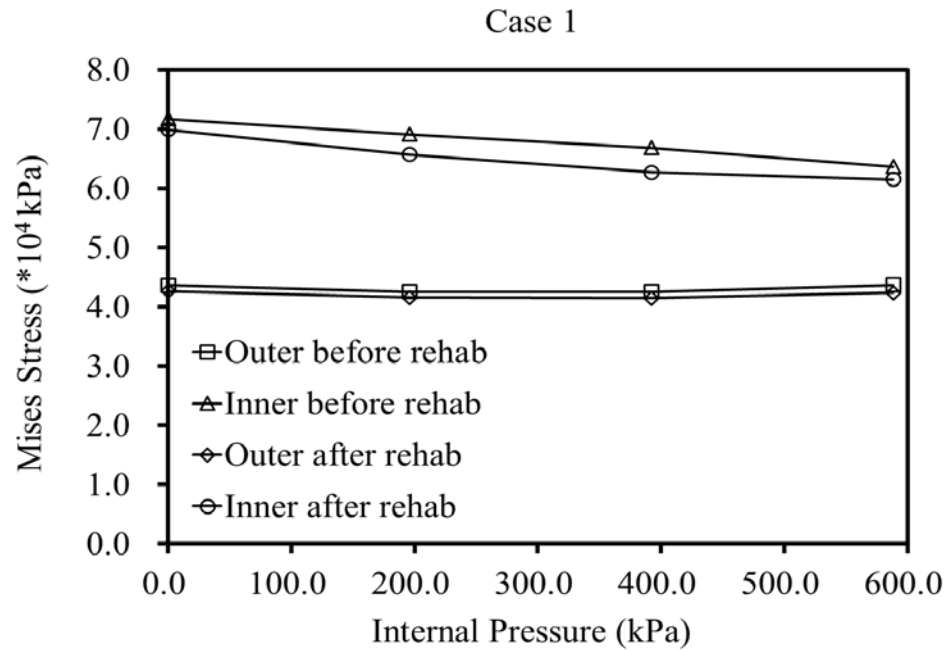
The stress fields before and after the installation of liner for the straight-line case with internal pressure 588.4 kPa.



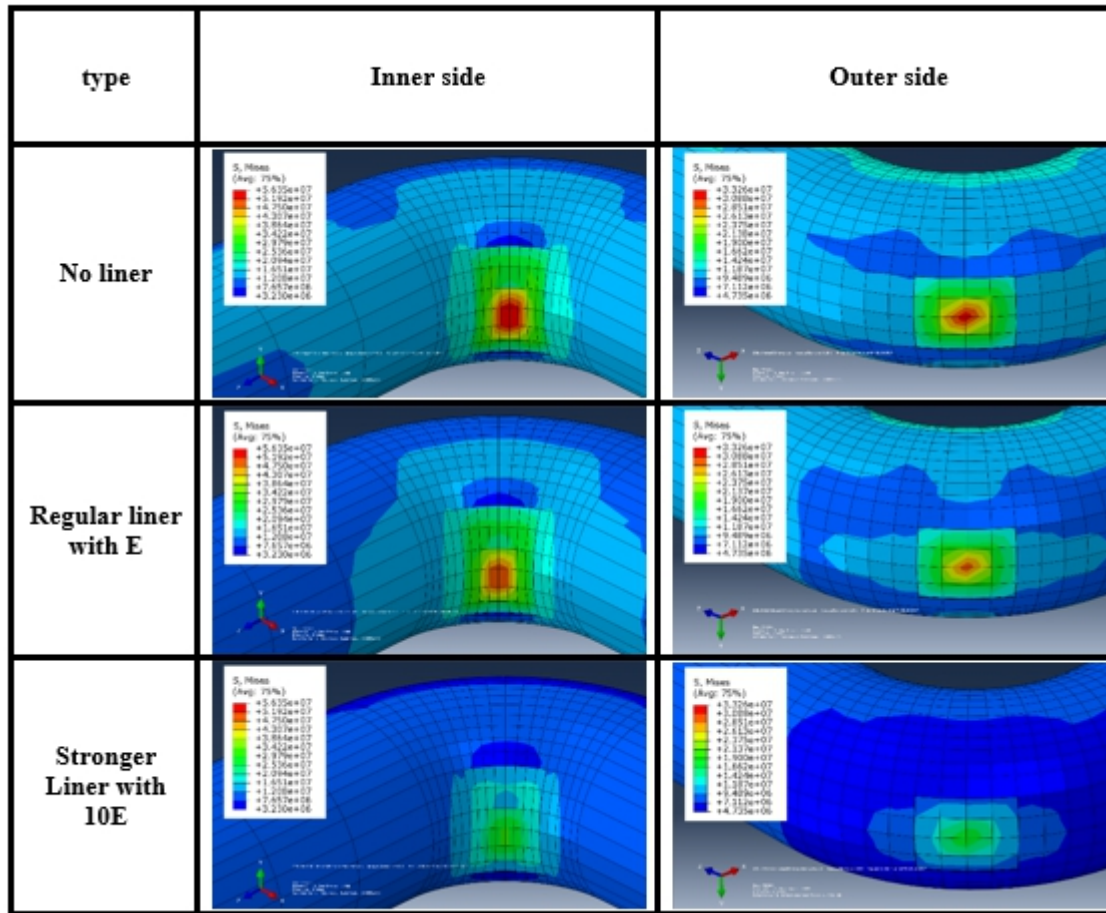
The stress and displacement at the void center before and after the installation of liner for the straight-line case with surface loading



