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

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3-year exposition of PerfDuB specimens in tidal zone: comparison between model predictions and experimental results

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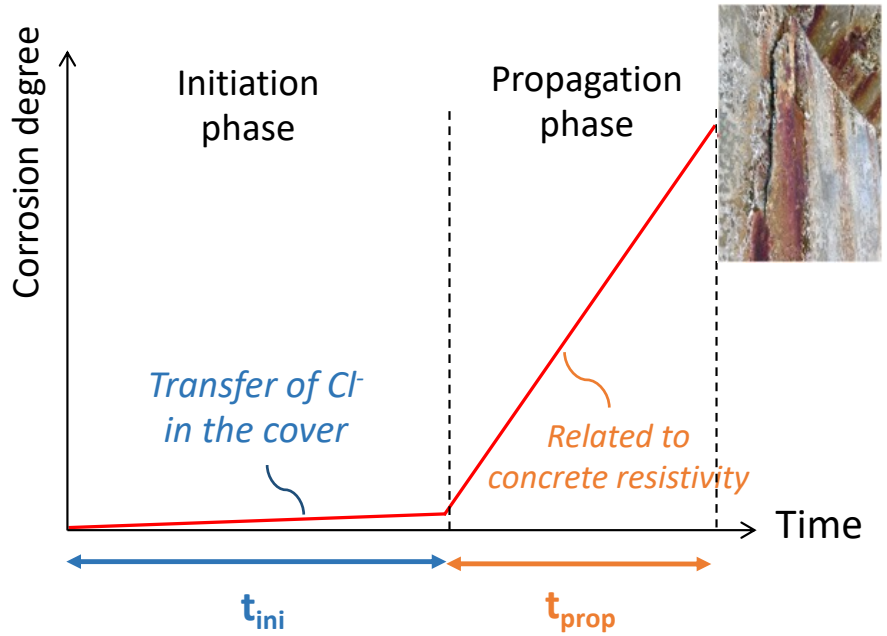
Introduction

National Project PerfDuB - Corrosion due to chloride ingress

✓ An experimental campaign launched in 2020

✓ A model to predict the service-life time (t_{ini}+t_{prop})



First results after 3 years: visual observations of corrosion, electrochemical characterisations → **Comparison with model results?**

Modelling

Initiation period *(modified fib Model-code)*

Chloride content profile (from Fick law):

$$C(x,t) = C_0 + (C_s - C_0)\left[1 - \mathrm{erf}\left(\frac{x - \Delta x}{2.\sqrt{D_m(t).t}}\right)\right]$$

Mean chloride diffusion coefficient: $D_m(t) = f_D(t, T, D_{RCM}, \alpha_M)$

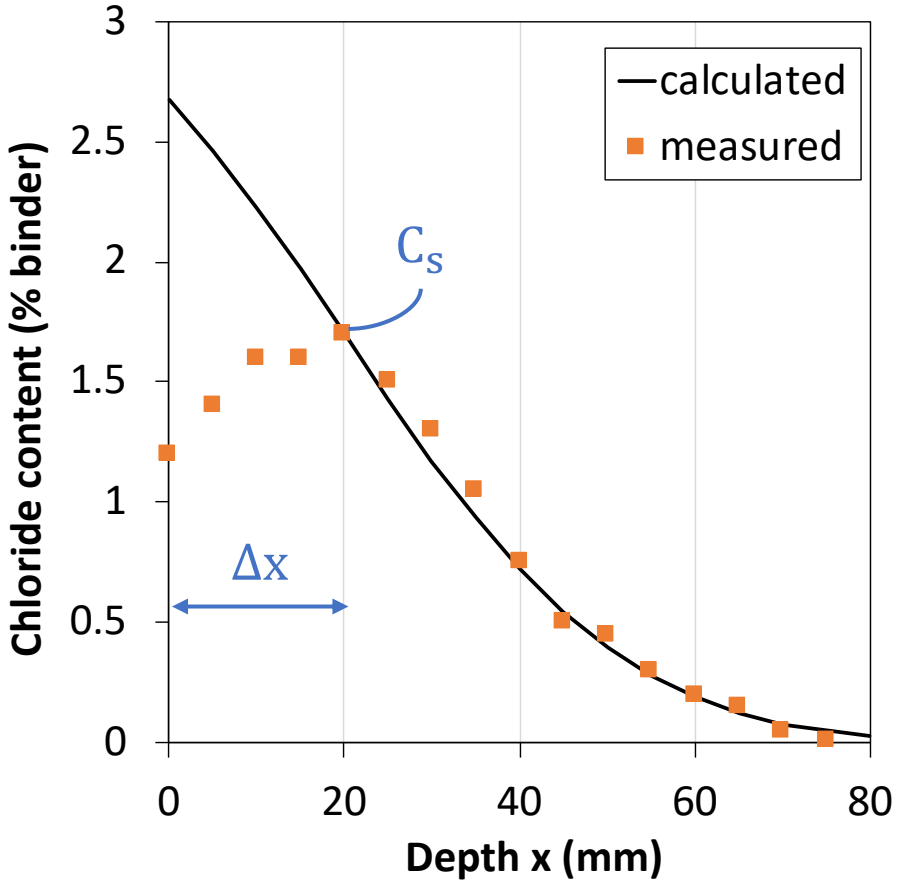
Thickness of the "convection zone": $\Delta x = f_{\Delta x}(\varphi)$

