Characteristics of today’s concrete surfaces

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Outline of the presentation

- Introduction
- Concrete roads in relation to the surface criteria
  - Driving comfort
  - Safety
  - Noise
- Short description and evaluation of different concrete surface textures
- Case-studies and examples
- Conclusions
Introduction (1/2)

Increasing importance of the quality of the road surface

- For road users
  - Safe and comfortable roads
- For the general public
  - Less hindrance by construction, rehabilitation, repair and maintenance
  - Sustainable approach in design, construction and use of the road
- For road authorities
  - Responsibility
Introduction (2/2)

- **Bad image of concrete roads**
  - Old (> 30, 40, 50... years)
  - Designed according to other criteria than today
  - Old techniques and equipment

- **Today, high quality concrete surfaces are possible**
  - Adapted designs
  - New construction techniques and modern equipment
  - New surface finishing methods
Concrete Roads in relation to surface criteria
DRIVING COMFORT

- **Decisive parameters are:**
  - Longitudinal evenness (megatexture)
  - Rutting
  - Macrotecture

- **The main problems with existing concrete roads are**
  - faulting joints (steps)
  - Cracked slabs

  *due to the old design of long slabs, wide expansion joints and erosive base layers*
Concrete Roads in relation to surface criteria

DRIVING COMFORT

Cracked slabs and wide expansion joints on a 58-year old road

Joint faulting

Portorož, Slovenia
Concrete Roads in relation to surface criteria

DRIVING COMFORT

- **Adapted design since 1970’s**:  
  - Shorter slabs (max. 5 m length)  
  - Narrow contraction joints  
  - Dowels (load transfer)  
  - Non erosive base layers

Lorraine Avenue - Brussels

Portorož, Slovenia
Concrete Roads in relation to surface criteria

**DRIVING COMFORT**

- **Technique of Continuously Reinforced Concrete Pavements (CRCP):**
  - Absence of transverse joints
  - Shrinkage controlled by a network of fine micro-cracks that don’t affect smoothness and comfort

*Crack in CRCP*

*CRC road*
Concrete Roads in relation to surface criteria

DRIVING COMFORT

- Modern construction techniques and machines
  - On site batching plants
  - Wireless guided slipform pavers
  - Supersmooth
  - Smoothness control systems

Portorož, Slovenia
Concrete Roads in relation to surface criteria

**DRIVING COMFORT**

- Concrete surfaces are not susceptible to rutting!
- No problem of ravelling
- Scaling is prevented by adequate concrete mixes (air entrained)

*Measurement of air content in the fresh concrete*

*Scaled surface*
Concrete Roads in relation to surface criteria

SAFETY

- Same aspects as for driving comfort
- + Skid resistance
- + Hydroplaning
- + Driver’s visibility
Concrete Roads in relation to surface criteria

SAFETY

- **Skid resistance**: preventing dry and wet weather accidents
  - No problem for most of the concrete surfaces (see Case studies)
  - Right choice of aggregates: PSV, abrasion, frost resistance,…
  - Friction OK immediately after construction

- **No risk for hydroplaning**

- **Limited splash and spray water**

- **Bright surface**: better night time visibility
Concrete Roads in relation to surface criteria

- Optimising noise levels without jeopardising safety-aspects!

- Maintained characteristics over the lifetime

- Thus finding the best combination for skid resistance, durability and noise.

- Trends:
  - EU: fine grained exposed aggregate concrete
  - US: longitudinal tining, diamond grinding
Evaluation of concrete surface textures
TRANSVERSE BROOMING/BRUSHING

- Most commonly applied texture (manually or mechanically)
- Simple and inexpensive
- Good compromise for noise and skid resistance for secondary roads
Evaluation of concrete surface textures
TRANSVERSE TINING

- By mechanical device with a metal rake
- Transversely or skew
- Belgian motorways 1970’s
- Good water drainage
- Very noisy ("whine" sound): no longer applied