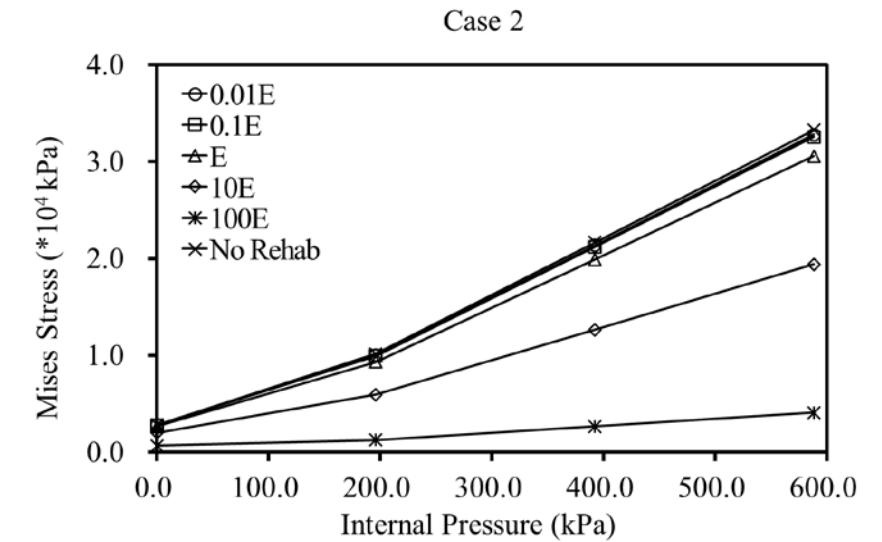
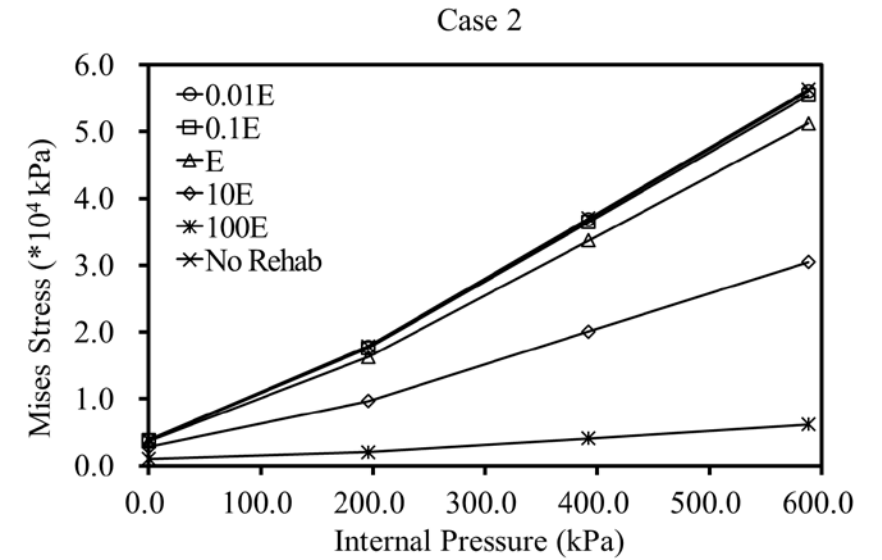
The stress fields and the stress at the void center before and after the installation of liner for the curved case without internal pressure

