# BRIDGOLOGY

**Ground Penetrating Radar**
**2020**

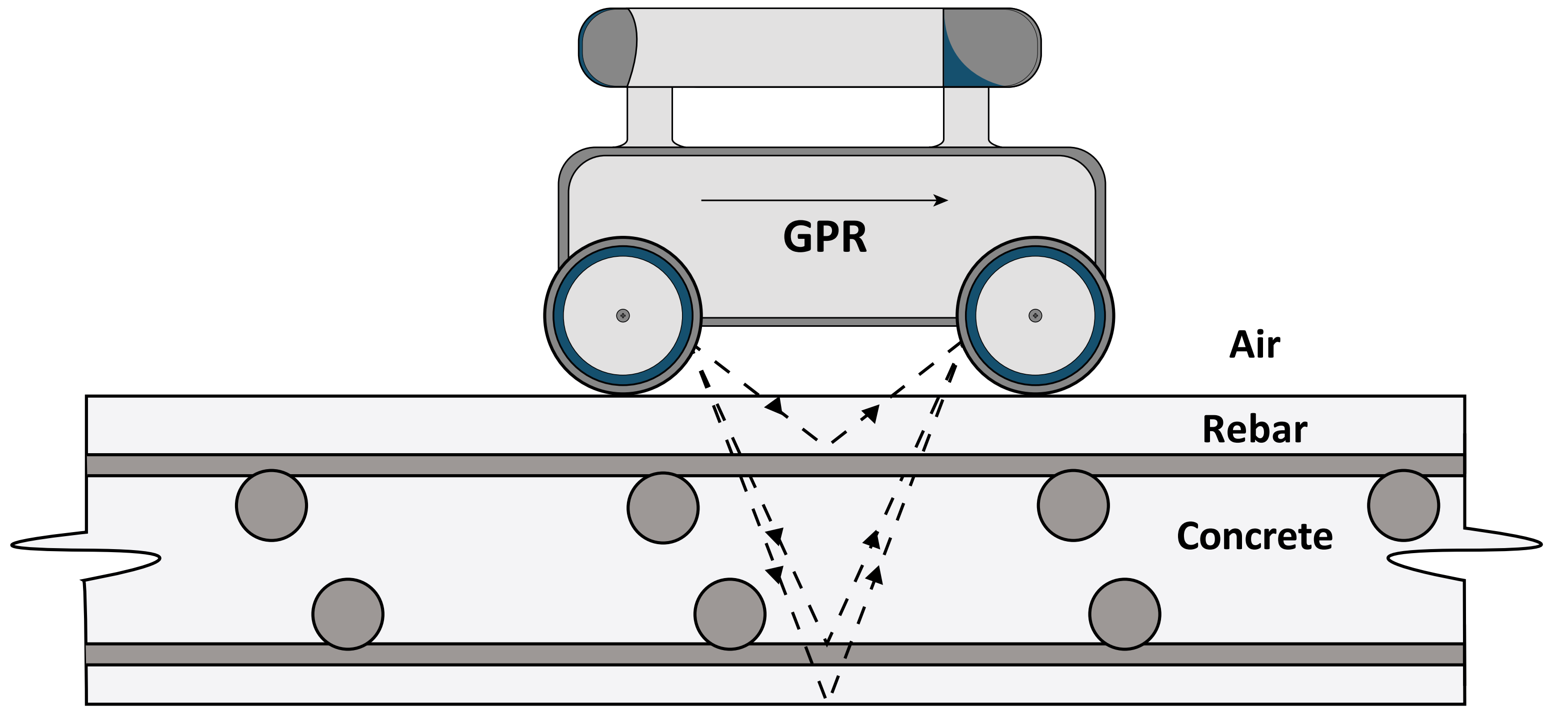
BRIDGOLOGY

Bridgology SA is a consulting firm specialising in non-destructive data analysis, founded in 2013.

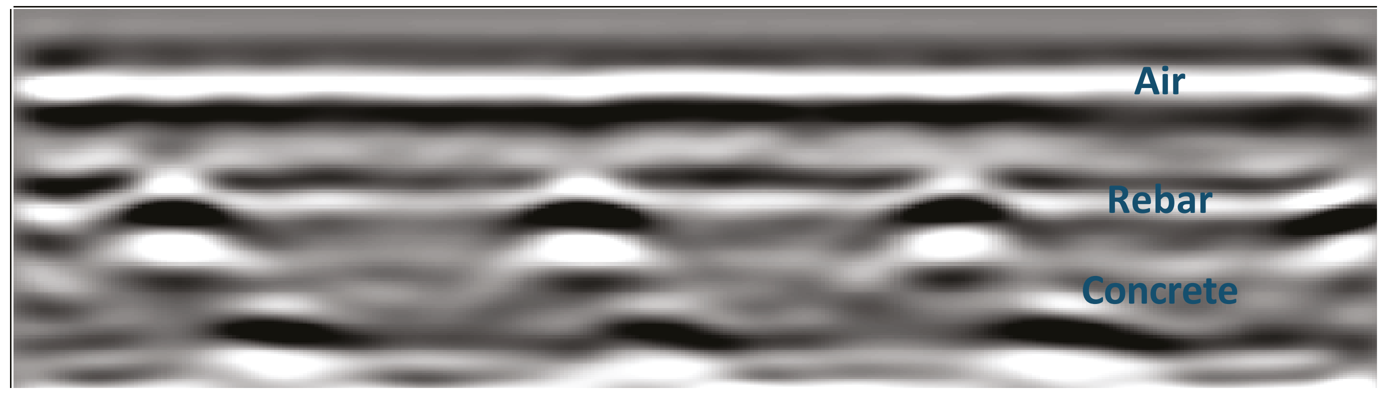
We operate in infrastructure maintenance, offering clear and synthetic visualisation tools.

We intervene on all types of new and existing structures in reinforced concrete and masonry.

This brochure presents typical analyses using the Ground Penetrating Radar [GPR] method.




Data: Radargram

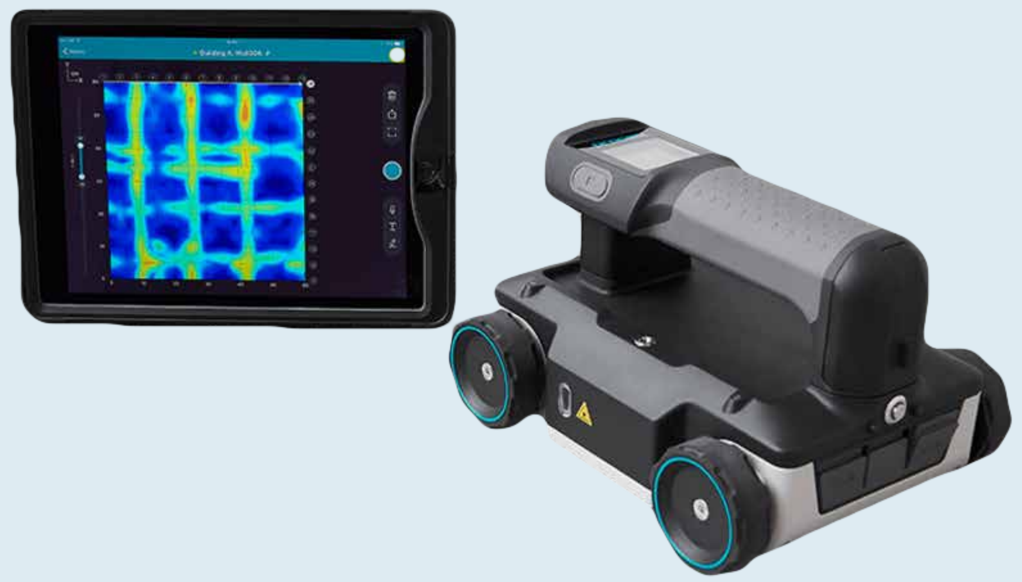



GPR is a non-destructive testing method based on the propagation of electromagnetic waves. The Georadar emits waves that propagate through the structure. These waves are reflected towards the GPR when they encounter an obstacle.

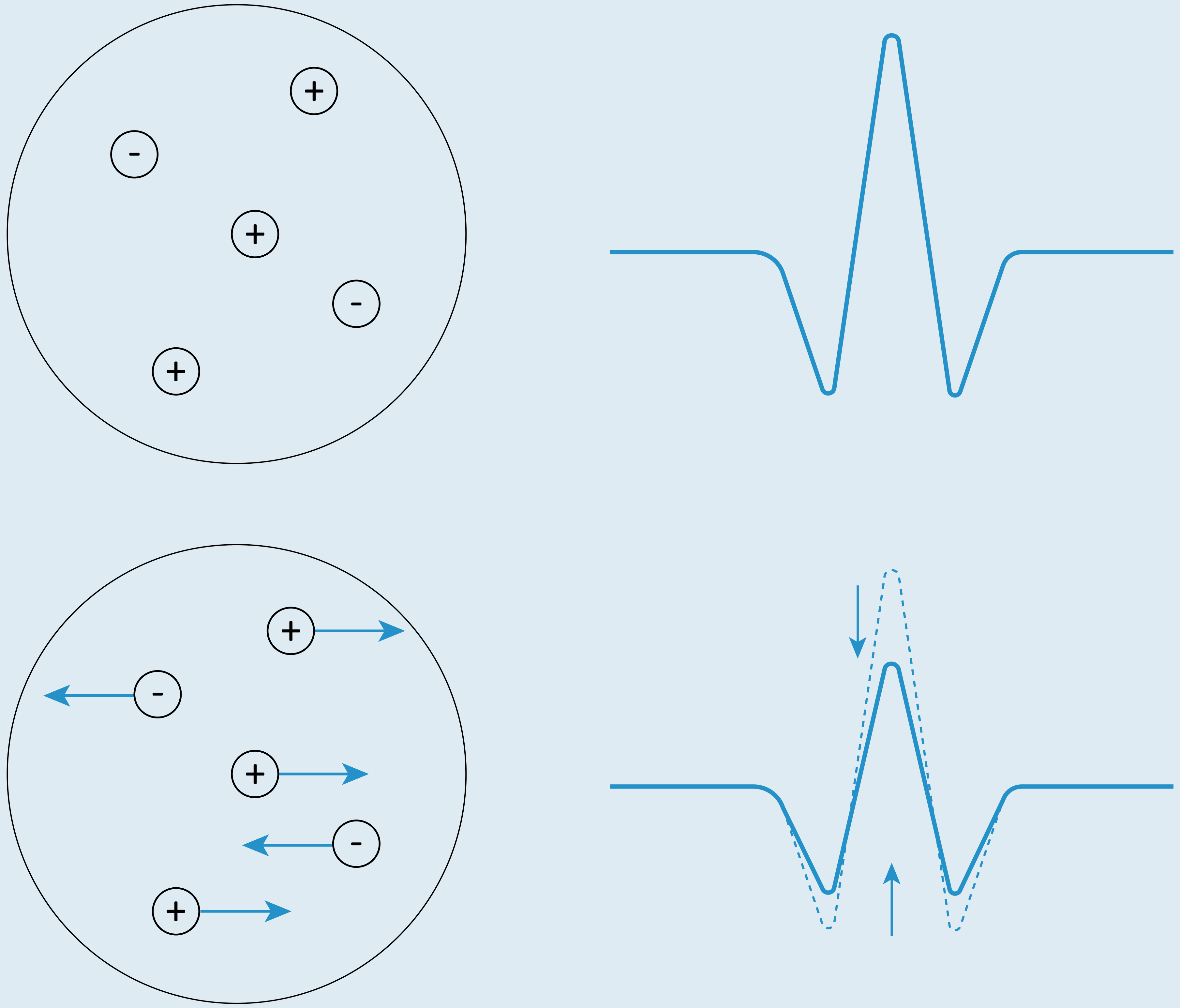
The GPR then records the arrival times of the waves and sums them up as it progresses along the object under study. This sum of measurements forms a radargram which is a cross-section of the structure and the objects that make it up.

