Using Epoxy Adhesives in place of Hot Metal Welding

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Repair • Protect • Improve

What's the Problem?

Pipework, pipelines, tanks and other metal structures

Thin-wall and pitting

Through-wall defects

Large assets

Localised damage

Pipe support erosion/corrosion

The Challenges

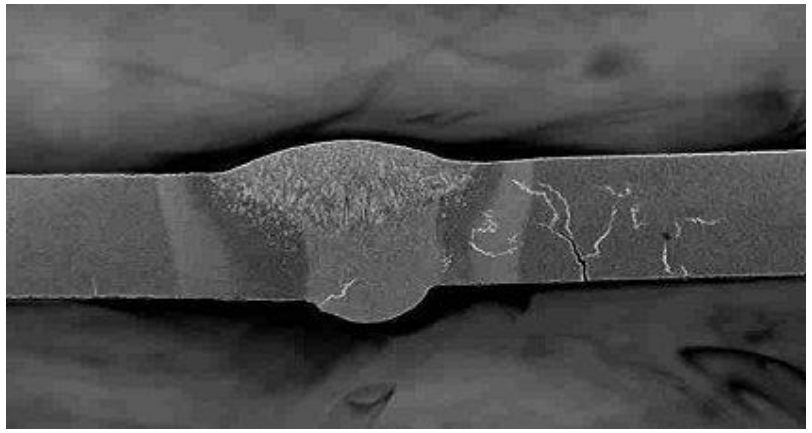
Issues – Existing assets

Three main factors cause deterioration on structures

- Environmental - Corrosion
- Process – Acidic/alkali
- External – Abrasion, impact and erosion

- Wear and through-wall defects take place

- Stress concentration nodes
  - A combination of these factors are often found working together e.g. stress corrosion cracking



The Challenges

Issues – New build

Traditional joining methods during fabrication are not always achievable

- Changing the substrate microstructure as a result of hot work
- Creation of cavities behind welded patches or brackets

Welding: Hot Works

Advantages

- Can restore metalwork to almost original condition
- Alloys can be added for additional strength
- Can be tested/inspected after
- A proven solution

Disadvantages

- Dissimilar metals can be difficult to weld
- Distortion & Stress due to heat introduction
- Safety risks associated with the heat
- Heat Affected Zone
- Internal linings can be affected by the heat
- **Requires Trained Personnel**

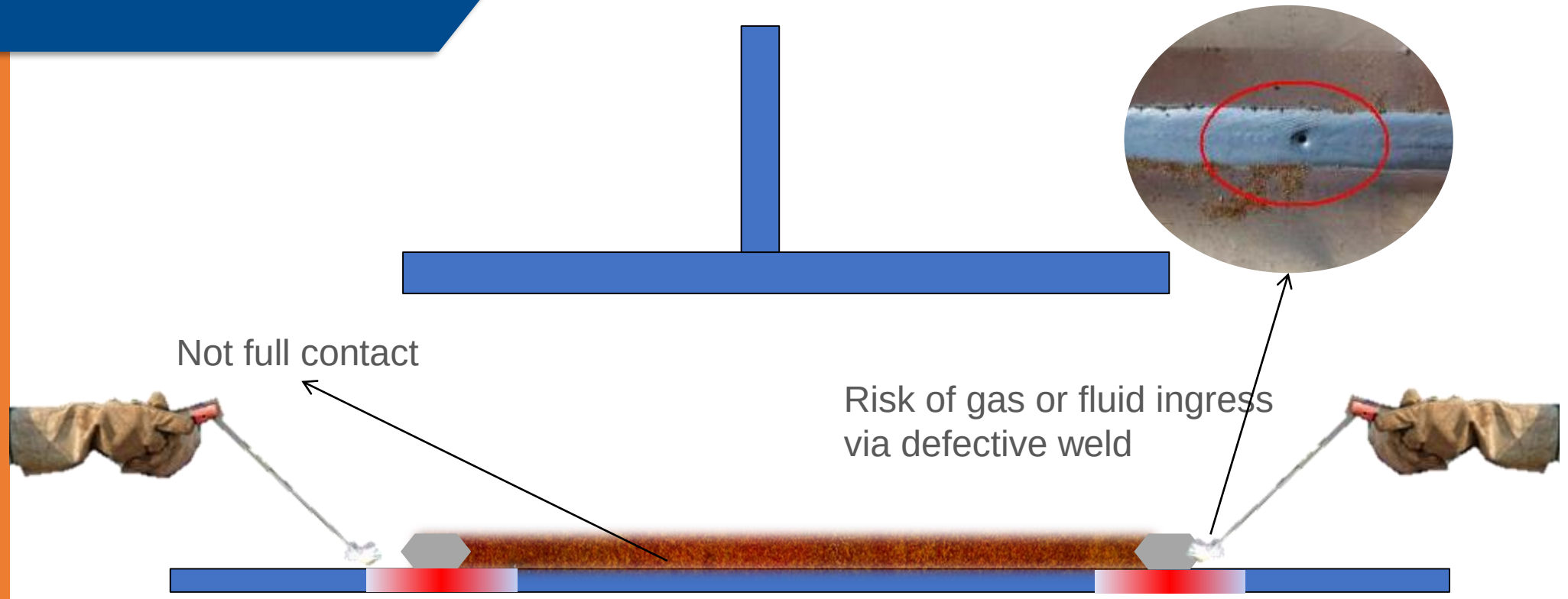
Welding

Hot Works

Additional Control Measures

HAZ

Corrosion



Example: welding deck, tank external, separator internal fittings

What is the Alternative?