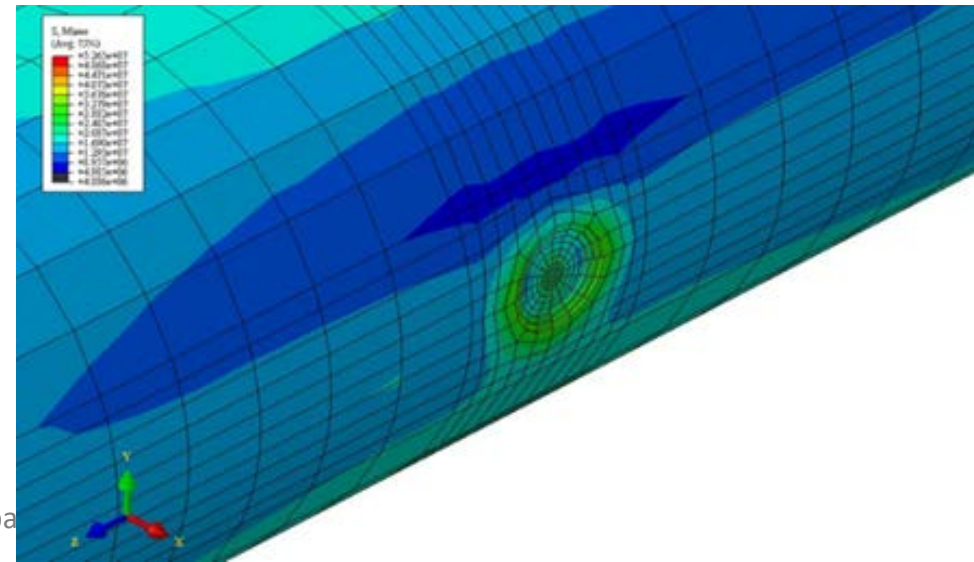
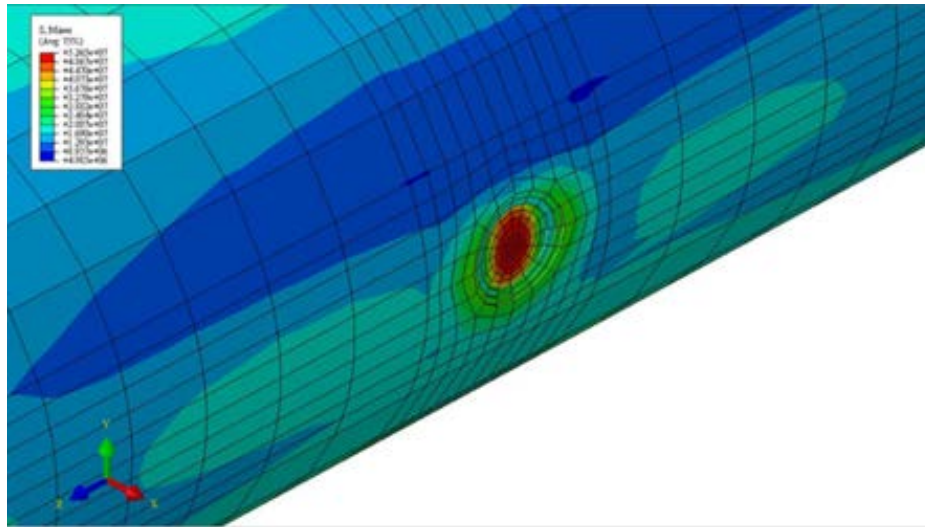
