



Belgian Road Research Centre
Together for sustainable roads



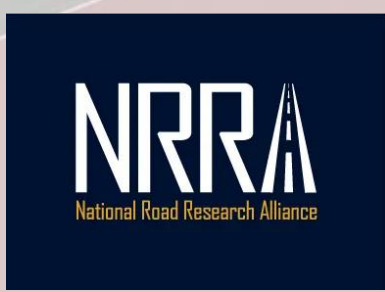
Internationale ontwikkelingen in de betonwegensector

Verslag van de “13th International Conference on Concrete Pavements”, Minneapolis (VS)

8^{ste} Provinciale Contactdag Antwerpen en Vlaams-Brabant, Febelcem, Stadion OHLeuven - Leuven

Elia Boonen (Opzoekingscentrum voor de Wegenbouw)

21 november 2024



13TH INTERNATIONAL CONFERENCE ON CONCRETE PAVEMENTS

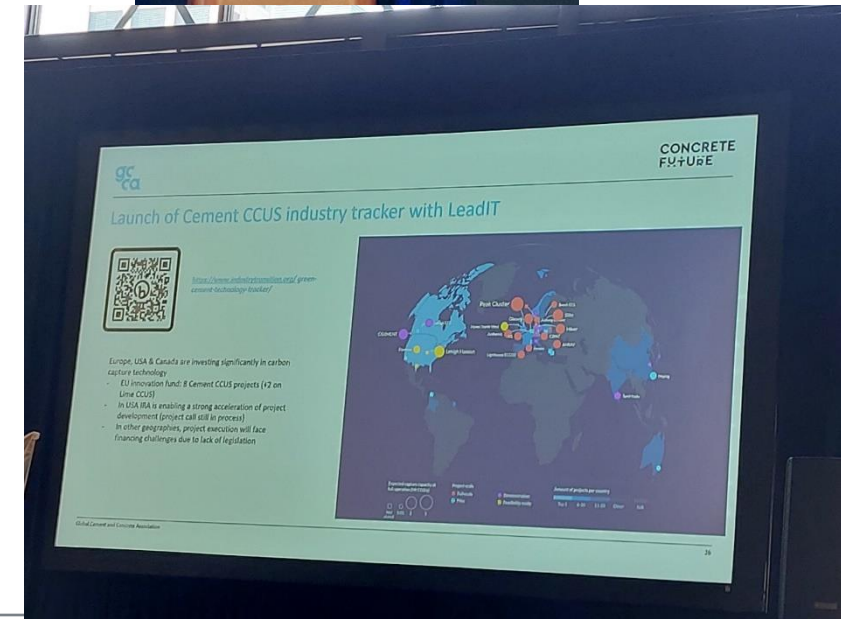
August 25-29, 2024 | Minneapolis, Minnesota, USA

*“Innovative Paths Toward
Lower Carbon in Concrete Pavements”*

10 Themes, 80 technical paper presentations, 16 podium sessions + 10 practical workshops



- Lower Carbon
- Testing & Instrumentation
- Design
- Performance modeling
- Surface characteristics
- Sustainability & climate change
- Construction
- Recycled Materials
- Materials
- Durability



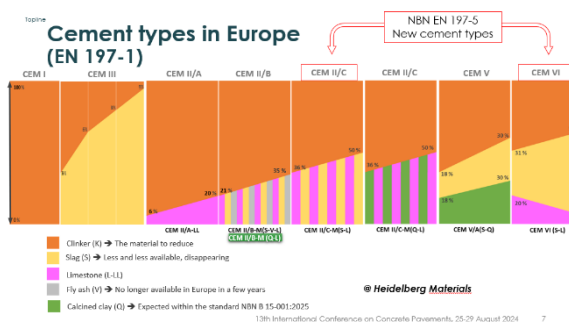


10 practical workshops by Sponsors (*no paper*)

- Rapid Strength Concrete for Highways and Airport Pavements (CTS)
- **Advancements in Optimized Concrete Pavement Design (OptiPave – FORTA)**
- Sustainability and Performance can Coexist: *Low Embodied Carbon Concrete Pavements Leading the Way* (FHWA)
- ***Impact of NRRA on Advancing Concrete Pavement Technology*** (NRRA)
- Roller-Compacted Concrete Pavements (RCC Pavement Council)
- Airport Pavement – ACPTP (Airport Concrete Pavement Technology) Research Program
- Fiber-Reinforced Concrete Materials for Pavements (FRCA)
- Concrete Pavement Preservation – Sustainable Solutions for Tomorrow, Today (IGGA – ACPA)
- Pavement Foundations: Review of Foundation Requirements and Measurements (FHWA – CP Tech Center)
- Mine and Ready-Mix Plant Tour (NSSGA)

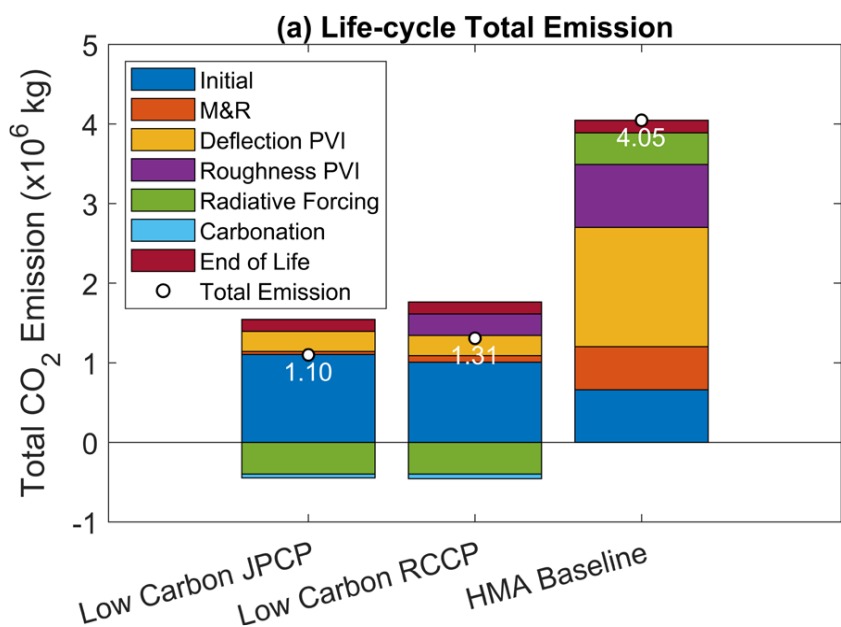
Vier Belgische bijdragen (van/met OCW)

- New Belgian Guidelines for Pattern Imprinted Concrete Pavements
(*L. Rens*)
- Pervious (Lean) Concrete for Sustainable Road Pavements: Results of the Belgian Be-Drain Project
(*A. Van der Wielen*)
- Evaluation of the Suitability for Use of Ternary Cements with Carbonate Fillers Or Calcined Clays: Concrete Compositions Subjected to De-Icing Salts
(*E. Boonen*)
- Optimizing Vibration Parameters of Thick Single-Layer Concrete Pavements: Results of the Belgian Monocrete Project (*poster – A. Van der Wielen*)



1) Lower carbon (*beperkte bijdragen!?*)

- CO₂-reduction – alternative binders – new cements – recycling...



