Belgian Road Research Centre
Together for sustainable roads

EUPAVE
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Influence of hydrophobic impregnation on resistance of road concrete to de-icing salts

EUPAVE webinar “Enhancing concrete durability”
15 February 2022

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Overview

- Introduction
- Laboratory results
- Results from « on-site » samples (cores or fresh concrete)
- Effect of ageing of the products
- Conclusions

Introduction

Durability of concrete road in Belgium largely dependent on freeze-thaw resistance in the presence of de-icing salts.

Long term experience and limiting values in Belgium as a function of traffic load:

- ✓concrete composition: C_{min}, w/c factor, air content
- ✓test method: resistance to scaling

Limiting values prescribed in all regional tender specifications as a function of traffic load

Traffic classes and concrete composition in Belgium

	D_{max} aggregates (mm)	Cement content (kg/m^3)	Water/cement ratio (%)	Air content (%)
Heavy trafficked roads (B1-B5/ Réseau I)				
Top layer (1 or 2 layers)	> 20 mm 6,3 mm < D_{max} ≤ 20 mm ≤ 6,3 mm	≥ 400 ≥ 400 ≥ 425	≤ 0,45 ≤ 0,45 ≤ 0,42	- ≥ 3(1) ≥ 5(1)
Bottom layer (2 layers)	≥ 20 mm	≥ 375	≤ 0,45	-
Low trafficked roads and bicycle lanes (B6- B10, BF/Réseau II-III)				
Top layer (1 or 2 layers)	> 20 mm 6,3 mm < Dmax≤ 20 mm ≤ 6,3 mm	≥ 350 ≥ 375 ≥ 400	≤ 0,50 ≤ 0,50 ≤ 0,45	- ≥ 3(1) ≥ 5(1)
Bottom layer (2 layers)	≥ 20 mm	≥ 350	≤ 0,50	-

(1)In the last version of Flemish SB 250, the air content is to be declared during the initial type testing

Limiting values SLAB test

- In the past: all regional tender specifications based on "ISO/DIS 4846.2" test method
- New testing method CEN/TS 12390-9: "Slab-test", converted into "RNR 06" applied in SB 250 specification (Flanders)
- Limiting values (on site cores) :

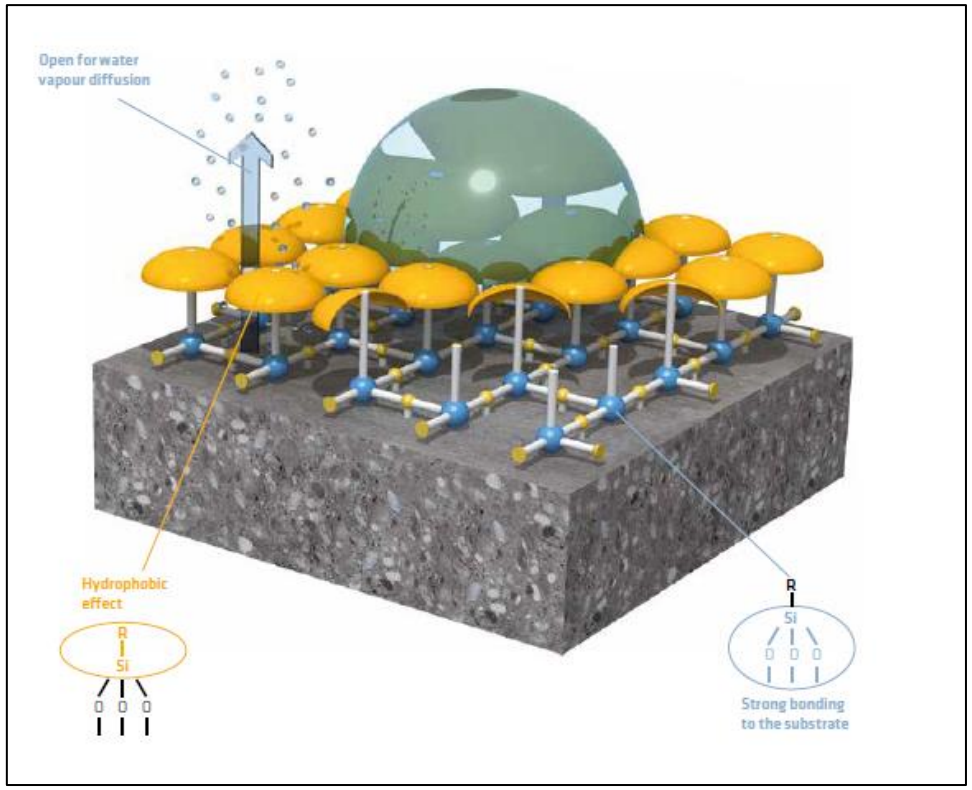
Specification	Test method	Number of cycles	Unit	Traffic class	
				B1-B5/RI	B6-B10, BF/ RII,RIII
Qualiroutes	ISO/DIS 4846.2 ("CME 53")	30	g/dm^2	**≤5**	**≤ 10**
CCT2015	ISO/DIS 4846.2	30	g/dm^2	**≤ 5**	**≤ 10**
SB 250	CEN/TS 12390-9	28	kg/m^2	**≤1,500**	**≤3,000**

Hydrophobic impregnation: current practice

- In some specific cases, scaling is observed, even with the concrete composition meeting the requirements.