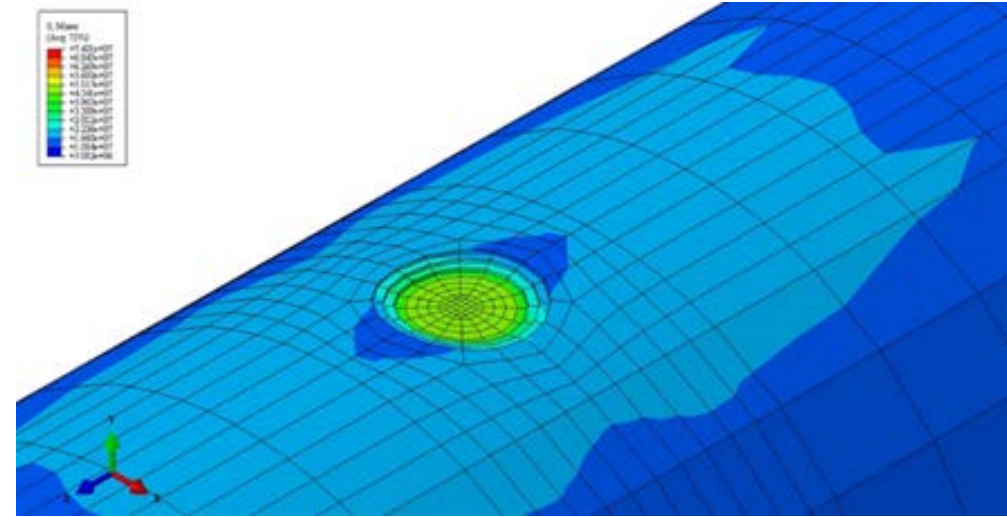
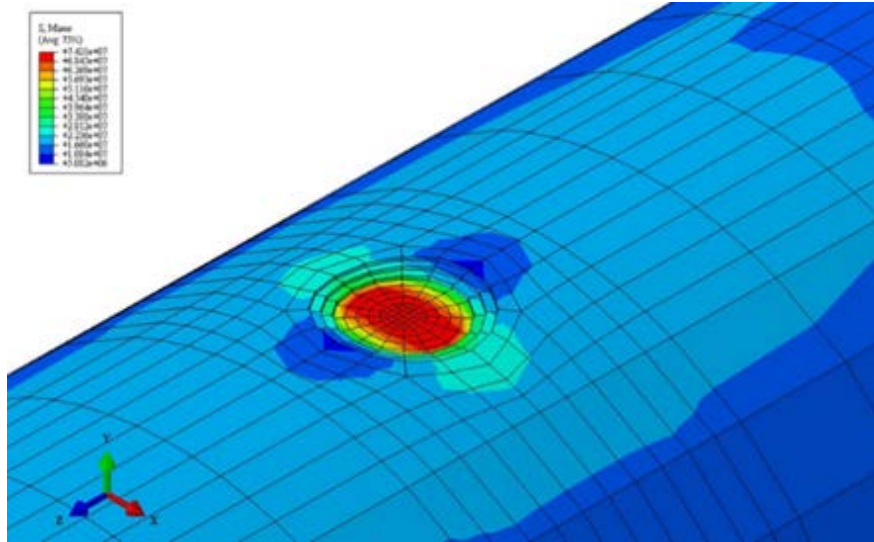