Li et al., LCA-analyse (US)

Lopez et al., *Barriers Limiting Innovation in Concrete Carbon Reduction* (US)

The “Green Premium”
Risk Aversion
Materials Production
Cement and Concrete Codes
and Specifications

King et al., LCA-analyse voor concrete overlays (US)

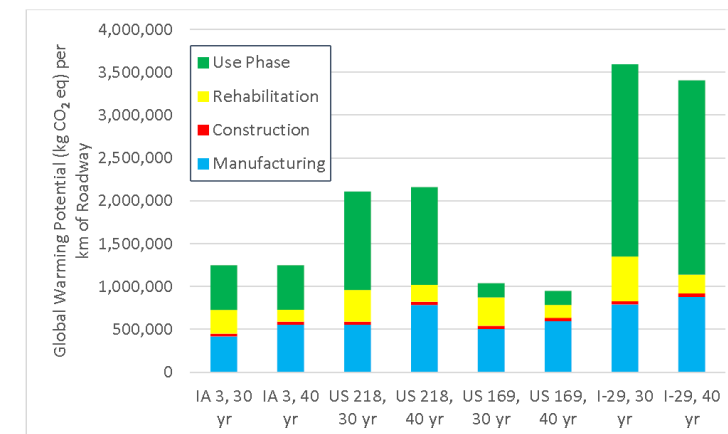


Figure 2: LCA Results for All Case Studies



Athena
Pavement
LCA

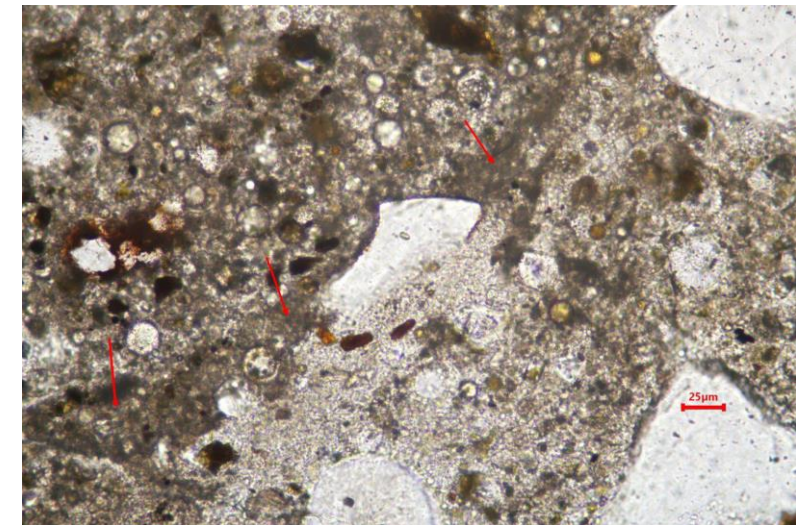
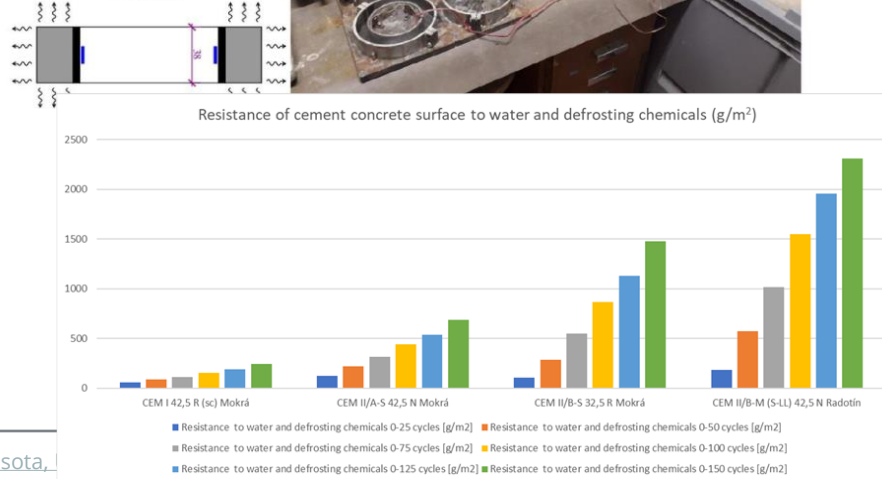
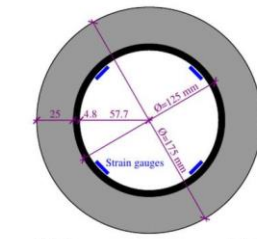
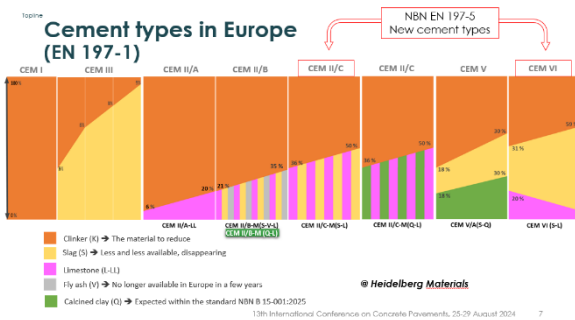
Free online tool for pavement LCA analysis
<https://pavementlca.com/>

Decarbonization (2)

- CO₂-reduction – alternative binders – new cements – recycling...

Slansky et al. (CZ), “Performance-based testing of new cements for concrete pavements” (poster)

Izevbekhai & Aili, “Evaluation of the Beneficial Use of **Recycled Concrete Aggregates** in the MnROAD Test Cells” (US)



Smets et al., Neocem (Belgium)

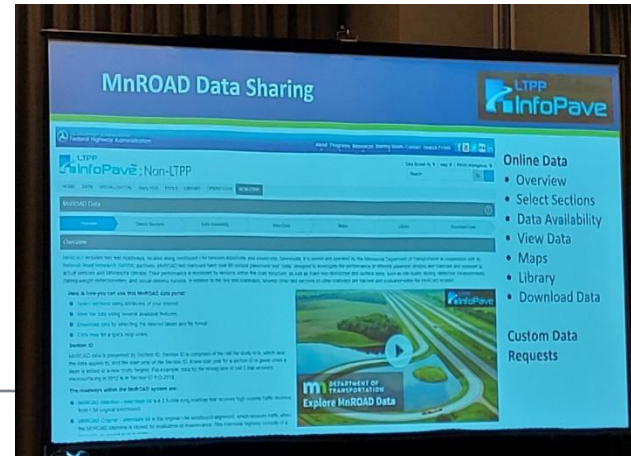
NB: National Road Research Alliance (NRRA) Workshop



- MnROAD facility testing:
 - **Highlights from Low Cementitious Content Concrete Pavement Research Projects** – Bernard Izevbekhai (MnDOT)
 - **Findings from 2022 MnROAD Alternative Cement Cells** – Prashant Ram (Applied Pavement Technology – APTech)
 - **Panel Discussion of Industry Implementation Plans for Low Carbon Concrete** – Moderator Glenn Engstrom:

Focus on EPD's, performance-based requirements, incentives for contractors...

