fib Symposium2025
Antibes - France
Concrete Structures :
extend lifespan, limit impacts

16-18 June, 2025

3-year results on the corrosion of reinforced concrete specimens exposed to carbonation at natural ageing sites (PerfDuB project)

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and

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I- Background, main objective and questions

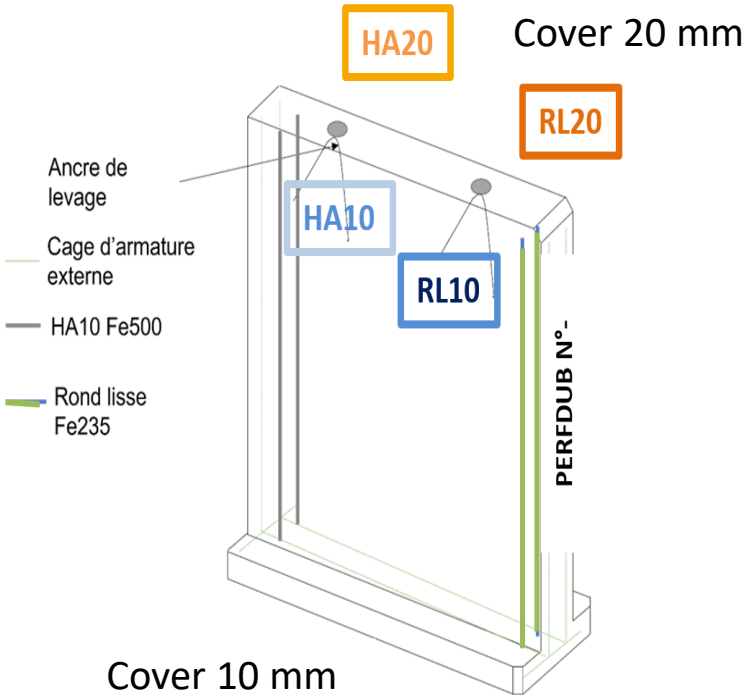
- **French national PerfDuB project (2015-2022)**
  - Performantial-based approach
  - + Corrosion approach

- **Study the durability of metric reinforced concrete specimens exposed in natural ageing sites**
  - Fib Symposium, Antibes
  - Special session 12: "On-going durability and corrosion studies on the metric specimens cast as part as the PN PerfDuB and exposed to natural ageing sites"

- **Questions**
  - ? Concrete mix performances: Portland and new binders
  - ? Corrosion assessment: background for CEM I but what about the other binders, particularly the ones with a lower carbon footprint
  - ? Corrosion testing and interpretation for steel reinforcement that are in concrete made of materials with a lower carbon footprint (validity of Rilem TC154 recommendations)
  - ? Durability with time (corrosion monitoring) ➔ long-term research

II- Experimental program (1/3)
Metric reinforced concrete specimens

❑ Reinforced concrete specimens (11 + 3)



❑ Steel reinforcement

- Smooth (RL)
- Corrugated (HA)
- Mesh (T)

❑ Concrete mix

Concrete number_Binder_Addition_addition content_ binder content (kg/m³)_water-binder ratio

B01	B01-CEM I_280_0.62
B02	B02_CEM I_V30_330_0.52
B04	B04_CEM III/A_290_0.61
B05	B05_CEM I_S60_310_0.57
B07	B07_CEM I_L41_450_0.42
B31	B31_CEM III/A_385_0.4
B36	B36_CEM V/A_ (S-V)_365_0.46
B37	B37_CEM V/A_(S-V)_370_0.45
B38	B38_CEM I_V8_390_0.5
B40	B40_CEM I_Qz30_370_0.47
B41	B41_CEM I_MKf20_380_0.35

II- Experimental program (2/3)
Natural ageing sites for carbonation

- Exposure class XC4
- Since 2020

11 specimens
at CERIB
in Epernon (EP)

3 specimens with sensors
at the Université Gustave Eiffel
in Champs-sur-Marne (CSM)