The stress at the void center before and after the installation of liner for the curved case with surface loading.

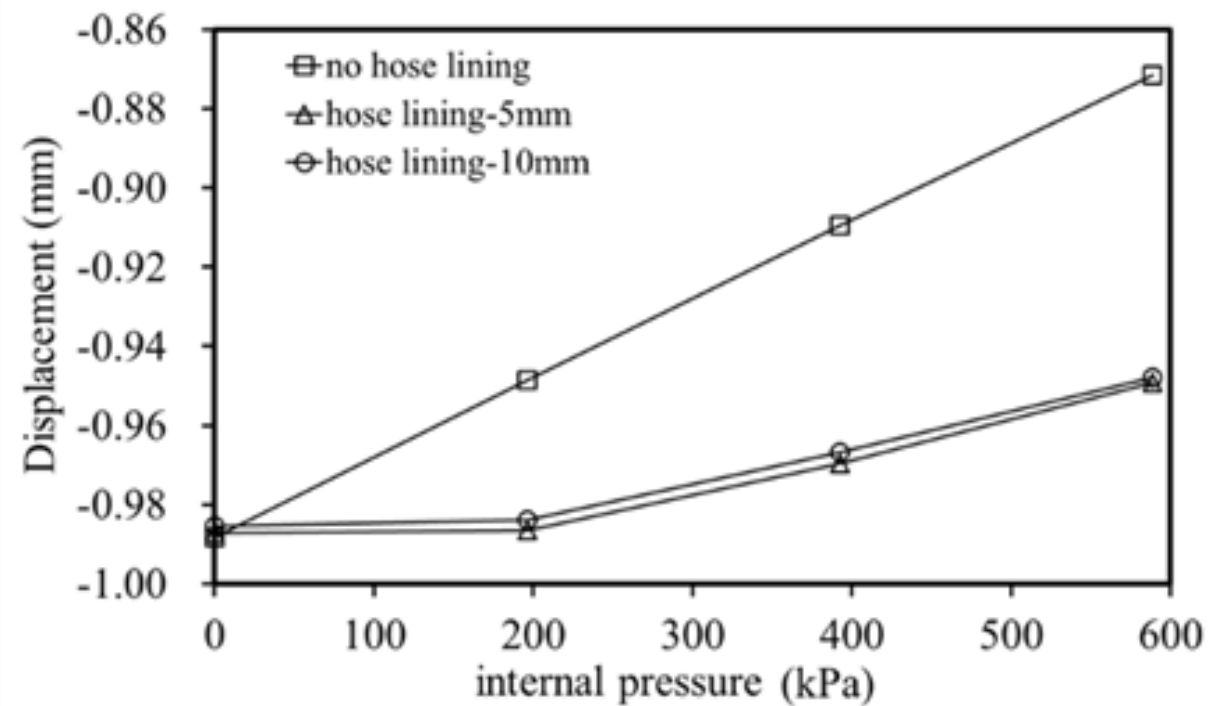
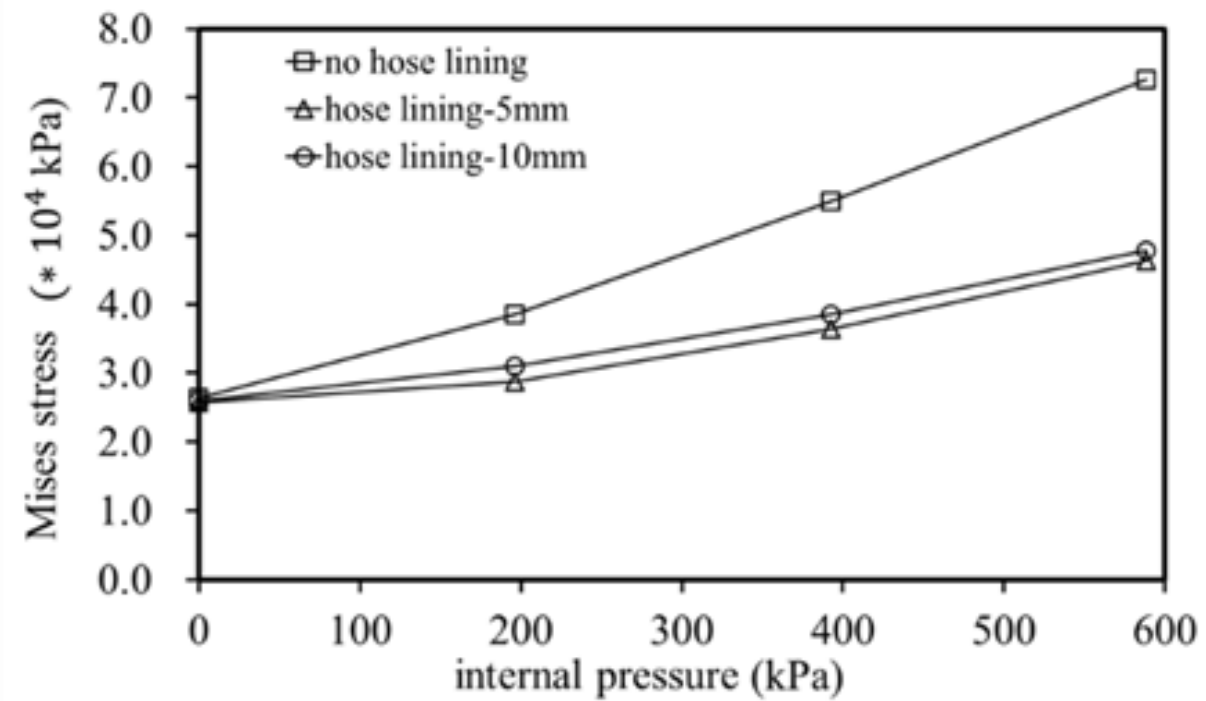


