Belgian Road Research Centre
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EUPAVE
EUROPEAN CONCRETE PAVING ASSOCIATION

“Pervious (lean) concrete for sustainable road pavements: first results of the Belgian Be-Drain project”

EUPAVE Workshop on Pervious Concrete Pavements

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20th October 2021

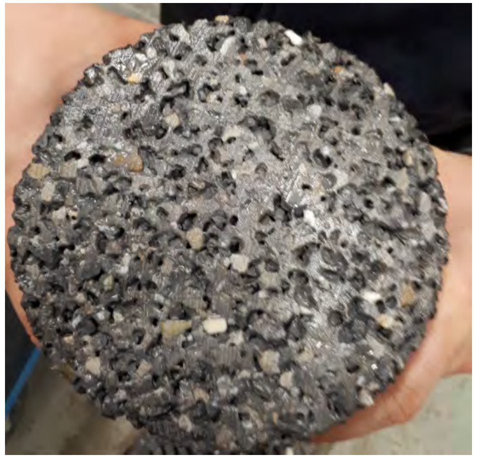
General context

- Climate change & integral, sustainable water management

https://www.operatieperforatie.be/

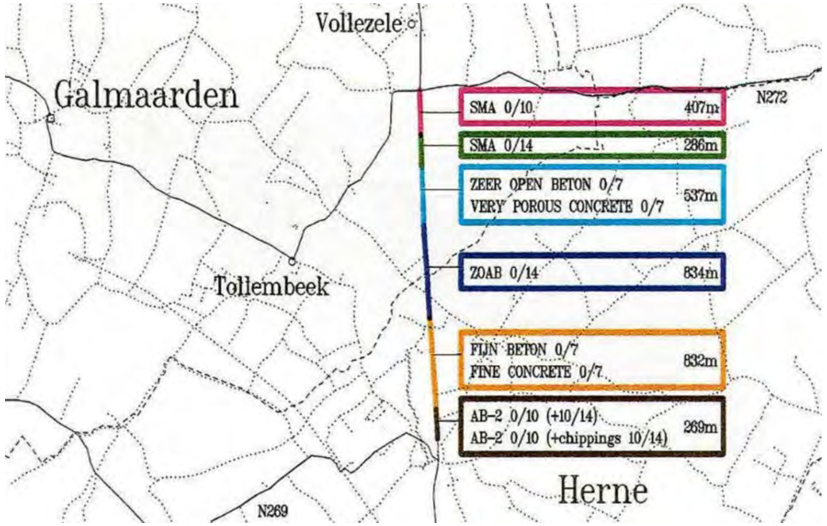
https://www.meteobelgie.be/klimatologie/nieuws/la-suite/2309-watersnood-juli-2021

- Pervious concrete as one possible measure (SUDS):
  - Discontinuous grading (no or limited sand fraction)
  - 15-25% void content
  - Water permeability of $10^{-4} – 10^{-2}$ m/s
  - Compressive strength: 10-25 MPa



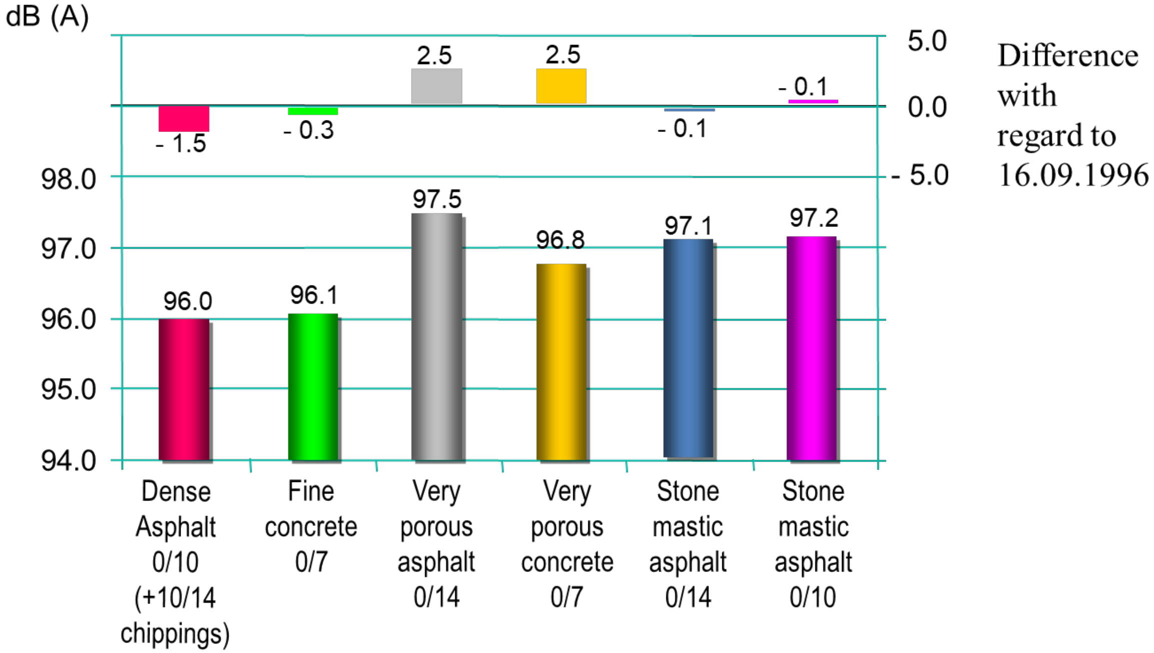
History: past research on pervious concrete

- Open, porous concrete as **noise reducing** top layer
  - Pervious concrete composition with polymers for increased strength and freeze-thaw durability
  - **1996:** Test sections of low noise pavements at N255 in Herne
    - Two-lift CRCP with different top layers
    - One in porous concrete 0/7 mm (+ polymers)



Open, porous concrete as noise reducing top layer

- Conclusions from test sections in Herne (1996):
  - Very porous concrete gave best initial results for noise reduction
  - However, similar problems as porous asphalt:
    - Clogging of the voids;
    - Loosing aggregates on the surface.