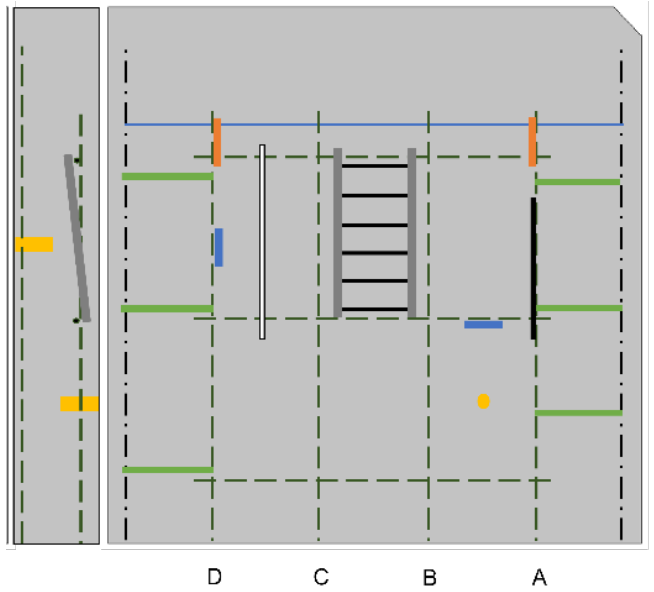
II- Experimental program (3/3)
Corrosion diagnosis (Non Destructive Techniques)

Instant evaluation with laboratory potentiostat

- ❑ Potentiostat Vionic from Metrohm
- ❑ Electrochemical cell: 3 electrodes (WE, RefE and CE)
- ❑ 1 location per reinforcement (2 per faces)
- ❑ Measurements:
  - Half-Cell Potential
  - Linear Polarisation Resistance
  - Half-Cell Potential
  - Impedance spectroscopy
  - Half-Cell Potential
- ❑ Calculation of corrosion current density (Randles circuit and Stern and Geary equation)
- ❑ Yearly basis

Continuous monitoring using embedded sensors

- ❑ Embedded sensors
  - ERE20
  - MRE
  - AL
  - HMP110
- ❑ Weather station in the site



- ❑ Measurements every hour with the acquisition system (Ibac, Aachen University)