Chloride content at depth Δx: $C_s = f_C(\varphi)$

Main input (durability indicators):

- D_{RCM}: migration coefficient ($m^2.s^{-1}$)
- φ: porosity (-)

Example



A. El Farissi, Prédiction de la durée d'utilisation des ouvrages en béton armé par une approche performantielle dans le cas de la corrosion induite par la carbonatation ou l'attaque des ions chlorure, PhD Thesis, La Rochelle Université, 2020
E. Poulsen, On a model of chloride ingress into concrete having time dependent diffusion coefficient, Chloride Penetration into Concrete Structure, Nordic Miniseminar 1993.

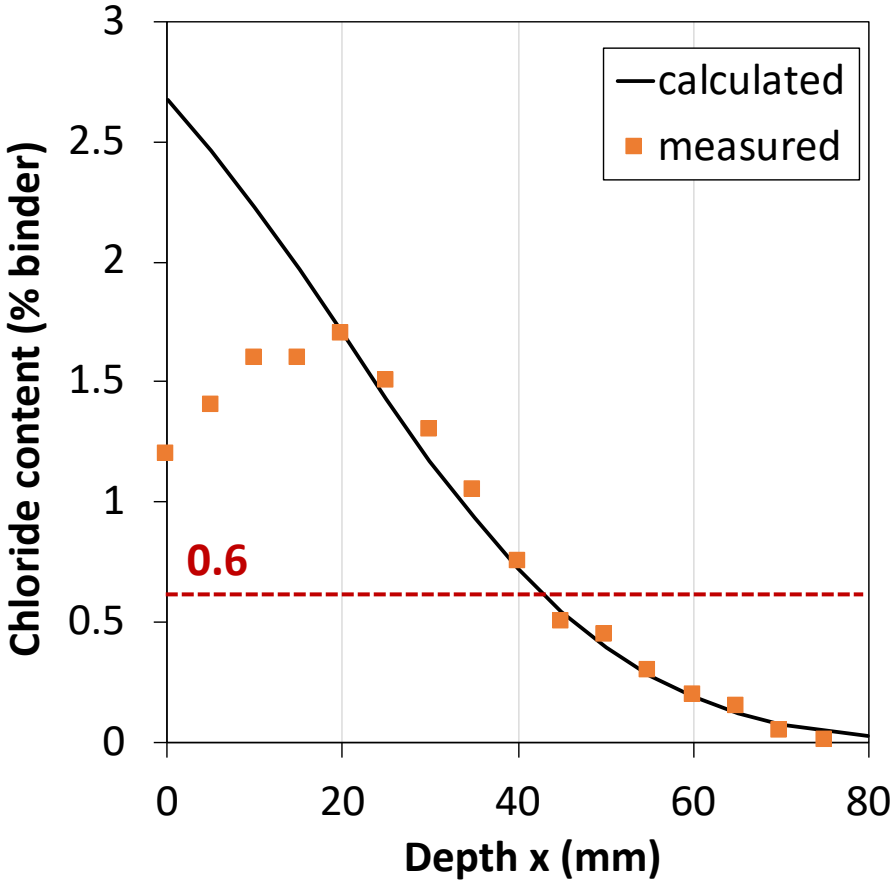
Modelling

Initiation period *(modified fib Model-code)*

Initiation time t_{ini}

Determined so as: $C(x = d, t_{ini}) = C_{crit}$

with:
d: cover depth
Critical content resulting in corrosion : C_{crit} = 0.6% wt of binder

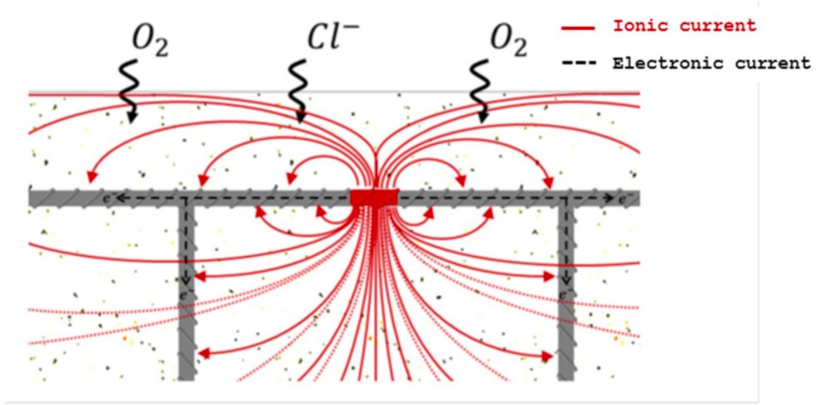


Model

Propagation period

Propagation time:

$$\mathbf{t_{prop} = 2\mu \left(\frac{S_a}{\emptyset}\right) i_{corr}^{-1}}$$



Constant (from Faraday's law): 2μ

Diameter of the steel bar: ∅

Local cross-section loss resulting in **surface cracking**: $S_a = f_{Sa}(\emptyset, d, \text{geometric factors})$