History: pervious lean concrete as base layer for (water permeable) pavings

- Research by University of Louvain-la-Neuve (UCL), ~2000
- Example of composition in standard tender specifications:

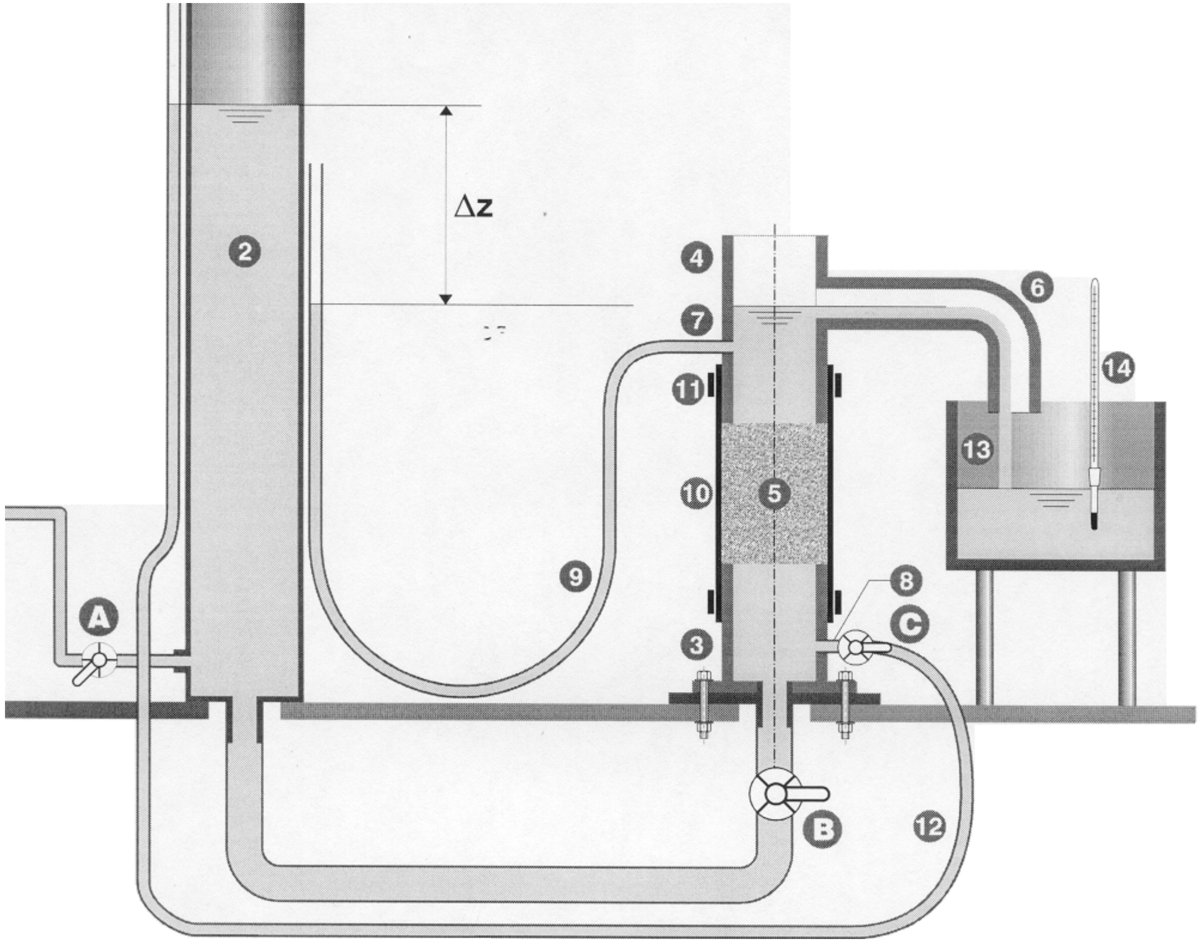
coarse aggregates 6.3/20 mm: 1,130 kg
fine aggregates 2/6.3 mm: 565 kg
cement: minimum 200 kg/m³
water: ± 100 l/m³

Pervious lean concrete: current specifications

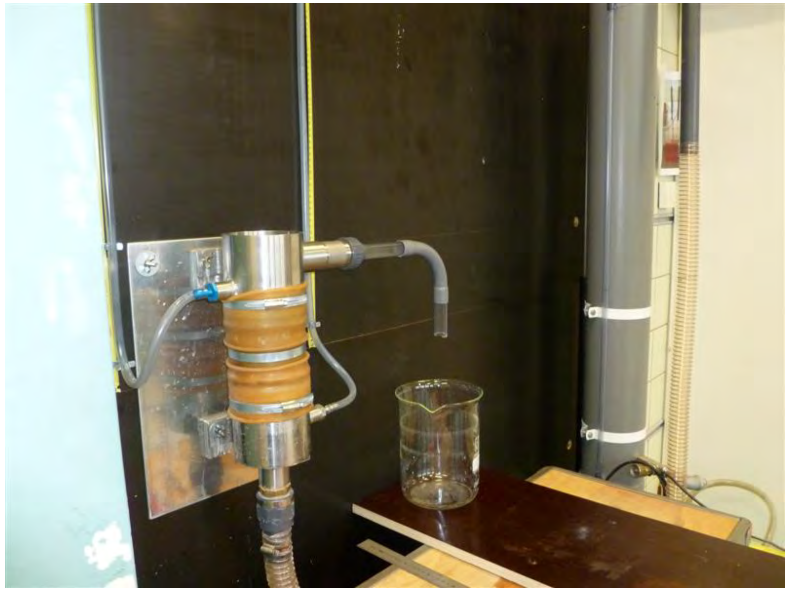
- Compressive strength after 90 days, determined on cores:
  - individual value **Wi ≥ 10,0 Mpa**
  - average value **Wm ≥ 13,0 MPa**

- Water permeability on cores of 100 cm² surface area and 10 cm high:
  - **ki ≥ ki,min = 4*10^{-4} m/s**
- “Effective” porosity on same type of cores (Wallonia):
  - $P_{i,\ min}$ = 6,5 %
  - $P_{m,min}$= 8,0 %

Experimental setup to determine the water permeability of porous lean concrete



- Constant or variable water level depending on permeability
- **BRRC:** Δz ≈ 1-2 cm, constant head permeameter



Current context in Belgium (2018-…)

- Increased interest & demand for water permeable pavements among which **cast-in-place pervious concrete** (cf. ISCR 2018-Berlin + Belgian road sector)

- Demand for representative compaction method in the lab for **porous lean concrete** (cf. certified mixture for base layers)

Hydromedia @ Holcim

For example: Porous concrete for road pavements

- ***Promising application for lightly trafficked areas and public spaces***

Batezini et al. (Brasil)

Vogel et al. (Germany)

Recent testing on pervious lean concrete

- Preliminary testing with pilot sections in collaboration with AC Materials in Puurs, Antwerp (*August 2018*):

- 2 different methods of laboratory compaction tested

Conclusions – test tracks AC Materials

- Vibro-compression ≠ representative compaction method

- Double-ring infiltrometer to test in situ permeability?

Recent testing on pervious “road concrete”

- New test tracks with Holcim executed at BRRC premises in Sterrebeek (*August 2019*)

- *Promising experience with several lab testing methods*

Start of prenormative research Be-Drain (1/11/2020-1/11/2022)

- “***Bé**ton (maigre)* ***drain****ant pour revêtements routiers durables*”
- Problem statement:
  - No general technical guidelines for concrete composition and/or performance requirements for application of pervious concrete as **surface course**
  - Lack of representative test/compaction method for pervious lean concrete as **base layer** in the preliminary lab study (certification)

Be-Drain: porous (lean) concrete for sustainable road pavements

- Belgian prenormative research:
  1. **Technical guidelines, performance requirements and adapted testing methods** for pervious (draining) concrete mixes as a function of:
     - Application (top or base layer)
     - In situ compaction method
     - Functional requirements (comfort, freeze-thaw resistance, ravelling, etc.)