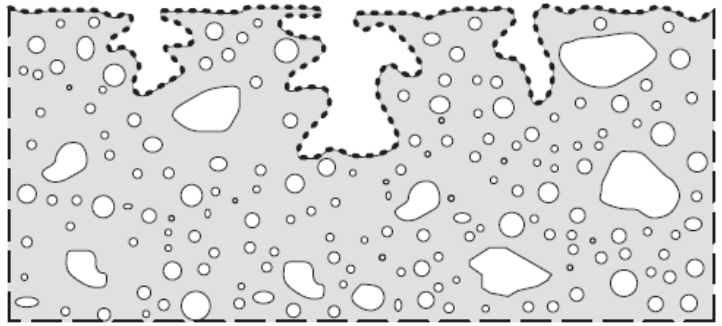
- In Belgium, hydrophobic impregnation is required in some specific cases:
  - ✓ manual placement
  - ✓ colored concrete
  - ✓ imprinted concrete

Effect of impregnation on concrete surfaces



Source SIKA

- Silanes and/or siloxanes
- Non film forming: pores and capillaries lined but not filled
- Hydrophobic effect reduces surface tension, creating a water repellent surface
- “Penetrating Sealers”, “Pore liners”



Source BBRI

Hydrophobic impregnation: current practice

- Performance characteristics defined in **EN 1504-2**:
  - ✓ Penetration depth
  - ✓ Water absorption and resistance to alkali (EN 13580)
  - ✓ Drying rate coefficient (EN 13579)
  - ✓ Resistance against freeze-thaw salt stress (EN13581)

Tests on reference concrete compositions, not specific road concrete compositions

Freeze-thaw test method is different from test method prescribed in tender specifications (total immersion in NaCl solution, thawing in water, T° measurements…)

Regional tender specification

- Efficiency of impregnation against scaling for one given road concrete composition?
- Criteria?
- Effect of curing on the efficiency of impregnation?

→ Topics included in pre-normative research project GELAVIA

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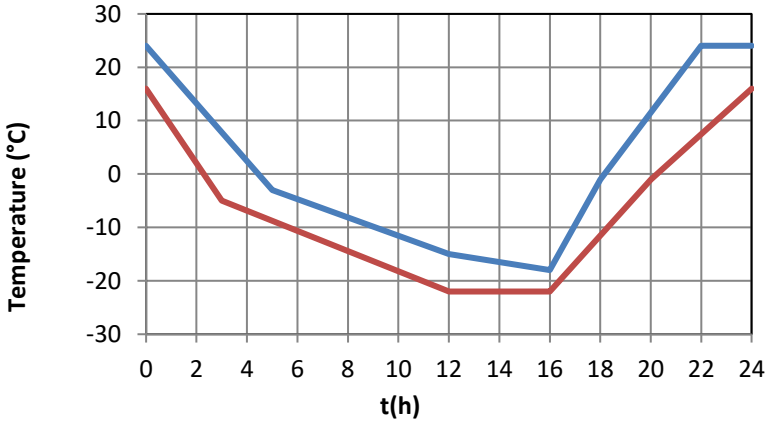
Methodology

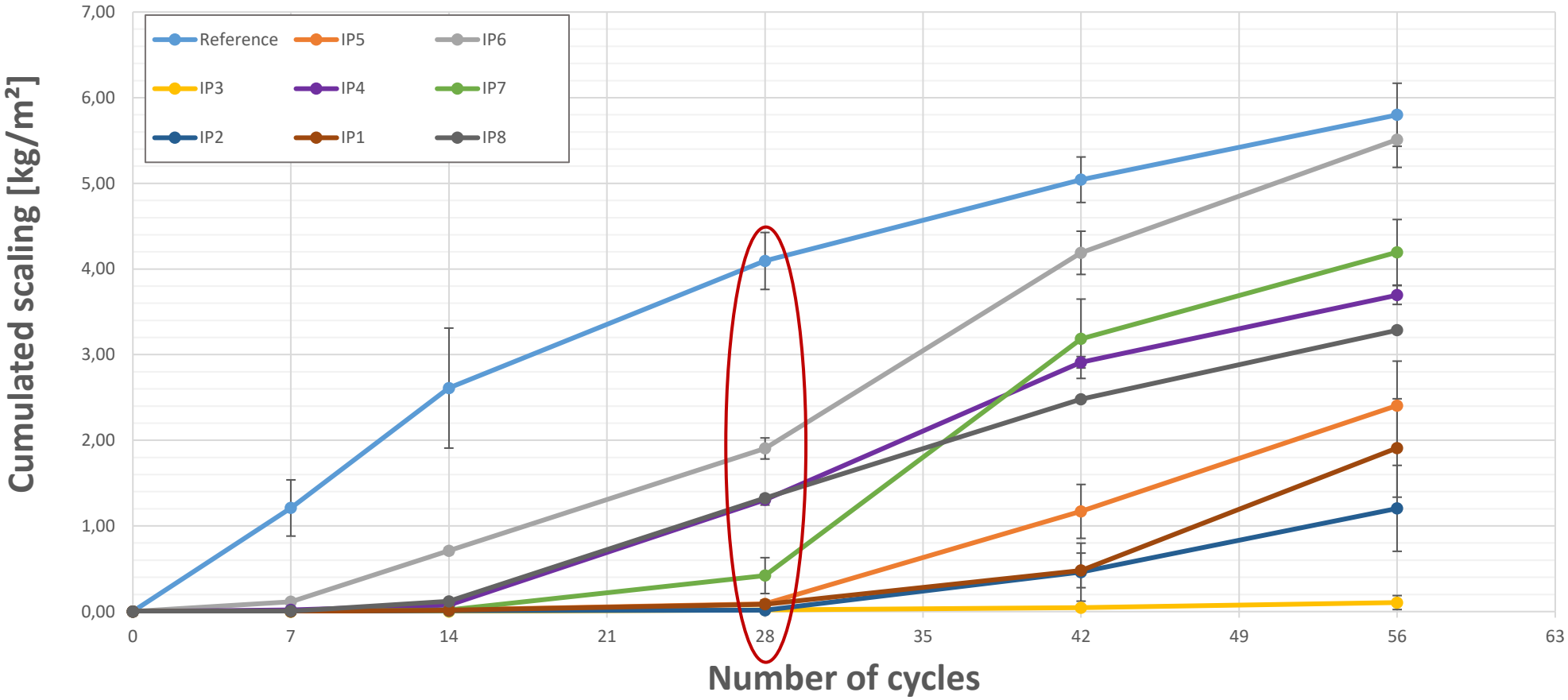
- 7 Impregnation products, silane and/or siloxane based
- Measurements on road concrete composition (laboratory): Porphyry aggregates – water to cement ratio = 0,50 - 375 kg/m^3 CEMIII/A 42,5 N
- Moderate/low resistance to scaling: 4,5 kg/m^2 after 28 cycles on cast surface (no AEA)
- Impregnation of cast surface at 35 days, slab test at 49 days
- Cubes: application by immersion (2x2 min)
- Cores from slab: application following maufacturer's recommandations