Induced **galvanic current**: $i_{corr} = f_{corr}(\boldsymbol{\rho}, C, \text{ambient parameters})$

Main input (durability indicator): ρ, concrete resistivity

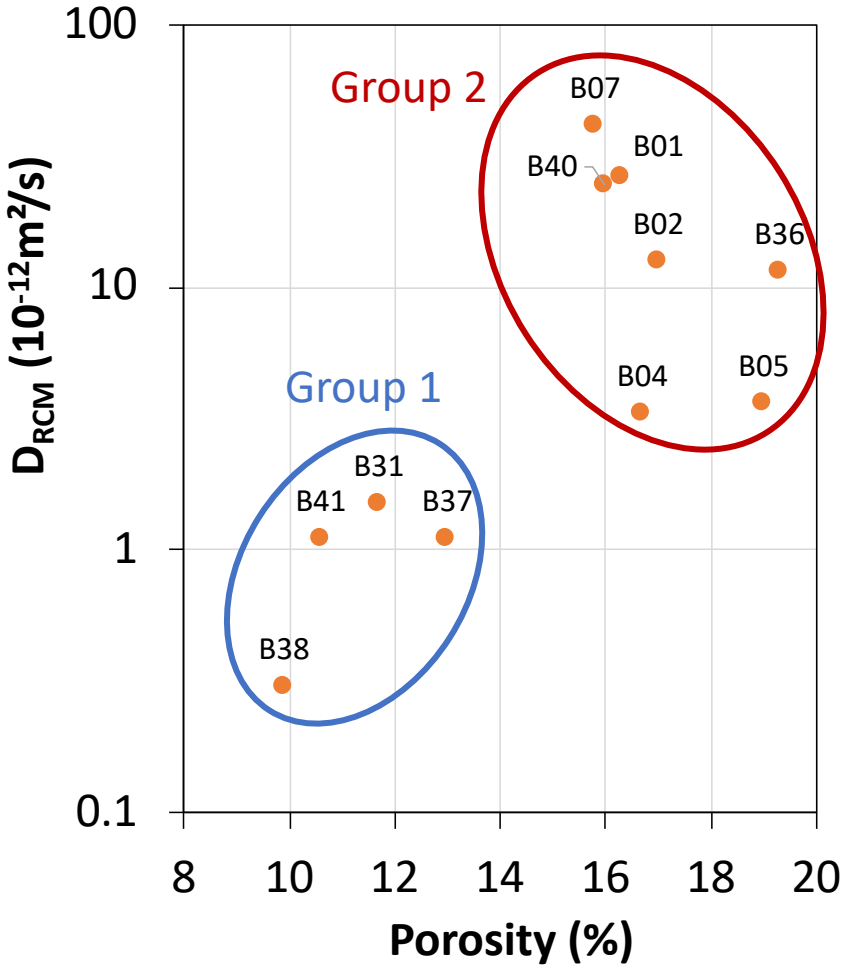
C. Chalhoub, Study of the initiation and propagation phases of chloride induced corrosion in reinforced concrete structures, PhD Thesis, Unv. Toulouse, 2020
R. Français et al, Corrosion and its Consequences for Reinforced Concrete Structures, ISTE Press, 2018