  2. **Recommendations for Belgian standard tender specifications** and possible normalization

Be-Drain: research plan

Opzoekingscentrum voor de Wegenbouw

WP 1 - Literatuurstudie –
Selectie van materialen en proefvoorbereiding.
- Recensie van bestaande technische richtlijnen
- Opname van contact met bedrijven voor commercieel product en overzicht van werven om op te volgen

WP 2 - Beproevingen in het labo
- Optimisation des études de laboratoire
- Studie van andere functionele eigenschappen

WP 3 - In situ validatie
- Opvolging van werven
- Aanleg van proefvakken

WP 4 - Synthese en valorisatie van de resultaten

WP	Sous-tâches	Trimestres							
		1	2	3	4	5	6	7	8
Tâche 1	1.1 Literatuurstudie	■	■						
	1.2 Selectie van materialen en proefvoorbereiding	■	■						
Tâche 2	2.1 Optimisation des études de laboratoire		■	■	■	■			
	2.2 Studie van andere functionele eigenschappen			■	■	■	■	■	
Tâche 3	3.1 Opvolging van werven			■	■	■	■	■	■
	3.2 Aanleg van proefvakken					■	■	■	■
Tâche 4	Synthese en valorisatie van de resultaten								■

Timing : 1/11/2020 - 31/10/2022

Literature review

- Examples from Germany:

Tabelle 7: Anhaltswerte für die Zusammensetzung von Dränbeton

		Decke DBD 8		Tragschicht DBT 16, 22, 32	
		mit PM [kg/m³]	ohne PM [kg/m³]	mit PM [kg/m³]	ohne PM [kg/m³]
Gesteinskörnung	fGK 0/2[1)]	60–100	–	–	–
	fGK 0/1 oder 0/2	–	–	150–180[2)]	150–180[2)]
	gGK 5/8	1.400–1.500	1.500–1.600	–	–
	gGK 8/16, 8/22 oder 8/32	–	–	1.500–1.600	1.500–1.600
Zementfestigkeits-klasse	32,5 R/ 42,5 N	300–350	300–350	150–300[3)]	150–300[3)]
Wasser	Frischwasser	40–75[5)]	85–115	52–73[5)]	60–90[3)]
w/z-Wert (eq)	–	0,25–0,30	0,28–0,33	0,30–0,40	0,30–0,40
Polymer (PM) (z. B. Polymer-dispersion)	15–20 M.-% v.Z.	45–70	–	–	–
	10–15 M.-% v.Z.	–	–	15–34	–
Zusatzmittel	FM oder BV	1–3	–	–	–
Kunststofffasern (z. B. PAN, PVA)	Länge 6–12 mm	1–2	–	–	–
Konsistenz (Einbau)	Verdich-tungsmaß	1,30–1,34[4)] (steif, C1)	1,30–1,34[4)] (steif, C1)	1,30–1,45[4)] (steif, C1)	1,30–1,45[4)] (steif, C1)
Druckfestigkeit	Würfel 150 KL oder Zylinder mit Schlankheit h/d = 1	20–30 MPa	20–30 MPa	10–20 MPa	10–20 MPa

[1)] Die Verwendung einer polierresistenten feinen Gesteinskörnung (z. B. Quarzsand) ist für die Verbesserung der Griffigkeit von DBD zweckmäßig. Polierversuch (PWS) gemäß den TP Gestein-StB, Teil 5.4.2 (PWS-Wert ≥ 0,55).
[2)] Die Verwendung von Sand 0/1 oder 0,2 kann vorteilhaft sein.
[3)] Die höheren Werte werden bei der Verwendung von Beton-Recyclingmaterial benötigt.
[4)] Die Einbaukonsistenz ist auf das Einbauverfahren abzustimmen.
[5)] Der Wasseranteil der PM ist beim Zugabewasser berücksichtigt.

Selection of materials & concrete compositions

- **Base materials:**
  - Limestone aggregates: 4/6 – 6/10 – 10/14 – 14/20 mm (Holcim)
  - CEM III/A 42,5 N LA (CBR-Heidelberg)
  - Sand?
  - Polymeric admixtures (Sika)

- **Concrete compositions:**
  - Compo 1 = béton 4/14 (**CS**)
  - Compo 2 = **BMD 4/20**
  - Compo 4 = béton 4/10 (CS)

  - Commercial mixes (construction sites)

480 kg kalksteen 10/14
480 kg kalksteen 6/10
480 kg kalksteen 4/6
250 kg CEM III/A 42,5 N LA
100 kg water

960 kg 6/20 {
320 kg kalksteen 14/20
320 kg kalksteen 10/14
320 kg kalksteen 6/10
}
480 kg kalksteen 4/6
200 kg CEM III/A
100 kg water

Testing in the laboratory

- **2.1: Optimisation of lab testing methods**
  - ⇒ **Representative compaction method**
  - ⇒ **Influence of different parameters:**
    - Cement content
    - W/C ratio
    - Admixtures
    - (Colour pigments)

vs.

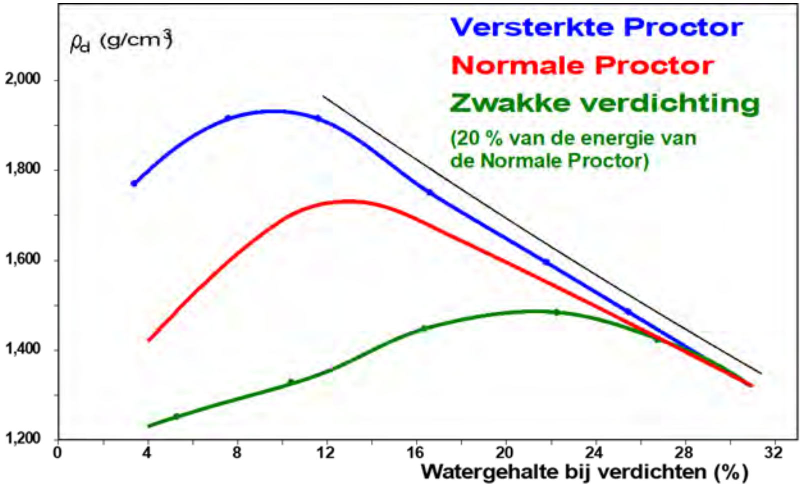
- 2.2 Study of other functional properties

Lab testing – some first results

- *Most promising compaction method so far =*

« Proctor allégé » - « Proctor light »: 2 layers - 2,5 kg - Hc 305mm; 56 blows/layer, with:

  - **Coring** after 7 days (D 113 mm, H = 100 mm) 3 échantillons par mélange + rectification
  - Common curing protocol BRRC-CRIC (under water after 3 days)
  - Testing of permeability *k* + effective porosity [CME 52.20] and Rc28 [NBN EN 12390-3]



?