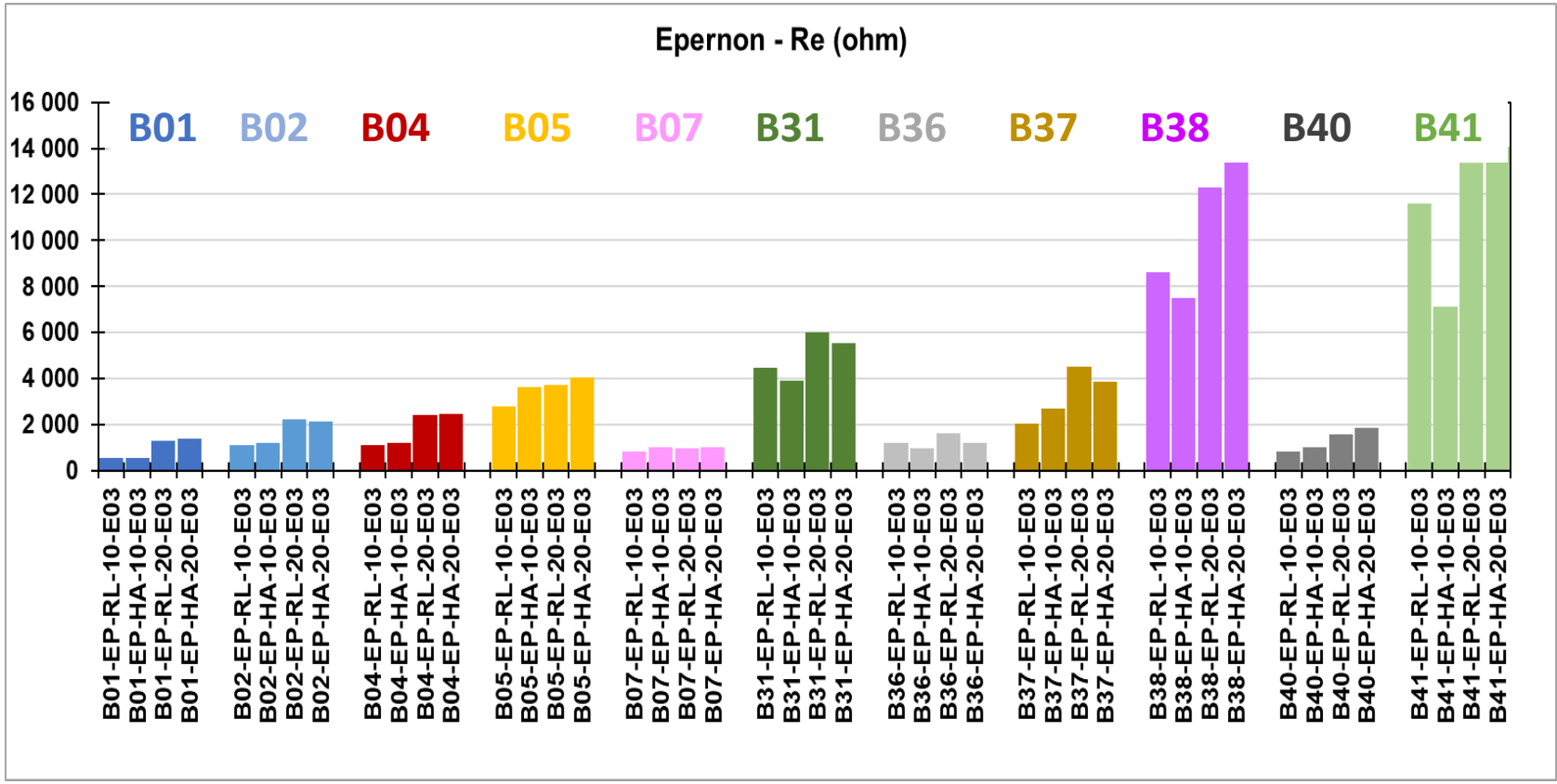
III- Visual results

- **Visual observations after 4 years**
  - Corrosion products are not visible
  - Vertical cracks were observed in reinforced concrete specimens B02, B04 and B07.
  - For example, in specimen B04, on the face with a 10 mm cover, the length and width of the vertical cracks along rebars RL and HA were 50 cm and 0.1 mm respectively.

IV- Electrochemical results: resistance