Cold Bonding

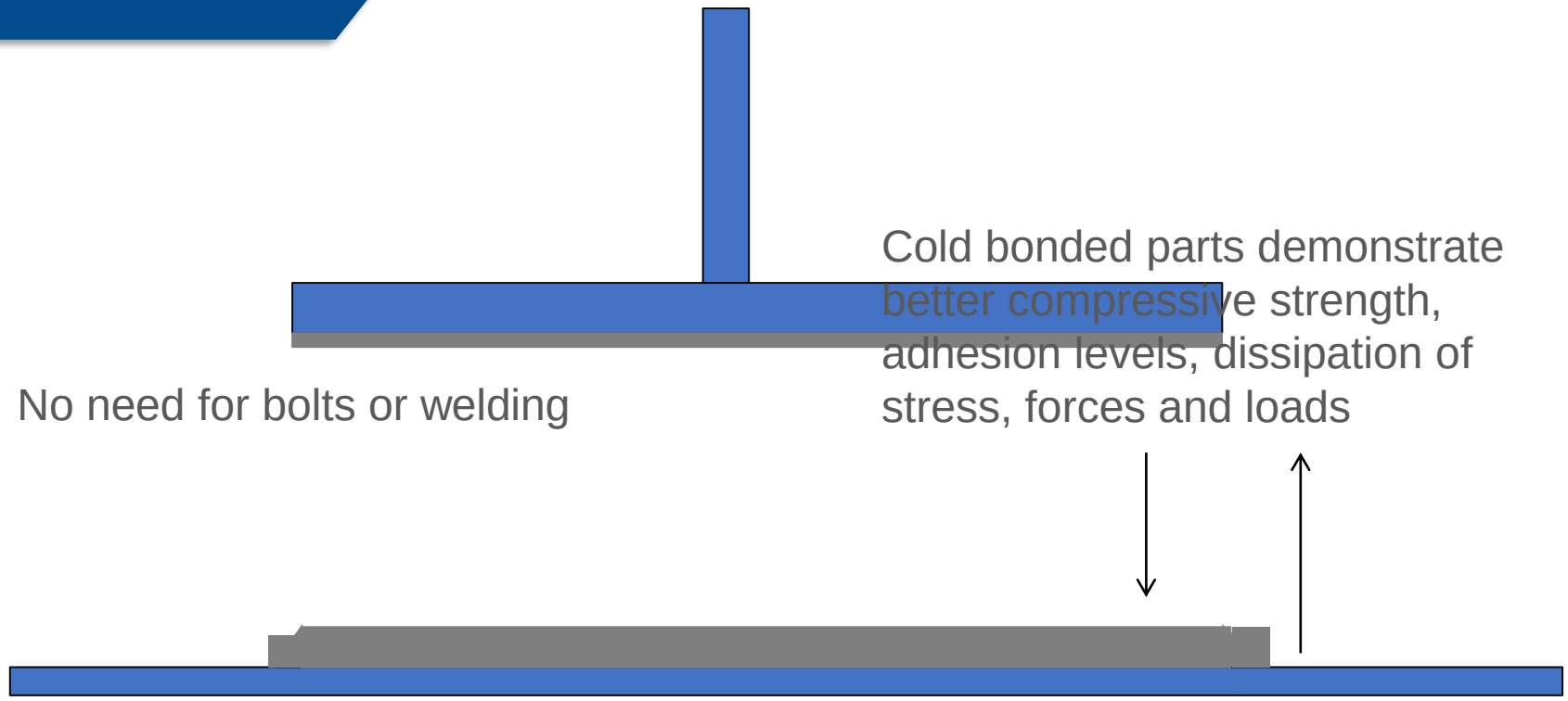
This method offers numerous advantages:

- No external heating
- Inert once cured
- Relatively high strength
- Will adhere to an extensive range of substrates
- Some varieties suitable up to 200^{0}C service temperature

Cold Bonding

- No Hot Works
- Easy to Apply
- No HAZ
- Corrosion Protection

Think of it as a “composite sandwich”



No need for bolts or welding

Cold bonded parts demonstrate better compressive strength, adhesion levels, dissipation of stress, forces and loads

Example: bonding deck, tank external, separator internal fittings

How do we test these materials and prove that they work?

Two methods, and two types of repair

Method 1: Hand Calculation

Unlike steel, the failure mode of these materials is notoriously difficult to predict. Failure happens on a small scale.

With that in mind, let’s take the example on the left. This is based on a similar, real life application – attaching a bracket onto the external wall of a tank.

The key to this is simplicity.

Inputs:

Steel Support (Cantilever)

- Profile: 40mm (L) x 40mm (W) x 4mm (T)
- Material: S235JR (Structural Steel)
- Yield: 235 N/mm^2
- Section Modulus: 1560 mm^3

Glue

- Type: 2-part Epoxy Bonding Agent
- Tensile Strength (20^0C): 23.02 N/mm^2

The support is 50mm in length, and a force of 4888N (equipment weight) is presumed to act on the end (worst case). This gives:

Reaction Force: 4888 N

Area: 1600 mm^2

Maximum moment: 244,400 N/mm^2

Reaction Force per Area: 3.055 N/mm^2

Safety Factor: 7.5

Method 2: Finite Element Analysis (FEA)

FEA can be used to predict stresses in certain applications involving epoxy materials.