To calculate the depths of the elements encountered, the recorded arrival times are converted using the speed of propagation of the waves. These propagation velocities must be calibrated punctually by soundings.

# GPR



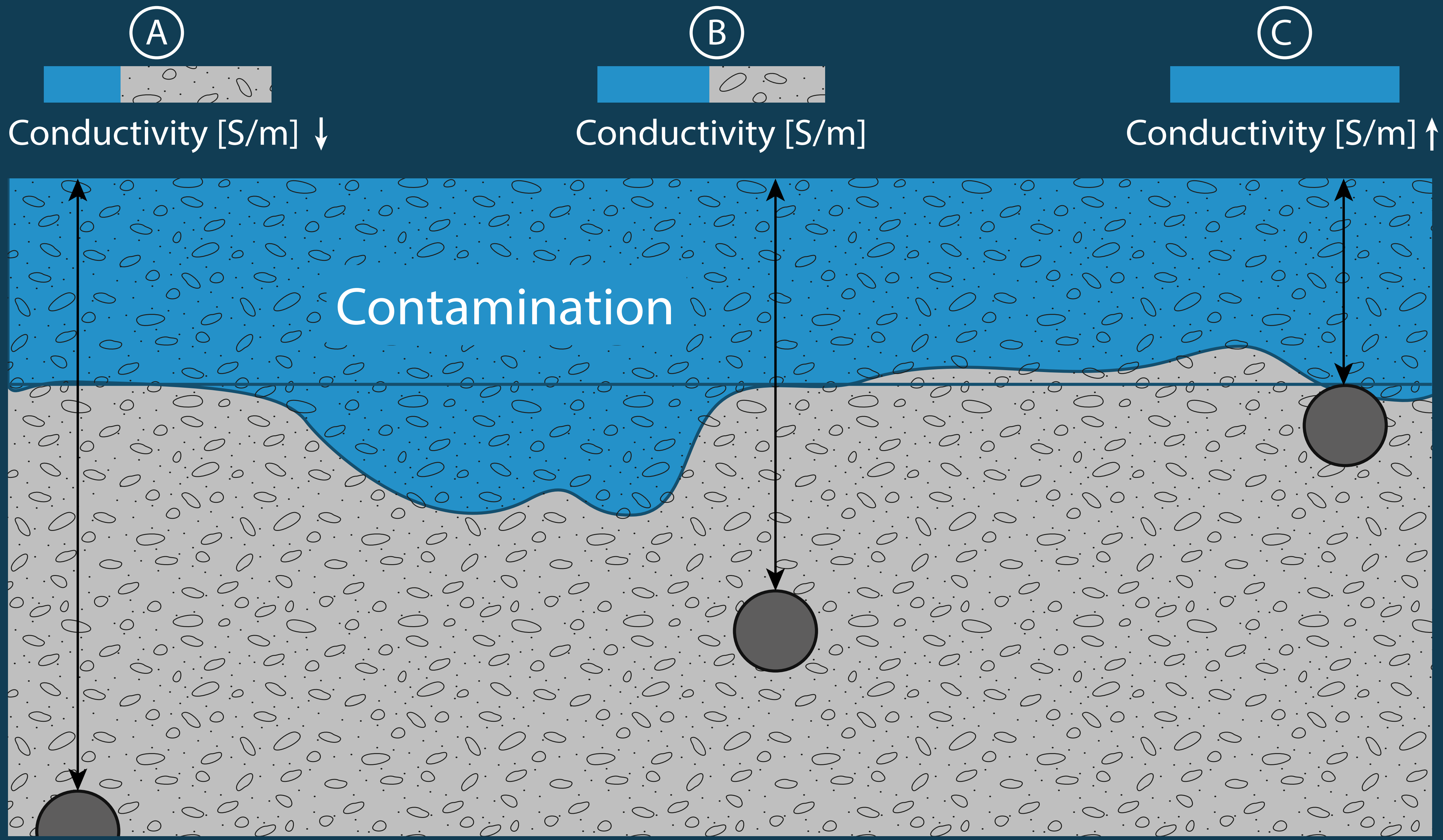
# Conductivity



Electrical conductivity is the ability of a material or solution to conduct an electric current. It is expressed in Siemens per meter [S/m] and varies with the amount of ions present in solution in the pores of the concrete. The electromagnetic wave emitted by the ground penetrating radar creates a local electric field that displaces the ions in the water in the pores. This displacement of ions consumes part of the energy of the wave. Conductivity is calculated by measuring the amount of energy dissipated.

The calculation of conductivity from GPR data is the result of the EPFL thesis n°5354 (2013) by Dr. Alexis Kalogropoulos.

# Corrosion risk




The conductivity of the concrete cover reflects the risk of corrosion of the reinforcing bars:

**Risk = Hazard x Vulnerability**

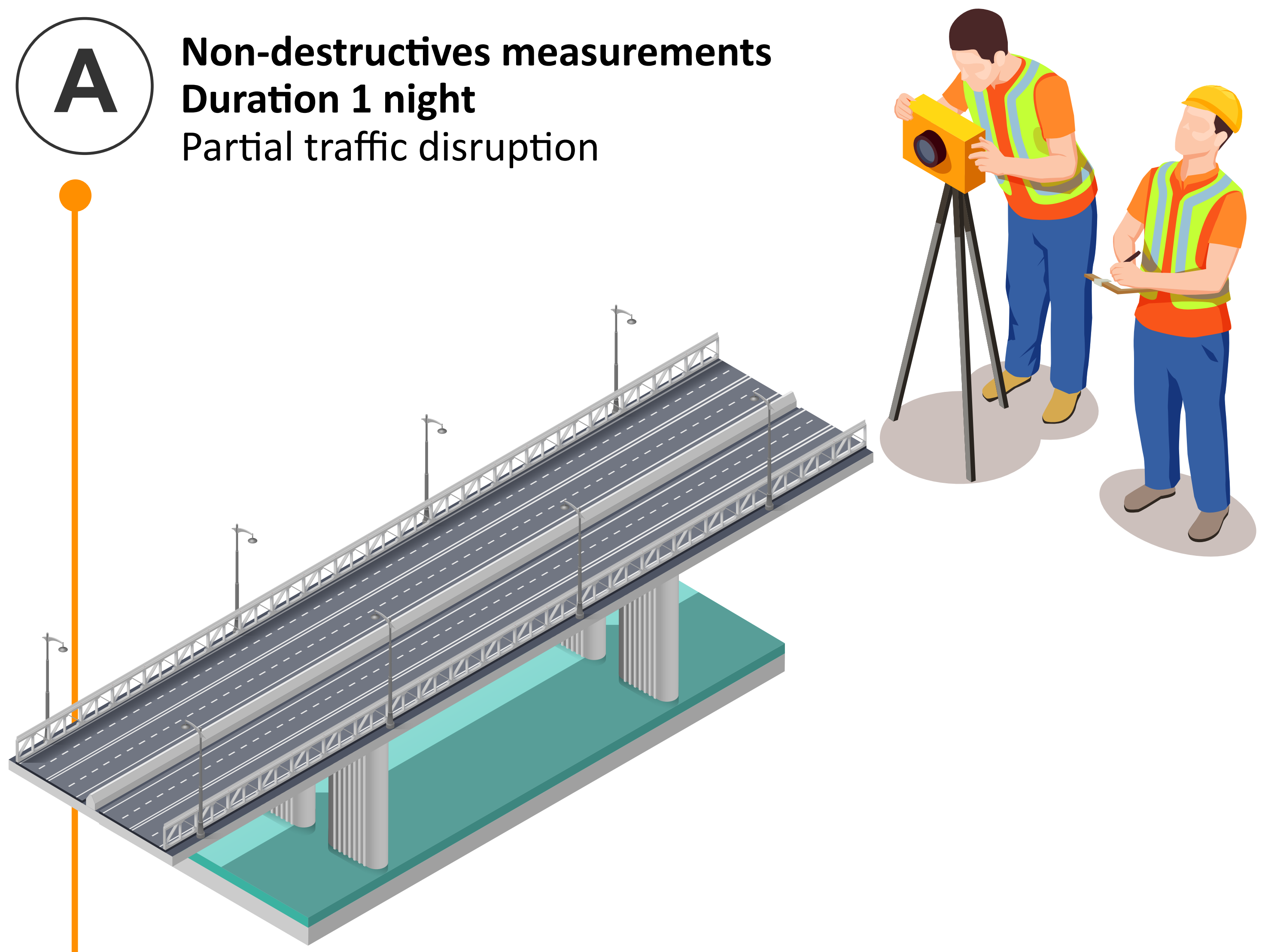
with:

Risk = Measured conductivity [S/m].
Alea = Conductance [S], directly proportional to the contamination (% Cl-)
Vulnerability = exposure of the reinforcing bars to contamination, inversely proportional to the coating thickness.

Thus, with equal contamination, conductivity decreases when the coating is thick (A) and increases when the coating decreases (C). Conversely, for the same coating thickness, conductivity increases for high contamination and decreases for lower contamination.