Lab results – influence of compaction energy

Type of test	Characteristics of test	Symbol	Dimension	Proctor mould A	Proctor mould B	Proctor mould C
Proctor test	Mass of rammer	m_R	kg	2,5	2,5	15,0
	Diameter of rammer	d_2	mm	50	50	125,0
	Height of fall	h_2	mm	305	305	600
	Number of layers	–	–	3	3	3
	Number of blows per layer	–	–	25	56	22
Modified Proctor test	Mass of rammer	m_R	kg	4,5	4,5	15,0
	Diameter of rammer	d_2	mm	50	50	125,0
	Height of fall	h_2	mm	457	457	600
	Number of layers	–	–	5	5	3
	Number of blows per layer	–	–	25	56	98

$$\text{Specific energy} = \frac{\text{mass of rammer} \times \text{height of fall} \times \text{number of blows per layer} \times \text{number of layers x gravity}}{\text{volume of mould}}$$

Abstract from EN 13286-2

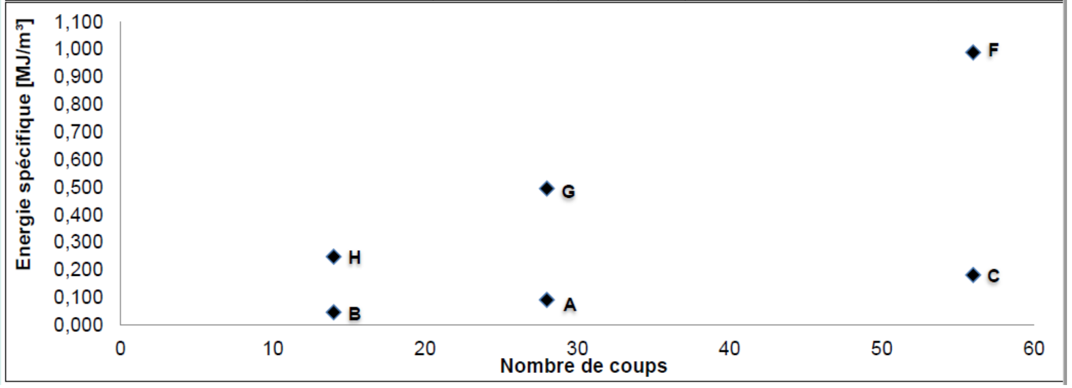
Table 1 — Dimensions of new cylindrical test moulds

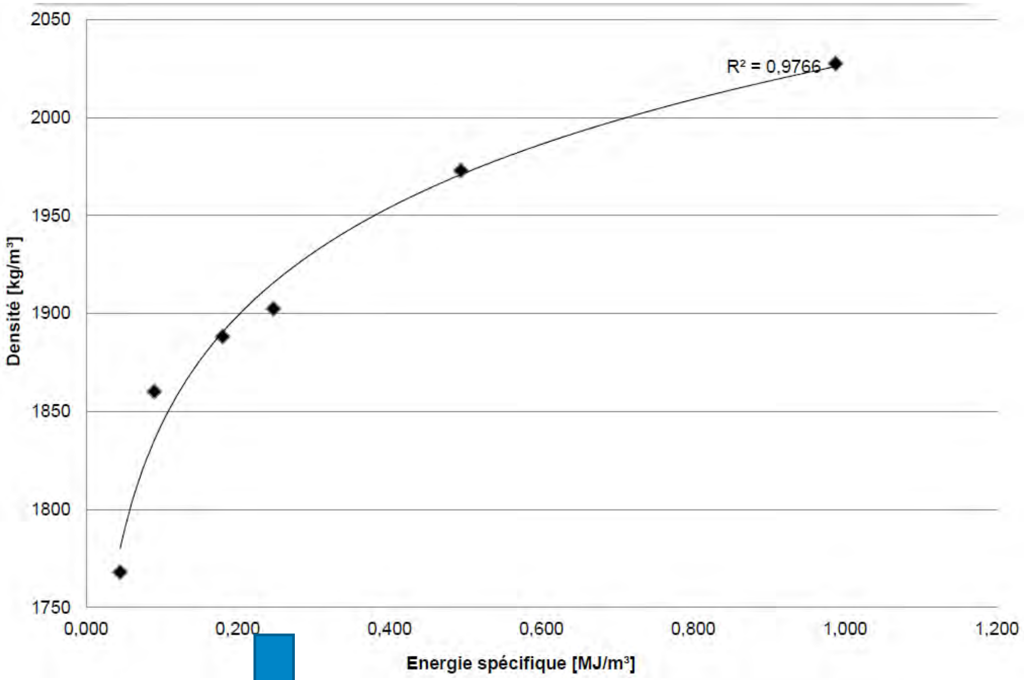
Proctor mould	Diameter d_1 mm	Height h_1 mm	Thickness: Wall w mm	Thickness: Base plate t mm
A	100,0 ± 1,0	120,0 ± 1,0	7,5 ± 0,5	11,0 ± 0,5
B	150,0 ± 1,0	120,0 ± 1,0	9,0 ± 0,5	14,0 ± 0,5
C	250,0 ± 1,0	200,0 ± 1,0	14,0 ± 0,5	20,0 ± 0,5

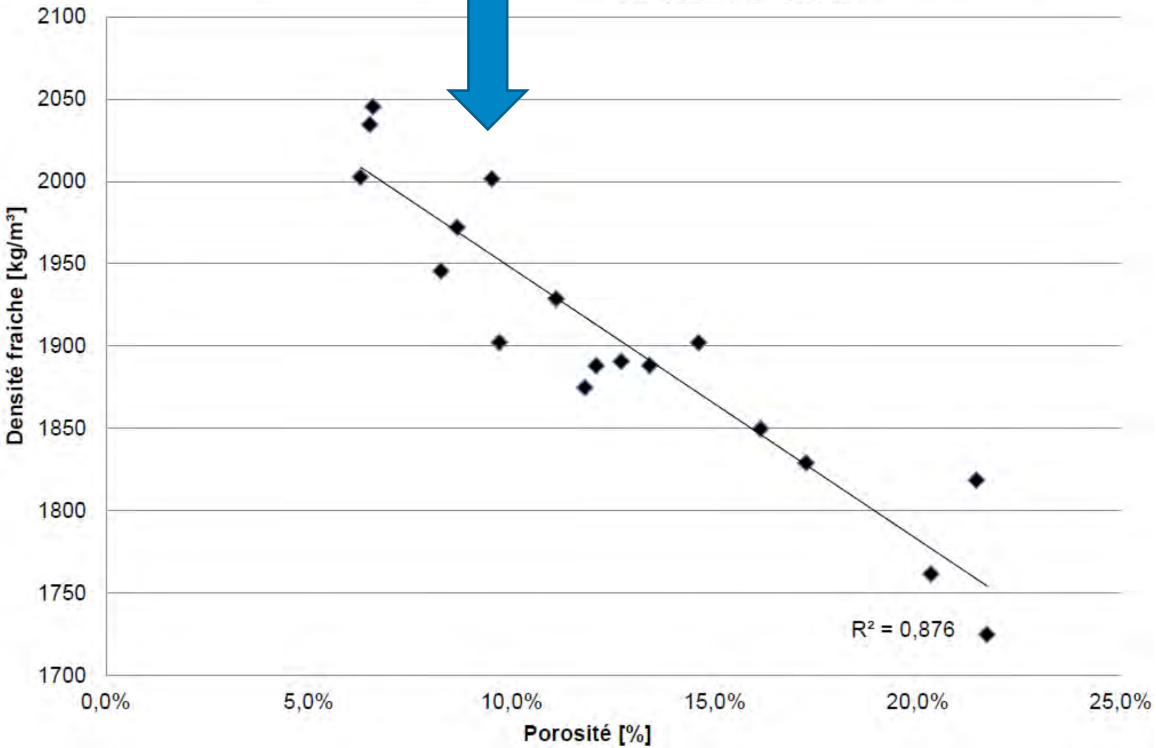
NOTE Annex A gives details of other cylindrical test moulds which may be in current use.