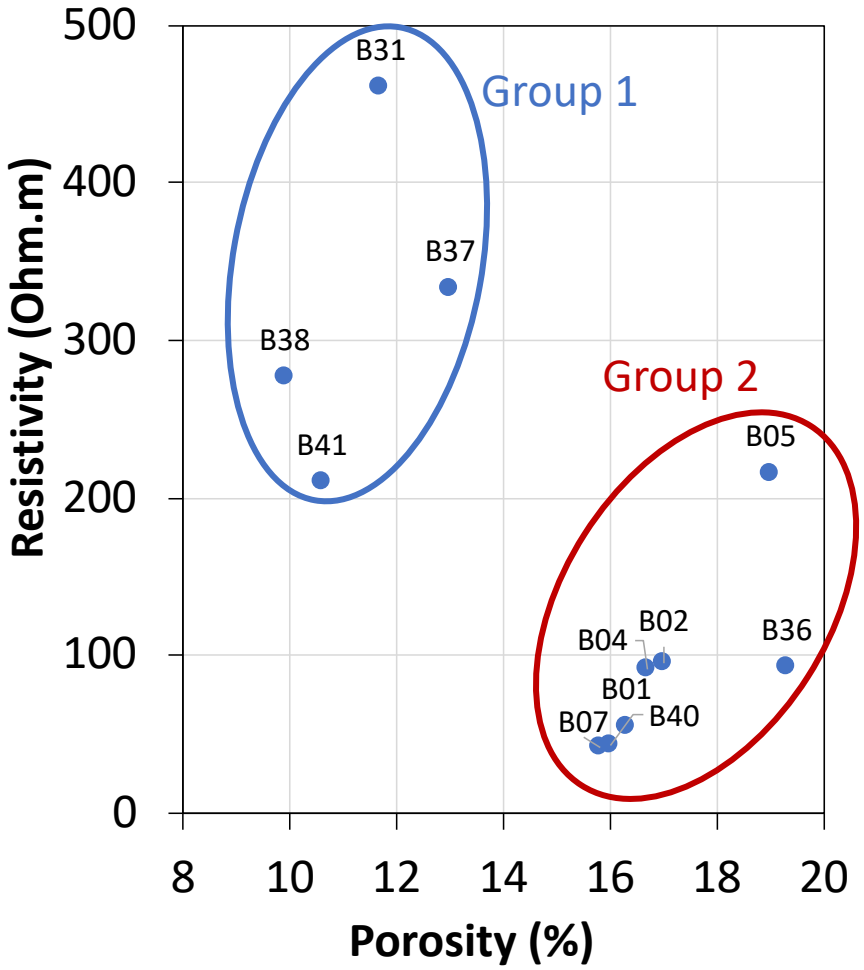
Case study: Perfdub specimens

Data

11 concretes:
2 groups

2 cover depths:
10 and 20 mm





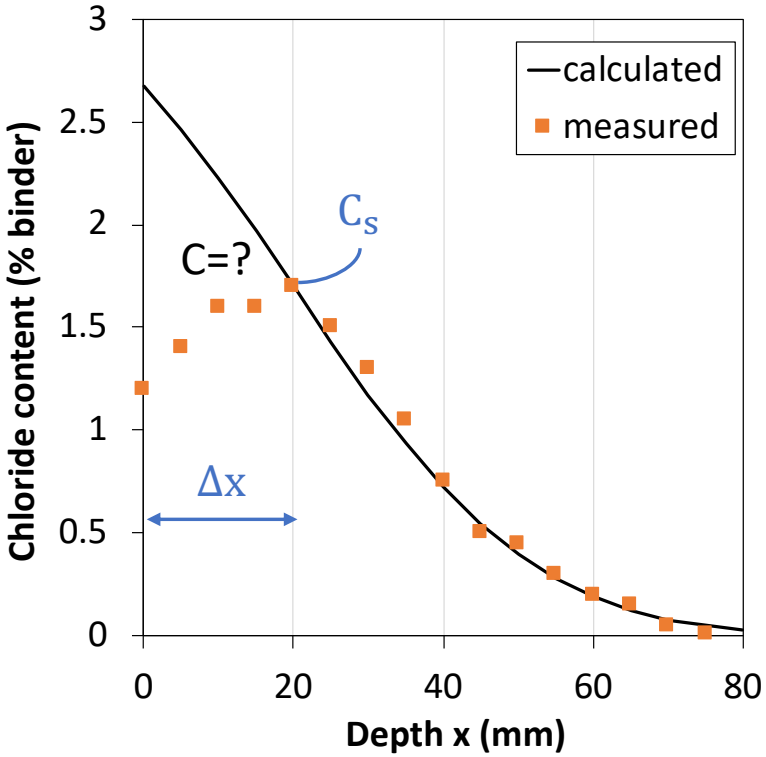