# Our method

**A** **Non-destructives measurements**
**Duration 1 night**
Partial traffic disruption



**B** **Data processing and analysis**
**Duration 1 week**
Production of reports

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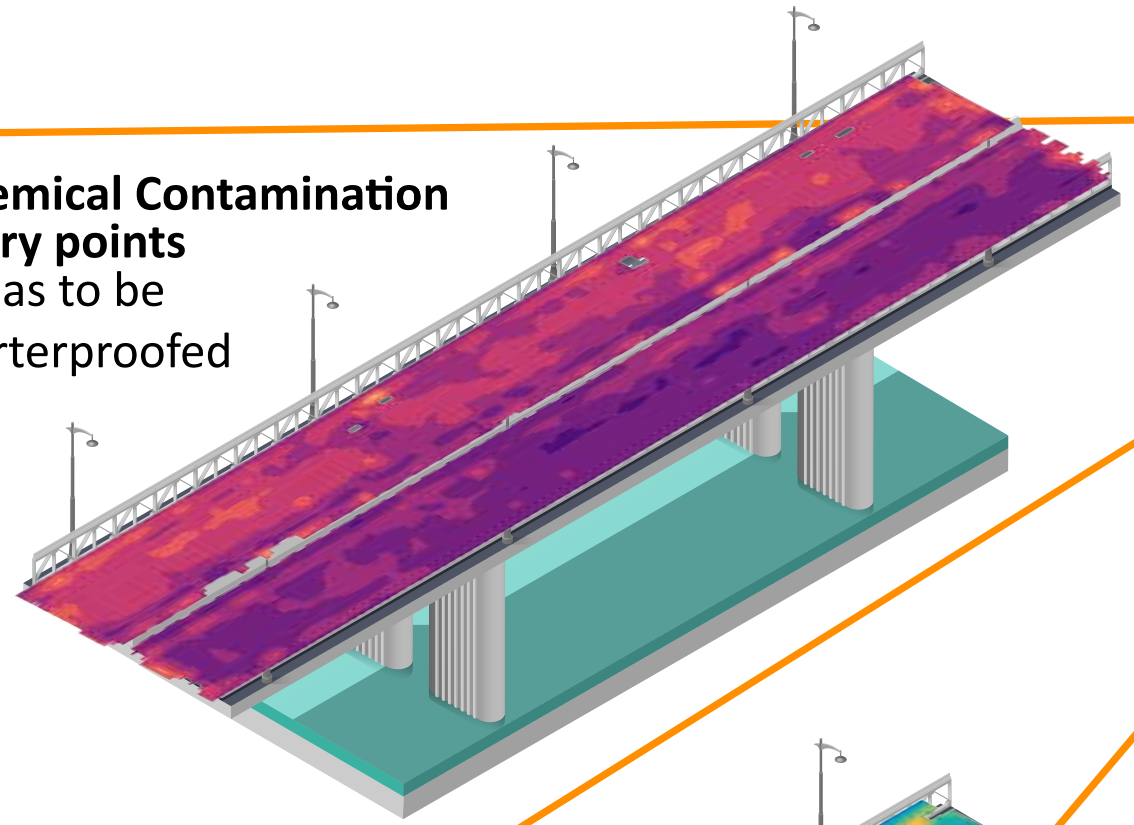
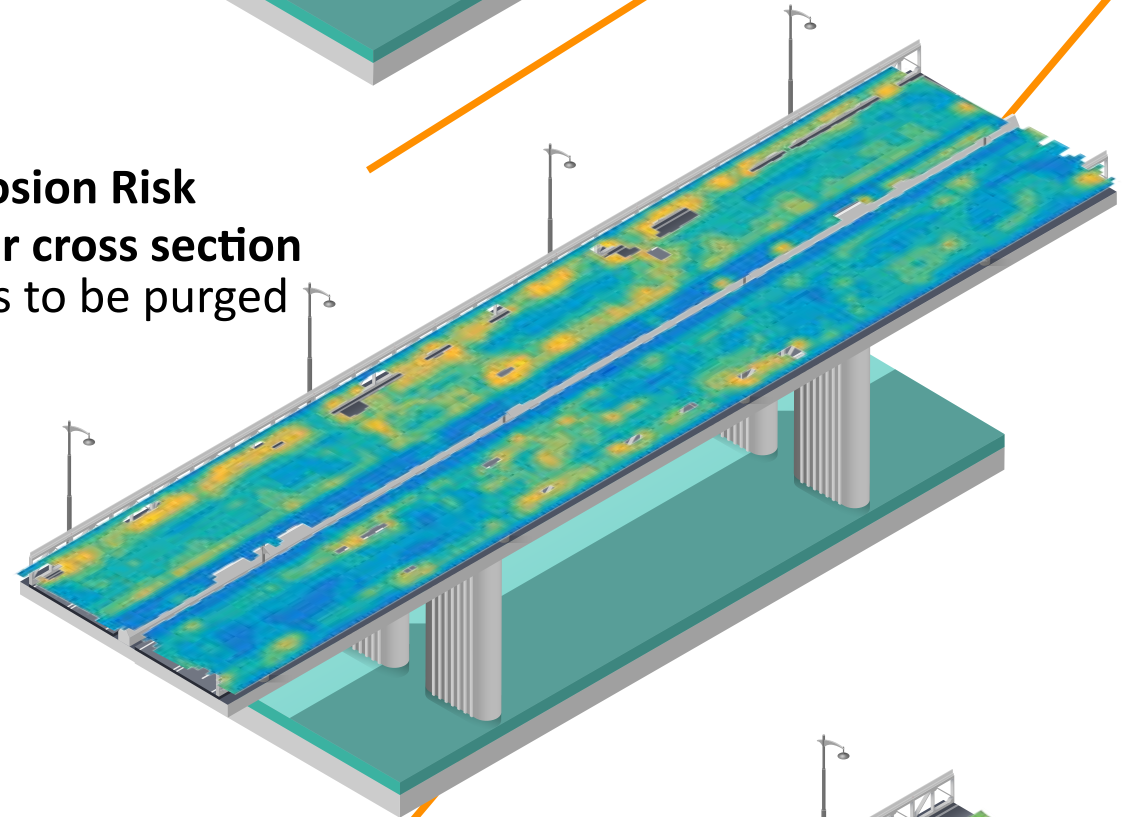
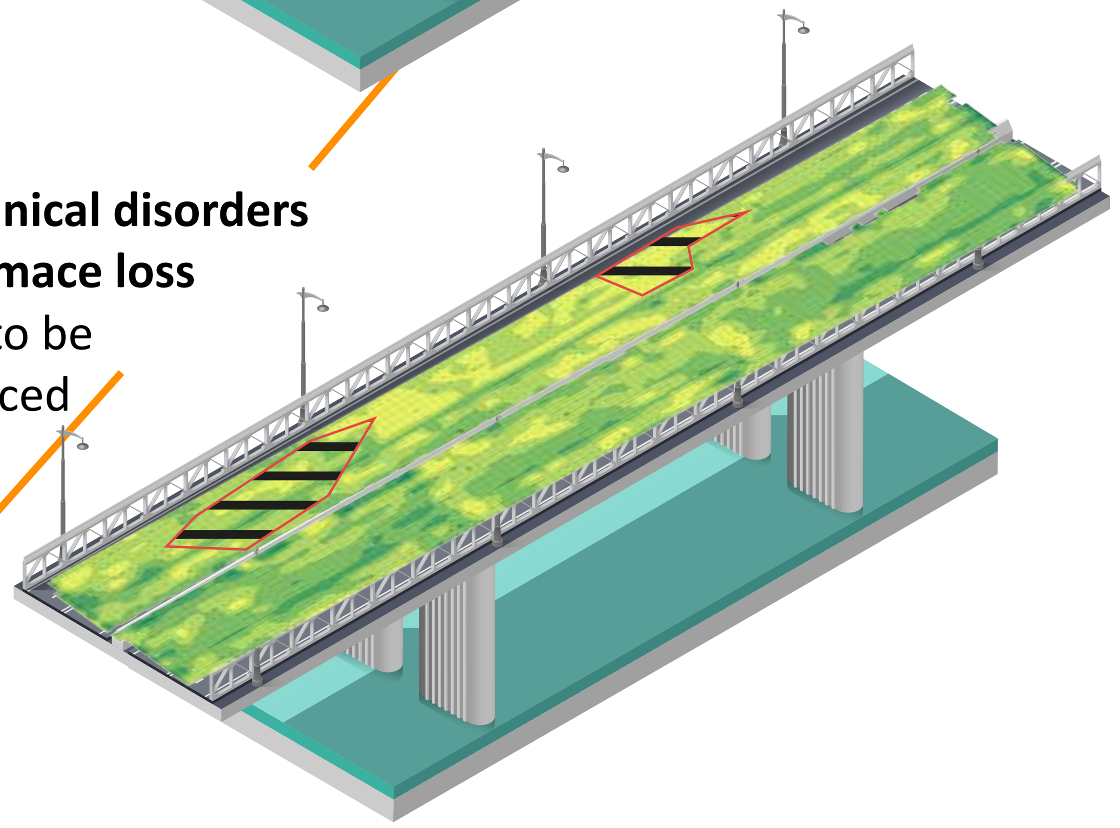
**C1** **Chemical Contamination**
**Entry points**
Areas to be warterproofed



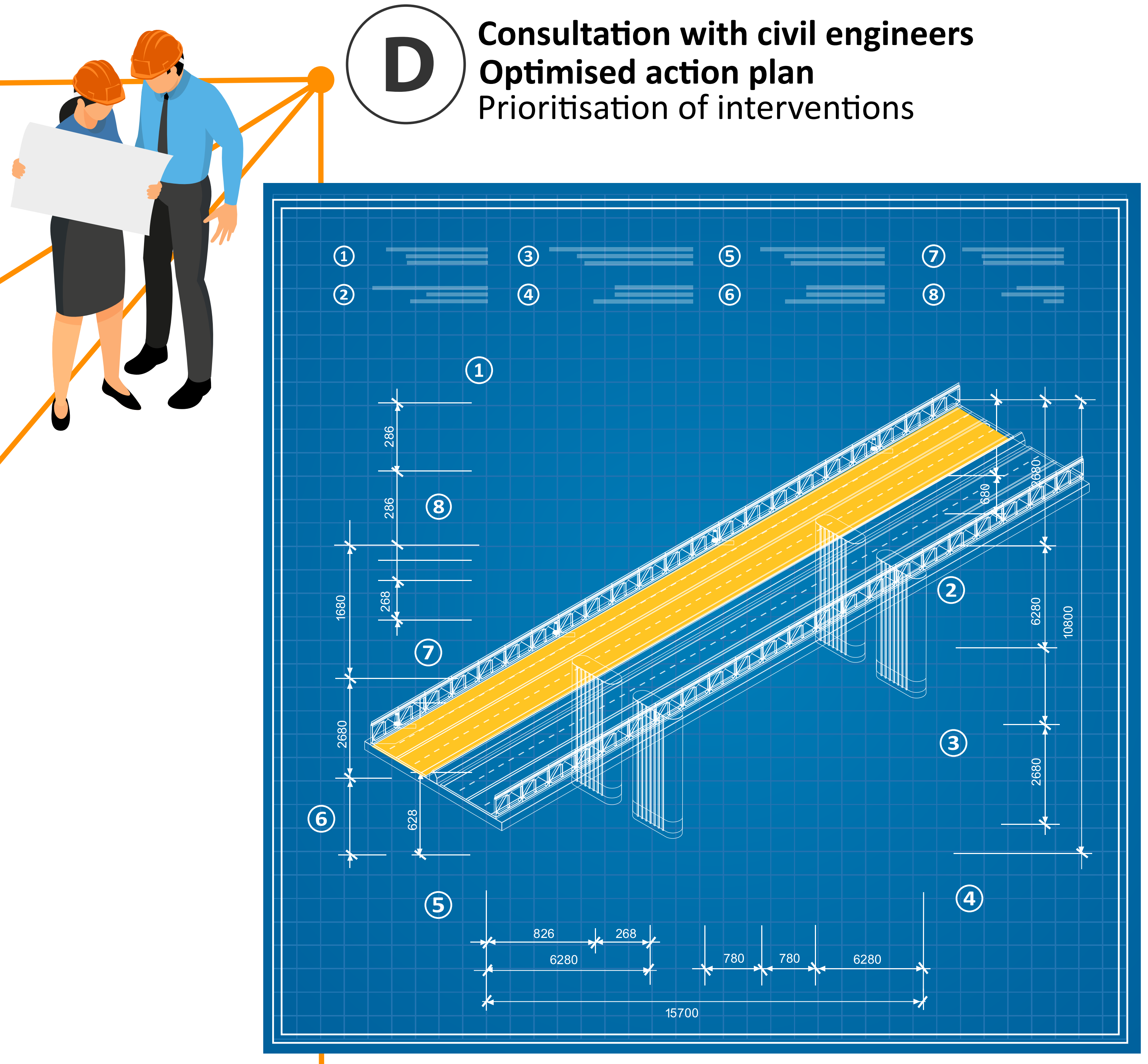
**C2** **Corrosion Risk**
**Rebar cross section**
Areas to be purged