Influence of compaction energy

Combinaison	E-19-272-A	E-19-272-B	E-19-273-C	E-19-273-F	E-19-280-G	E-19-281-H
Fabrication	18/06/2019	18/06/2019	1/08/2019	1/08/2019	1/08/2019	1/08/2019
Eprouvettes	6	6	3	3	3	3
Dame [kg]	2,488	2,488	2,488	4,50	4,50	4,50
Hauteur chute [mm]	305,0	305,0	305,0	457,0	457,0	457,0
Nbr coups par couche	28,0	14,0	56,0	56,0	28,0	14,0
Nbr de couches	1,	1,	1,	2,	2,	2,
Pesanteur [N/kg]	9,810	9,810	9,810	9,810	9,810	9,810
Diamètre moule [mm]	152,50	152,50	152,50	152,0	152,0	152,0
Hauteur moule [mm]	126,50	126,50	126,50	126,0	126,0	126,0
Volume [mm³]	2310575	2310575	2310575	2286376	2286376	2286376
Energie spécifique [MJ/m³]	**0,090**	**0,045**	**0,180**	**0,988**	**0,494**	**0,247**







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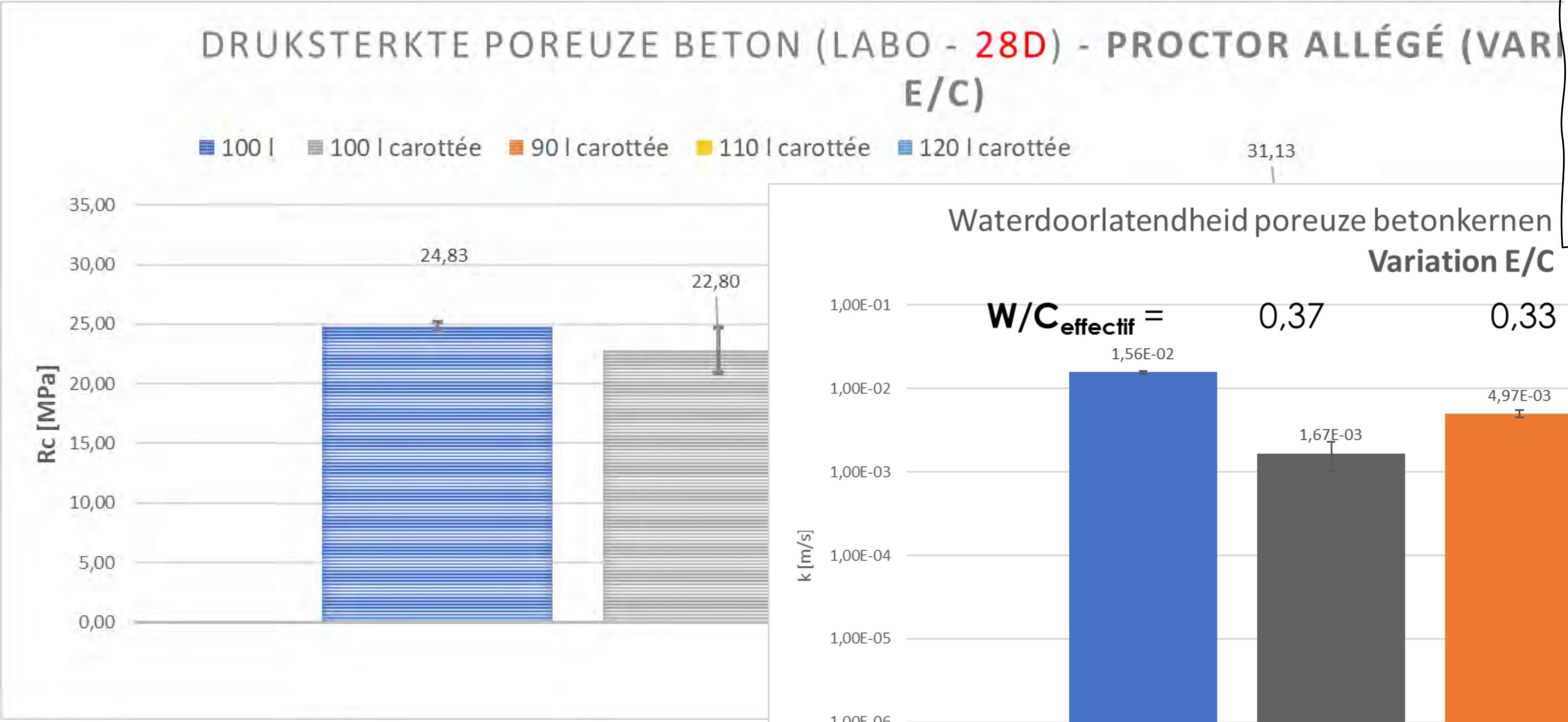
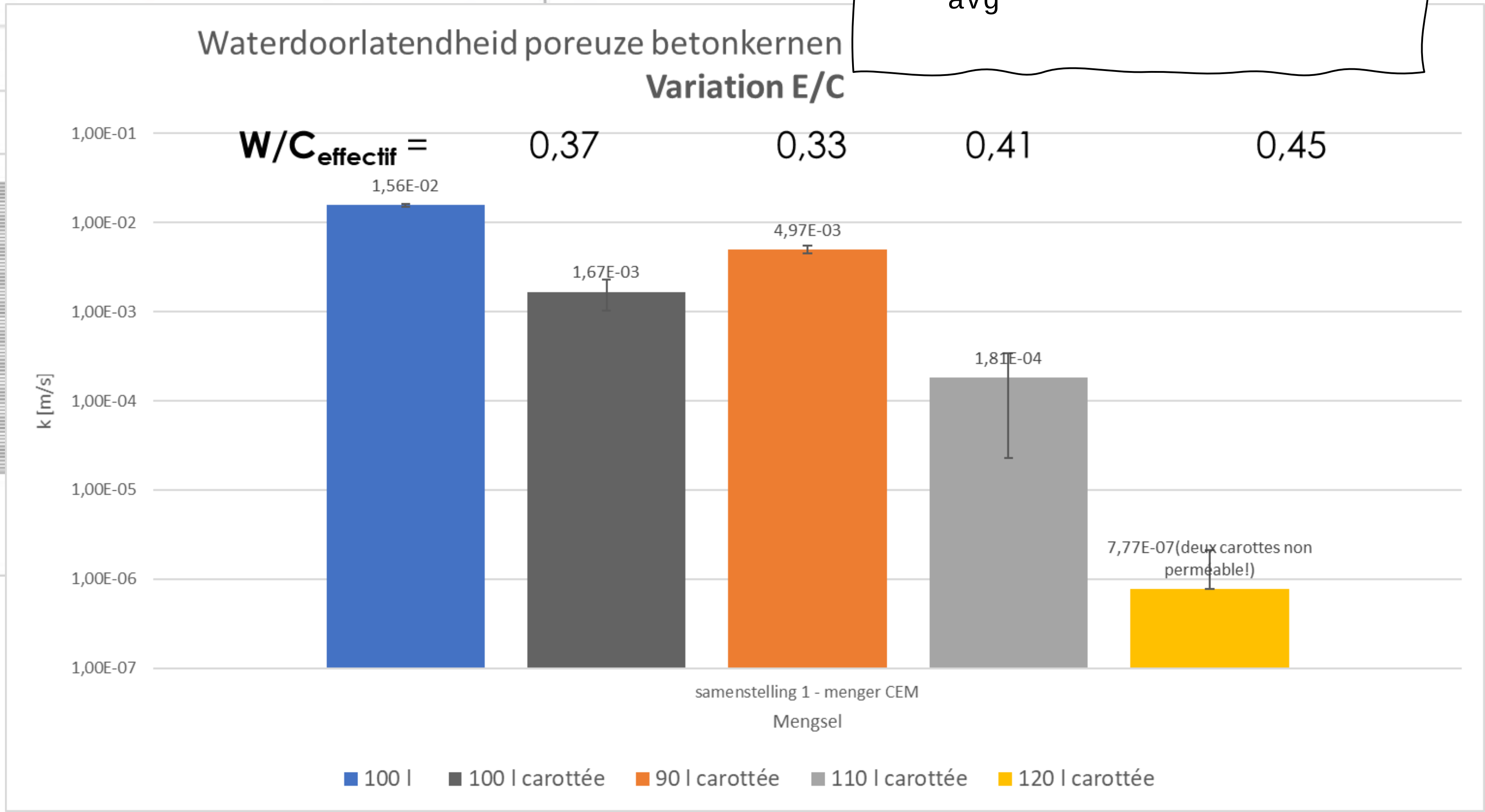
Lab results – Rc versus permeability