Determining resistance to scaling

- CEN/TS 12390-9, SLAB test converted into “RNR06”, applied in certification of road concrete
- Freeze-thaw cycles on samples whose surface is covered with a layer of de-icing salt solution (SLAB-test: 3%NaCl)
- Evaluation of freeze-thaw resistance by weighing the scaled material after a specified number of cycles



Resistance against scaling of impregnated slabs



Reduction of scaling value after 28 cycles:

36 to 83%

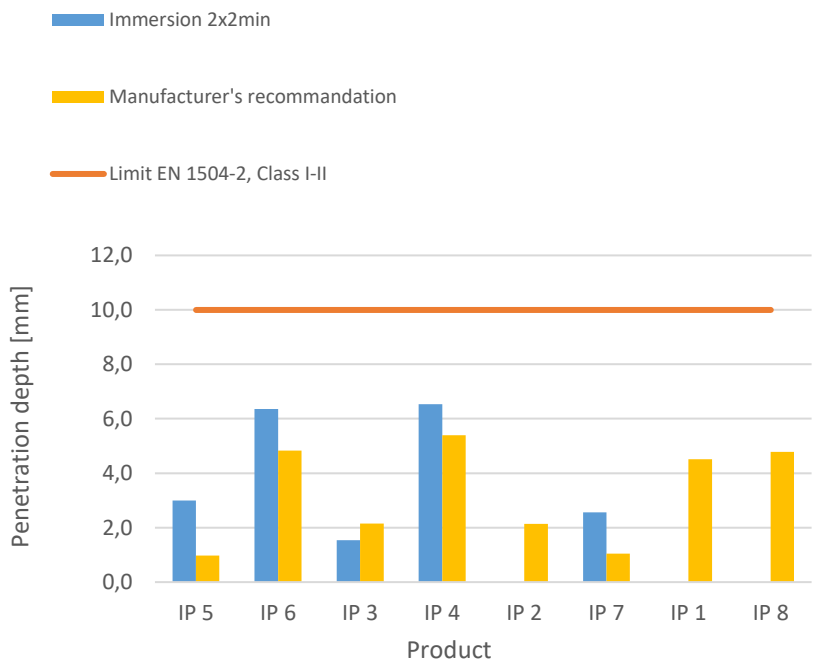
Penetration depth

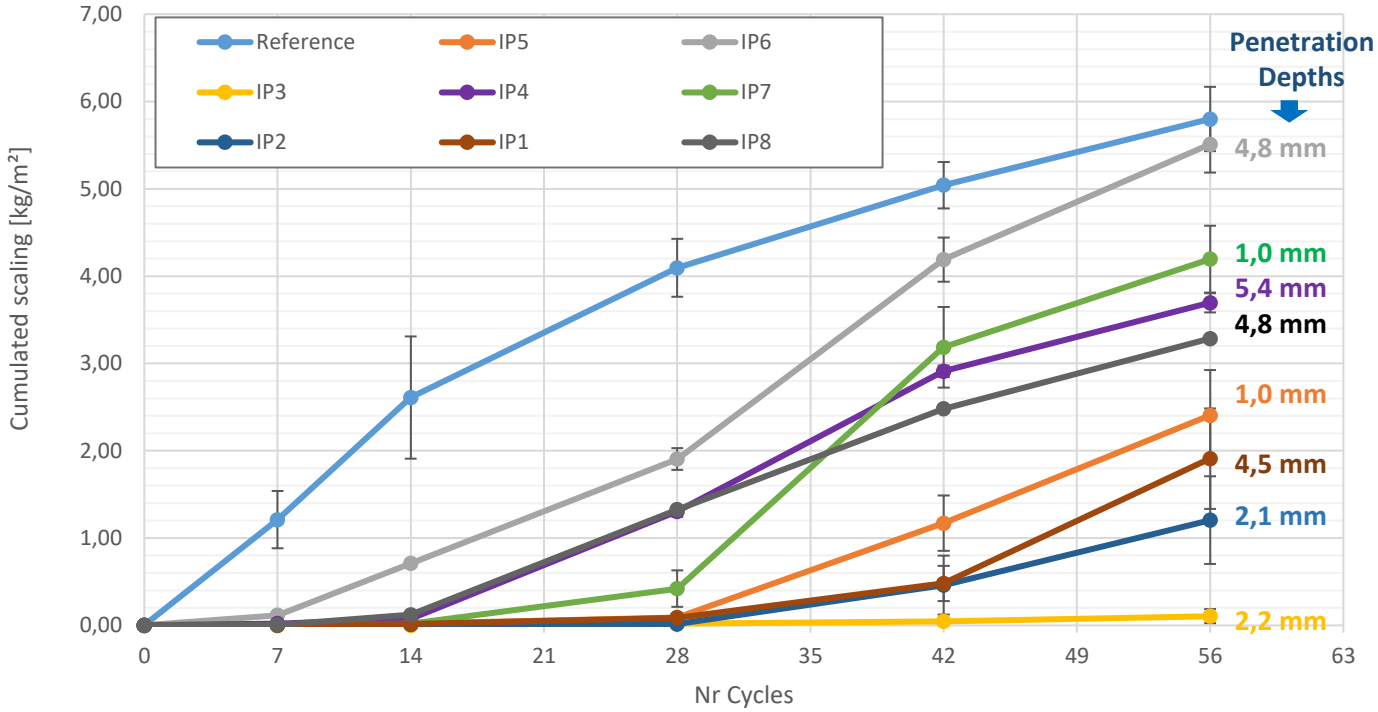
Method cf. Table 3 of NBN EN 1504-2:

The depth of penetration is measured with an accuracy of 0,5 mm by breaking open the treated specimen and spraying the fracture surface with water (using the phenolphthalein test method with water instead of phenolphthalein) according to prEN 14630. The depth of the dry zone is taken as the effective depth of hydrophobic impregnation.

- Some measurements at 1mm! Accuracy?
- Variability in measurements!