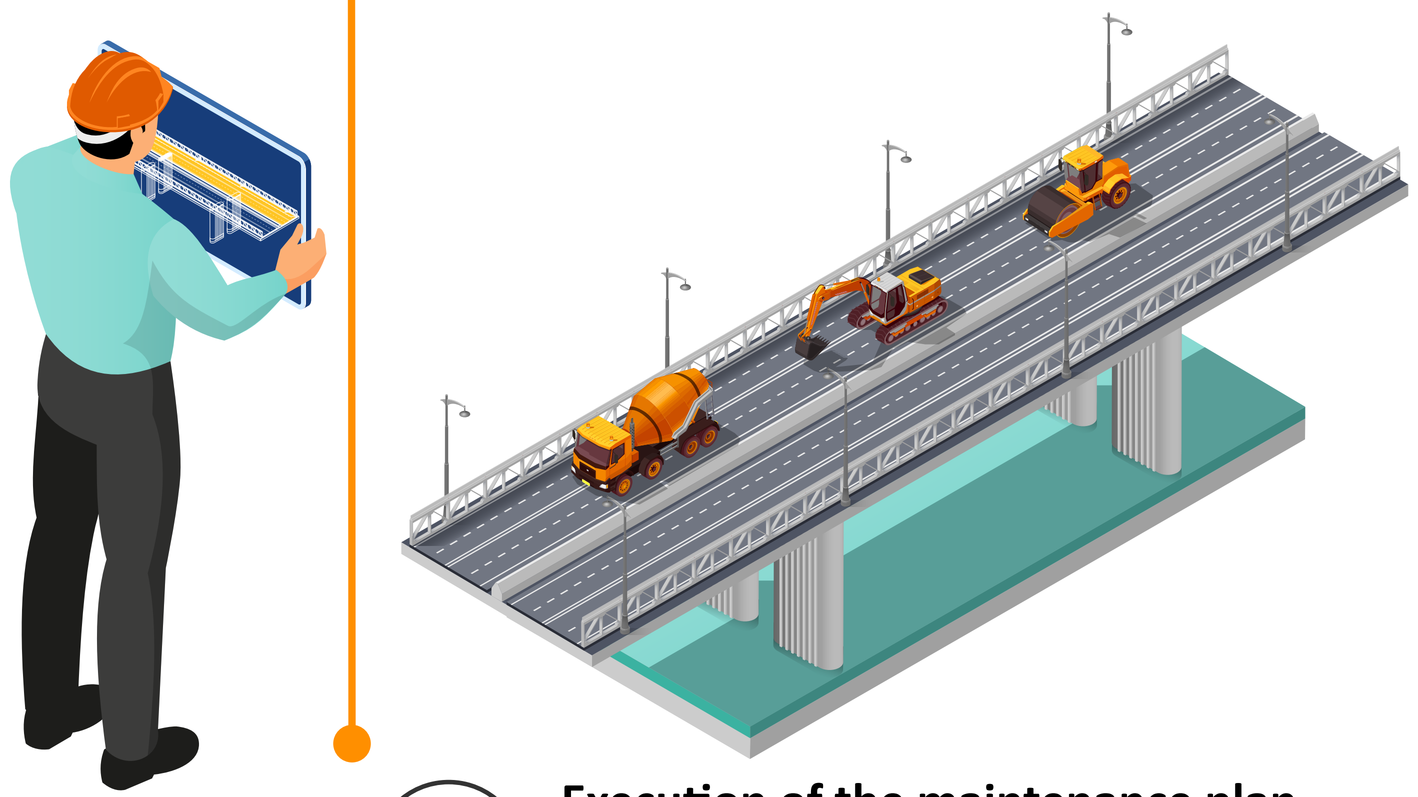


**C3** **Mechanical disorders**
**Performace loss**
Areas to be reinforced



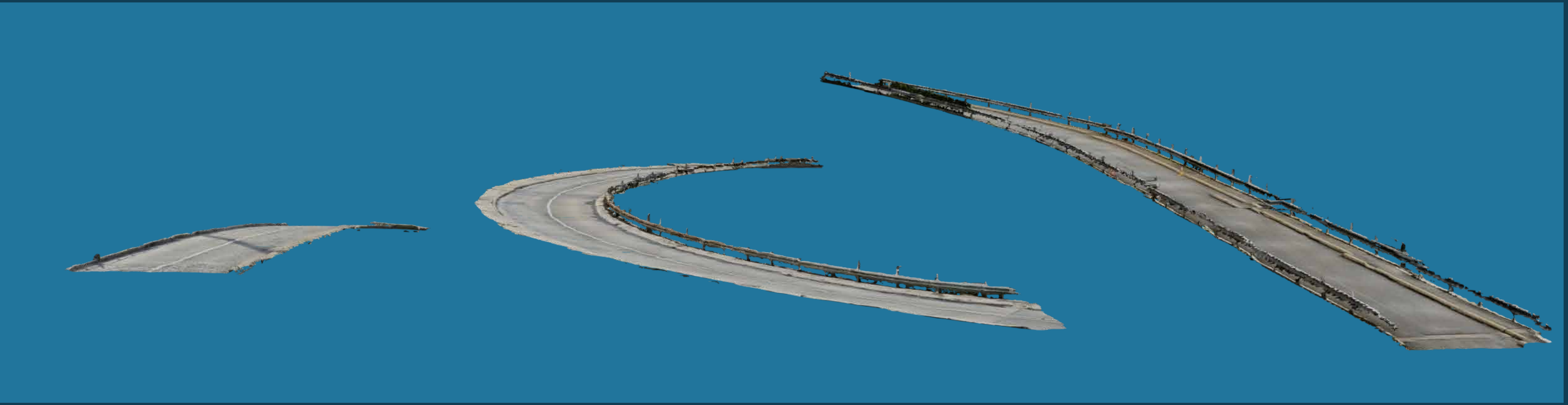
**D** **Consultation with civil engineers**
**Optimised action plan**
Prioritisation of interventions





**E** **Execution of the maintenance plan**
**Minimisation of costs and durations**
Contingencies limitation

# Structure Mapping

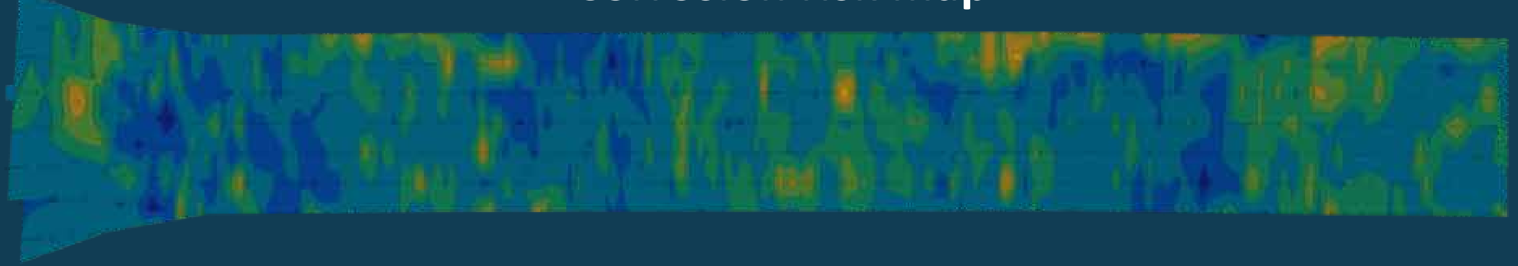


Catalogue of available cards according to the client’s needs and the state of the structure :

- (A) The corrosion risk map of the reinforcement corresponding to the conductivity in [S/m].
- (B) The map of the thickness of the embedding concrete indicates the vulnerability of the reinforcement.
- (C) The contamination map corresponds to the [S] conductance. It allows the identification of areas of high contamination.
- (D) The mechanical disorders map shows all the disorders observed in the concrete.
- (E) The waterproofing condition map describes the quality of the contact between the waterproofing and the concrete.
- (F) The map of the thickness of the asphalt mix provides information on over- or under-thickness.
- (G) A 3D Lidar survey of the surface of the structure listing the geometry, previous repairs and surface di-sorders.