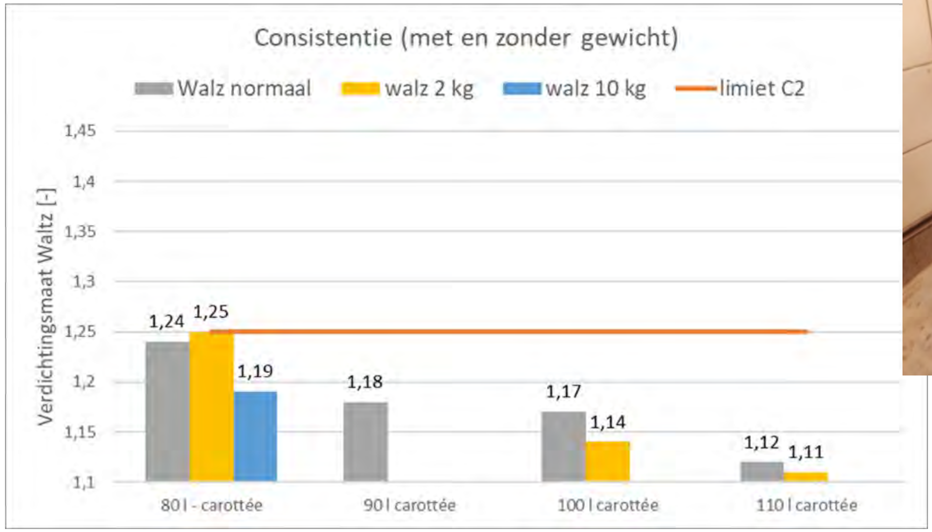


Compo 1 with 100l water
= good compromise:

- $R_{c,avg}$ >= 20 MPa
- k_{avg} >= $4*10^{-4}$ m/s

Other testing in the lab/on site

- **Workability?**
  - EN 12350-4 (Waltz)
  - EN 12350-3 (VeBe)



- **Fluidity/workability period?**
  - EN 13286-45 “Proctor différé”

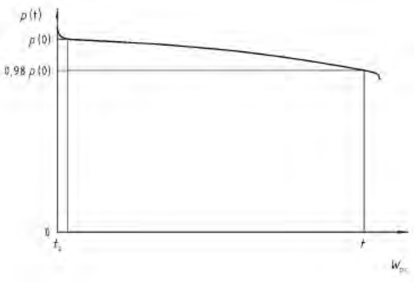
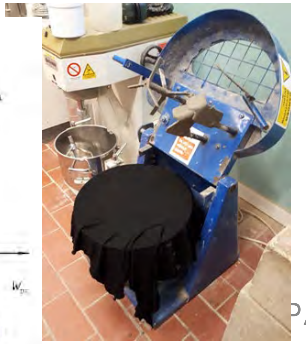
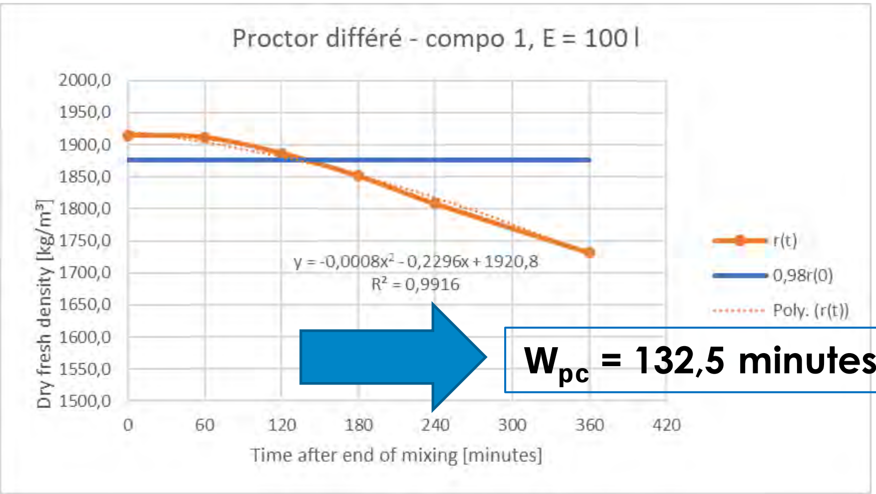