<https://www.dot.state.mn.us/mnroad/nrra/structure-teams/rigid/index.html>





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Together for sustainable roads

Evaluation of the suitability for use of ternary cements with carbonate fillers or calcined clays: concrete compositions subjected to de-icing salts

Elia Boonen
Sylvie Smets*
Belgian Road Research Centre (BRRC)

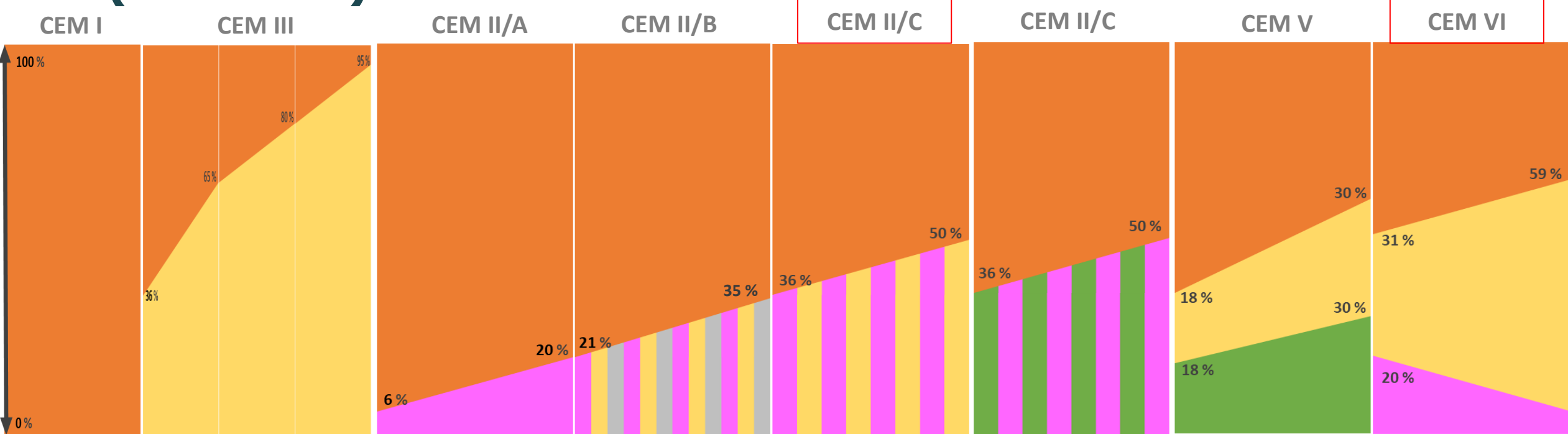
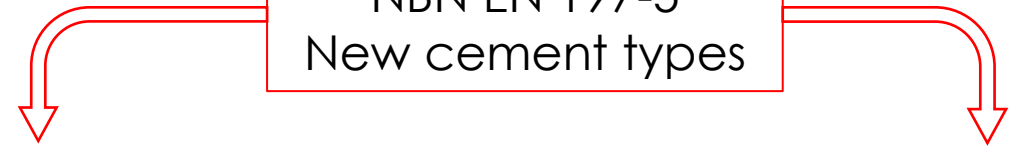
13th International Conference on Concrete Pavements

28/08/2024 (Session 15)



Cement types in Europe (EN 197-1)

NBN EN 197-5
New cement types



- Klinker (K) → The material to reduce
- Hoogovenslak (S) → **Minder en minder beschikbaar, verdwijnt metertijd**
- kalksteen (L-LL)
- Vlieggas (V) → **Niet langer beschikbaar in Europa binnen enkele jaren**
- Gecalcineerde klei (Q) → Verwacht binnen norm NBN B 15-001:2025



No.	cement "type"	Name	%CEM I 52.5	% Q1	% Q2	% Q3	% S	% L	% L"	% Ld	% LL	% Gypsum
1	CEM II/B-M (Q1-L)	C1(65)Q1(25)L(10)	65	25				10				(1)
2	CEM II/B-M (Q3-L)	C1(65)Q3(25)L(10)	65			25		10				(1)
3	CEM II/C-M (S-LL)	C1(50)S(30)LL(10)	50				30				20	(1)
4	CEM II/C-M (S-L)	C1(50)S(30)L(20)	50				30	20				(1)
5	CEM II/C-M (S-L")	C1(50)S(30)L"(20)	50				30		20			(1)
6	CEM II/C-M (S-Ld)	C1(50)S(30)Ld(20)	50				30			20		(1)
7	CEM V/A (S-Q1)	C1(45)Q1(25)S(30)	45	25			30					(1)
8	CEM V/A (S-Q2)	C1(45)Q2(25)S(30)	45		25		30					(1)
9	CEM II/C-M (Q1-L)	C1(50)Q1(40)L(10)	50	40				10				(1)
10	CEM II/C-M (Q3-L)	C1(50)Q3(40)L(10)	50			40		10				(1)
11	CEM VI (S-LL)	C1(35)S(45)LL(20)	35				45				20	(1)
12	CEM VI (S-L)	C1(35)S(45)L(20)	35				45	20				(1)
13	CEM VI (S-L")	C1(35)S(45)L"(20)	35				45		20			(1)
14	CEM VI (S-Ld)	C1(35)S(45)Ld(20)	35				45			20		(1)
15	CEM I 52.5 N	C1(100)	100									(1)
16	CEM III/A	C1(45)S(55)	45				55					(1)

(1)Quantity necessary for the total sulphate content of the cement to be equal to 3.5%

