Over 15 years experience of water permeable pavement blocks in Belgium: how legislation promotes the application

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What I learned during my stay in Bonito...

- You know what heavy rains are!

- You know how to deal with it!

- BUT ... what to do in the cities where place is lacking?
Over 15 years positive experience in Belgium and growing!

- Mainly parking lots and low volume roads
- Mainly pavement blocks, some pervious asphalt, pervious concrete as base layer
Why do we apply permeable pavement blocks?

- To optimize water management (storage and infiltration) by a minimum of investment

- To comply with legislations: new legislation in Flanders encourages and even enforces in some cases the use of permeable surfaces as storage and/or infiltration system

- To combine an environmental friendly structure with traffic: combination of bearing capacity and water permeability/storage, taking into account the necessary frost protection of the soil
All types of water permeable pavement blocks
More recent applications due to legislation and increased knowledge and confidence through better material specifications

Nieuwpoort - Okselaar - Ghent - Beringen - Paris - ...

Anne Beeldens - 3rd INTERNATIONAL CONFERENCE ON BEST PRACTICES FOR CONCRETE PAVEMENTS, Bonito
The permeable pavement system in Belgium

- Pavement blocks: passing the water
- Base layer: bearing capacity
- Sub base layer: storage capacity and frost protection
- Drainage system: infiltration in the soil or retarded drainage of the water to an infiltration system

NO gullies needed at the surface - extra security through adjacent green surfaces
NO slope required (0,5 % as min by preference - max. 5% - application in terraces)
NO extra water storage capacity needed: reduced outlet in order to store the water in the structure
The permeable pavement concept

- Water infiltration at the surface => no ponding
- Water infiltration in the sub grade => no water evacuation or drainage needed
- Water storage in the structure, by preference in the sub grade (4)
- Drainage at bottom of structure if infiltration is not possible or limited
- The whole structure permeable!
From 2004 on: water permeable pavements admitted as infiltration system - reduced extra water storage capacity necessary

New regulation (in Flanders) on rainwater: water permeable pavements do not need extra storage or infiltration system if no drainage beneath or evacuation of the water at the surface is foreseen

If infiltration in the soil is not possible, water permeable pavements can be designed as storage system

Water permeable pavements can be designed as storage for rainwater from adjacent housing or surfaces

More confidence and better applications through insertion of technical requirements in standard specifications
Water storage from adjacent housing or surfaces - directly in sub base layer
Growing production due to legislation and experience

- Legislation in order to promote water permeable pavement structures at regional level as well as at local level
New technical prescription PTV 827: Water permeable pavement system - certification

- Evaluation and certification of the whole system: drainage, sub-base layer, base layer, pavement blocks
- Specific structure is certified, taking into account the material characteristics as well as the placing of the structure on site
- Other technical prescriptions: PTV 122 for water permeable paving blocks and tiles and PTV 121 for concrete grass tiles
Design of permeable pavements with concrete pavement blocks

- Base layer: thickness and choice of material in relation with traffic
  - Pervious lean concrete
  - Unbound granular mixture with limitations on fines

- Sub base layer: thickness in relation with the needed storage volume

- Pavement blocks according to choice of designer

- Drainage: if no or very limited infiltration is possible
Standard structures in relation to traffic and soil permeability

<table>
<thead>
<tr>
<th>More traffic</th>
<th>Higher permeability of the soil</th>
</tr>
</thead>
</table>

| ![Diagram 1] | ![Diagram 2] | ![Diagram 3] |
| ![Diagram 4] | ![Diagram 5] | ![Diagram 6] |
| ![Diagram 7] | ![Diagram 8] | ![Diagram 9] |
| ![Diagram 10] | ![Diagram 11] | ![Diagram 12] |
Materials - properties

- **Base and Sub base layer - unbound granular mixture 0/32 - 2/32:**
  - fines (<0.063 mm) < 3%
  - Fraction < 2 mm < 25%
  - If recycled concrete aggregates are used, no aggregates smaller than 2 mm

- **Base layer - bound material**
  - Drainage lean concrete: Permeability of 4*10^{-4} m/s and strength of 14 MPa

- **Bedding layer**
  - fines (<0.063 mm) < 3%
  - Maximum grain size: 6,3 or 8 mm
  - LA < 20 - MDW < 15: reducing risk on formation of fines
  - Filter stability

- **Joint filling material - in relation to type of pavement block**
  - 0,5/2 sand for pervious pavement blocks
  - 2/4 porphyry aggregates for pavement blocks with enlarged joints or with drainage holes

**AT ANY TIME: COMPROMISE BETWEEN MECHANICAL STABILITY AND PERMEABILITY**
Permeable pavement blocks - in combination with the permeable structure
Research project at BRRC 2003-2007
Height of water in the structure