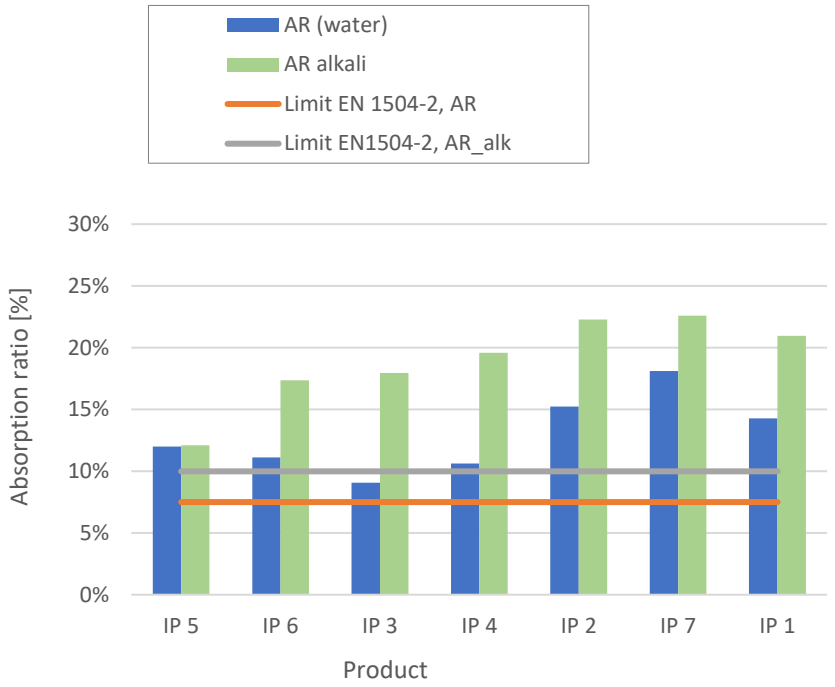
Penetration depth

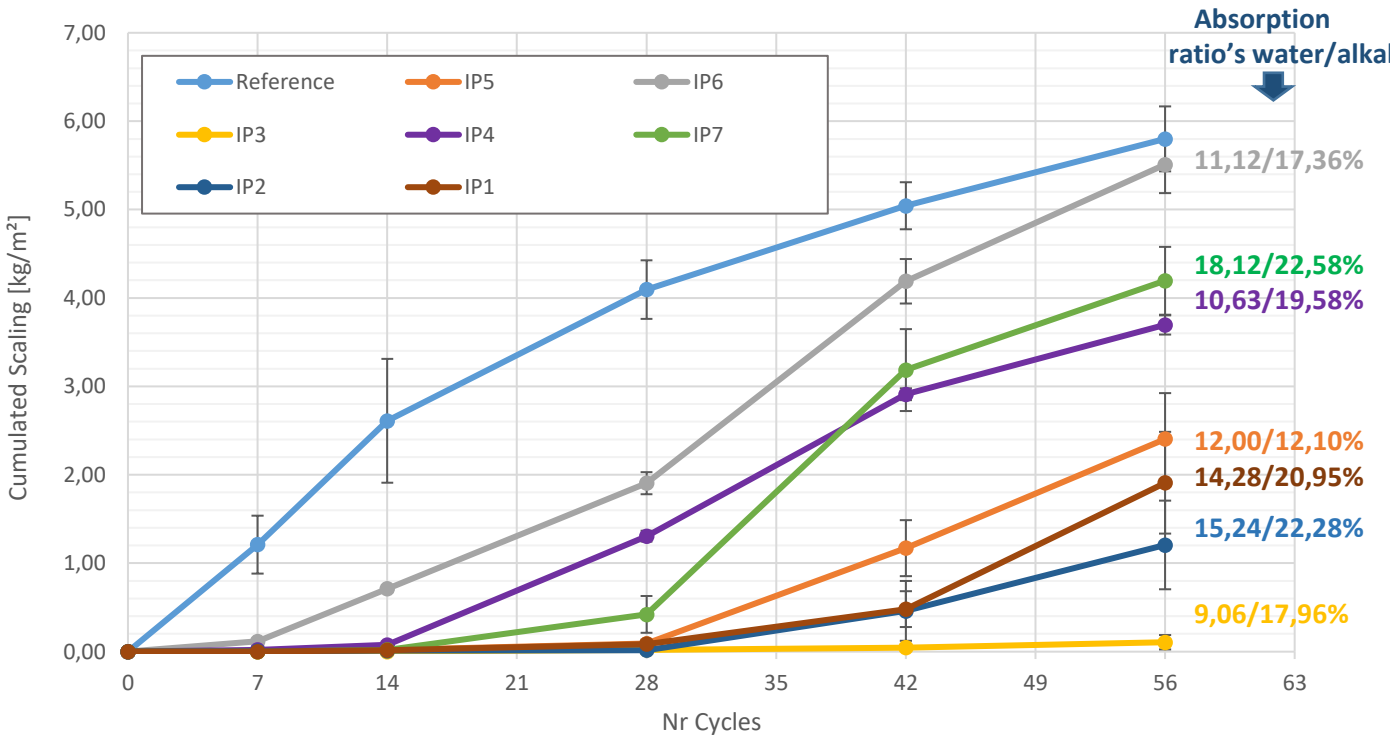




No obvious relationship scaling/penetration depth

Water absorption and resistance to alkali



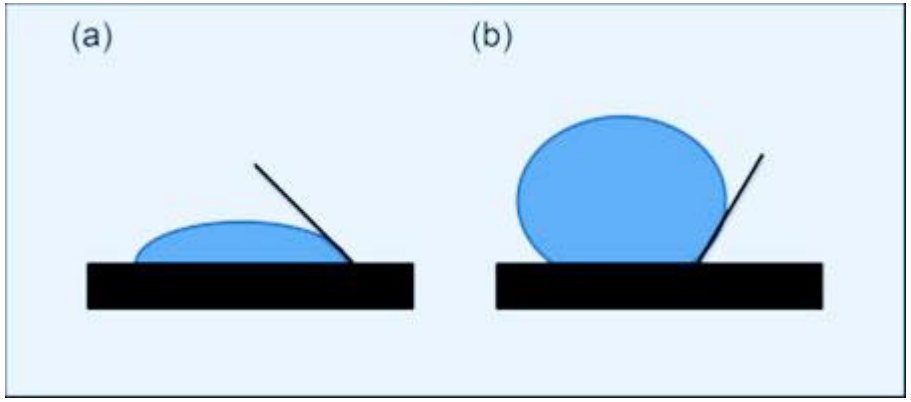


No obvious relationship scaling- absorption ratio

Discussion

- Penetration depth mesured by image analysis?
- Application rate and timing: effect on efficiency?

- + Contact angle?