- Resistance values for concrete cover 20 mm is higher than for concrete cover 10 mm (as expected)

- Comparison of resistance values with concrete mix:
  - Highest values: B38, B41, B31 and B05
  - Lowest values: B01, B07, and B36



IV- Electrochemical results: Potential and corrosion current density

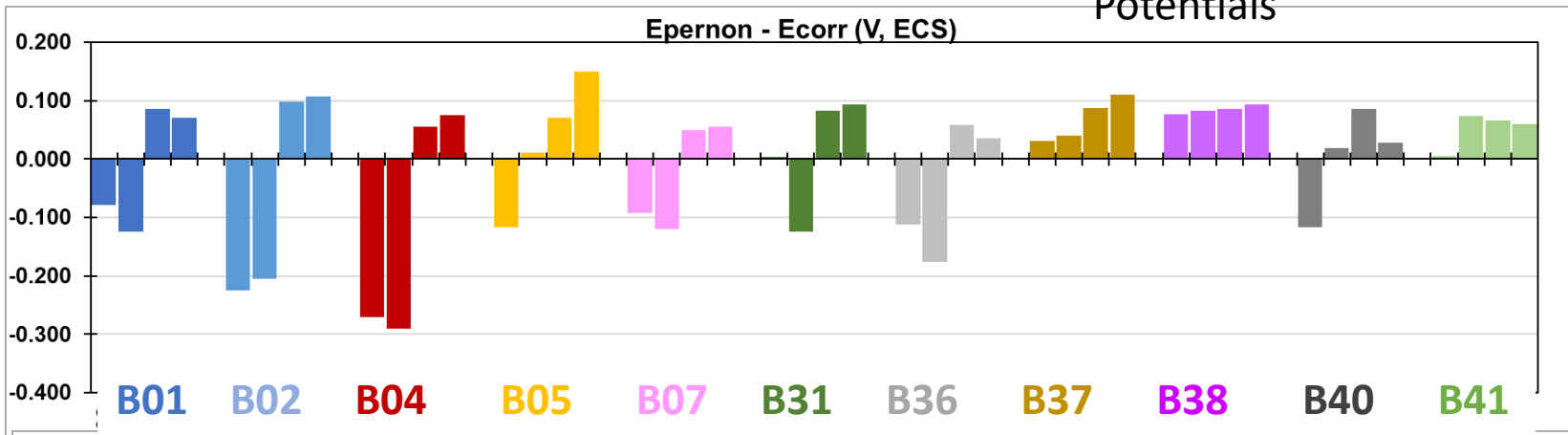
❑ Corrosion assessment

- Potential values increases when the concrete cover increases (as expected)
- Corrosion current density decreases when the concrete cover increases (as expected)