The stress fields and the stress at the void center before and after the installation of liner for the curved case with different liner deformation property





or pa



Summary

- From the parametric study for the corrosion damaged buried pipe, it shows that the thickness of the pipe wall is the most critical factor.
- A larger diameter to thickness ratio (D/t), i.e., a small pipe wall thickness, resulted in a greater increase of stress and displacement at the corrosion void. And the increase in stress and displacement was positively correlated to the size of the void.
- The results also suggest that the liner could be designed to economically optimize its thickness. In addition, more comprehensive analysis are necessary for the typical problems about the CIPP construction quality, such as the imperfect adhesion of the liner to the old pipe, etc.

- The influence of pipe wall thickness on the stress concentration at the void is similar for the straight-line case and the curved case. For the curved pipe, the stress at the center of the void increases as the internal air pressure increases, for both the case with a void at the inner side and the case with a void at the outer side. However, the case with a void at the inner side is more critical than the other case.
- The performance of the rehabilitation is strongly affected by the deformability of the liner. The higher the Young's modulus of liner is, the lower stress concentration at the center of the void will be. In addition, for the case of curved pipe, a relatively higher liner Young's modulus will be necessary to assure the rehabilitation performance.
- **Properly Installation of the CIPP liner in the corroded pipe can significantly reduce the stress concentration near the void area,** which can reduce the risk of pipe bursting and extend the service life of the pipe.

4. Further Development and Considerations

- Applications of CIPP for more **complicated scenarios**
- **Detailed considerations** of the conditions, such as wrinkles, backfill, etc.
- The influence of the **interface properties** and material property contrast.
- Laboratory testing and numerical analysis can be applied to perform the design analysis of the above conditions and influence factor
- The design can be optimized based on the above design analysis

Laboratory testing_CIPP for Connector

The preparation of test specimens



RCPs layout and liner curing.

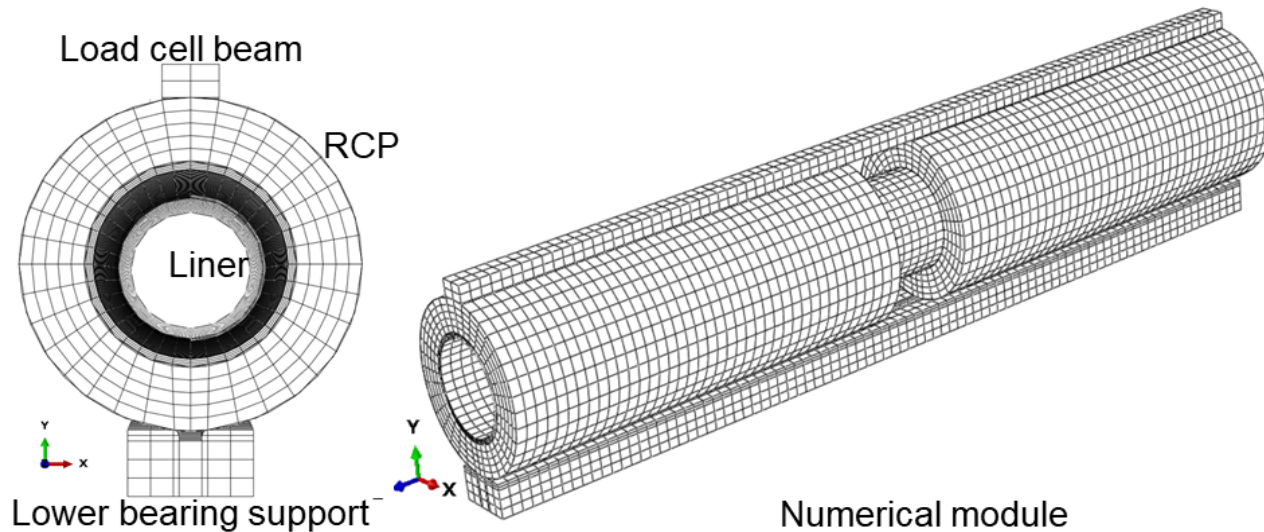


Cutting, transporting, testing of specimens.