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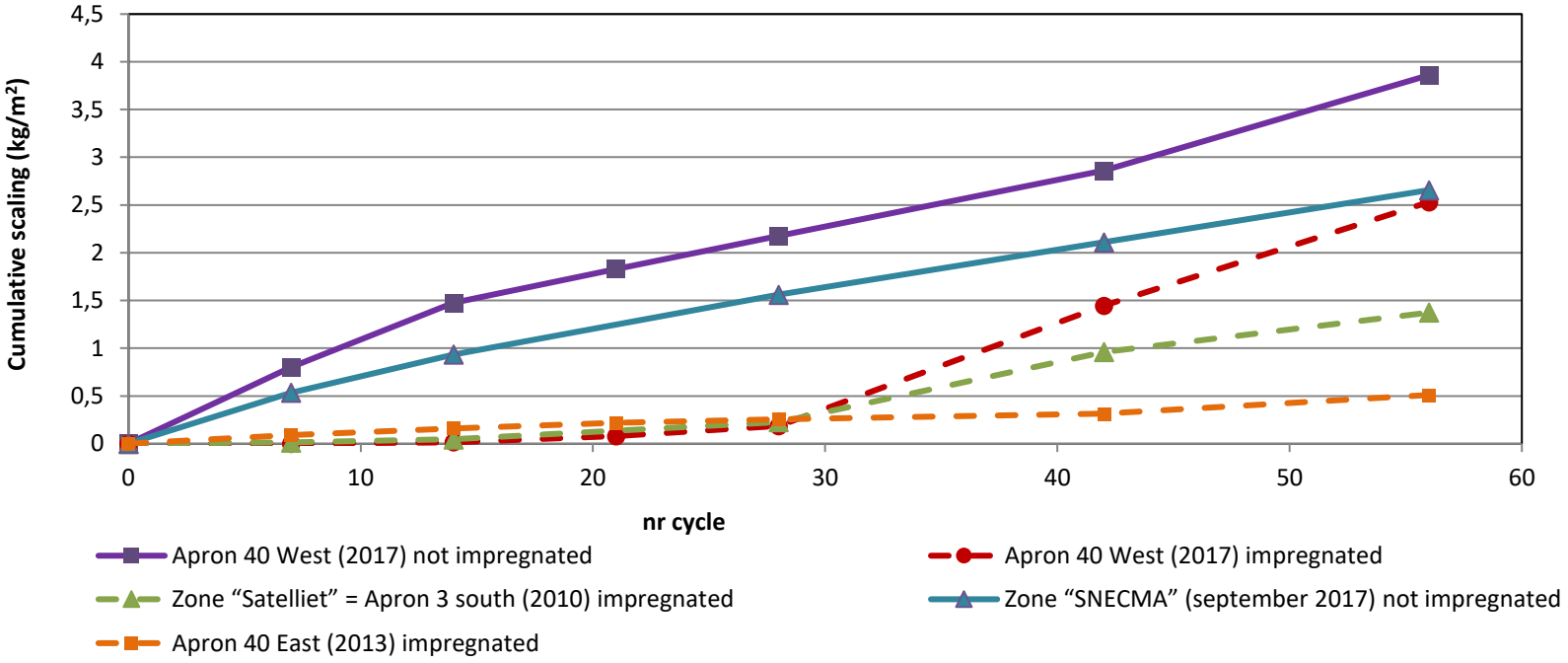