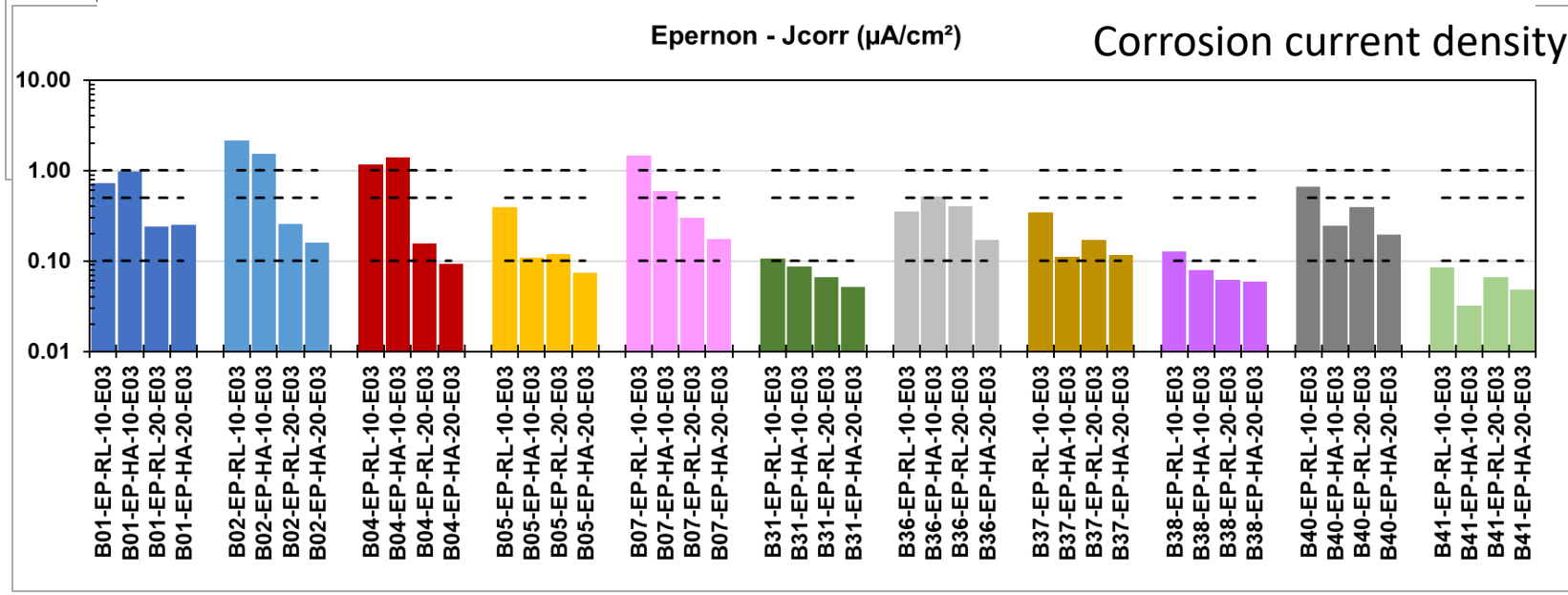
❑ Ranking Jcorr

- Highest: B02, B04, B07 and B01.
- Lowest: B41, B38 and B31 (in good agreement with resistance values)