After inputting all relevant data, we can build a simple design.

Testing

Finite Element Analysis

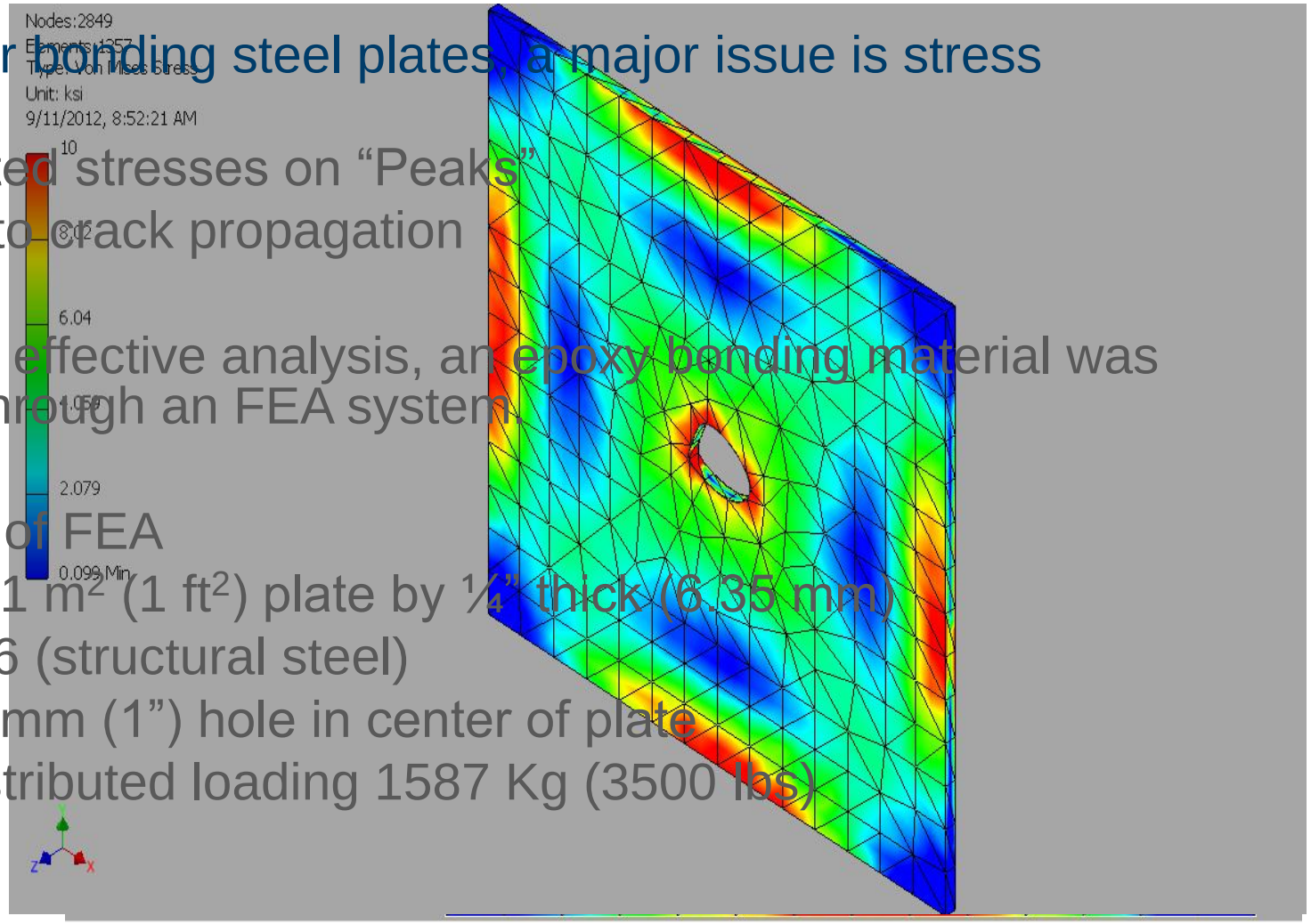
When welding or bonding steel plates, a major issue is stress concentrations.

- Exacerbated stresses on “Peaks”
- Can lead to crack propagation

To obtain an effective analysis, an epoxy bonding material was processed through an FEA system.