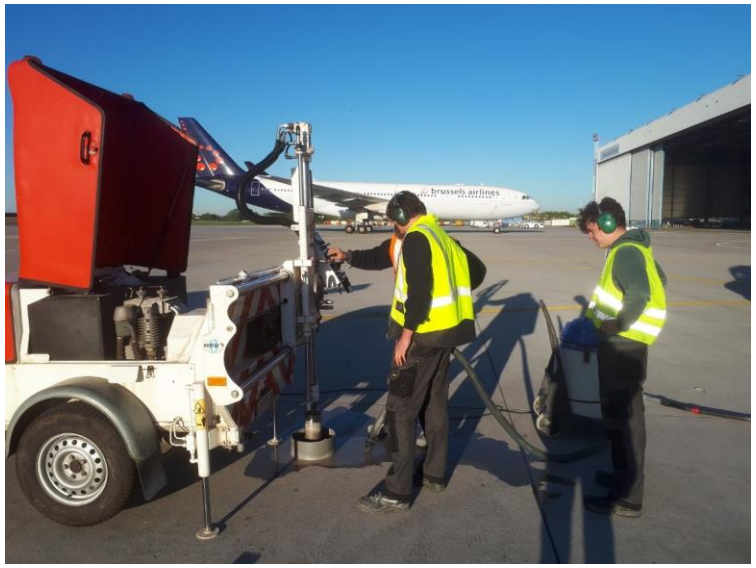
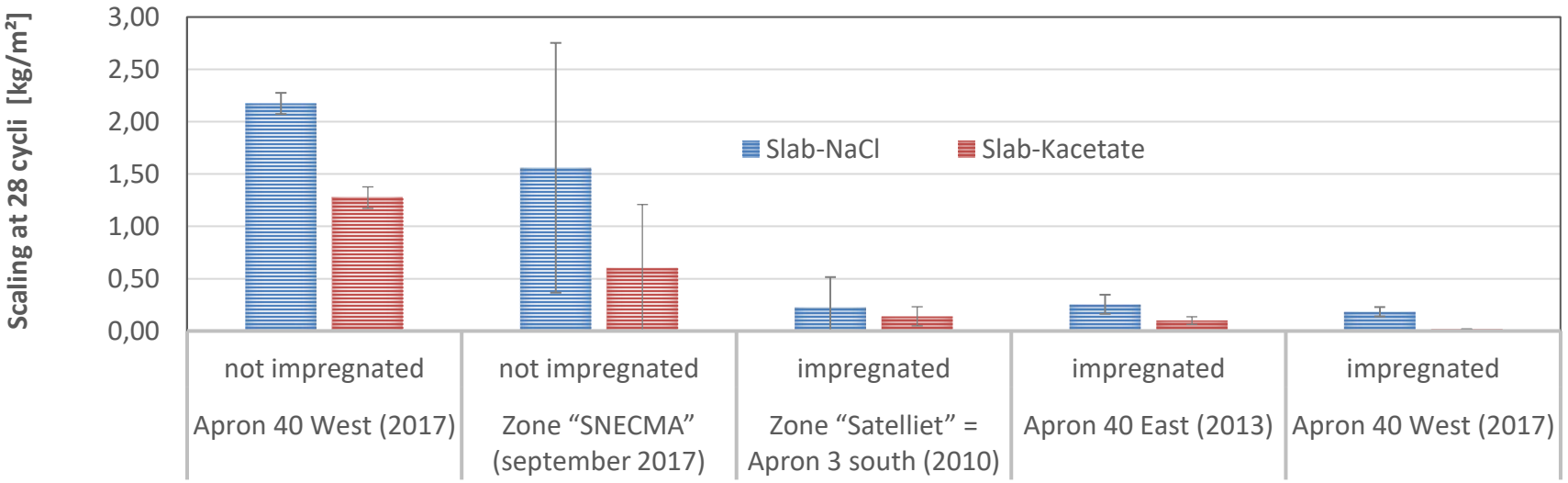
Zaventem airport





