Concrete pavements: sustainability through durability

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Managing director FEBELCEM
Sustainable construction
# Sustainability - Durability

<table>
<thead>
<tr>
<th>Country</th>
<th>English</th>
<th>French</th>
<th>Dutch</th>
<th>German</th>
<th>Spanish</th>
</tr>
</thead>
<tbody>
<tr>
<td>UK</td>
<td>Sustainability</td>
<td>Sustainable development</td>
<td>Pavement durability</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Durability</td>
<td></td>
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<tr>
<td>FR</td>
<td>Durabilité</td>
<td>Développement durable</td>
<td>Durabilité du revêtement</td>
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<tr>
<td>NL</td>
<td>Duurzaamheid</td>
<td>Duurzame ontwikkeling</td>
<td>Duurzaamheid van de verharding</td>
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</tr>
<tr>
<td>D</td>
<td>Nachhaltigkeit</td>
<td>Nachhaltige Entwicklung</td>
<td>Dauerhaftigkeit von die Straße</td>
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<tr>
<td>ES</td>
<td>Sostenibilidad</td>
<td>Desarrollo sostenible</td>
<td>Durabilidad del pavimento</td>
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</tbody>
</table>
Importance of life-cycle approach

LCA is a method to evaluate the overall environmental impact of a (functional) unit (e.g. 1 m² pavement, 1 km motorway) over the entire life-cycle “from cradle to grave”, following standardized procedures (ISO 14040, ISO 14044).
Carbon Footprint

The Carbon Footprint is the overall amount of carbon dioxide (CO$_2$) and other greenhouse gas emissions (methane, nitrous oxide, fluorinated gases) associated with a product along its supply chain, including use and end-of-life recovery and disposal.

= part of a more complete approach (LCA)

If only greenhouse gases were to be considered, this could have a negative effect on other environmental aspects.
### Environmental indicators

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Unit</th>
</tr>
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<tbody>
<tr>
<td>Primary energy</td>
<td>MJ</td>
</tr>
<tr>
<td>Water Consumption</td>
<td>kg</td>
</tr>
<tr>
<td>Natural Resources</td>
<td>$10^{-9}$ (consumption compared to world reserves)</td>
</tr>
<tr>
<td>Wastes</td>
<td>t eq</td>
</tr>
<tr>
<td>Radioactive wastes</td>
<td>dm³</td>
</tr>
<tr>
<td>GWP$_{100}$ (greenhouse gases)</td>
<td>kg CO$_2$</td>
</tr>
<tr>
<td>Acidification</td>
<td>kg SO$_2$</td>
</tr>
<tr>
<td>Eutrophication</td>
<td>kg PO$_4^{3-}$</td>
</tr>
<tr>
<td>Ecotoxicity</td>
<td>m³ eq. polluted water</td>
</tr>
<tr>
<td>Toxicity to humans</td>
<td>kg eq. contaminated flesh</td>
</tr>
<tr>
<td>O$_3$ smog</td>
<td>kg eq. C$_2$H$_2$</td>
</tr>
<tr>
<td>Odour</td>
<td>m³ eq. air pollution due to ammonia</td>
</tr>
</tbody>
</table>
Cement production and CO$_2$

1 ton cement $\sim$ 1 ton CO$_2$

1 ton cement $\sim$ 750 kg CO$_2$ (EU average)
Cement production and CO$_2$
## Embodied energy

<table>
<thead>
<tr>
<th>Material</th>
<th>Embodied energy</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MJ/kg</td>
<td>MJ/m³</td>
</tr>
<tr>
<td>Concrete 30 MPa - CEM I</td>
<td>1,3</td>
<td>3180</td>
</tr>
<tr>
<td>Concrete 40 MPa - CEM I</td>
<td>1,6</td>
<td>3890</td>
</tr>
<tr>
<td>Asphalt</td>
<td>3,4</td>
<td>7140</td>
</tr>
<tr>
<td>Brick</td>
<td>2,5</td>
<td>5170</td>
</tr>
<tr>
<td>Timberwood</td>
<td>2,5</td>
<td>1380</td>
</tr>
</tbody>
</table>
LCA – French study on road structures