Corrosion risk map

A

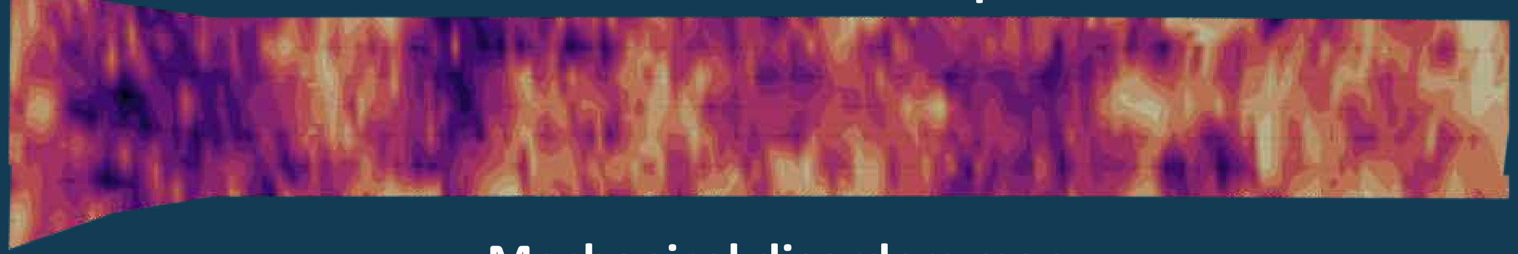


Concrete cover thickness map

B

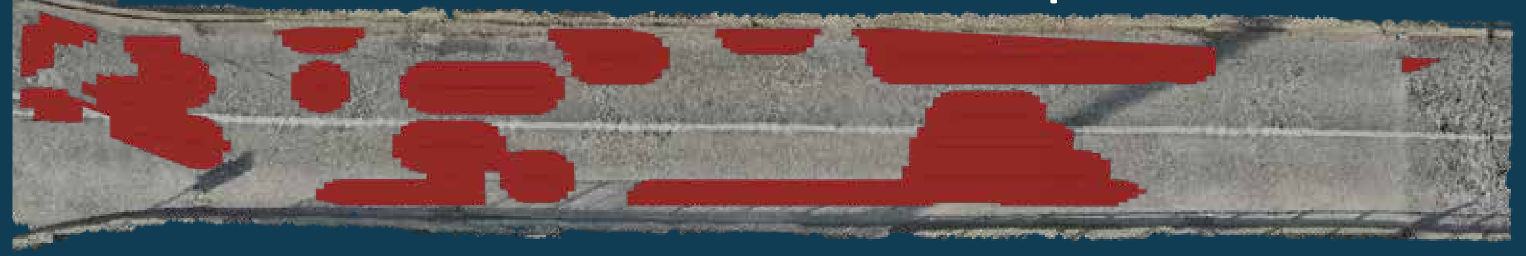
Contamination map

C



Mechanical disorders map

D



Waterproofing condition map

E

Asphalt thickness map

F

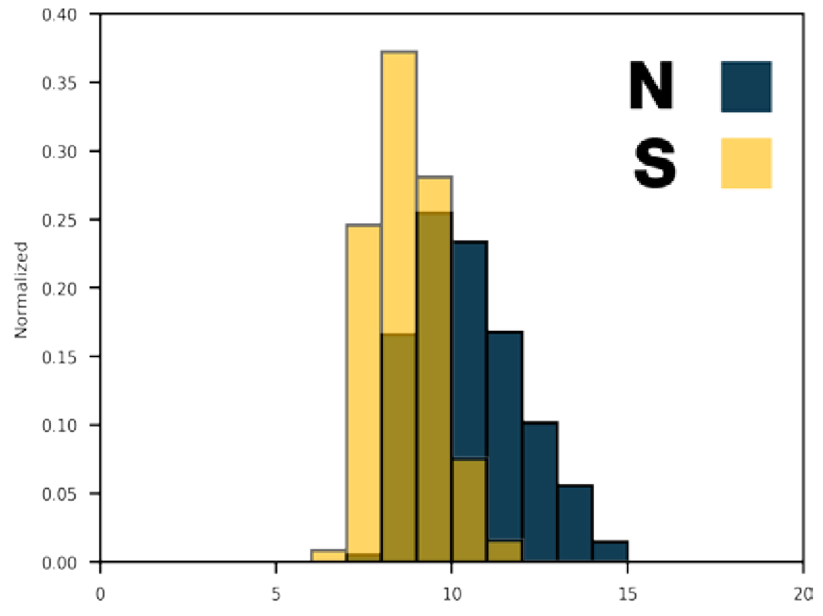
3D LIDAR map

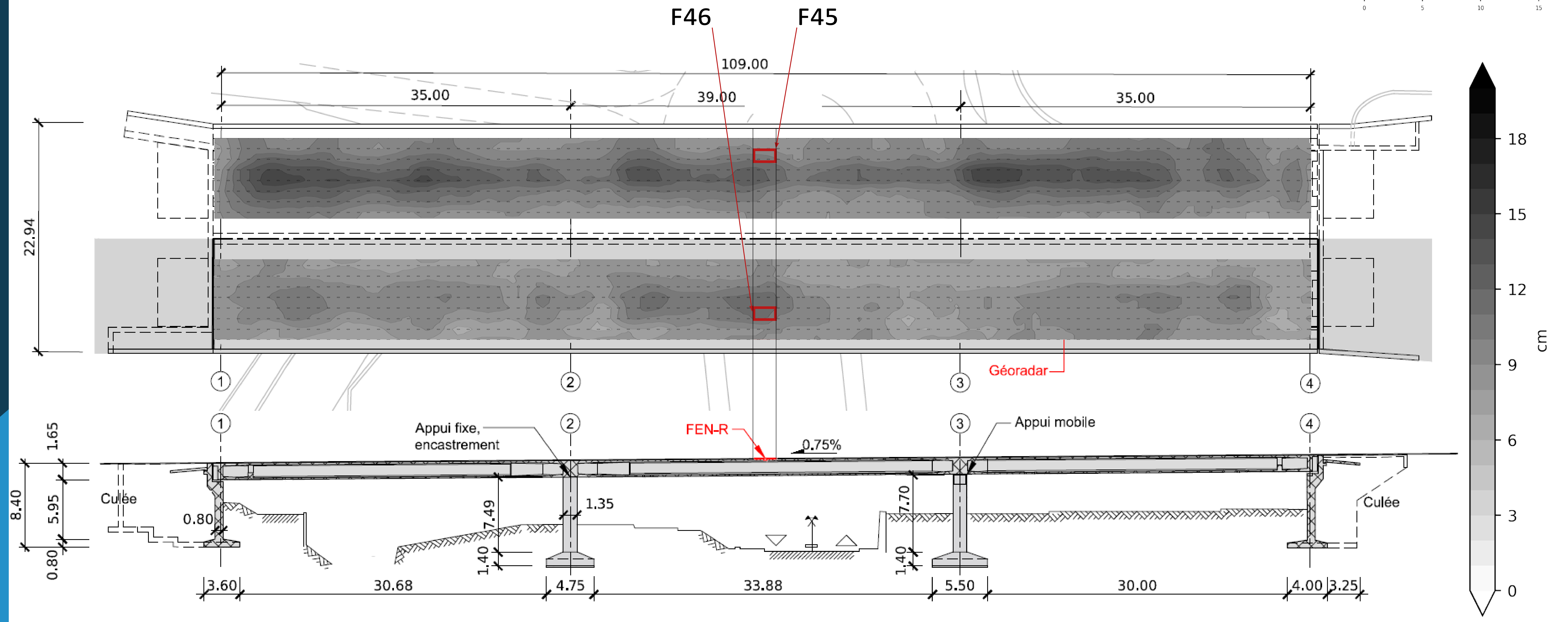
G

# Structure mapping – Motorway Bridge

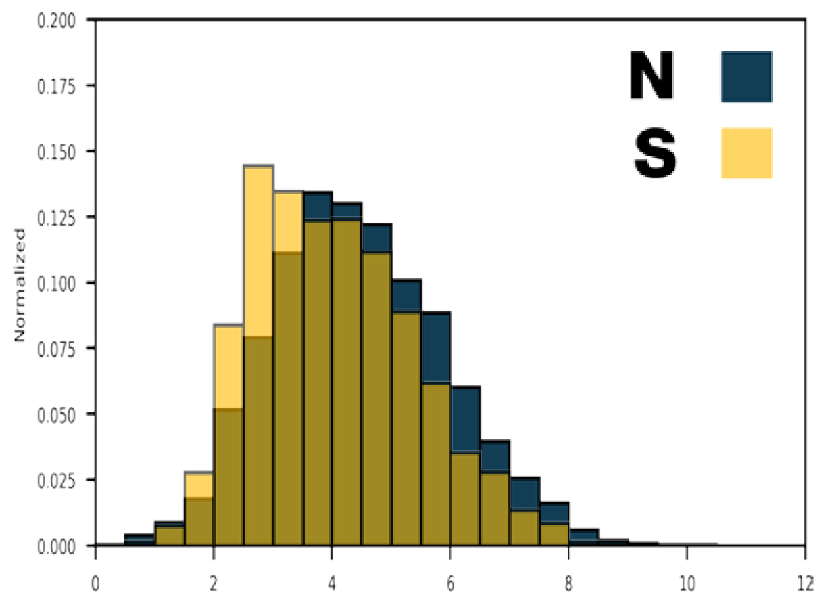
## Asphalt cover thickness

The thicknesses follow a normal distribution. The Nothern bridge has slightly higher asphalt thickness than de Southern bridge: 10.3 cm vs. 8.6 cm. Both decks have large concrete curbs without surfacing directly exposed to chlorides.



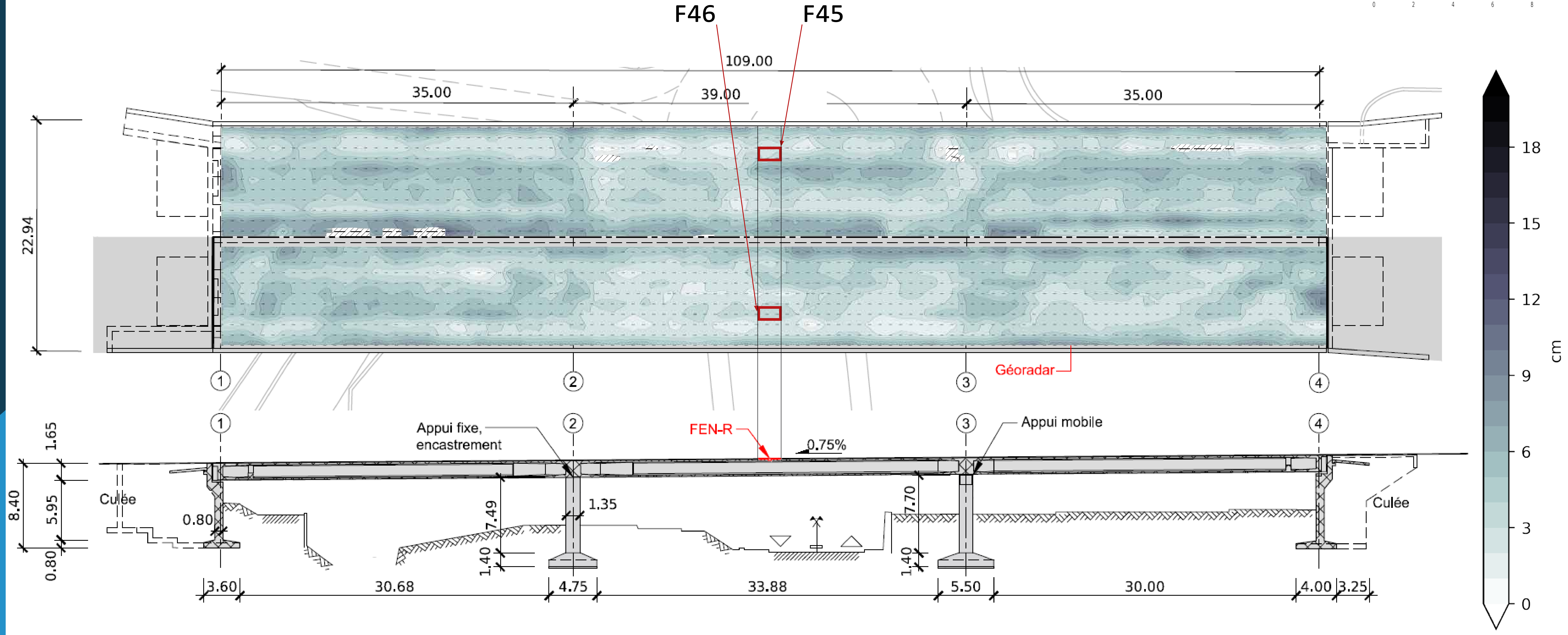



# Structure mapping – Motorway Bridge




## Concrete cover thickness

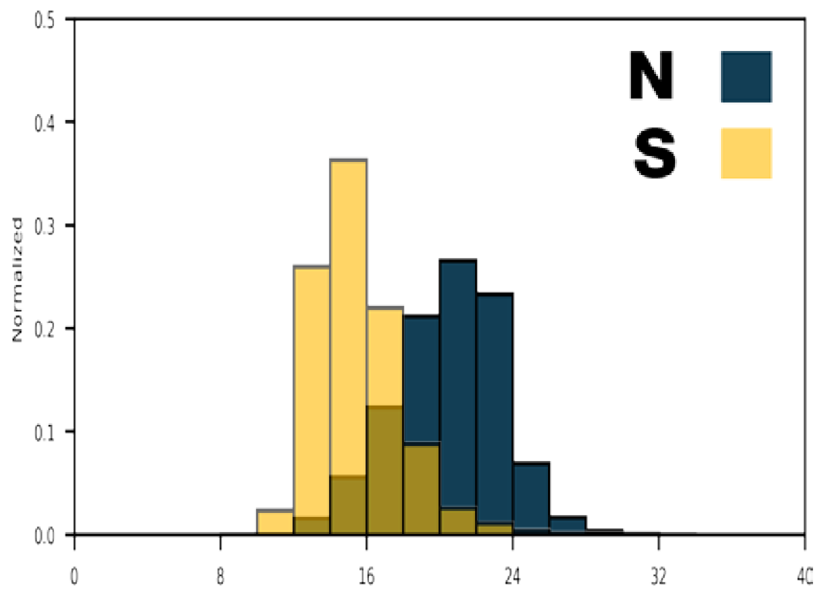
The measurements follow a normal distribution on both bridges. Both decks have significant under-thickness at the edges of the structure. This suggests that the reinforcement in the exposed areas is more vulnerable.