- Surfaces with and without impregnation
- Age of impregnation from 1 to 8 years

Zaventem airport

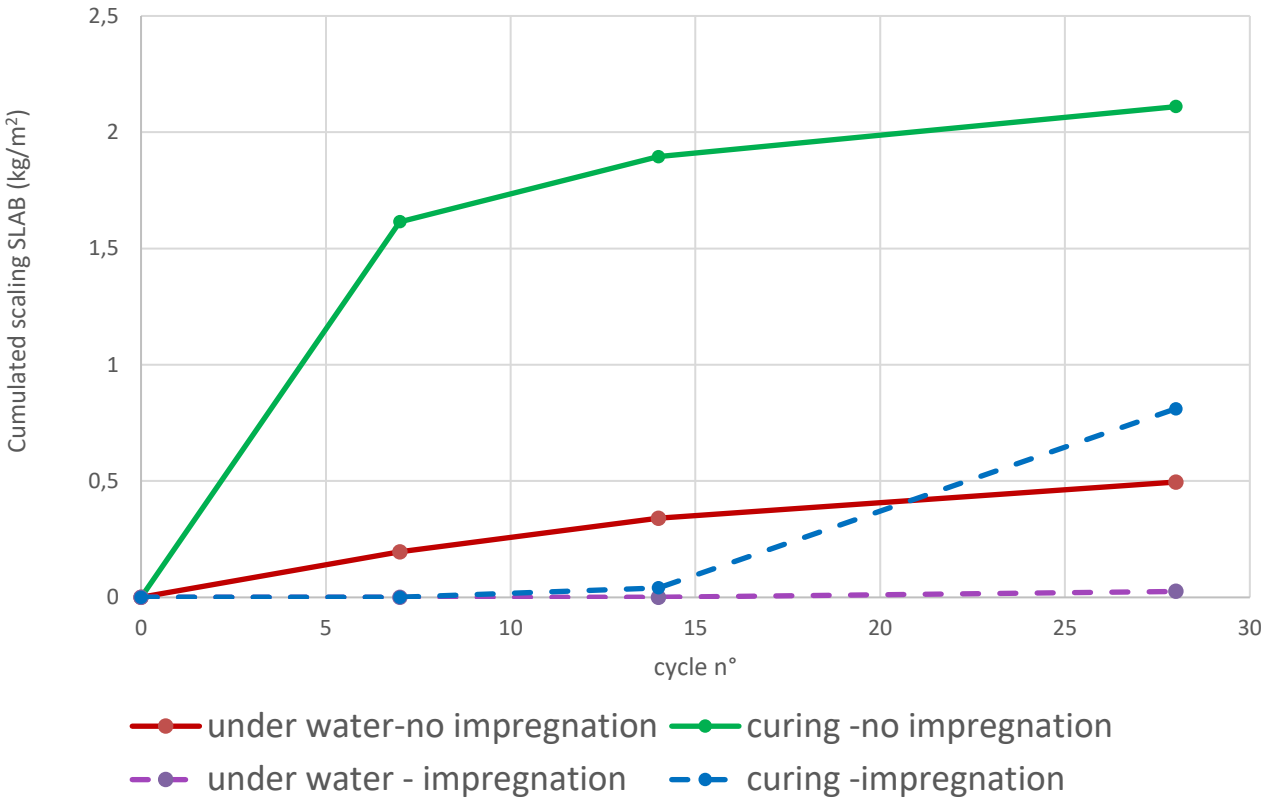


- Clear influence of impregnation on scaling
- Scaling strongly reduced, even after 8 years
- Effect of de-icing salt (K-acetate used on airport)

Effect of curing on hydrophobic impregnation

- Construction site: Couvin (highway, CRCP, 2 layers)
- Prisms on working site
- In laboratory, cores from cast surface, different treatments:
  - Under water - no impregnation
  - Under water – impregnation
  - Curing - no impregnation
  - Curing – impregnation

Effect of curing on hydrophobic impregnation



- In the presence of a curing product, the reduction of scaling by impregnation is effective during a more limited period.
- Impregnation should be applied on a washed surface and at least 4 weeks after execution.

Adaptation of tender specification

Flemish tender specification adapted:

- SLAB test on impregnated samples: limiting value of 0,5 kg/m^2 at 28 cycles.
- Execution of hydrofobic impregnation: cleaning of surface and waiting time of 28 days before application.