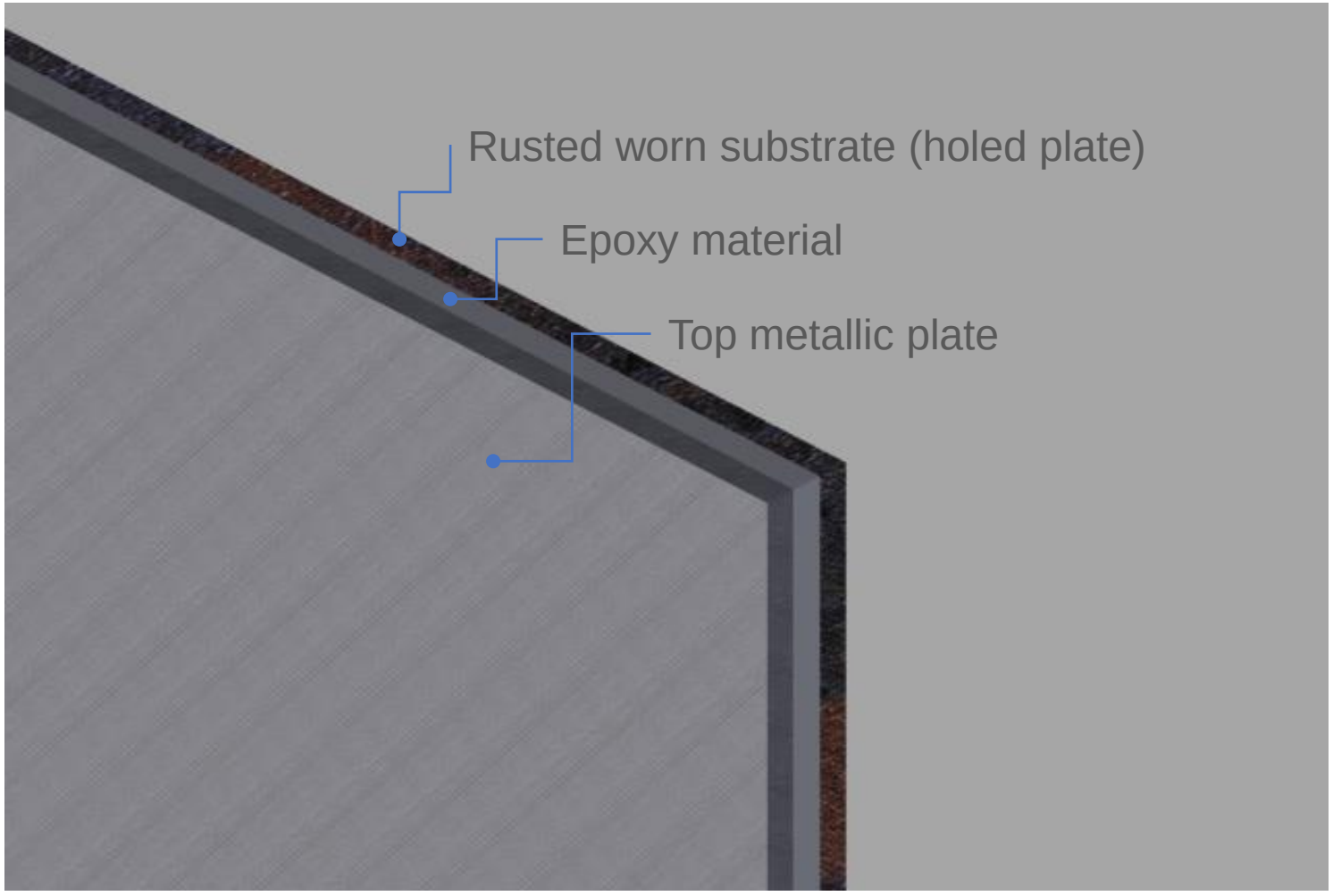
An example of FEA

- 0.01 m^2 (1 ft^2) plate by ¼” thick (6.35 mm)
- A36 (structural steel)
- 25 mm (1”) hole in center of plate
- Distributed loading 1587 Kg (3500 lbs)