Case study: Perfdub specimens

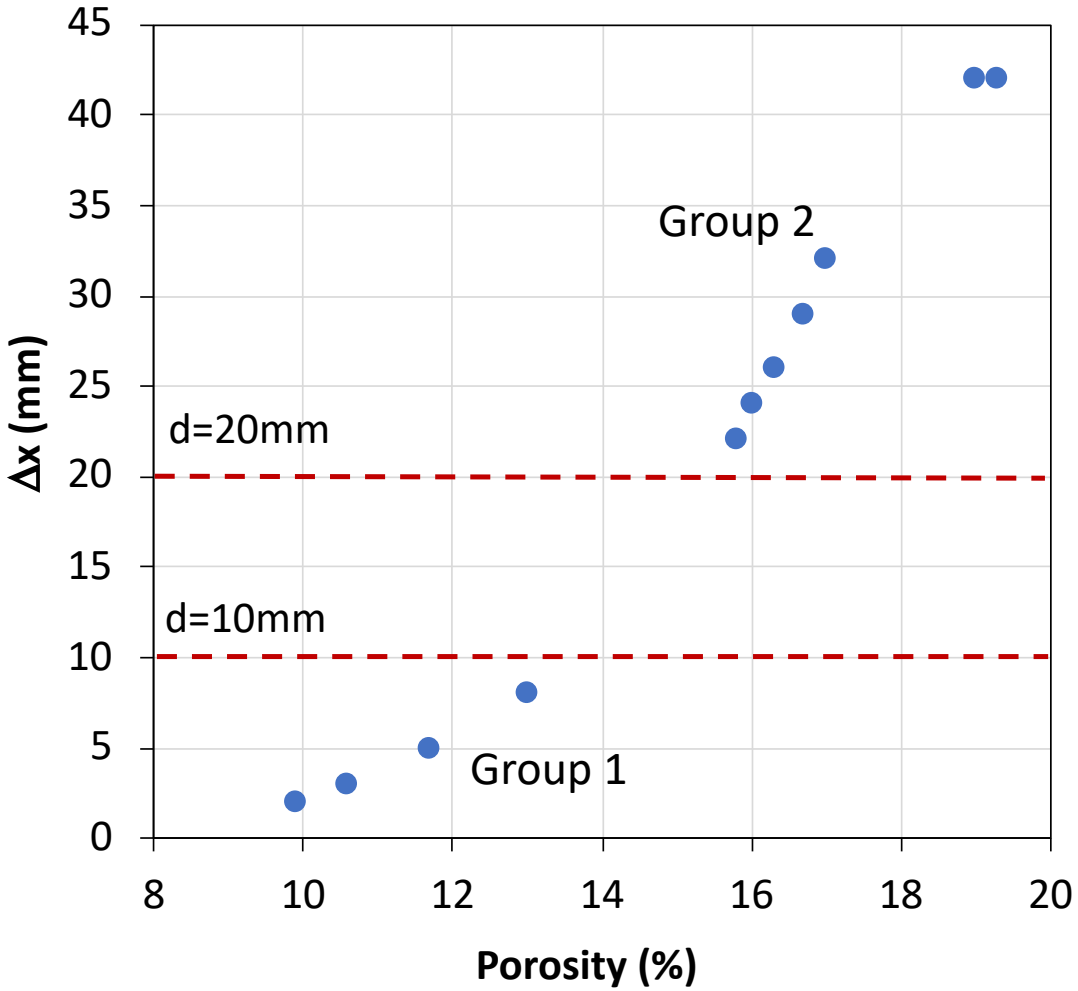
Model results

Calculated "convection zone" delta x

For group 2: $\Delta x > d \Leftrightarrow$ Steel bar in the "convective zone"!