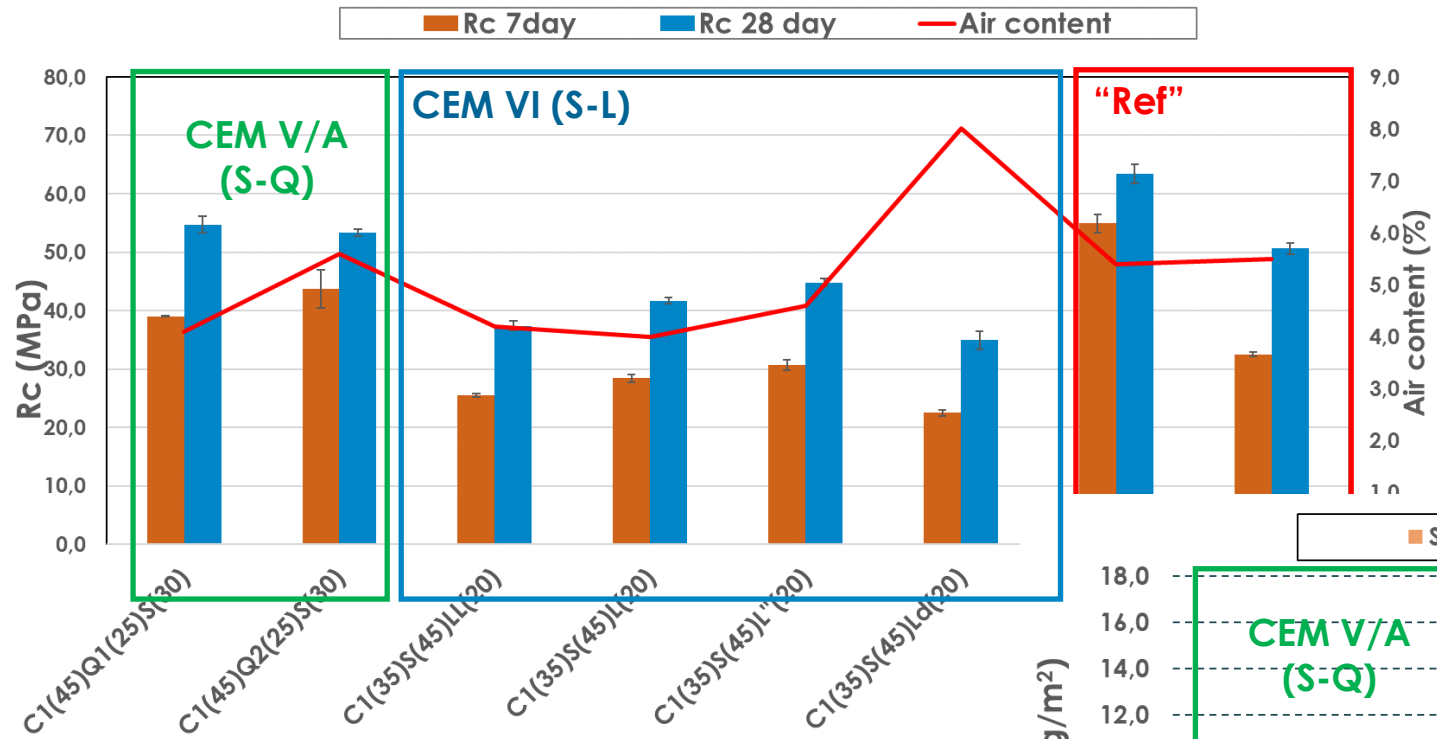
Betonsamenstelling voor EE4

- Norm NBN B 15-001: $w/c \leq 0.45$, met of zonder LBV
- Slump: (150 ± 30) mm
- Luchtgehalte: $(6 \pm 2)\%$

Bestanddeel	GEEN LBV (kg/m ³)	Met LBV (kg/m ³)
Cement CEM III/A	340	340
Kalksteen 4/6,3	169	159
Kalksteen 6,3/14	416	391
Kalksteen 14/20	446	419
Zand 0/2	195	184
Rond zand 0/4	654	617
Water	153	153
Absorptiewater	9	8
SP Sika Viscocrete (1020x of 1560 con 30)	2.0 to 4.0	1.6 to 3.0
LBV Sika LPSA-94	-	0.07 to 0.26

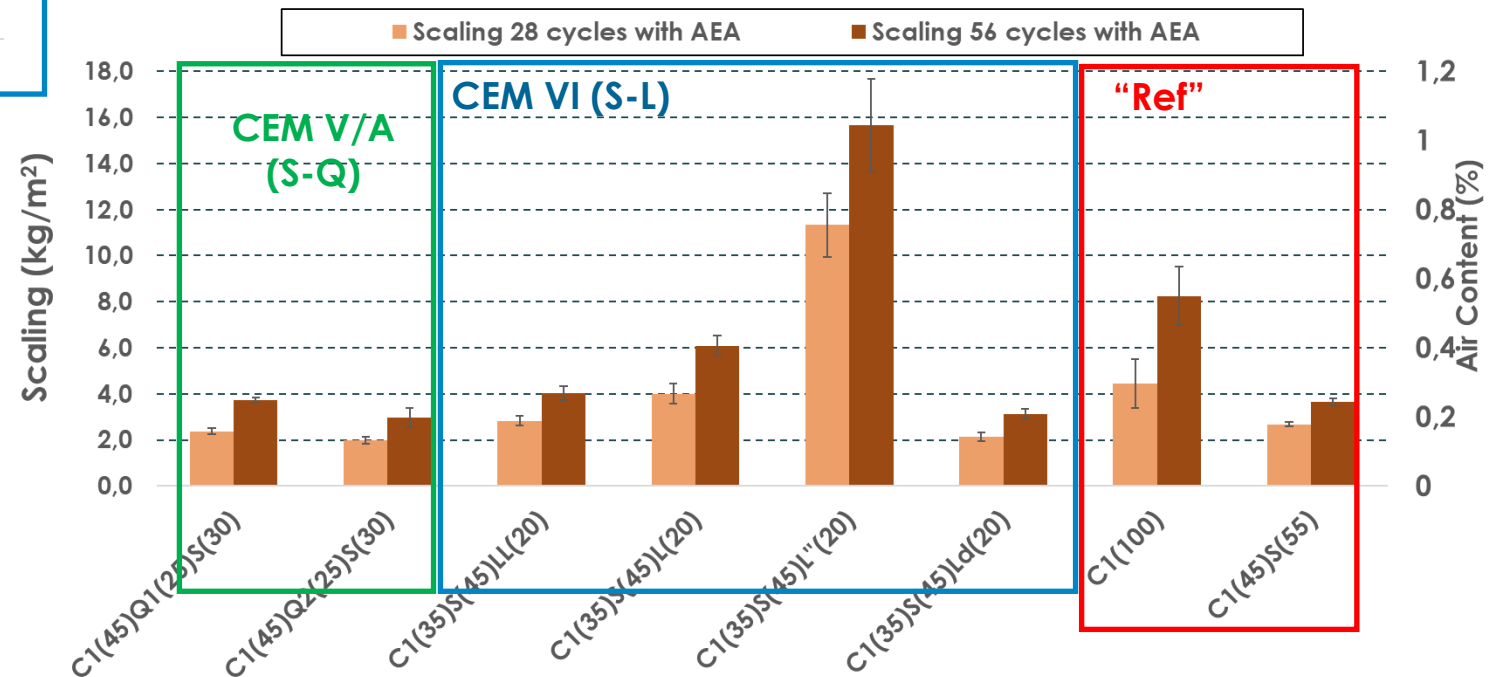


Resultaten voor CEM V + CEM VI (met LBV)