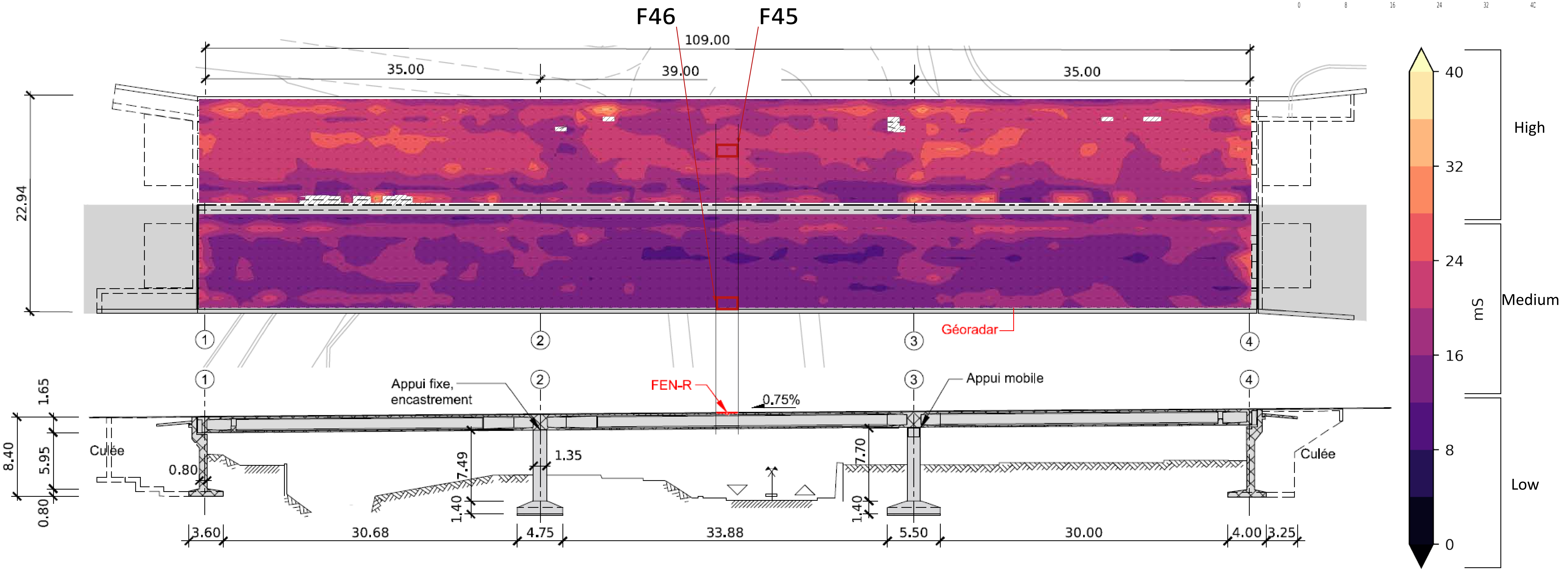


# Structure mapping – Motorway Bridge

## CONTAMINATION

Overall contamination is average.
However, in detail, the North deck is heavily contaminated compared to the South deck.

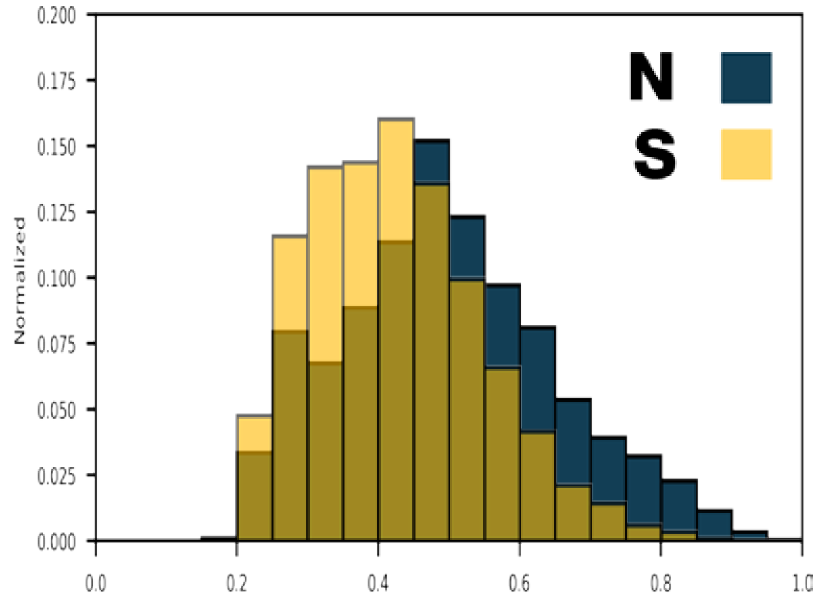


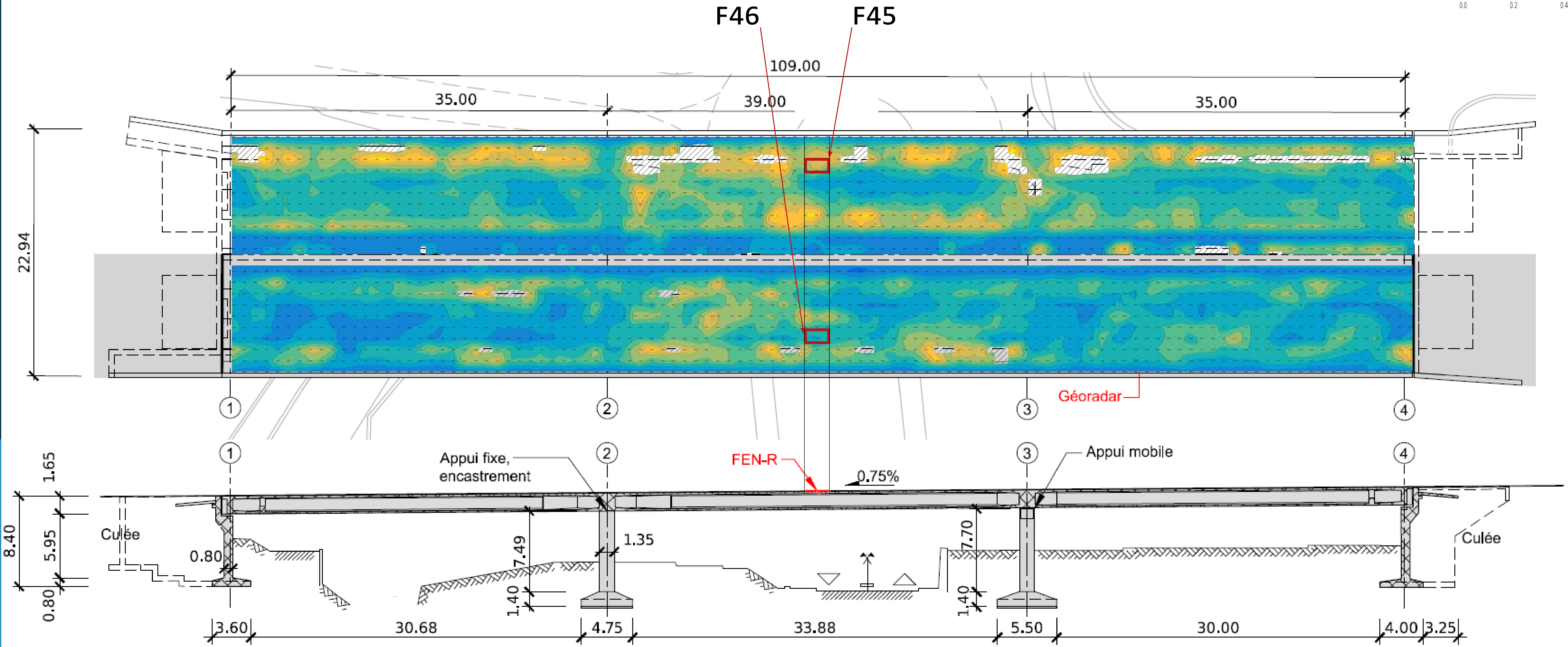



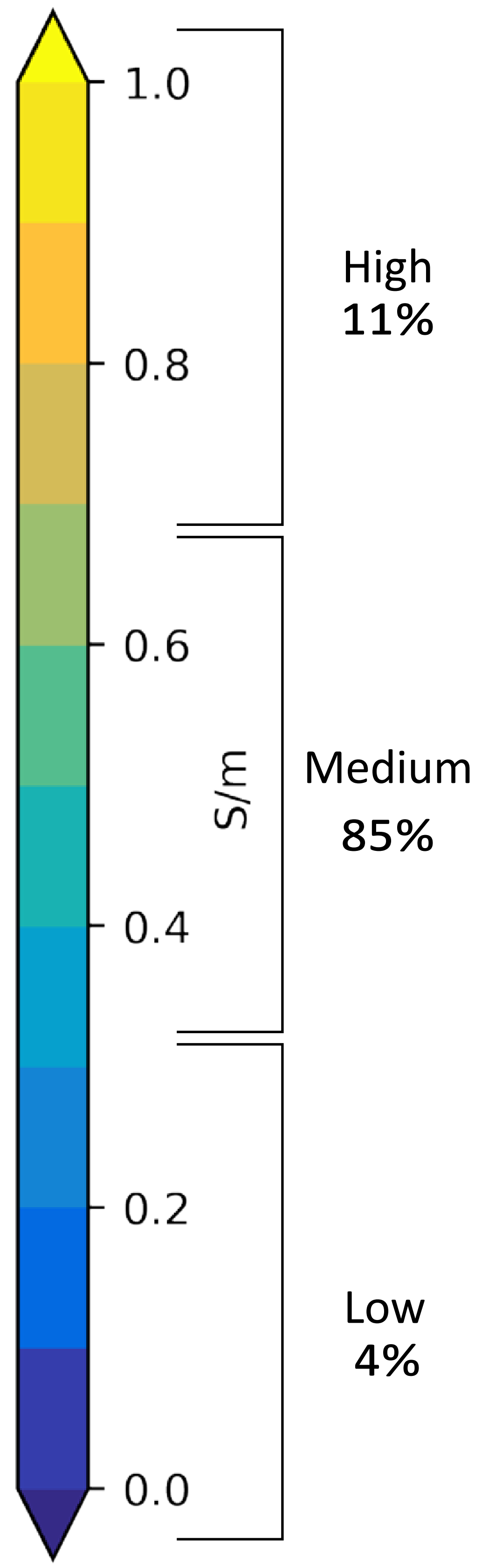
# Structure mapping – Motorway Bridge

## Corrosion Risk

The overall risk of corrosion is medium. However, our analysis reveals areas with a high risk of corrosion, mainly at the edges of both decks where the cover concrete is low. The generally higher values from the Nothern deck are due to the presence of a noise reduction wall at the Nothern border.