- The test specimens consisted of two 800-mm-long RCP pipes, arranged with 20mm separation distance, and then the liners were inserted by inversion. After the liner cured using hot water, the specimens were cut accordingly.
- The CIPP liners were made of EP resin provided by Yutaifeng Company, Taiwan. The flexural and tensile strength of liner after curing meets the test requirements of ASTM D790 and ASTM D638.
- The thickness of liner is calculated according to ASTM F1216 specifications, and is 7.5mm after calculation.

Numerical model_CIPP for connector

3.1 Mesh information and Boundary conditions.

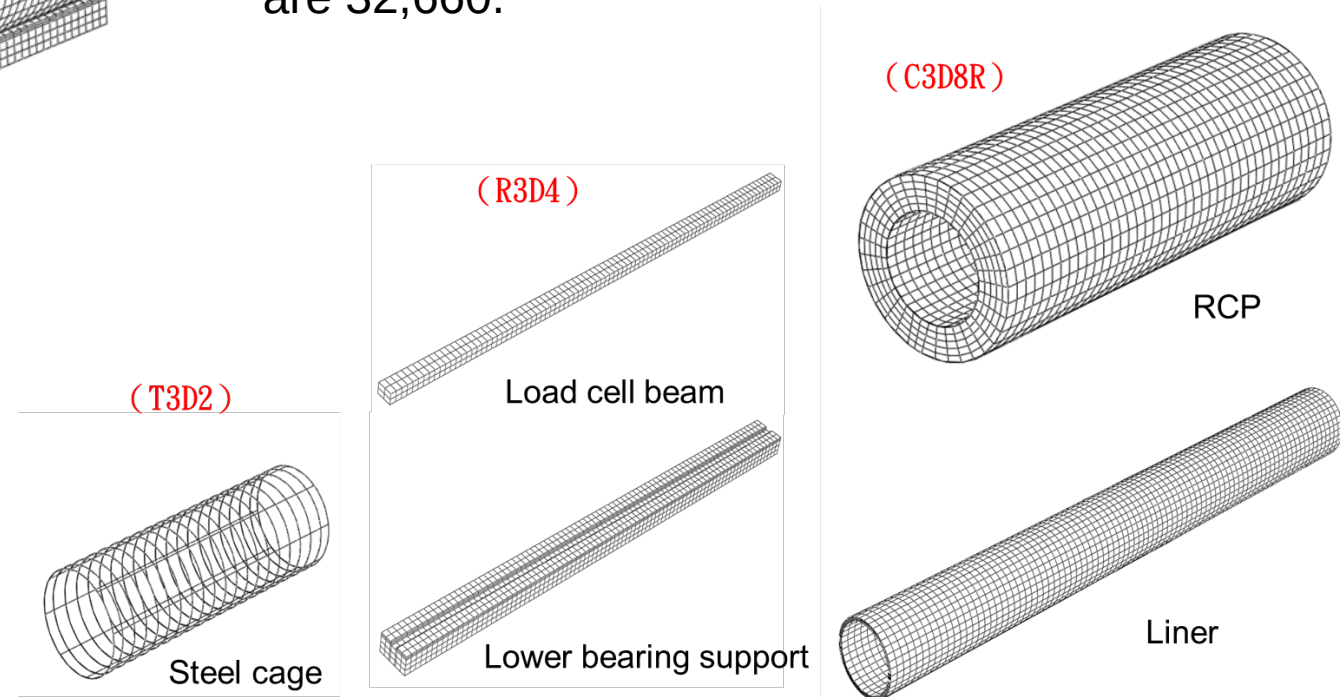


Boundary conditions :

- Bottom bearing supports were restrained in y direction, and the load cell beam was restricted in all directions except the y-axis.

Mesh information :

- Three types of elements used in the numerical model: C3D8R for concrete and liner, R3D4 for load cell beam and lower bearing support, and T3D2 for steel cage. Total number of elements are 32,660.



Thank You For Your Attention !!

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