Figure 1 — Determination of W_{pc} by compacting method



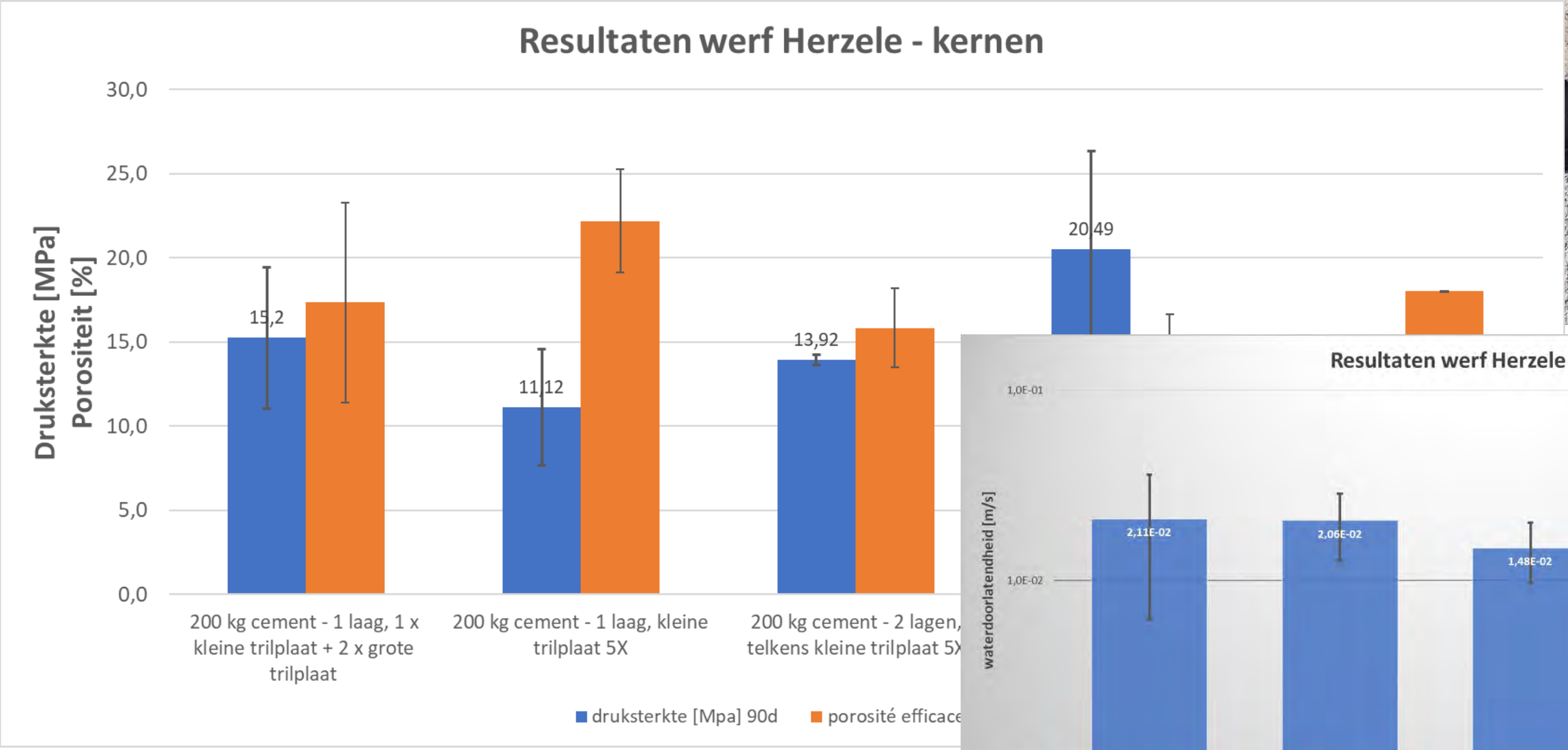


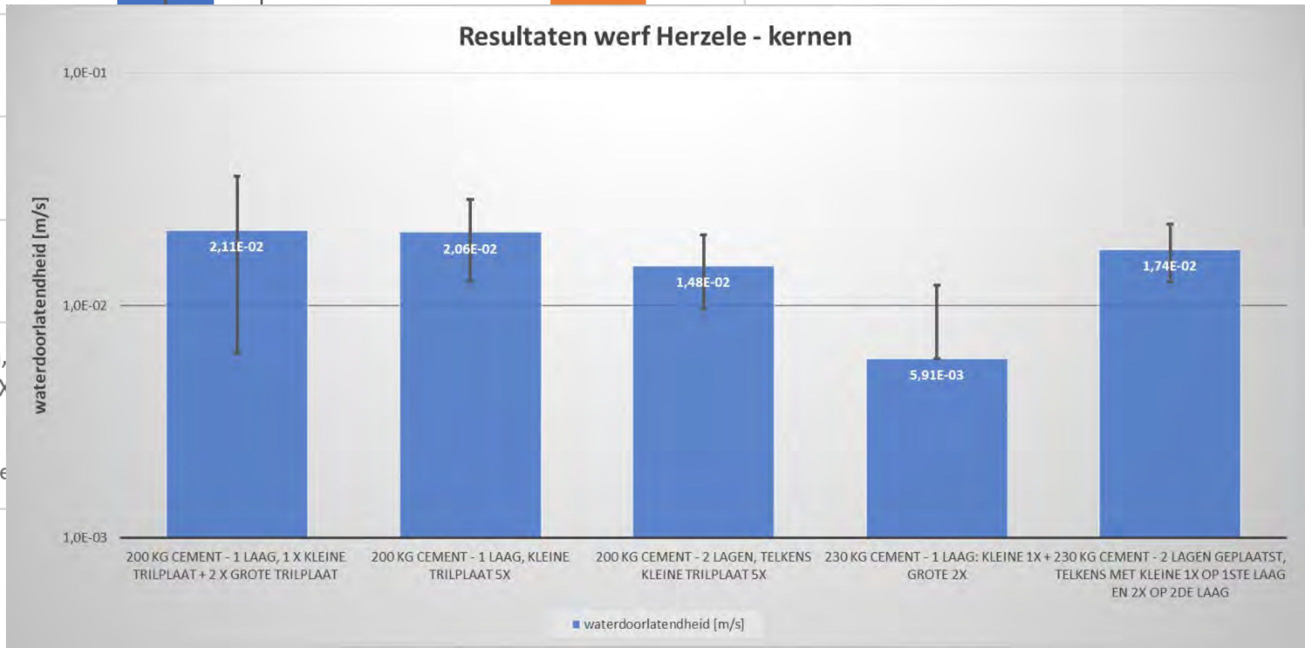
W_{pc} = 132,5 minutes ≈ 2h:12m

In situ validation – exemple of site in Herzele

- Different compaction methods experimented by the contractor + 2 different concrete mixes (C = 200 and 230 kg/m³)
- Samples taken on site by BRRC (PA + OPM)...