Portorož, Slovenia
Evaluation of concrete surface textures
LONGITUDINAL TINING

- **Best overall performer in the US**
  - Lowest sound levels
  - Good friction characteristics
- **Importance of the tine pattern**
Evaluation of concrete surface textures

BURLAP DRAG

- Moistened coarse burlap
- Shallow longitudinal texture
  - Relatively quiet
  - Possible problems with wet weather friction at high speeds
  - Decrease of friction over time
Evaluation of concrete surface textures
EXPOSED AGGREGATE CONCRETE (EAC)

- Set retarder immediately after placing of the concrete followed by washing/brushing away the surface mortar after about 24 hours

- **Coarse aggregates**
  - Very good skid resistance - very noisy

- **Fine aggregates**
  - Good skid resistance - low noise levels
Evaluation of concrete surface textures

POROUS CONCRETE SURFACE

- Concrete with large void content and high permeability
- Absorption of the noise
- Same problems as porous asphalt
Restoration techniques

- **Texture modification**: restoration of megatexture + noise reduction
  - Diamond grinding
  - Diamond grooving
  - Milling
  - Shotblasting

- **Overlaying the existing structure for structural reinforcement (concrete) or surface improvements (thin bituminous overlays)**
Evaluation of concrete surface textures

DIAMOND GRINDING

- Longitudinal closely spaced fine grooves in the hardened concrete
- Improves pavement profile and ride quality
- Restoration technique: restores surface friction and reduces rolling noise

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Remark: results of skid resistance and noise measurements must not be compared between different cases due to different situations, measurement techniques etc.
## Restoration techniques

### ROLLING NOISE PEAK LEVELS
120 km/h - 4 tyre types

<table>
<thead>
<tr>
<th></th>
<th>A2</th>
<th>DENSE ASPHALT</th>
<th>A3 (E40)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CEMENT CONCRETE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BEFORE</td>
<td>107.6</td>
<td>102.4</td>
<td>105.1</td>
</tr>
<tr>
<td>AFTER</td>
<td>102.0</td>
<td>100.8</td>
<td>102.3</td>
</tr>
</tbody>
</table>

- **dB(A)**
- **CEMENT CONCRETE**: Before and After noise levels
- **DENSE ASPHALT**: Before and After noise levels
- **A3 (E40)**: Before and After noise levels

<table>
<thead>
<tr>
<th></th>
<th>Transverse grooves</th>
<th>Transverse grooves + grinding</th>
<th>Transverse grooves + milling</th>
<th>Transverse grooves + double chipping (4/7 + 2/4)</th>
<th>Noiseless Cement Concrete</th>
<th>Longitudinal grooves</th>
<th>Shallow transverse grooves</th>
<th>Asphalt</th>
</tr>
</thead>
</table>

**Portorož, Slovenia**
Motorway A12 Meise (Belgium, 2001)
Motorway A12 Meise (Belgium, 2001)

Portorož, Slovenia
Burlap drag versus fine EAC on German motorway A4 near Aachen

![Graph showing sound pressure levels (dB(A)) for different materials and speeds.](image)

- **Waschbeton 0/5**:
  - CPX bei 80 km/h: 97.5 dB(A)
  - CPX bei 100 km/h: 100.8 dB(A)
- **Waschbeton 0/8**:
  - CPX bei 80 km/h: 97.1 dB(A)
  - CPX bei 100 km/h: 100.4 dB(A)
- **Beton mit Jutetuchtextur**:
  - CPX bei 80 km/h: 96.5 dB(A)
  - CPX bei 100 km/h: 100.4 dB(A)
Burlap drag versus fine EAC on German motorway A4 near Aachen

Portorož, Slovenia
Skid resistance measurements

- **SCRIM**
  - 50 km/hr, 20°C
  - $SFC \geq 0.48$
### Skid resistance - transverse tined surface