Study by the “Centre d’Energétique de l’Ecole des Mines de Paris”
Functional unity = 1 km motorway with 2 x (2 lanes + emergency lane)
Lifetime of 30 years, 100 million vehicles, 25 million heavy goods vehicles
Data from Ecole Polytechnique from Zurich (Oekoinventaire) and the University of Karlsruhe (Oekoinstituut Weimar)

Comparison of:

• 4 structures in concrete (plain concrete = slabs, reinforced concrete, different base-layers)
• 1 composite structure (thin bituminous wearing course on continuously reinforced concrete)
• 1 asphalt structure
Lifetime impact of a road – not including traffic
Comparison plain concrete, reinforced concrete and asphalt

- Odour (10E+09 m³)
- O3-smog (10E+04 kg)
- Toxicity to humans
- Ecotoxicity (10E+08 m³)
- Eutrophication (10E+03 kg phosphate ions)
- Acidification (10E+04 kg SO2)
- GWP100 - greenhouse gases (10E+06 kg CO2)
- Radioactive wastes (10E+02 dm³)
- Wastes (10E+04 t eq)
- Natural resources (10E-08)
- Water consumption (10E+07 kg)
- Primary energy (10E+01 TeraJoules)

Jointed plain concrete
CRCP
Asphalt
Lifetime impact of a plain concrete road – including traffic

- Primary energy (10E+01 TeraJoules)
- Water consumption (10E+07 kg)
- Natural resources (10E-08)
- Wastes (10E+04 t eq)
- Ecotoxicity (10E+08 m³)
- Eutrophication (10E+03 kg phosphate ions)
- Acidification (10E+04 kg SO2)
- Radioactive wastes (10E+02 dm³)
- GWP100 - greenhouse gases (10E+06 kg CO2)
- Ozone-smog (10E+04 kg)
- Odour (10E+09 m³)
- Toxicity to humans

Construction, maintenance and end-of-life phases
Usage phase (traffic)
Fuel savings

A series of four researches by the National Research Council of Canada on the fuel consumption on asphalt, concrete and composite pavements.

Conclusions of the last phase of the research:

*Fuel savings on concrete roads, compared to asphalt roads,*

*Both for an empty and full tractor-trailer unit,*

*Ranged from 0.8 to 3.9%*

*With statistically significant results with a reliability of 95%.*

An average fuel saving of 2.35% allows to compensate the complete CO$_2$ from cement production in 20 to 30 years lifetime.
Recycling

Concrete can be 100 % recycled

Sub-bases

Base layers (unbound and cement bound aggregate mixtures, lean concrete, roller compacted concrete)
Recycling concrete rubble in pavement quality concrete is perfectly feasible when used as twin course concrete

Up to 60% in the bottom layer

Example: work site N49 Zwijndrecht: first Belgian application of twin course CRCP with recycled aggregates in the lower course
Economic aspects

Minimal maintenance over the longest possible lifetime
Economic aspects

Comparison of lifecycle cost (construction + maintenance) for motorways in concrete and asphalt

![Comparison of Pavement Cost Graph]

Discount rate 2.6%
Economic aspects: price stability

+ importance of local materials (cement vs. bitumen)
Societal and social benefits

Safety for the road users
- skid resistance
- visibility
- absence of rutting
- no danger of aquaplaning
Societal and social benefits

Ride comfort for the road users

- evenness
- rolling noise
“Long-life pavements” are essential in LCA (environment) and LCCA (economy) and can only be achieved through

QUALITY

- Materials
- Concrete mix (cement, W/C, sand, air)
- Design
- Construction
- Maintenance

“Quality” will be one of the key drivers in the future structure and working of EUPAVE
Conclusions

- Performance in each of the three fields of sustainable construction:
  - Environment
  - Economy
  - Social and societal importance
- Improvement is still possible through research and study
- No short term gains which might compromise the long term behaviour

Choosing a concrete road is choosing a durable and sustainable solution
Thank you for your kind attention