- CEM V/A = 45% K
- CEM VI = 35% K

- Rc-28d > 50 (B1-B5) – 40 (B6-10) of 35 (BF) MPa



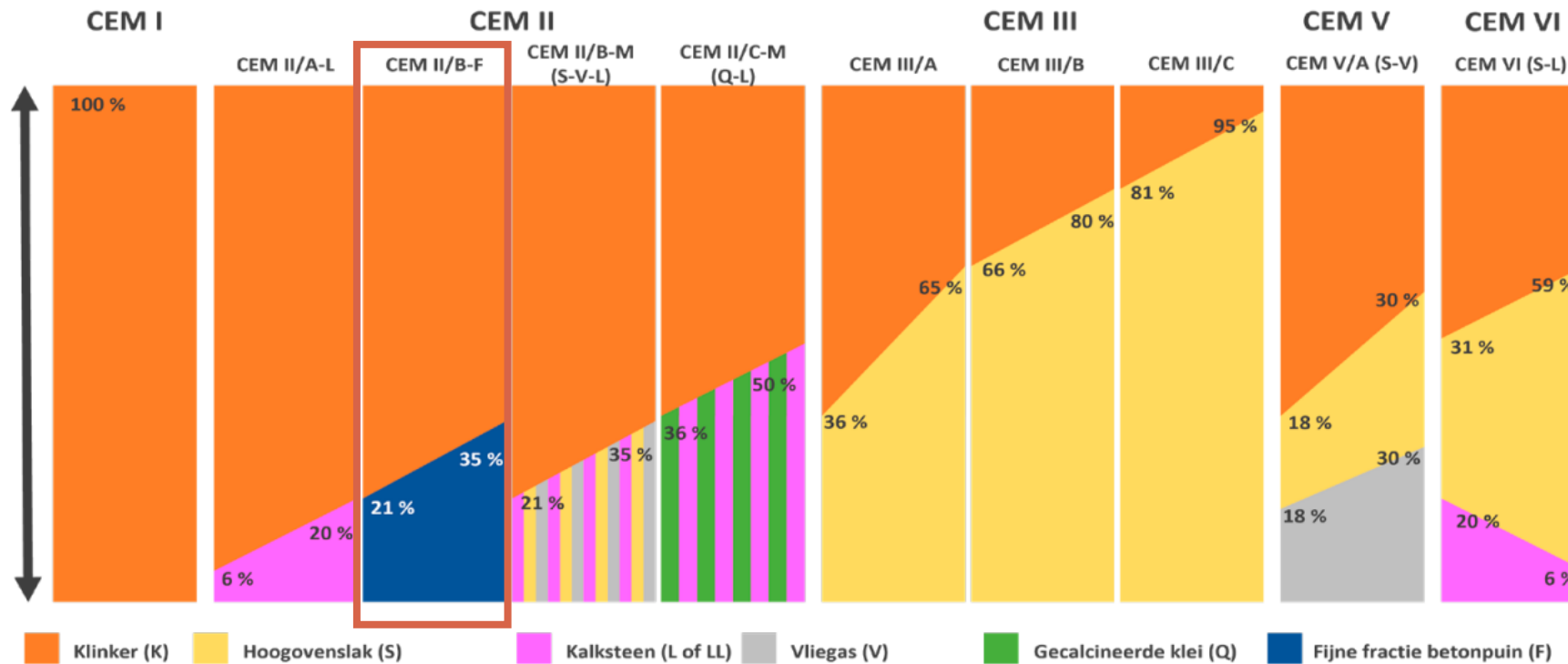
Conclusies Neocem (2020-2022)

- **Gebruik van nieuwe cementsoorten met alternatieve toevoegsels (SCMs) in Belgisch wegenbeton lijkt potentieel haalbaar;**
- **CEM V/A** met slakken en gecalcineerde klei is veelbelovend om in wegenbeton toe te passen, maar verdere validatie is nodig;
- Andere cementen met kalksteenfillers (**CEM VI**) zouden getest moeten worden met verschillende cementsamenstellingen (variatie in gehalte klinker en SCM);
- **Proeven met “echte” wegenbetonsamenstellingen zijn nodig in toekomst om toepasbaarheid in de wegebouw te valideren!**

Neocem II (2022-2024)



- “Gebruiksgeschiktheid van cementen met gerecycleerde betonfijnen” [EN 197-6]



2) Testing & instrumentation

- Gebruik van allerhande sensoren in/voor betonwegen:

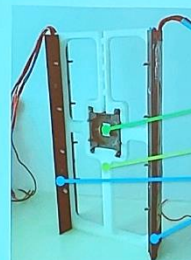


Wallace & Burnham,
“Quantifying Slab Movements in
Concrete Pavements Through
**Magnetic Induction
Sensors**” (US)

Alarab et al., “**Embedded Resistivity
Sensor** for Concrete Materials and
Structures: Vision and Prototype” (US)

Sensor Components

- Matrix
 - Shape: cuboidal or ellipsoidal
 - Materials: cementitious or metakaolin
- Packaging Plug
 - 3D-printed Polypropylene
- Placement Frame
 - Water-jet cutting Polypropylene
- Frame Stands
 - 3D-printed Polypropylene
 - Simulating Surface Resistivity

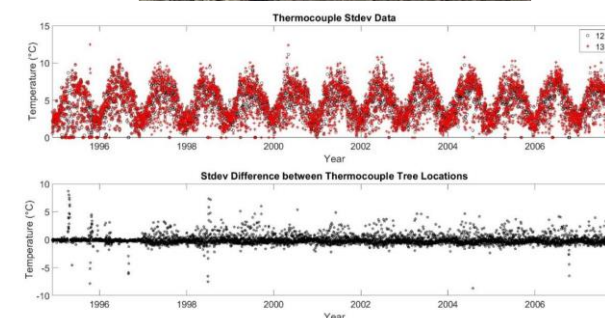
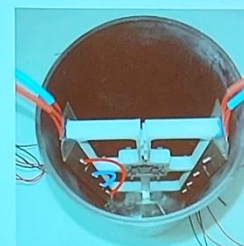
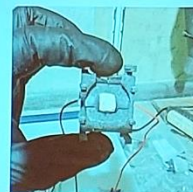
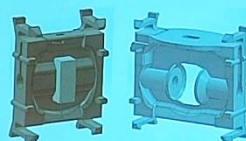


Designed for standard cylindrical
concrete molds: 4" x 8" (D x H)

Pore Solution Resistivity (PSR) sensor

Placement frame

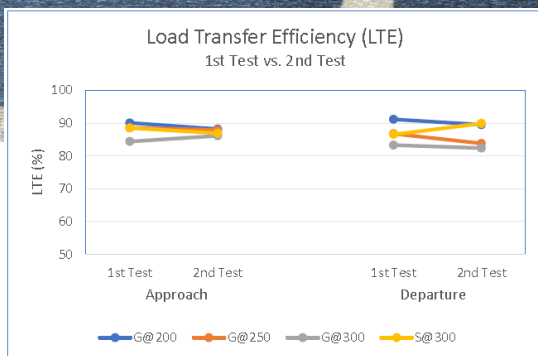
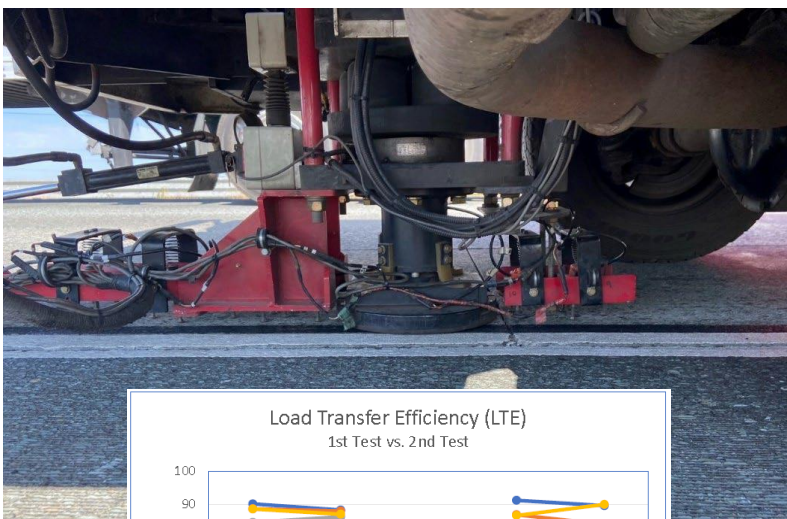
Frame stands measure mix resistivity