... and comparison with cores from the pavement





Functional properties in the lab

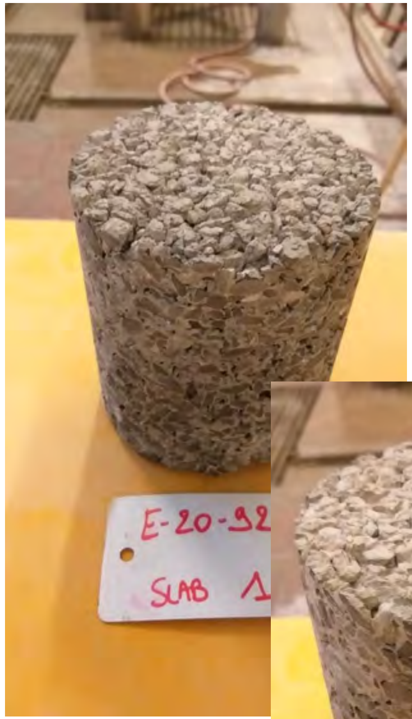
- E.g. Adapted freeze-thaw testing method

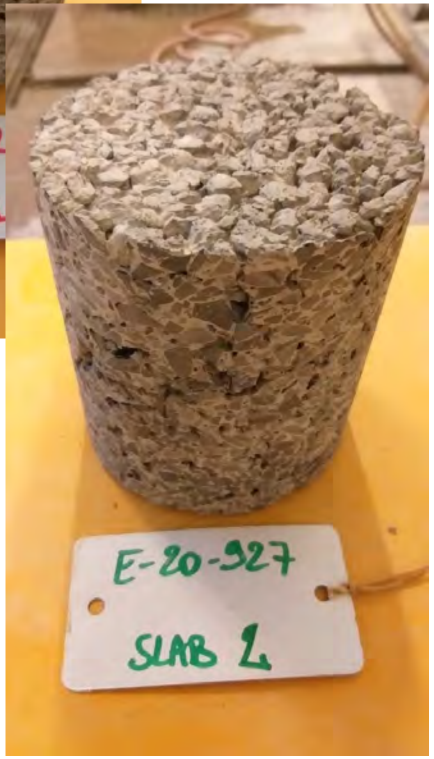
Tableau 5 : Résultats des gel-dégels sur les éprouvettes E-20-924.

N° échantillon	***Surface d'essai A*** mm²	***Sn*** [kg/m²] 7 cycles	14 cycles	28 cycles	42 cycles	56 cycles
E-20-924/1	10400	0.06	0.34	0.56	1.10	2.08
E-20-924/2	10400	0.02	0.16	0.42	0.68	1.16
E-20-924/3	10400	0.02	0.10	0.56	1.00	2.08

Tableau 6 : Résultats des gel-dégels sur les éprouvettes E-20-927.

N° échantillon	***Surface d'essai A*** mm²	***Sn*** [kg/m²] 7 cycles	14 cycles	28 cycles	42 cycles	56 cycles
E-20-927/1	10400	0.00	0.10	0.42	1.04	1.56
E-20-927/2	10400	0.00	0.02	0.04	0.04	0.06
E-20-927/3	10400	0.00	0.02	0.12	0.16	0.26



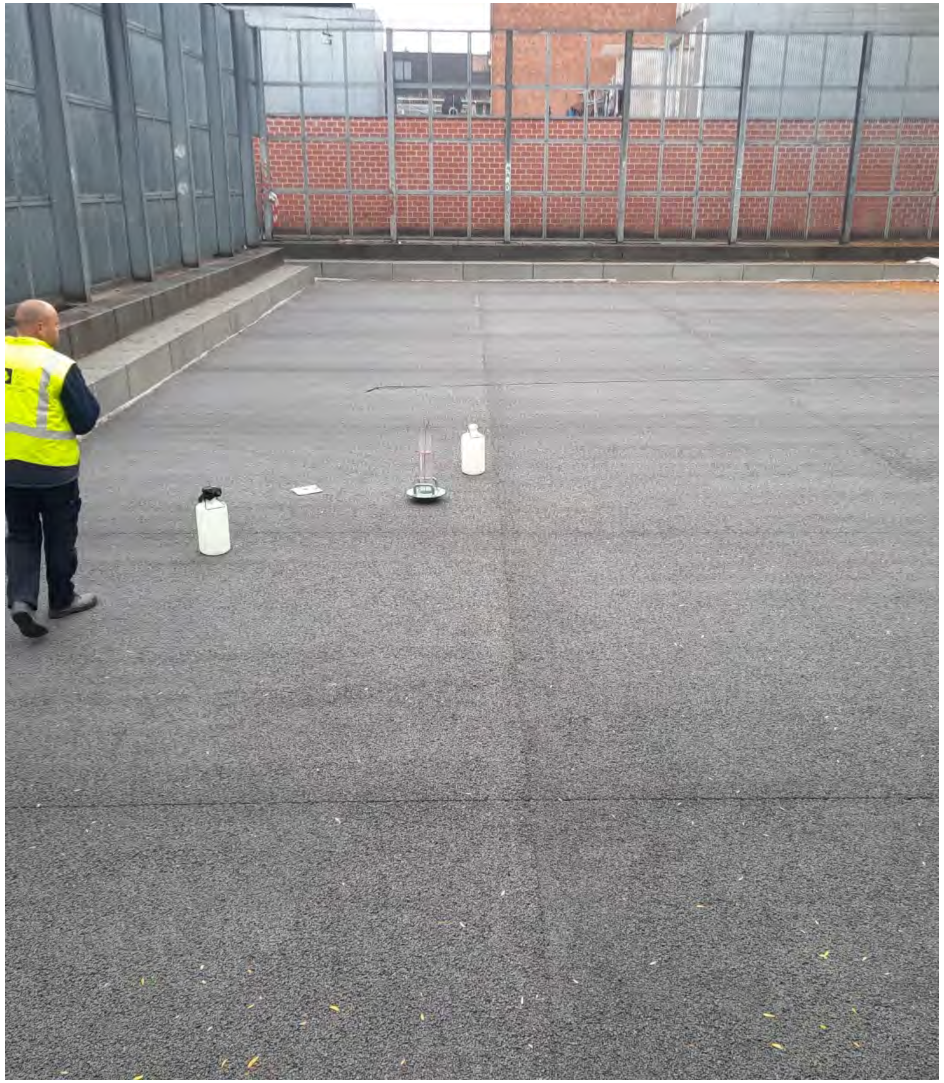


Conclusions & perspectives

Pervious (lean) concrete as promising solution for sustainable water management in urban areas

More experience & improved technical guidelines in Belgium under development: ***from base layer to surface course***

Current focus on functional properties of pervious concrete pavement



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