$\Rightarrow$ The "initiation phase" model *unsuitable*…





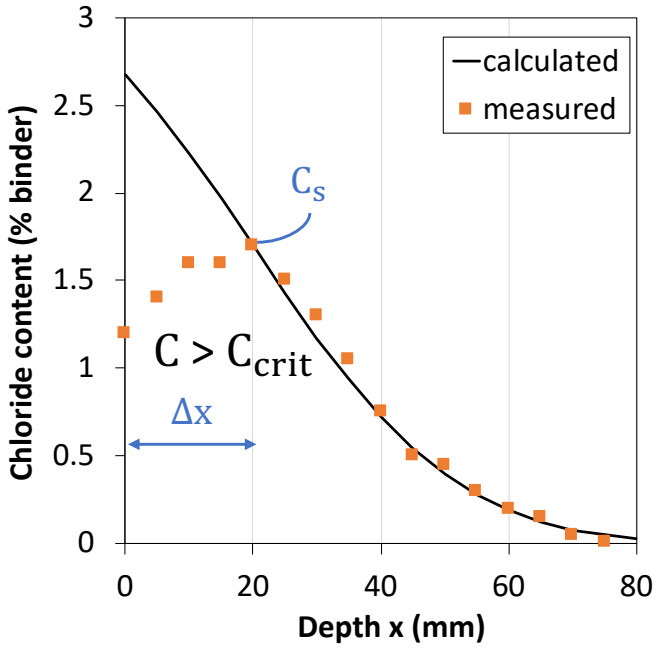
Case study: Perfdub specimens

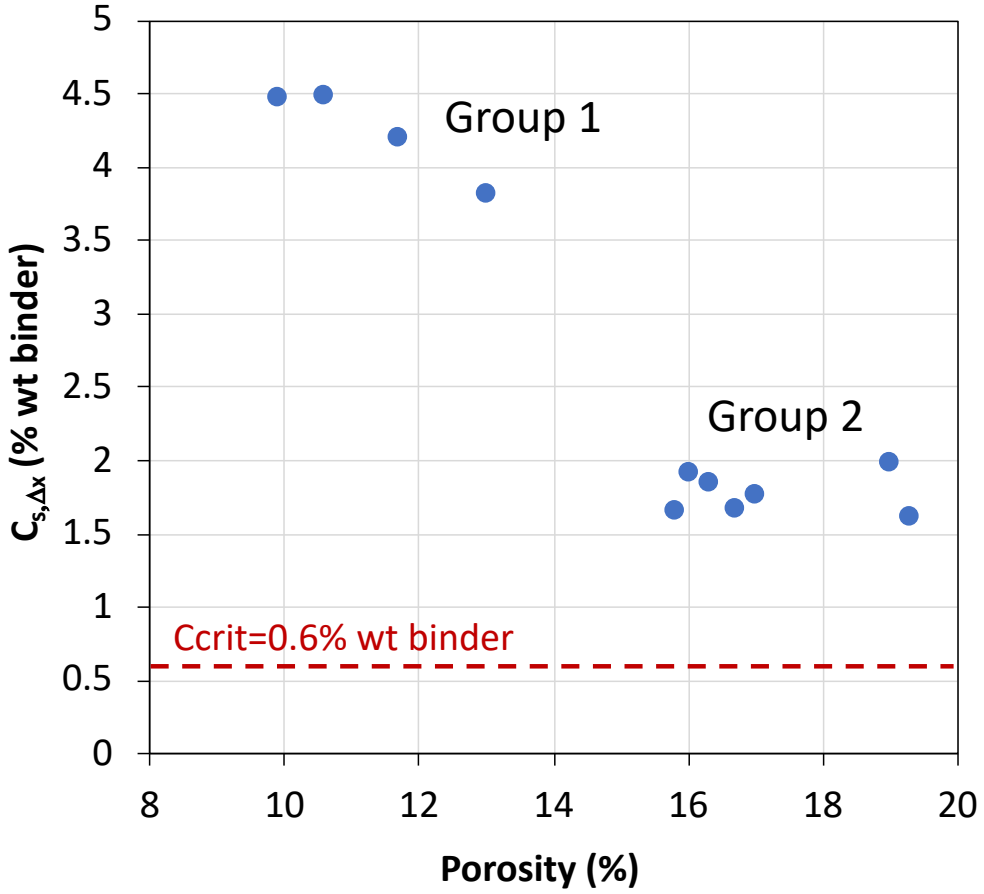
Model results

Chloride content at depth Δx:

C_s >> C_{crit} for all groups

⇒ at x = d, let's assume that $C(d) = C_{crit}$ for group 2
⇒ t_{ini} ~ 0 and $t_{sl} = t_{prop}$