<table>
<thead>
<tr>
<th>Route</th>
<th>2004 (32 years in service)</th>
<th>Apr 2008 (36 years in service)</th>
</tr>
</thead>
<tbody>
<tr>
<td>E40 Brussels – Liège km. 30 – km 34</td>
<td>62,1</td>
<td>57,9</td>
</tr>
<tr>
<td>E40 Liège – Brussels km. 30 – km 34</td>
<td>63,1</td>
<td>58,6</td>
</tr>
<tr>
<td>Route Description</td>
<td>2004 (3 years in service)</td>
<td>Apr 2008 (7 years in service)</td>
</tr>
<tr>
<td>-----------------------------------------</td>
<td>----------------------------</td>
<td>-------------------------------</td>
</tr>
<tr>
<td>A12 Brussels – Antwerp km. 4,7 – km 6,5</td>
<td>58,9</td>
<td>51,1</td>
</tr>
<tr>
<td>A12 Antwerp – Brussels km. 4,7 – km 6,5</td>
<td>61,8</td>
<td>51,3</td>
</tr>
</tbody>
</table>
### Skid resistance - EAC

<table>
<thead>
<tr>
<th></th>
<th>1999 (1st measurements)</th>
<th>2000</th>
<th>2002</th>
<th>2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>N25 Wavre-Nivelles km 33,1–km 36,6</td>
<td>60,9</td>
<td>56,7</td>
<td>47,9</td>
<td>52,6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>R3 Ring Charleroi km. 27,0 – km 24,0</td>
<td>56,1</td>
<td>56,5</td>
<td>57,8</td>
<td>59,4</td>
<td>54,9</td>
<td>52,7</td>
<td>57,7</td>
</tr>
</tbody>
</table>
### Herne, 1996 - test sections of low noise surfaces

<table>
<thead>
<tr>
<th>Material</th>
<th>Length (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SMA 0/10</td>
<td>407</td>
</tr>
<tr>
<td>SMA 0/14</td>
<td>296</td>
</tr>
<tr>
<td>ZEER OPEN BETON 0/7</td>
<td>537</td>
</tr>
<tr>
<td>VERY POROUS CONCRETE 0/7</td>
<td></td>
</tr>
<tr>
<td>ZOAB 0/14</td>
<td>834</td>
</tr>
<tr>
<td>PLUN BETON 0/7</td>
<td>832</td>
</tr>
<tr>
<td>FINE CONCRETE 0/7</td>
<td></td>
</tr>
<tr>
<td>AB-2 0/10 (+10/14)</td>
<td>299</td>
</tr>
<tr>
<td>AB-2 0/10 (+chippings 10/14)</td>
<td></td>
</tr>
</tbody>
</table>
Herne, 1996 - test sections of low noise surfaces
Herne, 1996 - test sections of low noise surfaces
Herne, 1996 - test sections of low noise surfaces

<table>
<thead>
<tr>
<th>Material Type</th>
<th>DB (A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dense Asphalt 0/10 (+10/14 chippings)</td>
<td>96.0</td>
</tr>
<tr>
<td>Fine concrete 0/7</td>
<td>96.1</td>
</tr>
<tr>
<td>Very porous asphalt 0/14</td>
<td>97.5</td>
</tr>
<tr>
<td>Very porous concrete 0/7</td>
<td>96.8</td>
</tr>
<tr>
<td>Stone mastic asphalt 0/14</td>
<td>97.1</td>
</tr>
<tr>
<td>Stone mastic asphalt 0/10</td>
<td>97.2</td>
</tr>
</tbody>
</table>

Difference with regard to 16.09.1996:

- Dense Asphalt 0/10 (+10/14 chippings): -1.5 dB
- Fine concrete 0/7: -0.3 dB
- Very porous asphalt 0/14: 2.5 dB
- Very porous concrete 0/7: 2.5 dB
- Stone mastic asphalt 0/14: -0.1 dB
- Stone mastic asphalt 0/10: -0.1 dB