Potentials



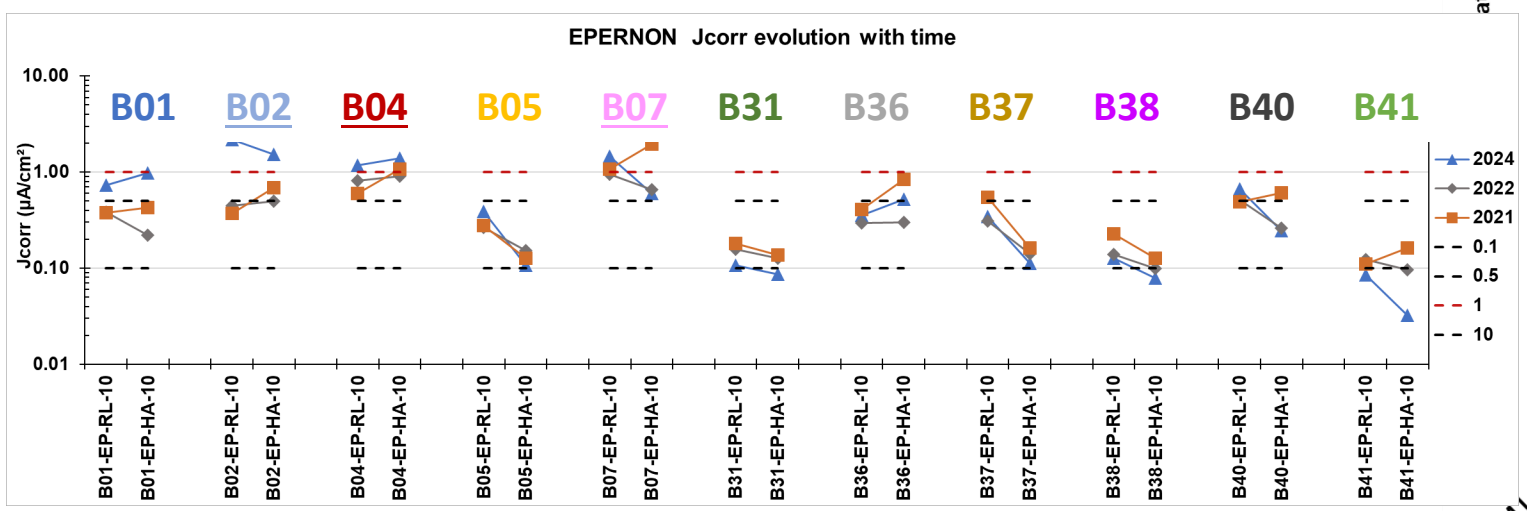
Corrosion current density

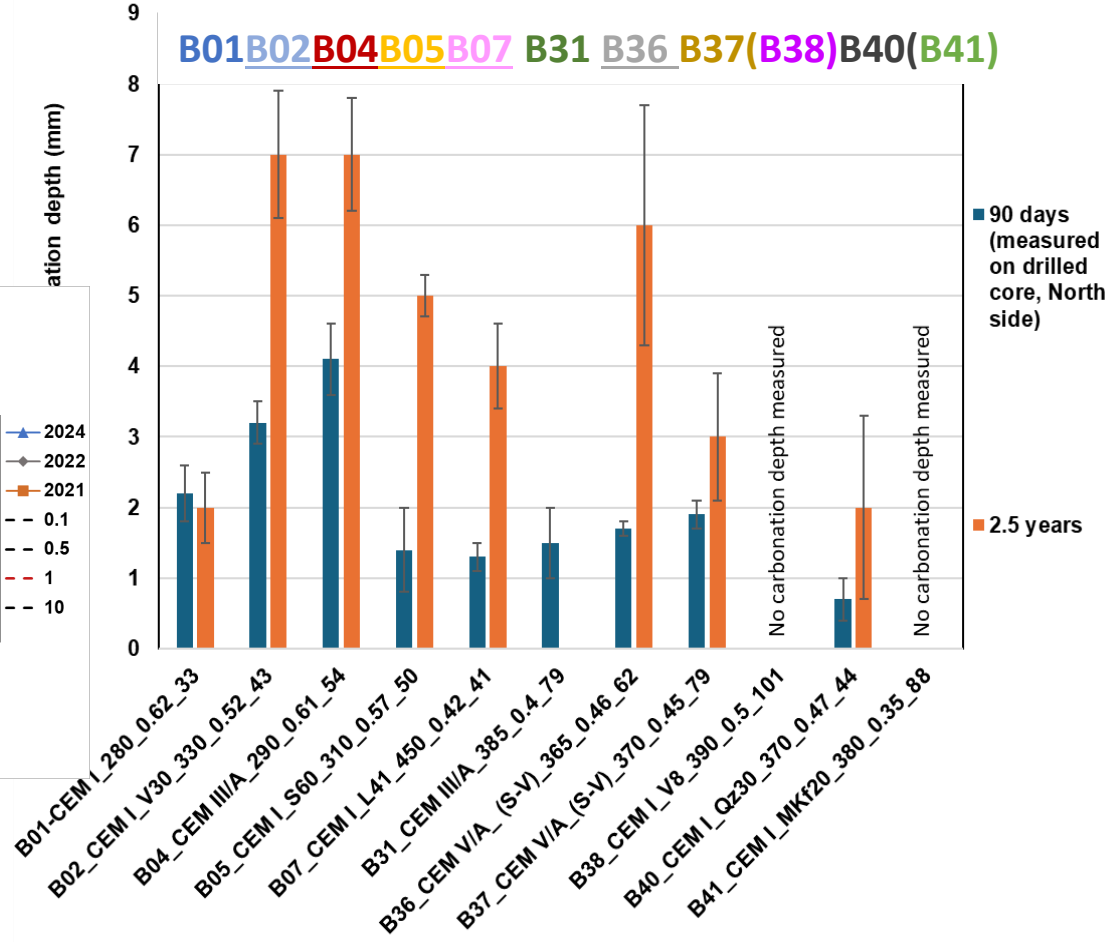


IV- Discussion: evolution of Jcorr with time and carbonation depth

- Jcorr after 4 years (cover 10 mm) ≥ 1µA/cm²
  - B01, B02 and B04 (increases with time)
  - B07