# Structure mapping – Motorway Bridge

## ADDITIONAL VERIFICATION AND CONFIRMATION OF CONTAMINATION

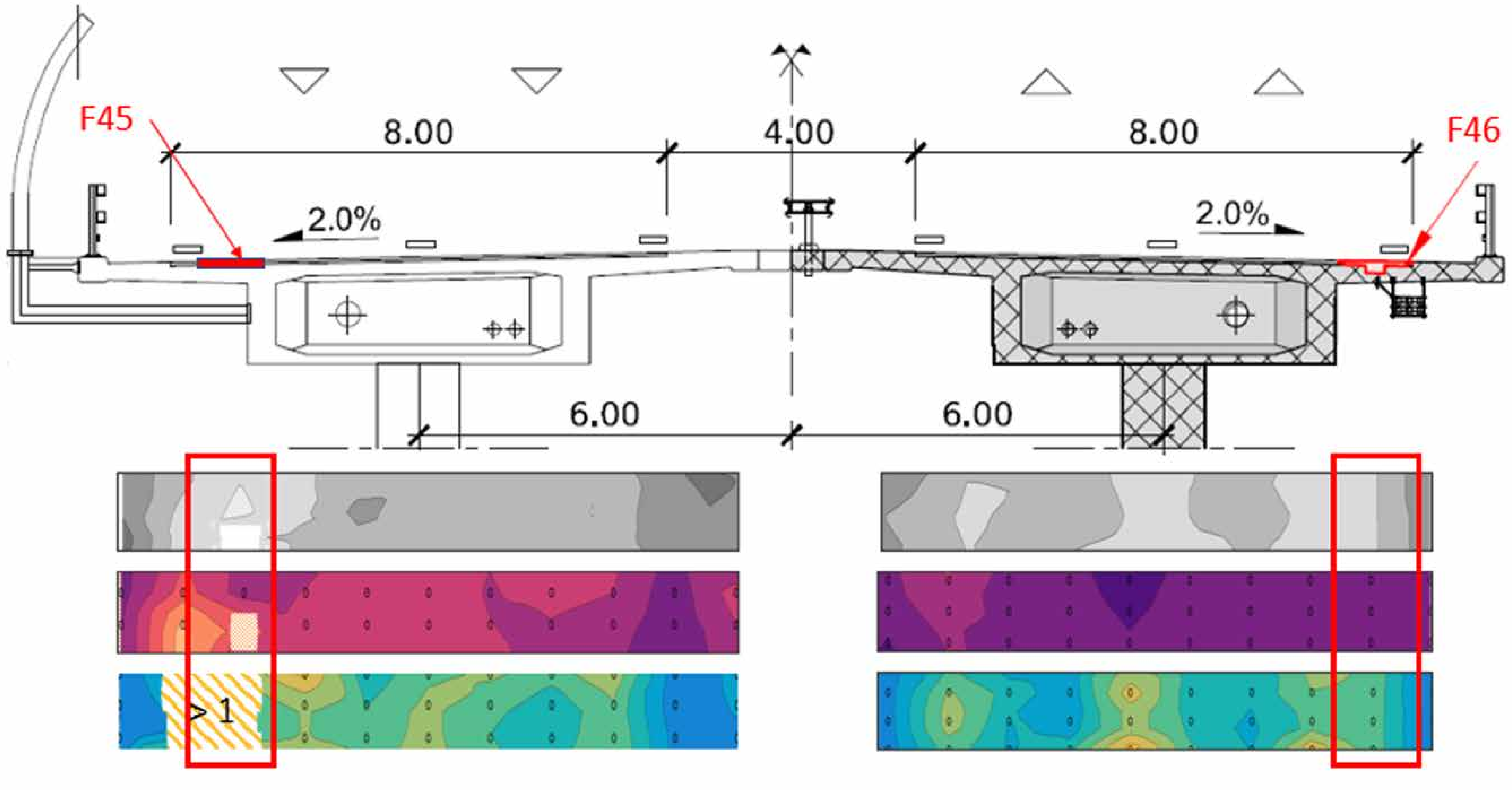
The structure having transverse prestressing, probing had been planned.

The first F46 probe was carried out in a low-contamination area.

Following signs of strand corrosion as well as high contamination values on the north deck, we recommended the opening of a second, initially it was an optional survey.

The F45 survey on the other deck confirmed the assumptions.

It was concluded that the exposed edges served as points of entry and accumulation of chlorides in the transverse prestressing ducts.

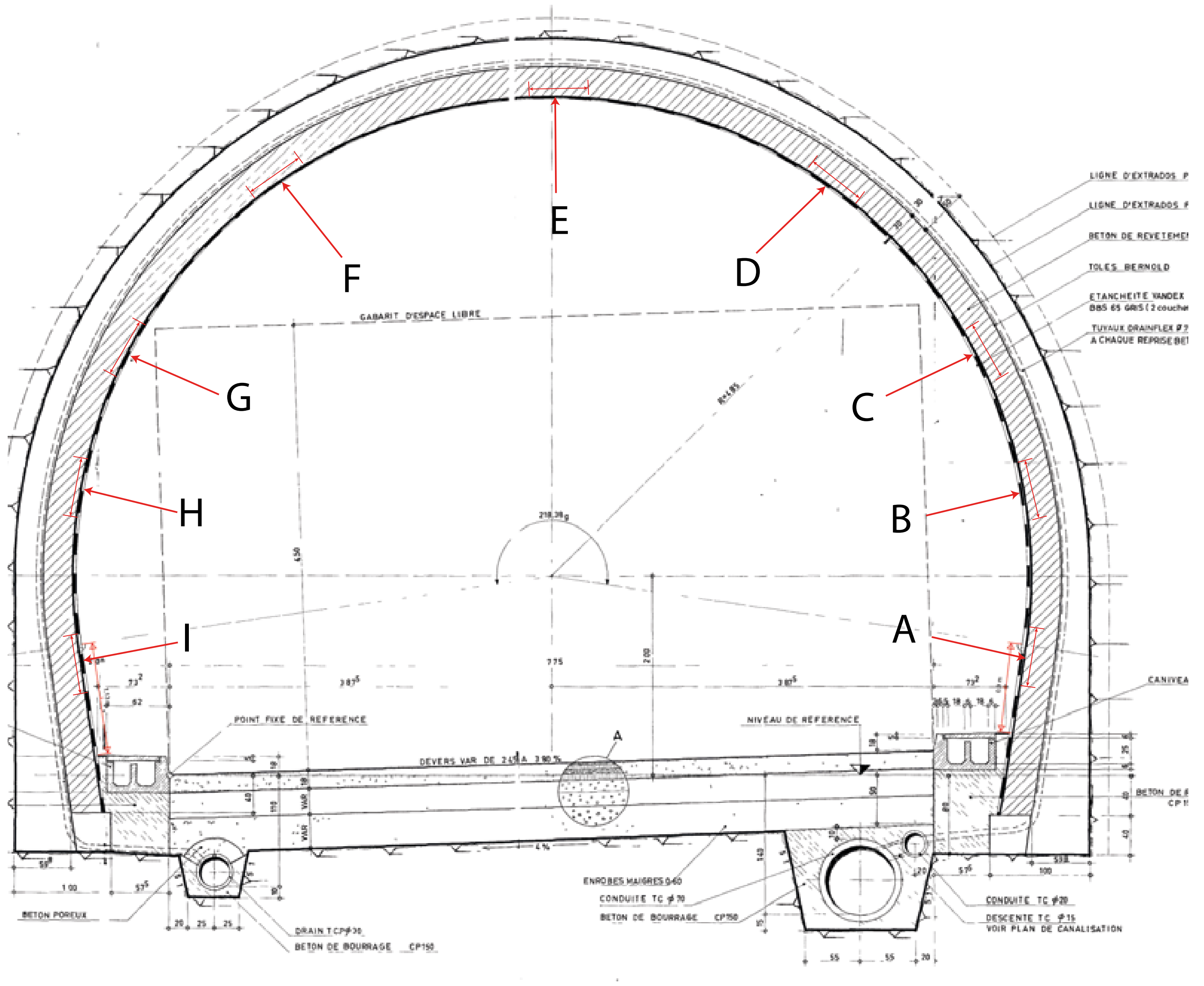



| Evaluation | Caracteristics | Evaluation |
|---|---|---|
| | Carbonatation | |
| 10 [mm] | Concrete Cover | 32 [mm] |
| 2.34[%] | [Cl-] | 0.06[%] |
| | Rebar condition | |
| | Strand condition | |
| | Waterproofing | |
| | ASR Top | |
| | ASR Bottom | |
| | Microstructure | |
| 50 MPa | Resistance | 44.2 MPa |

# Structure mapping – Tunnel

## Methodology

A series of 9 longitudinal profiles of 135 [m] at the nacelle. The traffic interruption lasted 2 x 6 hours. The measurement density was determined to maximise the area inspected and form a realistic compromise between the measurement time and the accuracy of the final result.




## Objectives

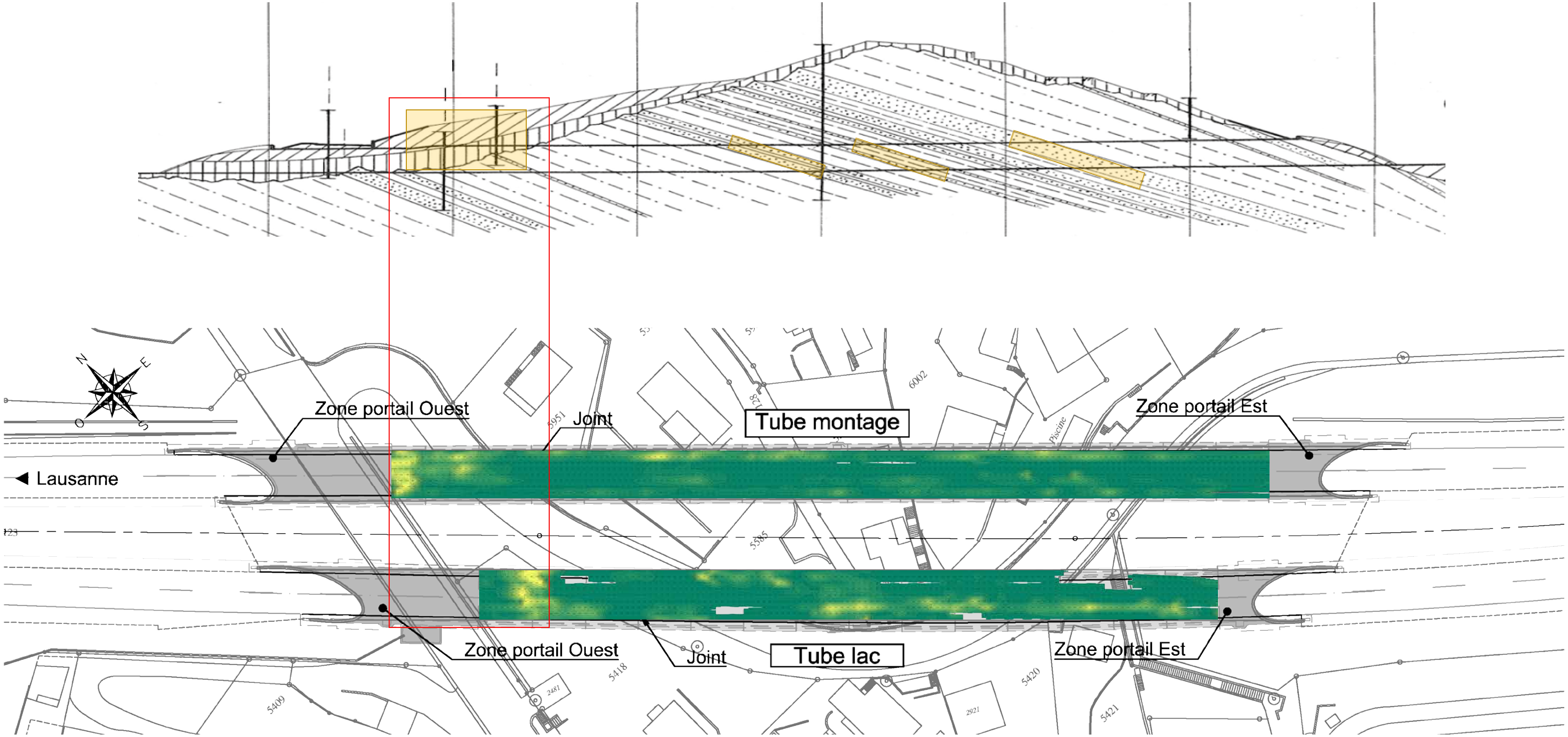
The first part of the study consisted of measuring the facing thicknesses of the structure in preparation for the renovation work.