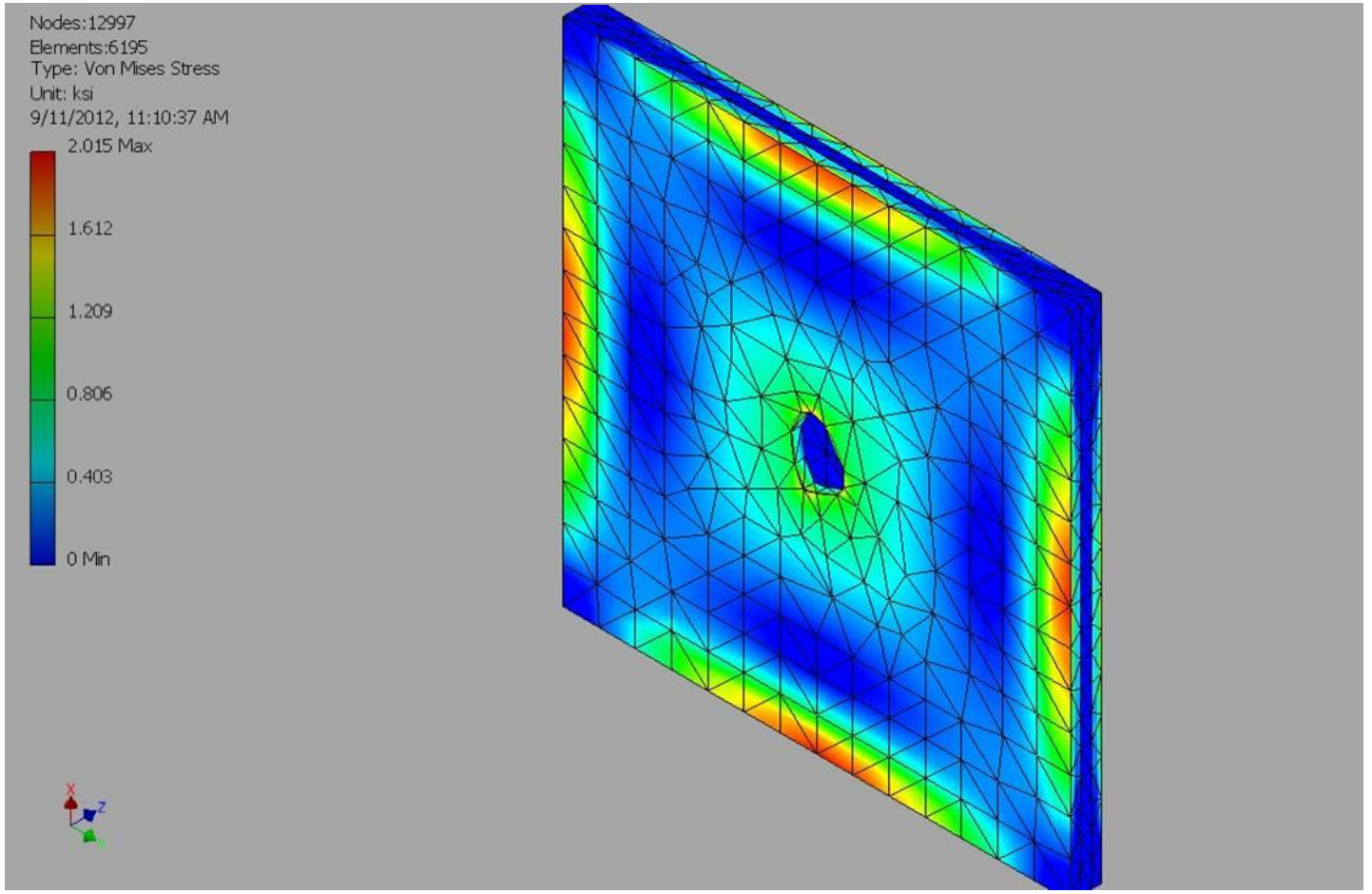
Testing

Finite Element Analysis



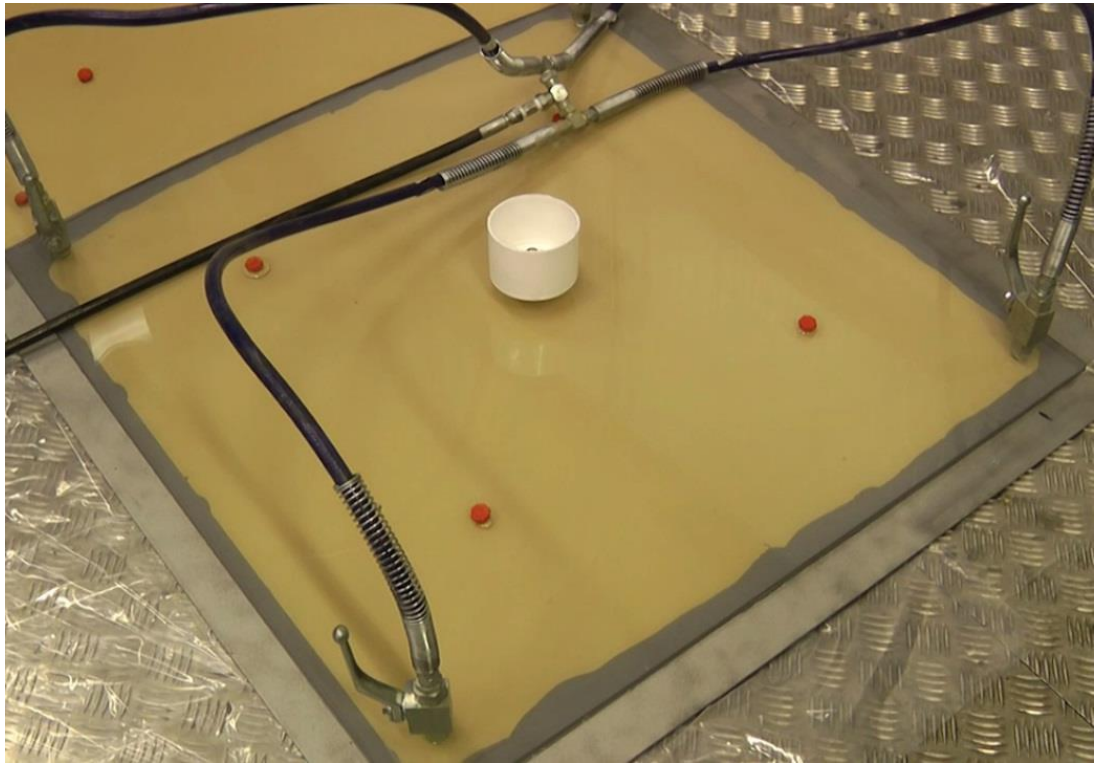
Testing

Finite Element Analysis



Application Techniques

Hand/Tools



Injection

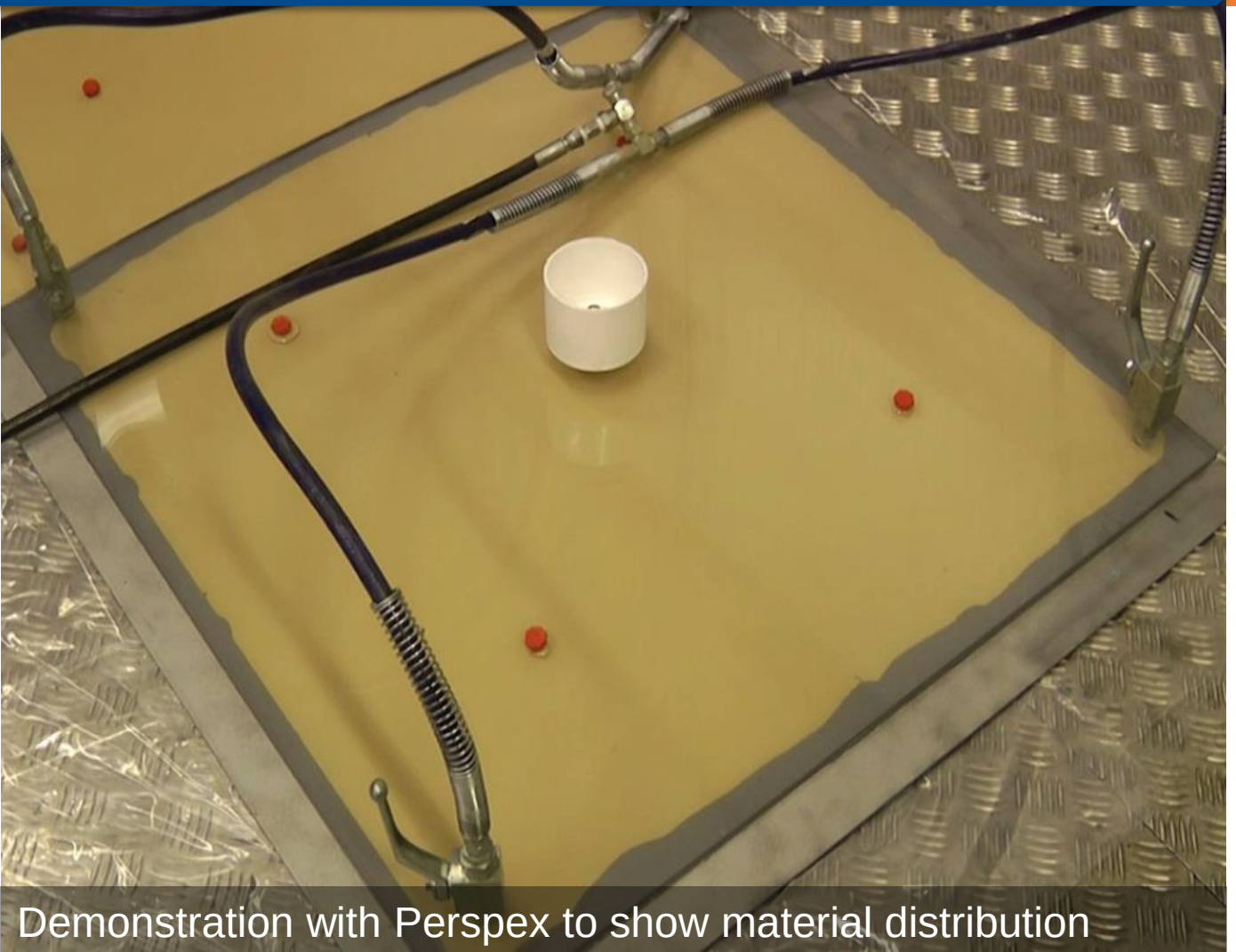
Case Study: Deck Bonding

Laydown area was badly corroded and weakened through daily operation

- North Sea
- Aberdeen
- 2004

Application: How it works

Injection Bonding Using Fluid Grade Systems



Demonstration with Perspex to show material distribution

Inspection

2012

2015

This type of bonding uses mostly indicative design methodology.

We know –

- Compressive strength
- Tensile strength
- Adhesive Strength etc.

However, not all applications are this straightforward, and will require more design input.