2024
2022
2021

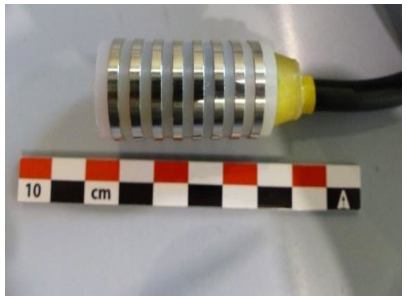


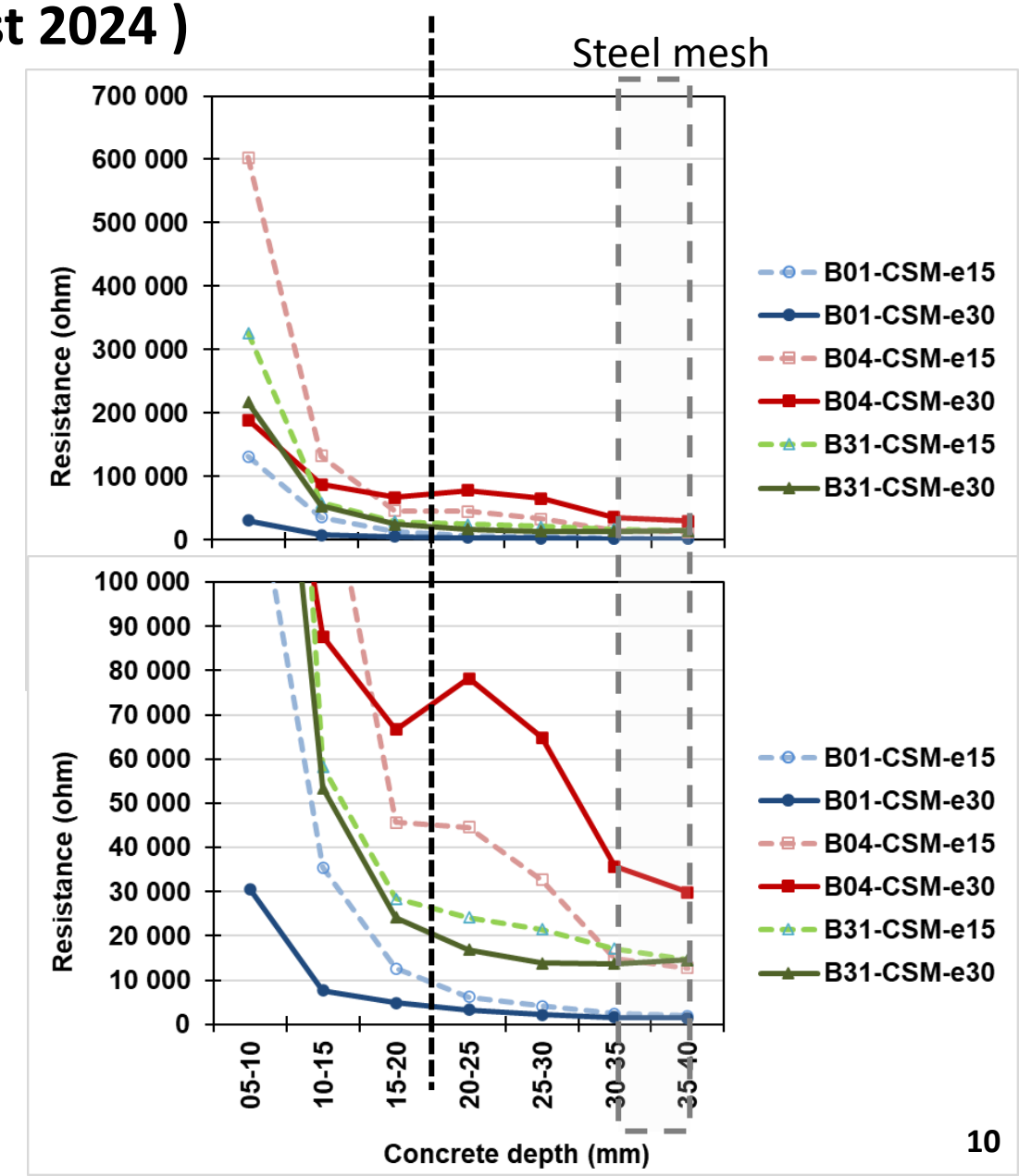


- Jcorr good agreement with carbonation depth for B02, B04 and B07
- Jcorr good agreement with visual observations for B02, B04 and B07

V- Continuous monitoring results MRE

Resistance Ai-Ai+1 profiles (28 August 2024)