Podolsky et al., **T-sensoren** in
MnRoad testsecties: “signature
response of pavement?” (US)

Testing & instrumentation (2)

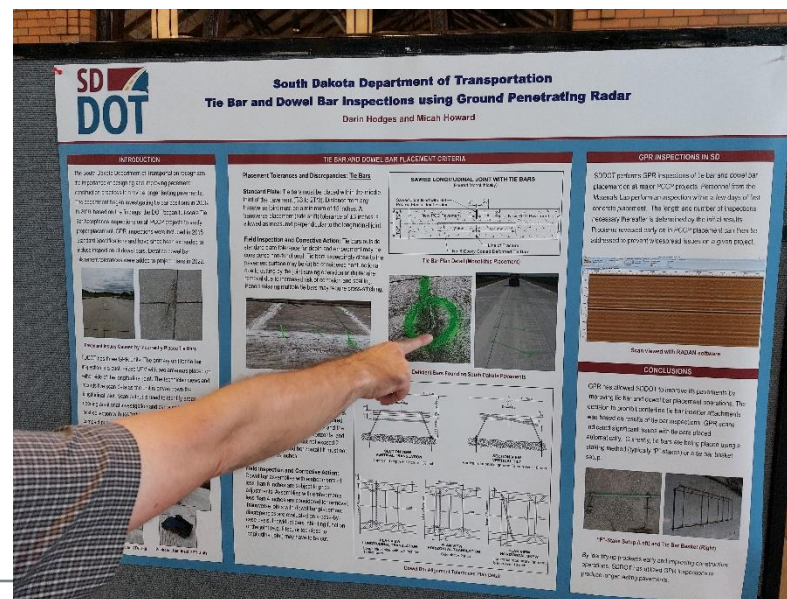
- Gebruik van NDT-technieken voor betonwegen:



Parvini M., "In-situ Performance Evaluation of Glass Fiber Reinforced Polymer (GFRP) Dowel Bars"(US)

"South Dakota DOT's use of **Ground Penetrating Radar** for Tie and Dowel bar inspection."

Darin Hodges and Micah Howard (poster)



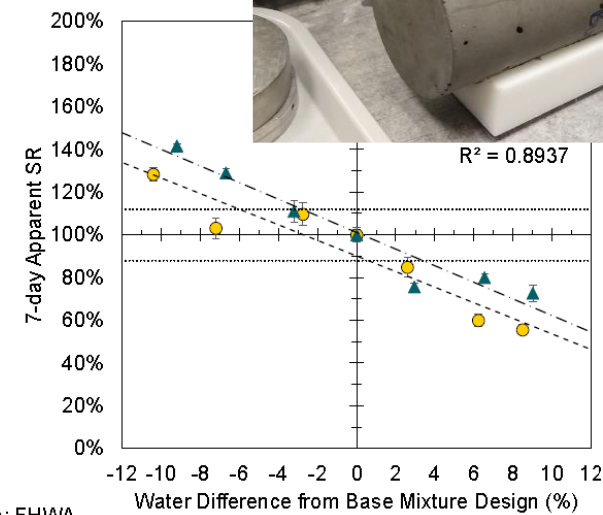
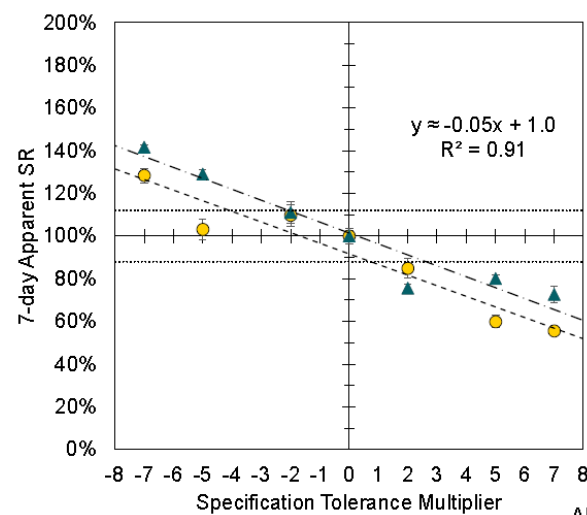
Site visit MnRoad test facility, with demo of **MIT-scan**

Testing & instrumentation (3)

- Gebruik van “surface resistivity” test (AASHTO T358) in US, als alternatieve proefmethode in BE?



Cooper & Spragg, *Resistivity's Sensitivity to Concrete Mixture Design Parameters* (US) + bezoek aan MCL




All figures source: FHWA.

3) Design

- *OptiPave, Short-Slab Concrete Pavements – Juan Pablo Covarrubias (TCPavements)*
 - Kortere platen om spanningen & “opwelling” te verminderen
 - Kunststofvezels (geen deuvels)
 - Platen van 1,8 m * 1,8 m
 - Dikte 10-14 cm
 - Industriële vloeren
 - Specifieke software (OptiPave2)

Table 3 Technical information Route G-84 Quilamuta La Manga Conservation

Location	V Región, Chile	
Length	500 m	10 cm with Structural Fiber– 1,5m x 1,75m
Design Traffic	384.000 Esal ´s	
Compressive Concrete Strength	30 MPa with fiber	
Year of Construction	2013	
Average Precipitation	500 mm/year	Subgrade CBR 10%+ 15 cm Existing Granular Layer CBR 60%
Cost Section	USD \$150.000	
Cost per km.	USD \$230.000	

FORTA[®]
OptiPave



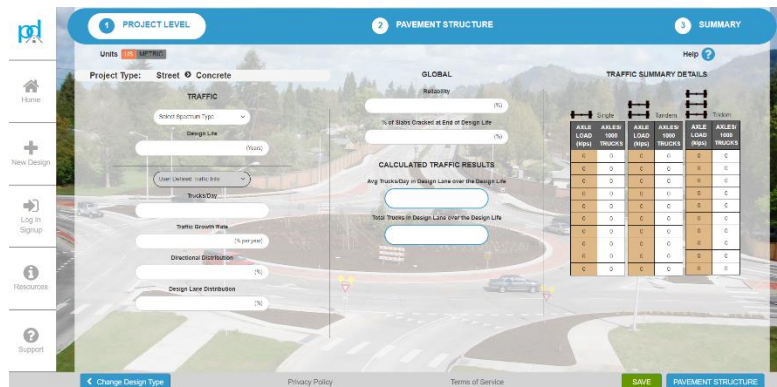
Workshop 2: Advancements in Optimized Concrete Pavement Design