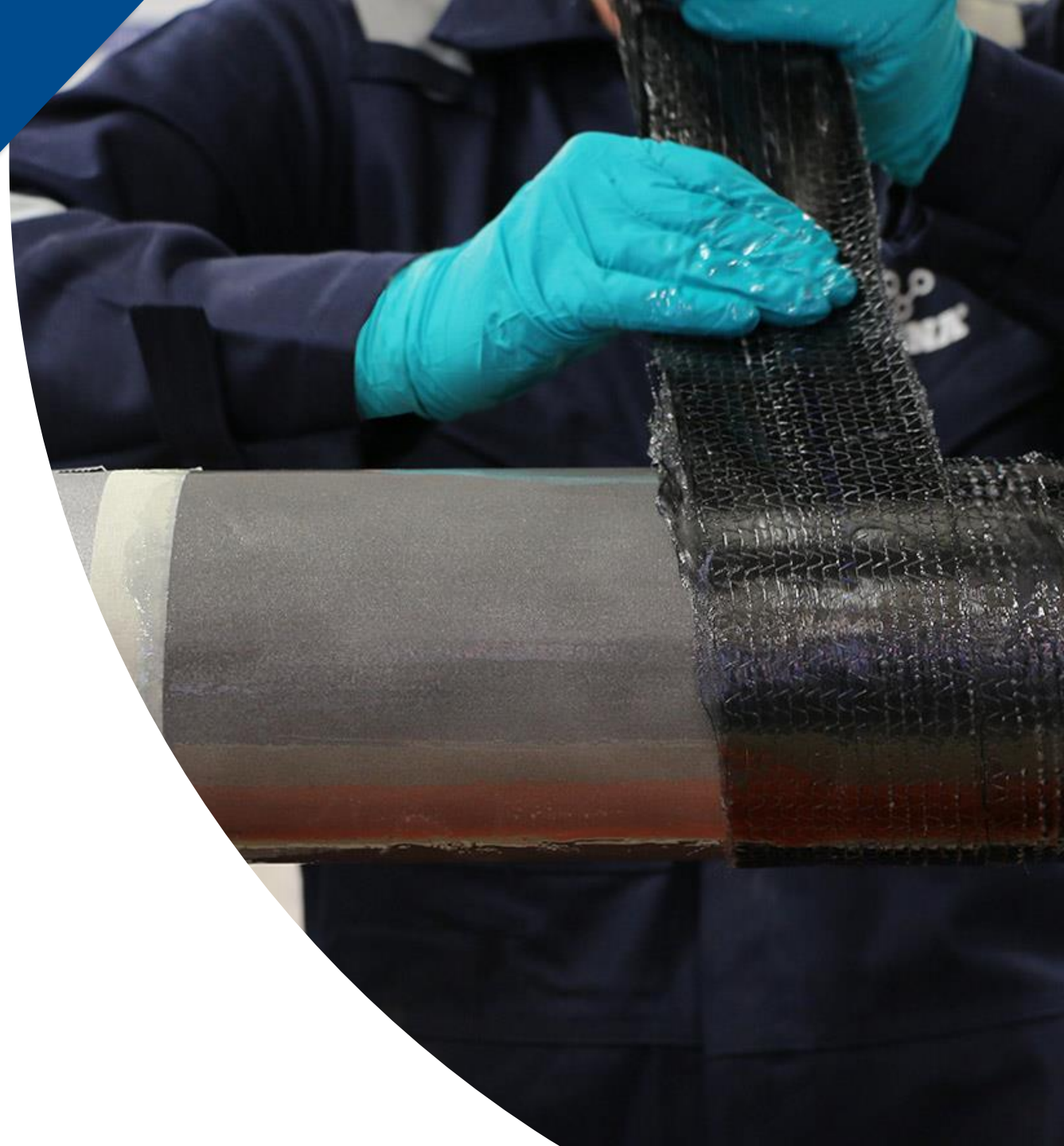
Composite Repairs

Repair system fabricated of a thermoset resin used in conjunction with fiber reinforcement sheet.

- **No heat involved**
- **No shutdown required**
- **Cost-effective when compared to other alternatives**

This is designed in accordance with two standards:

ISO 24817 & ASME PCC-2



Application Possibilities

Wrap

When a full circumferential wrap can be achieved.

Patch

When a full circumferential wrap is not practical.

Sample Design:

Inputs:

Design Temperature	- 20^0C
Design Pressure	- 5 bar
Process Fluid	- Cooling water
External Loads	- None
etc.	

Outputs:

Thickness	- 6 mm
Axial Extent	- 400 mm

How does this apply to patch repairs?

Patch repairs follow a similar methodology, although they lack the hoop strength provided by a full circumferential wrap.

How do we compensate for this lesser strength?

Increase the thickness

Advantages this repair type offers:

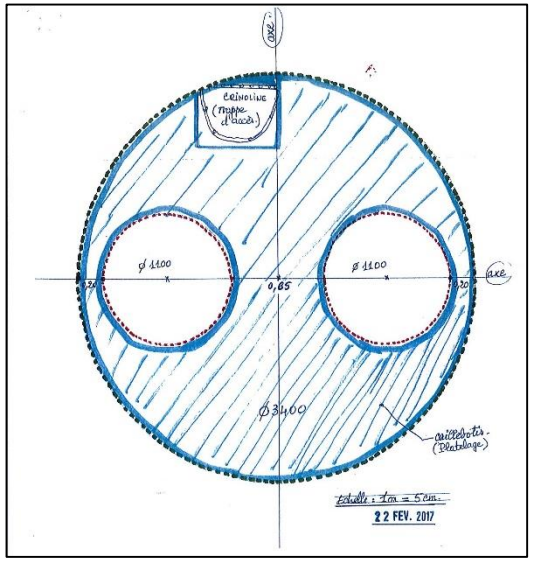
- Versatility as it can be applied on large diameter tanks/pipes
- Less material used than a wrap
- Can potentially provide the same strength as a wrap