- H = 153.63 cm => 3100 l
- Rain: 33.6 mm => 4071 l
- Outflow measured: 3328 l

- H = 121.6 cm => 512 l
- Rain: 13.9 mm => 1686 l
- Outflow measured: 1521 l
Surface permeability on parking lot

Drainage holes
Enlarged joints
Pervious pb
Pervious pb
Enlarged joints
Drainage holes
### Design volume for water storage in SUB BASE

- **Rain:** average rain of 10 minutes with a return period of 30 years = 270 l/s/ha

- **Successive rains:**

<table>
<thead>
<tr>
<th>Outflow</th>
<th>2 years</th>
<th>5 years</th>
<th>10 years</th>
<th>20 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 l/s/ha</td>
<td></td>
<td></td>
<td>180 m³/ha</td>
<td>240 m³/ha</td>
</tr>
<tr>
<td>25 l/s/ha</td>
<td></td>
<td>160 m³/ha</td>
<td>200 m³/ha</td>
<td>240 m³/ha</td>
</tr>
<tr>
<td>20 l/s/ha</td>
<td>120 m³/ha</td>
<td></td>
<td>210 m³/ha</td>
<td>260 m³/ha</td>
</tr>
<tr>
<td>15 l/s/ha</td>
<td>140 m³/ha</td>
<td></td>
<td>240 m³/ha</td>
<td>290 m³/ha</td>
</tr>
<tr>
<td>10 l/s/ha</td>
<td>160 m³/ha</td>
<td></td>
<td>270 m³/ha</td>
<td>330 m³/ha</td>
</tr>
<tr>
<td>5 l/s/ha</td>
<td>210 m³/ha</td>
<td></td>
<td>340 m³/ha</td>
<td>410 m³/ha</td>
</tr>
</tbody>
</table>
Design and choice of materials - general rules

- Increasing porosity with increasing depth: if clogging occurs, it will occur at the surface => cleanable!
- Joint filling is necessary to avoid clogging of the bedding layer
- Limited to low-volume roads with restricted speed limits (30 km/h) - most applications are parking lots or pedestrian areas
- Restrictions of amount of fines and limitations on the formation of fines: grading and quality of aggregates!
Project: D’Ieteren
D’Ieteren in Kortenberg
Sand bed 2/7; base layer 2/20; sub base layer 7/32 + 0/7

• Road in jointed concrete plates
• Transition in pervious concrete pavement blocks
• Parking area in concrete pavement blocks with drainage holes (>30% porosity)
• 70.000 m²
Good experience with existing parking lots towards long term permeability
Special applications: water permeable structures in allotments

- Risk of clogging of structure during construction of houses
Possible solutions to minimize risk of clogging

- Working in 2 phases: sub base and asphalt layer during phase 1, removal of asphalt layer (or piercing of the asphalt) and final base layer, bedding layer and pavement blocks in phase 2 after construction: water evacuation!

- Construction of final road with a very precise cleaning scheme and filling of joints
Use of recycled concrete aggregate as base layer - an example: parking SEG, KULeuven in Heverlee

- Two challenges:
  - integration of the slope
  - Choice of materials - use of recycled aggregates: bearing capacity and permeability
Storage capacity - integration of slopes

Slope 1% - 10 m further = 10 cm difference in height

=> Storage in sub base NOT in pavement blocks
Integration of slopes

- Working with obstructions to slow down the water outflow
- Working with terraces
Good compaction crucial for durability, but low-volume roads => 80 MPa in stead of 110 Mpa for M₁ (plate compression test)
Bearing capacity: M1 plate test
17 MPa soil - 35 MPa sub base layer - 80/110 MPa base layer
### Bearing capacity and permeability tested on site

<table>
<thead>
<tr>
<th>Material for the base layer, 250 mm thick</th>
<th>Bearing capacity</th>
<th>Permeability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crushed aggregate 2/32 mm</td>
<td>21 MPa</td>
<td>7*10^{-4} m/s</td>
</tr>
<tr>
<td>Recycled concrete aggregate 4/40 mm with 20% of crushed sand from recycled aggregate</td>
<td>40 MPa</td>
<td>1.2*10^{-10} m/s</td>
</tr>
<tr>
<td>Recycled concrete aggregate 0/40 mm</td>
<td>57 MPa</td>
<td>2*10^{-11} m/s</td>
</tr>
<tr>
<td>Recycled concrete aggregate 4/40 mm with up to 20% of crushed natural aggregate 0/8 mm</td>
<td>94 MPa</td>
<td>&gt; 10^{-4} m/s</td>
</tr>
</tbody>
</table>
Permeability measurements in laboratory

- Porous lean concrete
- Aggregates
Measurement of permeability: soil and structure

- Soil: Open-end-test
  (US Bureau of Reclamation: Earth Manual)

- Base layer

Surface: double ring test
BUT....
Problems with design

Ertvelde,
Market Place
2004
Inadequate integration
Problems with block paving material - concentrated on permeability