PavementDesigner

<https://www.pavementdesigner.org/>

- Free online tool (met metrisch systeem)
- For straten, parkings, overlagingen,...
- Vermoeiing en "faulting"
- Plaatafmetingen als output



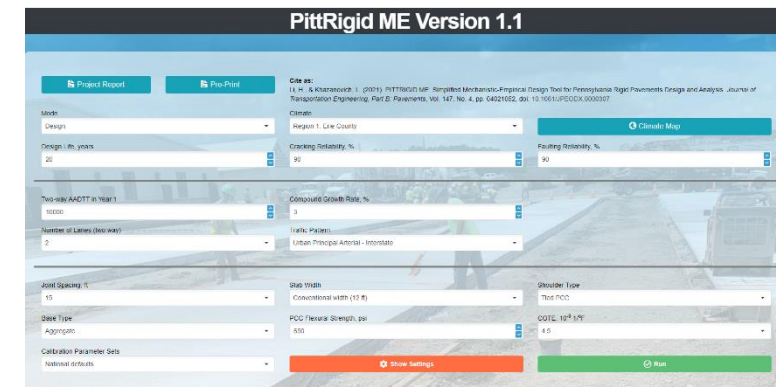
Pavement ME

- Meest uitgebreide dimensioneringssoftware in de VS
- Vrij duur
- Continue verbeteringen
 - "Slab-base bond degradation"
 - "Built-in curling"
 - ...
- Geoptimaliseerde oplossingen (kleinere diktes)

PittRigid ME

<https://software.pavements.pitt.edu/PittRigid>

- Free online tool (Geen metrisch systeem)
- Geoptimaliseerd voor staat Pennsylvania
- Goede benadering van *Pavement ME*



NB: Qualidim - software-update voor flexibele en halfstijve wegconstructies

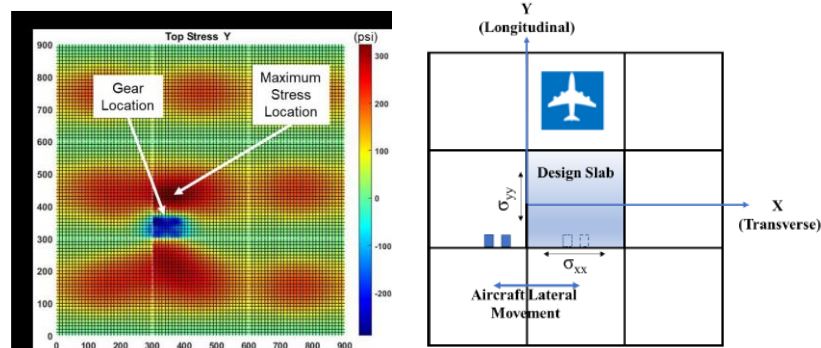
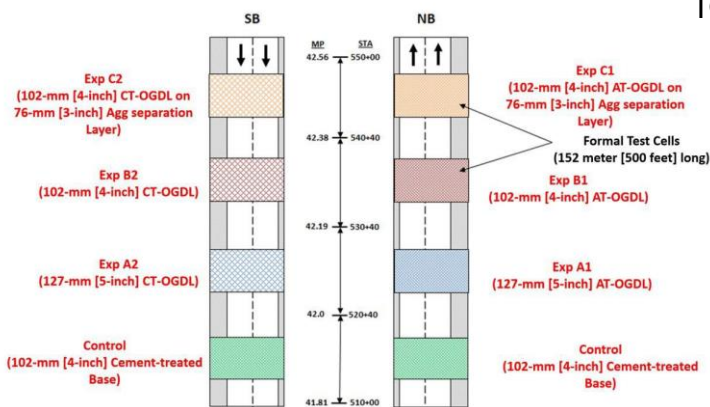


- Nieuwe versie binnenkort uitgebracht:
<http://qc.spw.wallonie.be/fr/qualiroutes/qualidim.html>
- **Opleidingen op 12/12 en 19/12/2024 (Sterrebeek)**
<https://brrc.be/nl/opleiding/opleiding-overzicht/qualidim-software-update-flexibele-halfstijve-bestratingen>

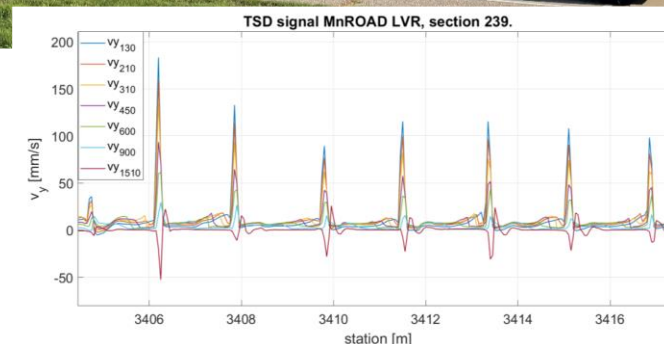
4) Performance modeling

- Eindige-elementen – Back-calculation – AI-modellen...

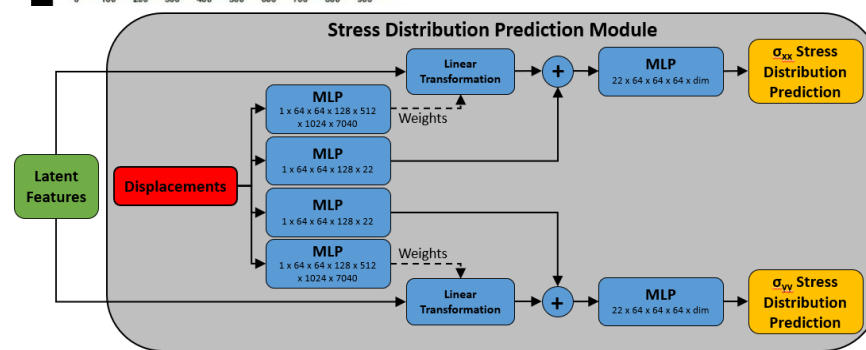
Ashtiani et al. (US), "A Deep-Learning Model to Estimate Rigid Pavement Stresses for Top-Down Cracking Airfield Pavement Design"



Scavone et al., "Mechanistic back-calculation of the LTE of jointed pavements at the corridor level from TSD deflection velocity measurements. Collected case studies." (US)



Alam-Khan et al., "Long-Term Performance of CRCP over OGDL in Illinois" (US)



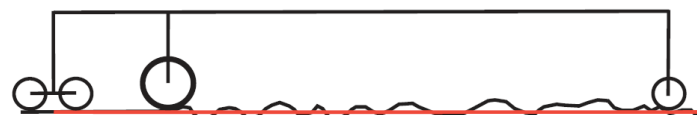
5) Surface characteristics

- Oppervlakttexturen – (diamond) grinding – NGCS...