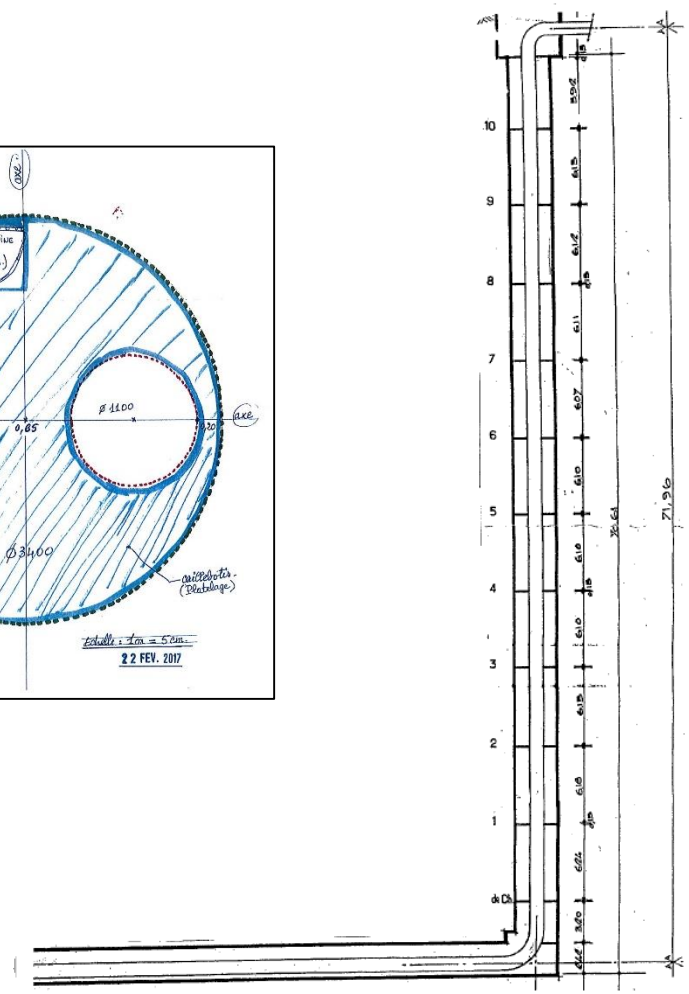
Drinking Water Plant, France

Corroded pipe requires reinforcement

Background

- 2 vertical pipes (diameter: 1.1m)
- On ~ 70m inside a concrete pit (3.2m diameter)
- Bad ventilation system inside the pit → condensation in the bottom section → **Corrosion**





Drinking Water Plant, France

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Corroded pipe requires reinforcement

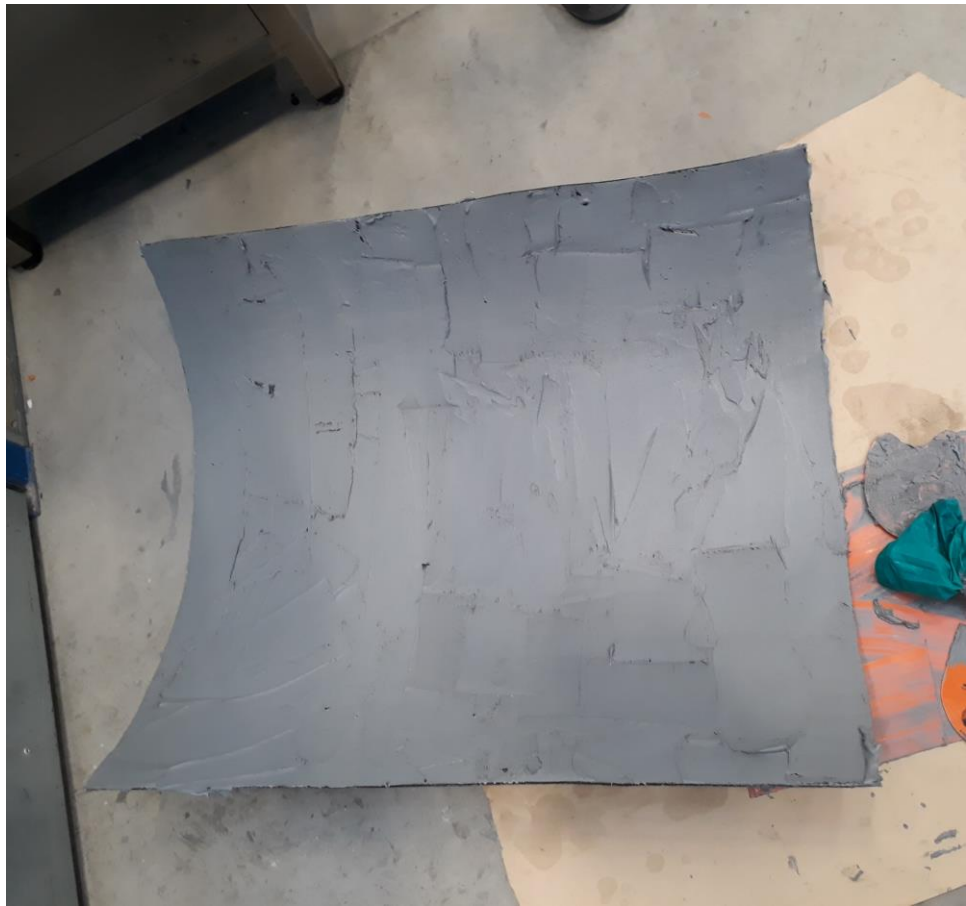
- Tests
  - Visual inspection
  - Ultrasonic tests
  - Laser profilometry on a few damaged sections
- Results
  - Visual inspection: Advanced deterioration of the external coating (only protection against corrosion), especially on the bottom section
  - Water flow alongside the outside of the pipes accelerates the corrosion rate of the steel where the coating is gone
  - Maximum thickness loss between 20.94% and 48.55%.
  - Surface prep. from previous coating was not conducted properly

Drinking Water Plant, France

Corroded pipe requires reinforcement

A composite patch was to be bonded in place on the external of the pipe.

This was to be completed using a pre-fabricated patch (500 x 500 mm), bonded with an epoxy.



Drinking Water Plant, France

Corroded pipe requires reinforcement

Workshop tests were completed:

Advantages of Cold Bonding

- Quick, safe-to-use, **cold-applied and cold-curing** solutions.
- **Simple application** procedures without specialist tools.
- Suitable for equipment operating at **elevated temperatures**.
- **Fast curing grades** for minimal downtime.

- **Excellent adhesion** to a variety of common substrates.
- Excellent **corrosion protection** in harsh environments.
- Outstanding **chemical resistance** to a wide range of chemicals.
- Can be **designed for compliance** with engineering standards.
- Proven **long-lasting** solutions which can **increase an asset's lifespan.**