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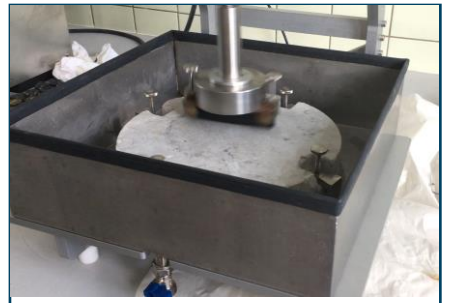
Ageing - methodology

- Measurements on road concrete composition (w/c 0,50, 375 kg/m^3 CEM III/A 42,5, no AEA) with moderate resistance to scaling (4,5 kg/m^2 after 28 cycles, cast surface)
- Impregnation with IP1
- Resistance to scaling before and after ageing:
  - Abrasion by steel balls, aluminium oxide and water: PEI (EN ISO 10545-7)
  - Abrasion by rubber (Wearing resistance EN 12274-5)
  - UV radiation: Q-SUN (5x12h at 0,63 W/m^2 , λ= 340nm, BPT 45°C, T=25°C)
  - 9 months on roof top at Sterrebeek (Belgium)

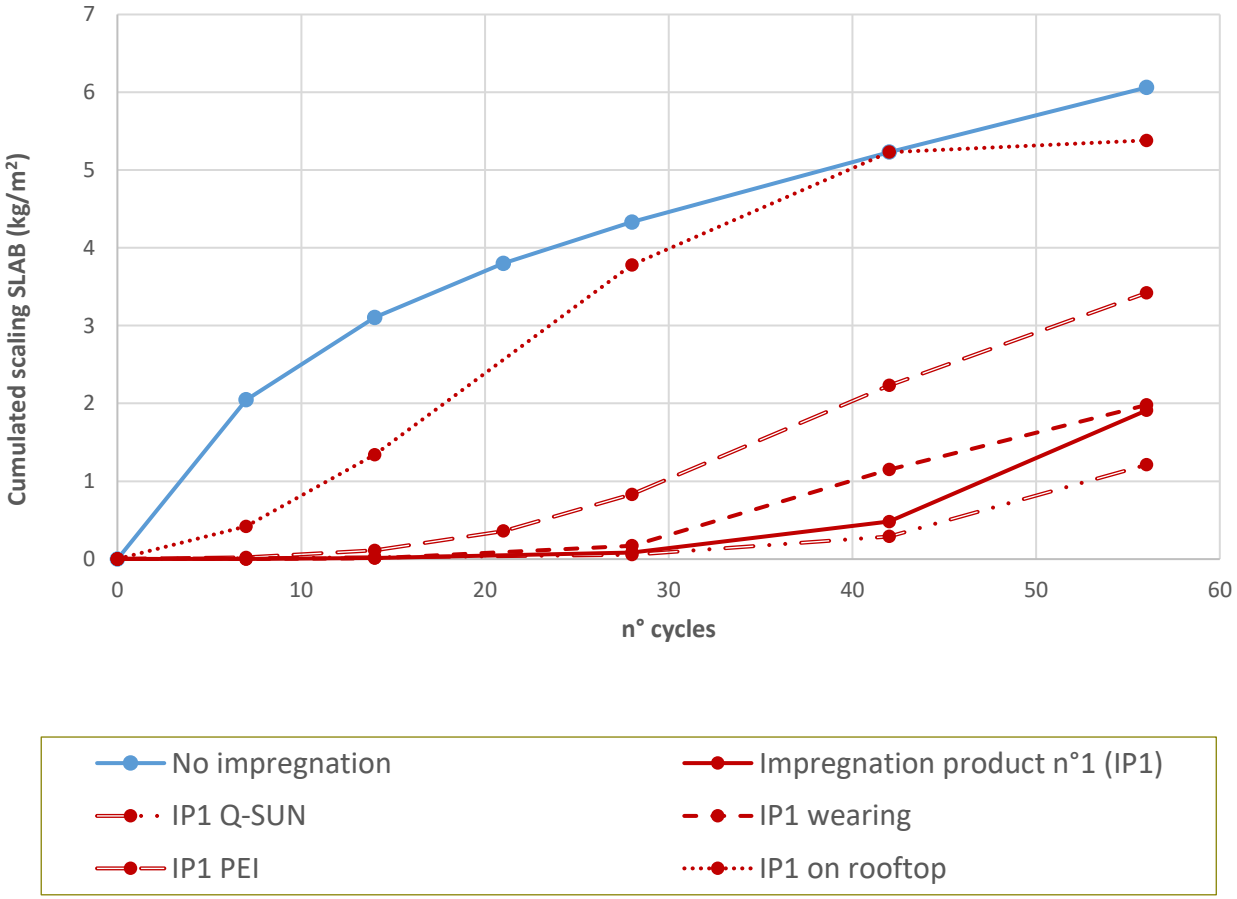
PEI



Wearing

Q-SUN

Ageing of impregnated concrete - results



- After 9 months on the rooftop, impregnation looses most of its effects.
- PEI abrasion also reduces strongly the efficiency of impregnation (but in a less extend)
- Weak effect of Q-SUN ageing and wearing (rubber) on efficiency of impregnation

Conclusions

- Hydrophobic impregnation can enhance durability of road concrete with respect to freeze-thaw cycles with deicing salts.
- No obvious relationship was observed between the properties of hydrofobic impregnation products following NBN EN 1504-2 and the resistance against scaling.
- Curing can have an influence on the efficiency of impregnation: waiting time is necessary
- Ageing could reduce the efficiency of impregnation products against scaling but more test results are needed to beter understand the individual effects

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