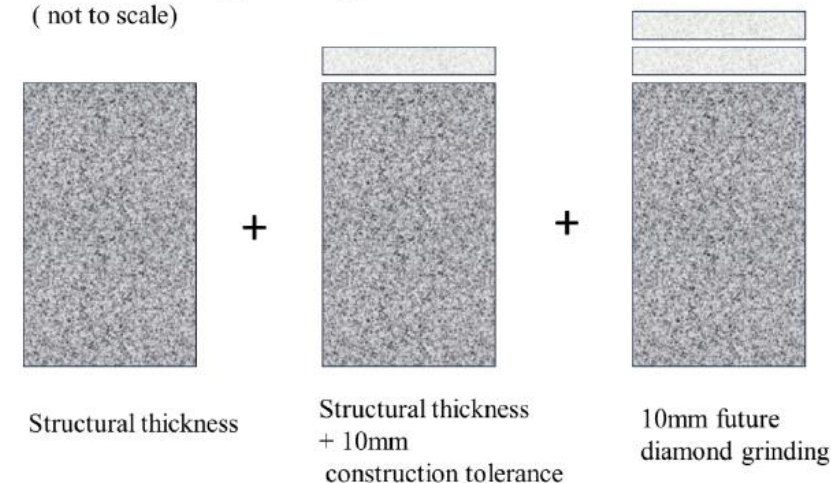
Rens & Boonen, Pattern Imprinted Concrete (Belgium)

T. Alte-Teigler, “High performance surface textures for concrete pavements designed according to requirements”
(Germany)



Hodgkinson & Dowsing, “Sustainable Concrete Highway Pavement Thickness Design: The Role of Diamond Grinding”
(Australia)

Thickness Design Strategy
(not to scale)



New Belgian guidelines for pattern imprinted concrete pavements

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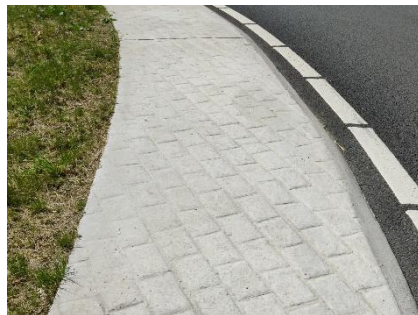
Inleiding – gefigureerd beton

- Decoratieve betonverharding voor:
 - Openbare ruimte en privé-toepassingen;
 - Verkeerseilanden, rotondes;
 - Wegen, busbanen, trambanen.



Context

- Specificaties bestaan reeds in Belgische typebestekken, MAAR:
 - Niet altijd coherent
- DAAROM: **Nieuwe WG bij OCW in 2022**
 - Richtlijnen verbeteren en actualiseren;
 - Onderverdeling in verschillende categorieën/systemen in functie van manier van uitvoering, kleuren en figureren;
 - Voor elke categorie/systeem = geactualiseerde technische specificaties voor:
 - Materialen – Betonsamenstelling – Eisen op vers en verhard beton – Uitvoeringstechnieken – Oppervlakkenmerken - Controles



Classificatiesysteem voor gefigureerd beton

- Gebaseerd op 3 parameters:
 - 1) Manier van **kleuren**;
 - 2) Manier van **uitvoering** en verwerking;
 - 3) Manieren van **figureren** (“printen”).
- 6 systemen:
 - 1A: kleurverharder + manuele aanleg + figureren met matten;
 - 1B: kleurverharder + manuele aanleg + figureren met rol;
 - 2A: in de massa gekleurd* beton + manuele aanleg + figureren met matten;
 - 2B: in de massa gekleurd* beton + manuele aanleg + figureren met rol;
 - 3A: in de massa gekleurd* beton + machinale aanleg + figureren met matten;
 - 3 B: in de massa gekleurd* beton + machinale aanleg + figureren met rol.



Voorbeeld – Landen (1/2)

- Landen, Stationsstraat
 - 1996, platenbeton, systeem 1A: kleurverharder + manuele aanleg + mallen met waaierspatroon



Voorbeeld – Landen (2/2)

- Landen, Stationsstraat
 - 1996, platenbeton, kleurverharder + mallen
 - Foto's anno 2024
 - **In goede staat nog, enkel afslijting op sterk belaste zones**



Besluit gefigureerd beton

- Toegepast & bekend over de hele wereld;
- Richtlijnen in België bestonden reeds voor publieke ruimte, maar niet volledig aangepast aan de huidige praktijk.

⇒ **Nieuwe OCW-handleiding “Ontwerp en uitvoering van verhardingen in gefigureerd beton”**

COMING SOON!

+ Webinar op 30/1/2025



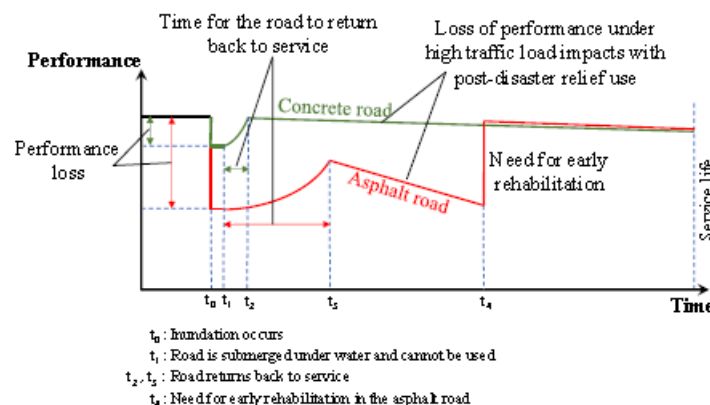
6) Sustainability & climate change

- Climate resilience – doorlatende verhardingen, waterbeheer

Akbelen et al. (Turkey) “An Overview of the Potential of Concrete Pavements in Turkey to Combat Climate Change” – literature review

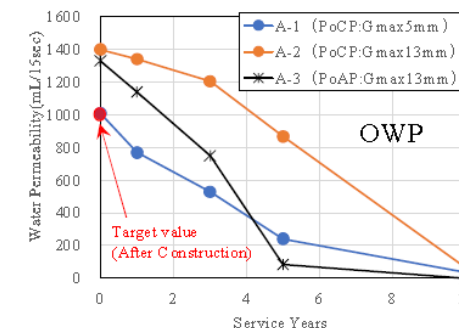


Sedran et al. (FR)



Boonen et al. (BE), Be-Drain project

Nakamura et al., Porous concrete (Japan - Poster)



(a) OWP

Geïntegreerde oplossingen voor waterbeheer



@Nonnenstraat, Turnhout



<https://www.vlario.be/infiltratie-onder-wegenis/>



@ Sterrebeek (OCW)



@Wiekevorst



<https://b-rainconnect.be/nl/cases/case-wiekevorst-apart-architecten>

Technical visit: MnRoad Test Sections



- Verschillende proefvakken met alternatieve materialen, experimentele technieken enz. + uitgebreide monitoring



Conclusies & vooruitzichten



Heel wat ontwikkelingen in de Betonwegenbouw, ook op internationaal vlak



België blijft bij de koplopers, maar cement- en betonindustrie in fase van transitie...



Kennisuitwisseling en (internationale) samenwerking blijven cruciaal op de (beton)weg naar innovatie & vooruitgang!



Belgian Road Research Centre
Together for sustainable roads



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