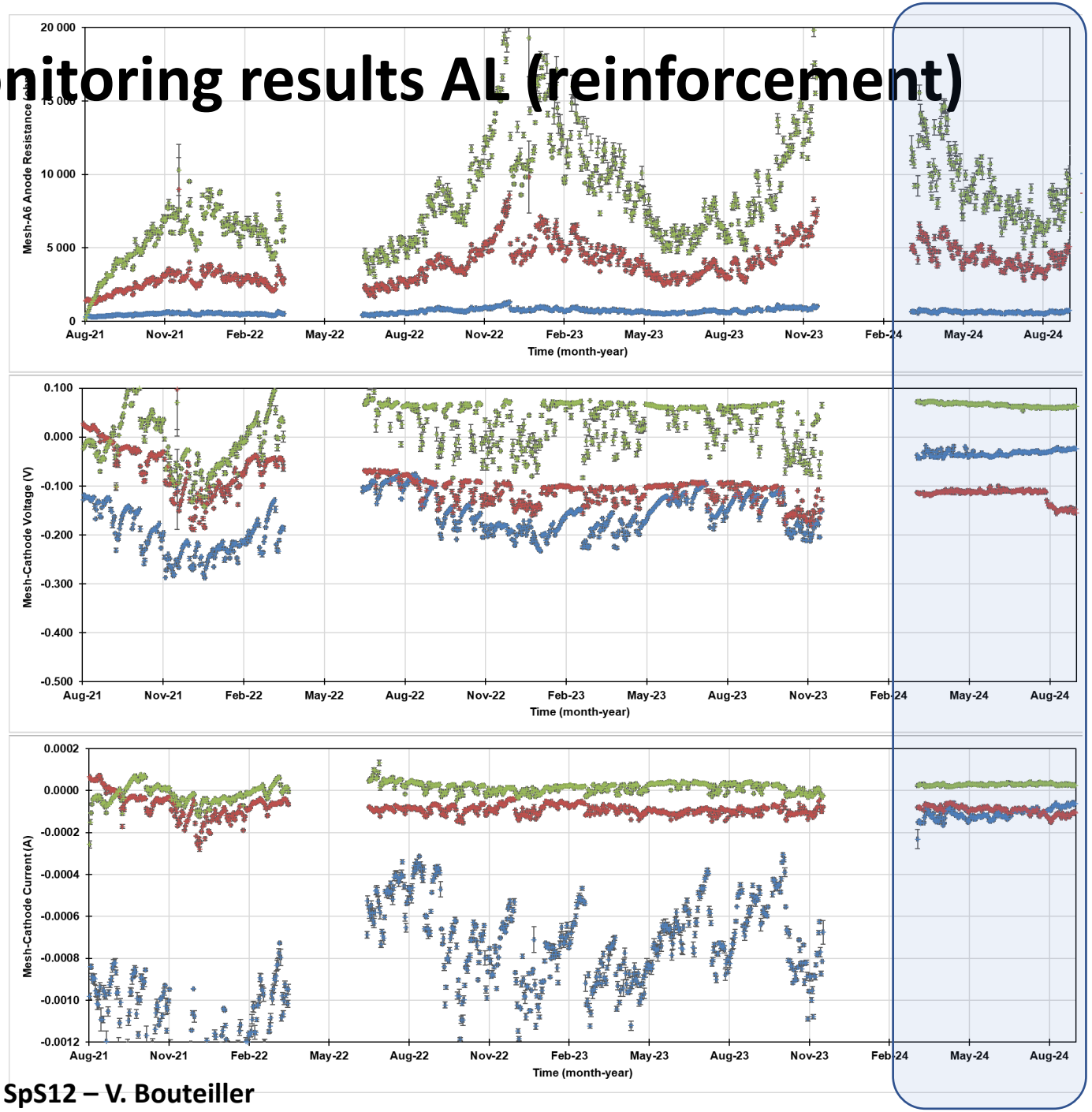


- **Profiles interpretation**
  - Weather influences the resistance values up to a 20 mm concrete depth.
  - One good way to check for the risk of the steel mesh corroding is to keep an eye on the concrete resistance at the reinforcement depth.

V- Continuous monitoring results AL (reinforcement)
(since August 2021)

- **Evolution with time?**
  - Daily average measurements
  - 2 repairs of the acquisition system in 3 years
  - No information yet on active corrosion from the anodes

- **Comparison of concrete mix (reinforcement)**
  - Resistance B01 < B04 < B31
  - Voltage B04 < B01 < B31
  - Current B31 < B01 ≈ B04
  - B04 carbonation?



VI- Conclusions and outlook

- Based on NDT, corrosion has already started on steel rebars in some mixes exposed at Epernon (B02, B04, B07 and B01) with the lower concrete cover of 10 mm. There are some cracks along the steel bars, but no sign of rust.

- Continuous corrosion monitoring is ongoing on the reinforced concrete specimens B01, B04 and B31 with cover thicknesses of 15 and 30 mm in Champs-Sur-Marne. The MRE and AL sensors are providing interesting comparative information on the mixes, which may help in assessing the corrosion behaviour based on Portland or Slag cements. After four years, it is too early to estimate the time to anode corrosion

- Discuss concrete cover performances together with corrosion resistance of the steel in different exposure classes ➔ Update database with time

- Increase reliability of corrosion results obtained with a laboratory potentiostat (University Gustave Eiffel) and on-site devices (Research Laboratory on Historical Monuments) and corrosion health monitoring

- Study the durability on the long-term (10-20 years) ➔ DÉCISION scientific chair and DECADES scientific interest group

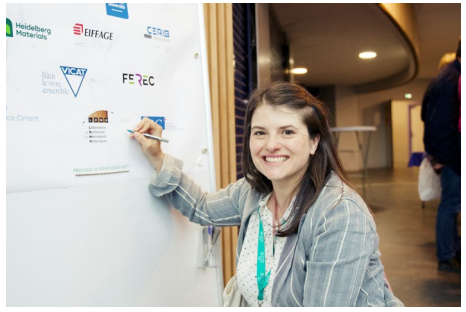
DÉCISION scientific chair

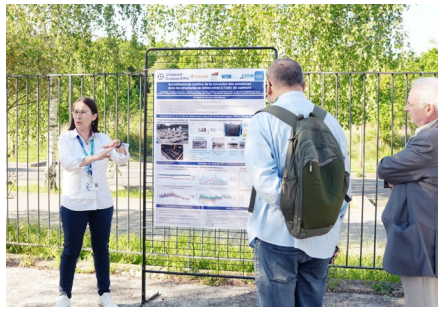
➔ performing collaborative work (2025-2030)

THANK YOU!

Launched on 29 April 2025 at the Gustave Eiffel University in Champs-sur-Marne, France





« Durabilité du bÉton et CorrosIon des armatureS en envIronnements chlOrure ou carboNatation