Melsele, Park & Ride, 2001

Relation porosity - strength was not respected
Influence of de-icing salts on the durability of pervious pavement blocks

- Adapted test method to determine the scalling resistance of pervious pavement blocks in the presence of de-icing salts
- Porosity-strength relation is very important to obtain a durable pavement block and consequently a durable pavement
Permeable pavements with dolomite - resistance to traffic!
Importance of quality of materials!
### Specifications

<table>
<thead>
<tr>
<th>Component</th>
<th>Specifications</th>
<th>Materials used</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Paving blocks</strong></td>
<td>Porous paving blocks 100 mm thick</td>
<td>Porous paving blocks 80 mm</td>
</tr>
<tr>
<td><strong>Bedding layer</strong></td>
<td>30 mm crushed aggregate; 75% 2/6.3 + 25% 0/6.3; high-quality stone to limit the formation of fines</td>
<td>Min. 30 mm “pouché” (untreated crushed stone)</td>
</tr>
<tr>
<td><strong>Base layer</strong></td>
<td>150 mm continuously graded crushed aggregate 0/32 mm with restrictions on fines (max. 3% &lt; 63 µm and max. 25% &lt; 2 mm); the use of recycled concrete aggregates is allowed</td>
<td>150 mm continuously graded recycled concrete aggregates 0/32 mm, with a limited amount of fines</td>
</tr>
<tr>
<td><strong>Subbase layer</strong></td>
<td>100 mm gap-graded crushed aggregate 2/20 mm (M1 &gt; 85 MPa)</td>
<td>100 mm gap-graded crushed aggregate 2/20 mm</td>
</tr>
</tbody>
</table>
Importance of quality of materials
**Clogging at the surface**

<table>
<thead>
<tr>
<th>Porous paving block</th>
<th>Permeability prior to cleaning</th>
<th>Permeability after cleaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>taken from structure</td>
<td>$3.45 \times 10^{-6}$ m/s</td>
<td>$7.64 \times 10^{-5}$ m/s</td>
</tr>
<tr>
<td></td>
<td>$1.59 \times 10^{-6}$ m/s</td>
<td>$1.85 \times 10^{-4}$ m/s</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Porous paving block taken from storage</td>
<td>$2.60 \times 10^{-4}$ m/s</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$8.66 \times 10^{-5}$ m/s</td>
<td></td>
</tr>
</tbody>
</table>
Gare de bus de Gembloux
Emplacement de stationnement

Surface pavée : 15615 m²
Réalisation des travaux : 2007

Structure
Type de pavés : Joints larges
Remplissage des joints : sable concassé 2/5
Couche de pose : Graviers concassés 2/5
          4 cm
Fondation : empierrage 0/20
          15 cm
Sous-fondation : empierrage 0/32
          Type II
          20 cm

Perméabilité du sol :
1 . 10⁻⁶ m/s (2007)
Perméabilité de la fondation :
5,4 . 10⁻³ m/s (2007)
Software to help with design of the pavement

Project name:
Address:
Designer:

Surface (m²):
Contrib. catchment (m²):

8 cm
3 cm
25 cm
34 cm

Base material:
Unbound granular material

Subbase material:
2/20

Soil permeability (m/s):
5,0E-07

Bedding layer:
2/6.3

Joint filling material:
2/5.6

Water management designed on:
Successive rainfall: 240 m³/ha

Storage in the subbase layer:
102 l/m²

Extra safety: storage in the base 01
75 l/m²
Other aspects: joint filling material and weed prevention
Water permeable pavements: what with pollution?
Structure on itself is purifying

- HC is retained in the structure if the pollution is not too high.
- Effect of micro-organisms: very limited concentration in the effluent at the bottom of the structure - simulation of 1 year rain.
- Increase in HC in the effluent if more than 3 litres of diesel was added.
Durability of the purifying effect in the lab
Durability of the purifying effect on real scale with and without micro-organisms

- Zone d'essai 4: Structure type + épandage de micro-organismes sur la surface
- Zone d'essai 3: Structure type + épandage de micro-organismes sur la surface + pollution artificielle
- Zone d'essai 2: Structure type + enrobage par micro-organismes des granulats de la couche de pose + pollution artificielle
- Zone d'essai 1: Structure type + pollution artificielle
Conclusions

- Large increase in application of water permeable pavement blocks in Belgium, due to new legislation and good knowledge distribution
- Application of standard structure, provision of software in order to design correctly water permeable structures
- Combination of bearing capacity and water storage is improved by splitting up these tasks over the different layers in the structure - water permeability throughout the whole structure
- Choice of material and control towards bearing capacity as well as permeability during execution
- Durability of the permeability is demonstrated by research project as well as on site
- Maintenance is limited, mainly filling up joints to avoid in depth clogging, weed control and if necessary cleaning with high pressure
Keep enjoying the water!

Thank you for your attention, questions?