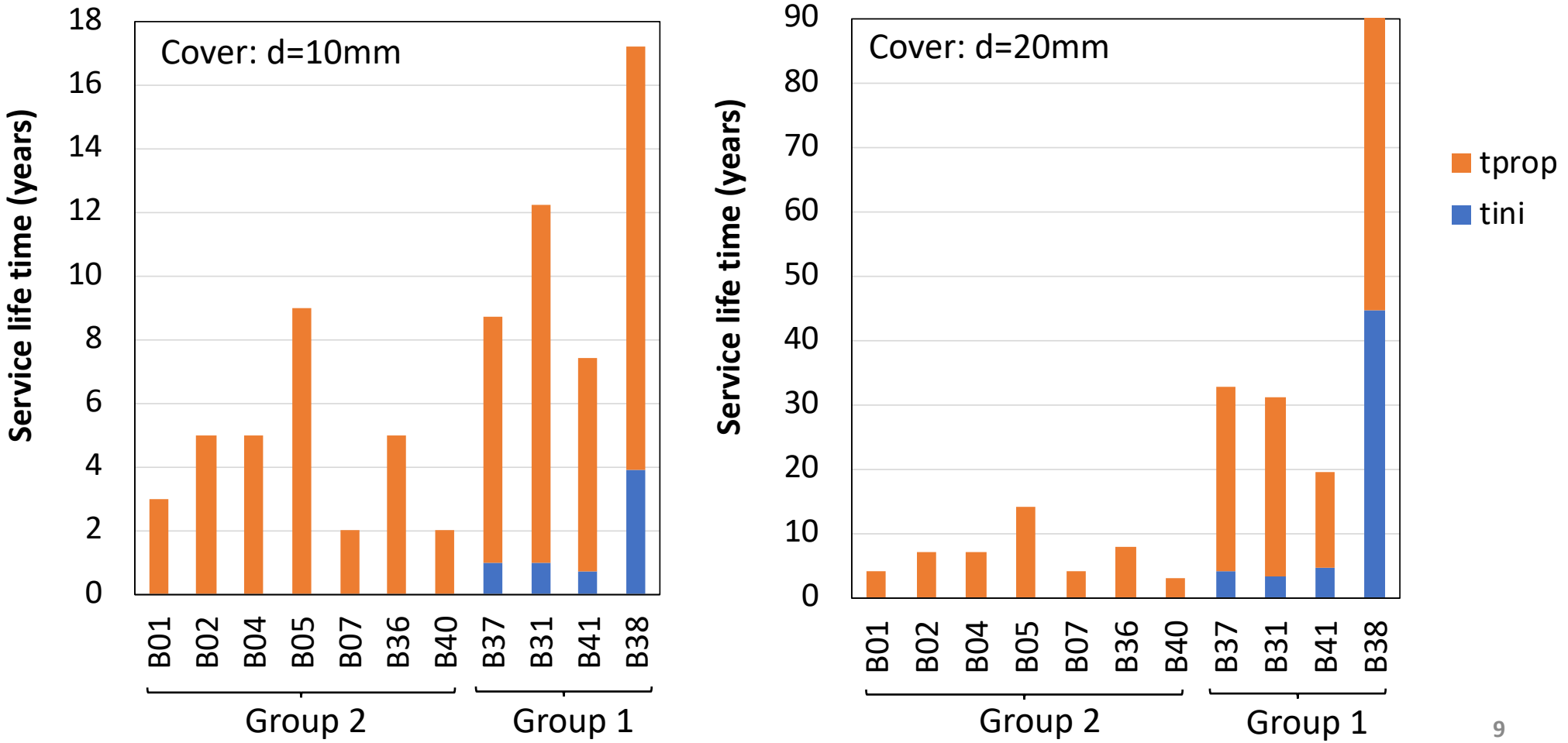




Case study: Perfdub specimens

Model results

Service life time



Case study: Perfdub specimens

Comparison with experimental results after 3 years

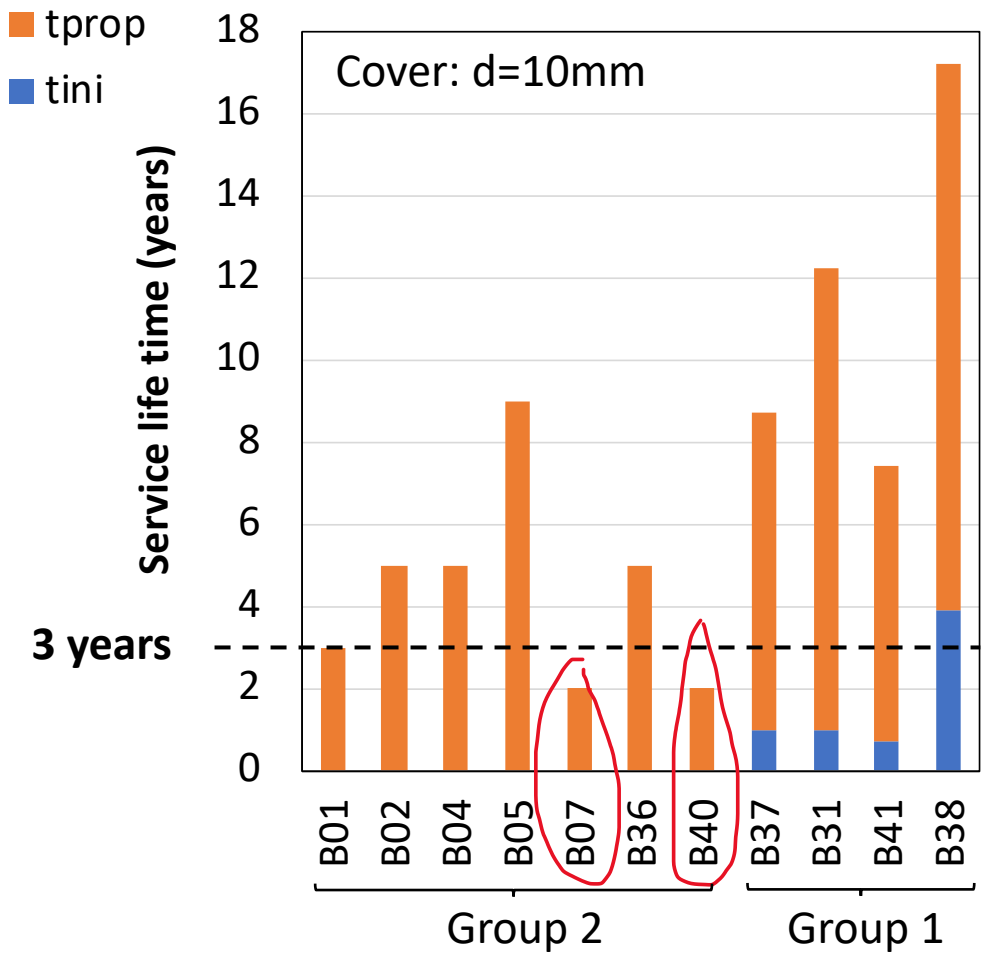
Agreement?