As the structure showed signs of degradation due to water circulation. The objective of the study was to determine the points of accumulation and weakness of the cladding.

# Structure mapping – Tunnel

## Observations

Link between the risk of detachment and the change in geological layers.
A particularly degraded area is observed at the western portal.

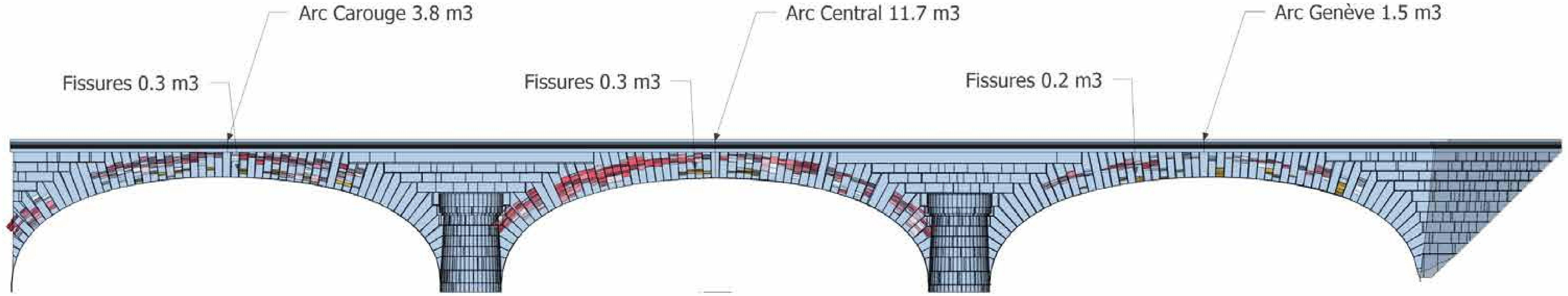


# Structure mapping – Tunnel

### Observations

An area of soft ground is located between two roads, this area being at the apex of the infiltration observations.
It could act as an entry point and reservoir, accelerating degradation.

# Structure Mapping – Masonry Bridge



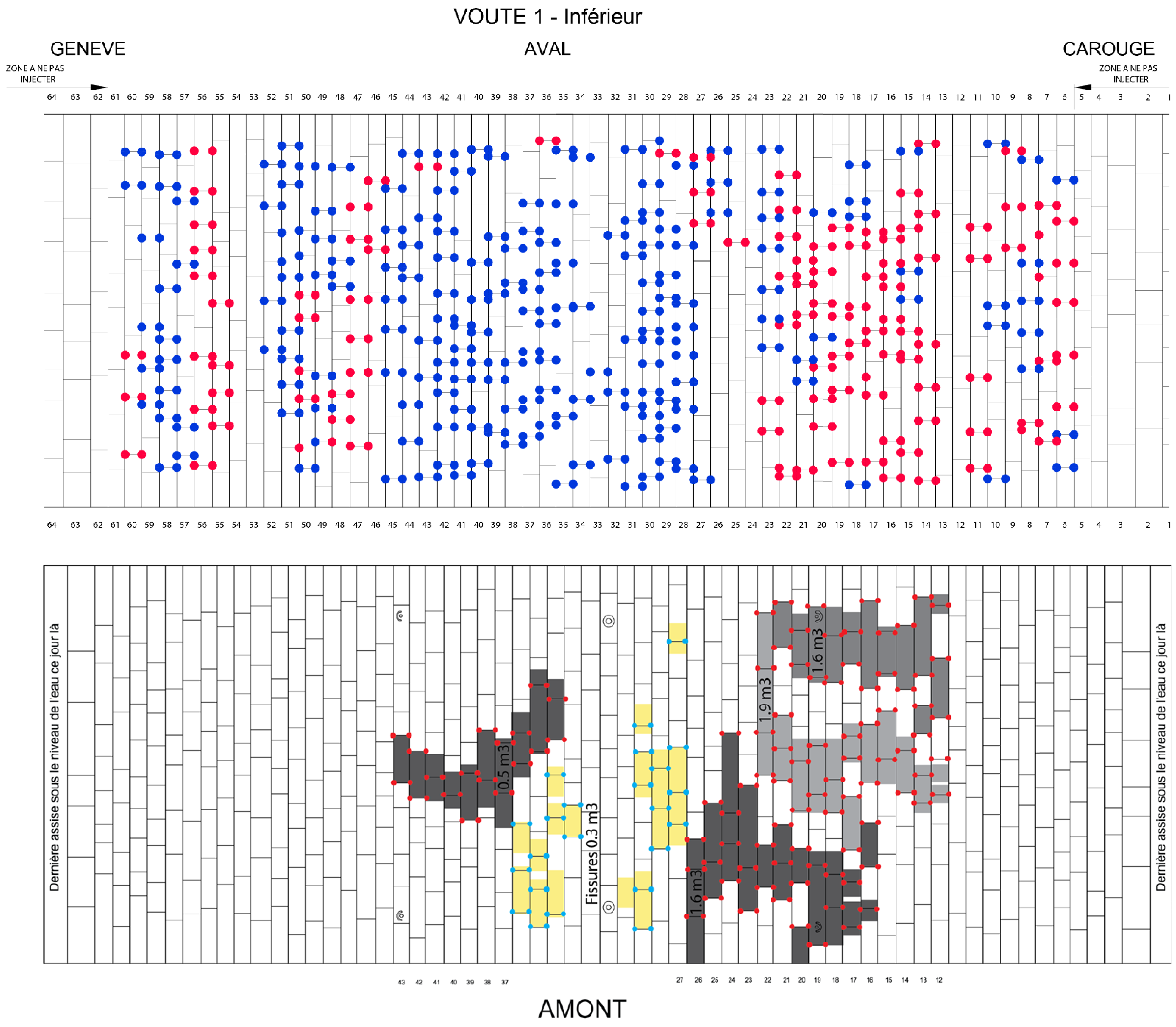

## Objectives

The bridge had a faulty waterproofing. We were mandated to determine the type and number of disorders present within the structure. Cracks, voids and joint defects. Finally, we were asked to estimate the filling volumes.

## Methodology

240 GPR profiles collected in 6 nights of measurements. 3D mapping of vaults

# Structure Mapping – Masonry Bridge



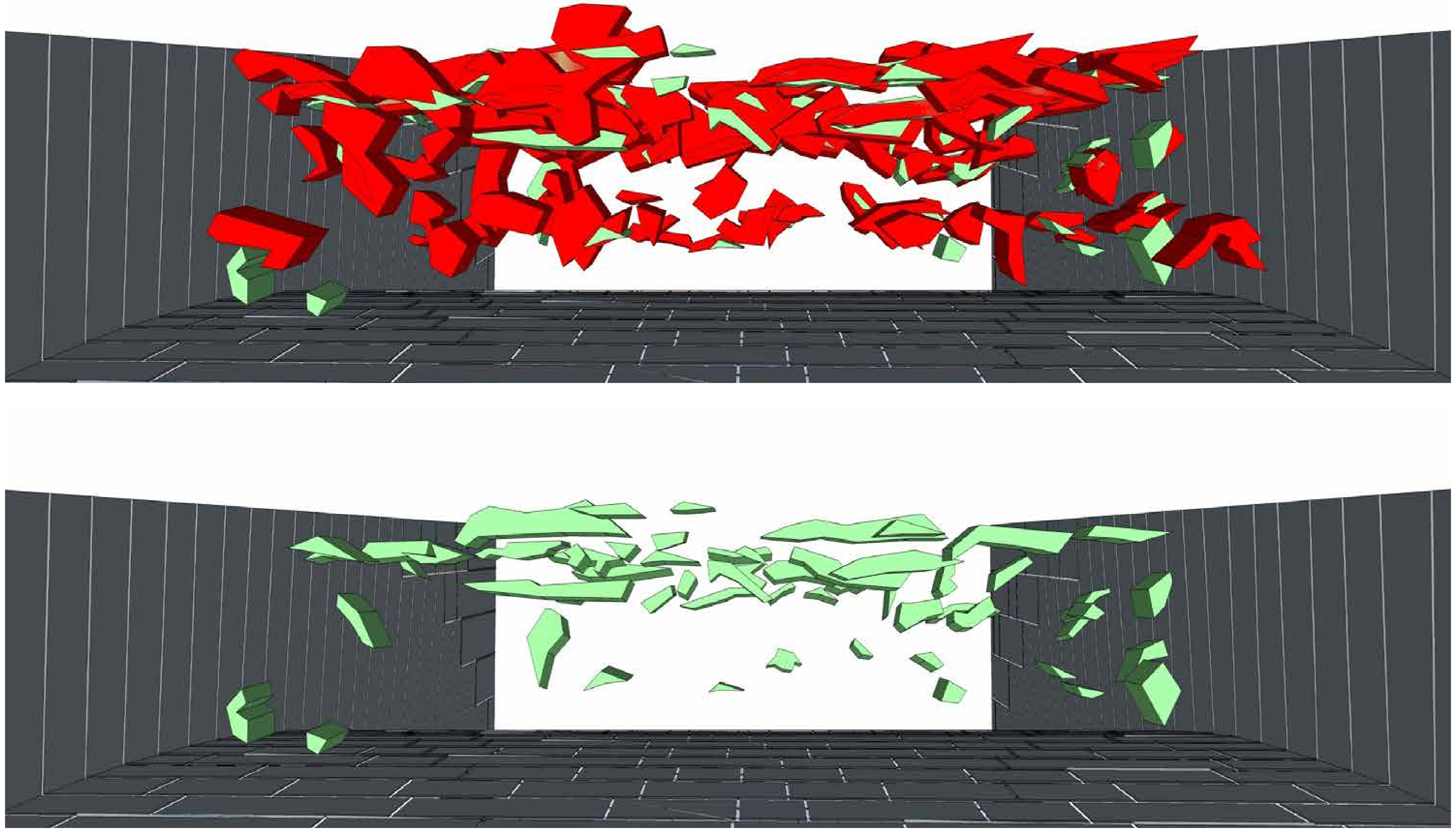

## Injection protocols

After the initial inspection, the injection points are installed on an unfolded view of the structure. A colour code indicates the depth, in red 1 [m] in blue 0.5 [m].

The piercing took place 10 days before the injections to allow the structure to dry.

Following the first stage of injections, a secondary inspection was carried out, the remaining volumes were estimated and further injections were targeted.

# Structure Mapping – Masonry Bridge



In red voids before injection, in green after 1st injection

## Results

The objective was a 75% void reduction achieved after two injections (79% void reduction). Intervention was effective, deadlines and volumes were respected.

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