Group	Concrete	Cover d=10 mm	Cover d=20 mm
		Visual observation	Visual observation
2	B01	Yes	Yes
	B02	Yes	Yes
	B04	No	No
	B05	Yes	Yes
	B07	Yes	Yes
	B36	Yes	Yes
	B40	Yes	Yes
1	B37	Yes	Yes
	B38	Yes	Yes
	B31	Yes	Yes
	B41	No	Yes

Case study: Perfdub specimens

Comparison with experimental results after 3 years

Predictions <u>in agreement</u> with observations



Crack predicted vs. crack observed

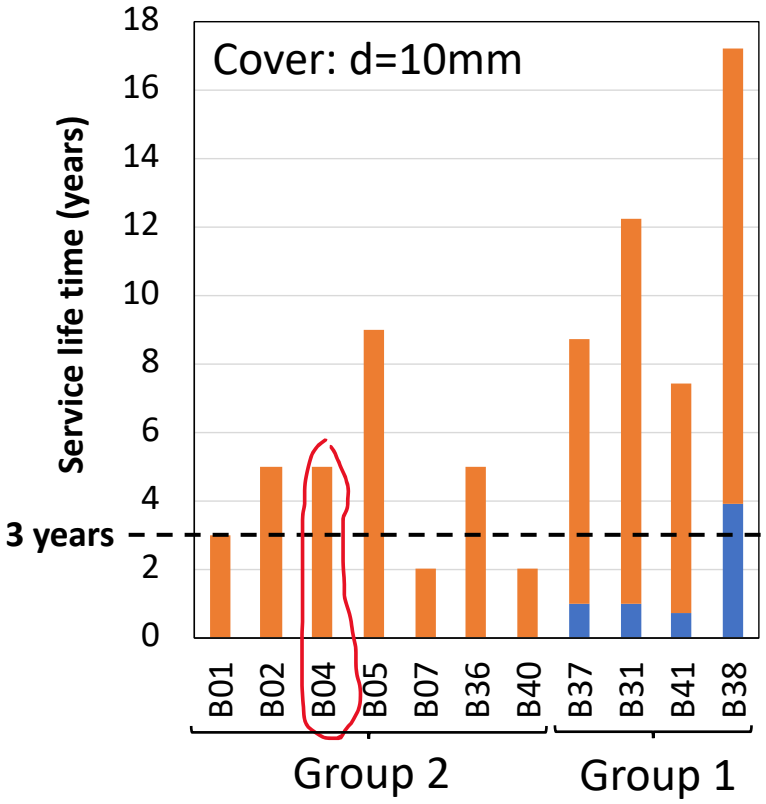
B07 d=10mm

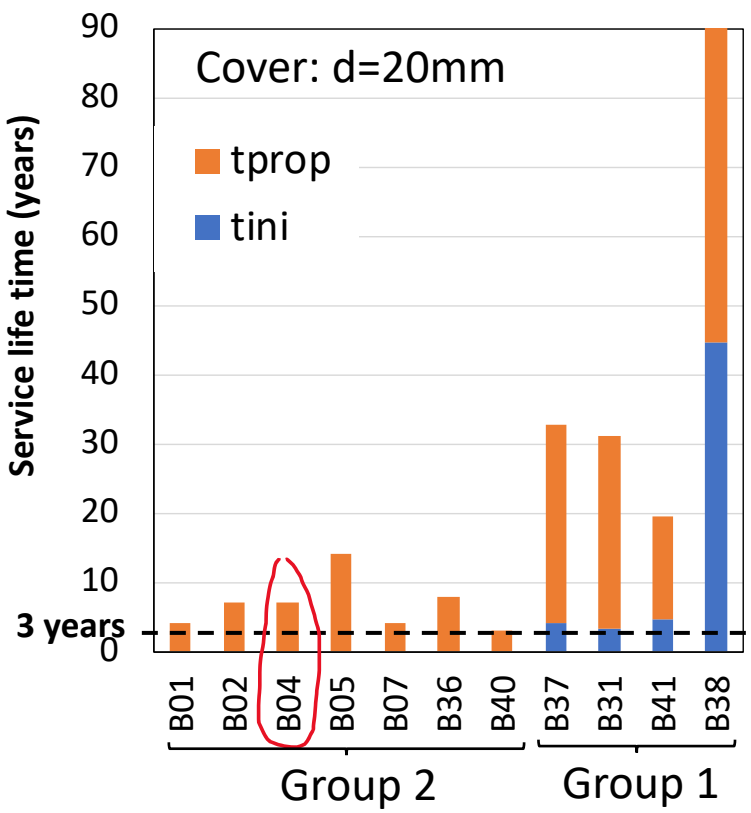
B40 d=10mm

Case study: Perfdub specimens

Comparison with experimental results after 3 years

Predictions NOT in agreement with observations





B04 d=10mm

B04 d=20mm

B04:
carbonation depth~5mm

Cover partially carbonated
Not taken into account in the modelling!

Conclusion

- ✓ A model to predict the service-life time (t_{ini}+t_{prop})
- ✓ Application of the model to predict the corrosion of Perfdub specimens
- ✓ The “Initiation phase model” unsuitable for (very) small cover depths... However, the “propagation phase model” could be used to assess corrosion in this particular case.
- ✓ Propagation time not negligible
- ✓ Globally, model predictions in accordance with observations
- ✓ **To be confirmed with further results in the coming years!**
- ✓ **Next step:** comparison between experimental chloride profiles and initiation time model results

Thank you

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