Portorož, Slovenia
Herne, 1996 - test sections of low noise surfaces

Measurements by TRANSTEC, 2007

<table>
<thead>
<tr>
<th>Material</th>
<th>A-weighted Total OASIL Level, 60 mph, SRTT (dB ref 1 pW/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DGA AB-2 0/10 (+10/14)</td>
<td>107.4</td>
</tr>
<tr>
<td>Exposed Aggregate 0/7</td>
<td>103.2</td>
</tr>
<tr>
<td>Porous Asphalt 0/14</td>
<td>106.1</td>
</tr>
<tr>
<td>Porous Concrete 0/7</td>
<td>104.2</td>
</tr>
<tr>
<td>SMA 0/14</td>
<td>103.8</td>
</tr>
<tr>
<td>SMA 0/10</td>
<td>104.5</td>
</tr>
</tbody>
</table>

N255 Herne (Site BE01) Test Section
Herne, 1996 - test sections of low noise surfaces
N511 Estaimpuis, 2002

- Double layered concrete – different aggregate sizes in the top layer
  - CRCP 20 cm thick / 9,50 m wide (6,5 + 4)
  - 4 sections ( +/- 300 m )

<table>
<thead>
<tr>
<th>Thickness</th>
<th>Aggregate</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 cm</td>
<td>0/32</td>
</tr>
<tr>
<td>14 cm</td>
<td>6 cm</td>
</tr>
<tr>
<td>12 cm</td>
<td>8 cm</td>
</tr>
<tr>
<td>12 cm</td>
<td>8 cm</td>
</tr>
</tbody>
</table>

Portorož, Slovenia
**N511 Estaimpuis, 2002**

- **Skid resistance - Odoliograph (SFC > 0,50)**

<table>
<thead>
<tr>
<th></th>
<th>Section 1 0/7</th>
<th>Section 2 0/10</th>
<th>Section 3 0/14</th>
<th>Section 4 0/20</th>
</tr>
</thead>
<tbody>
<tr>
<td>SFC</td>
<td>0.66</td>
<td>0.70</td>
<td>0.69</td>
<td>0.62</td>
</tr>
</tbody>
</table>
N511 Estaimpuis, 2002

- **Mean evenness coefficient, wavelength 2.5 m, measured every 10 m with APL, requirement 0.35 on fine EAC**

<table>
<thead>
<tr>
<th></th>
<th>Top layer 0/7</th>
<th>Top layer 0/10</th>
<th>Top layer 0/14</th>
<th>Top layer 0/20</th>
</tr>
</thead>
<tbody>
<tr>
<td>EC(2.5m)</td>
<td>15.15</td>
<td>16.20</td>
<td>14.70</td>
<td>17.05</td>
</tr>
</tbody>
</table>
**N511 Estaimpuis, 2002**

- Mean evenness coefficient, wavelength 10 m, measured every 20 m with APL, requirement 0.70 on fine EAC

<table>
<thead>
<tr>
<th>Top layer 0/7</th>
<th>Top layer 0/10</th>
<th>Top layer 0/14</th>
<th>Top layer 0/20</th>
</tr>
</thead>
<tbody>
<tr>
<td>EC(10m)</td>
<td>33.30</td>
<td>31.40</td>
<td>28.95</td>
</tr>
</tbody>
</table>
N511 Estaimpuis, 2002

- Noise measurements with the Statistical Pass-By Method

Influence of the size of the aggregates on the noise emitted by the traffic (reference speed 90 km/h)

\[ \text{dB (A)} = \text{average of the maximum noise level recorded with the passage of the vehicles} \]

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**N49/E34 ZWIJNDRECHT, 2007**

- Double layered CRCP
  - Bottom layer: 0/32 with recycled crushed concrete (60% replacement of virgin aggregates)
  - Top layer: 0/6,3 (no recycling)
- Measurements by U.S. Team (NITE program)

![Image of road and measurement chart]

- 1 course 0/20
- 2 courses 0/32 + 0/6,3
- $\Delta = 3\text{dB}$
N49/E34 ZWIJNDRECHT, 2007

105.3 dBA

On-Board Sound Intensity (OSBI)

Mean Profile Depth (MPD)

Site BE02 – BELGIUM (N49, Zelzate)
Exp. Agg. 20 mm, Age ~3 years

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Portorož, Slovenia

Site BE03 – BELGIUM (N49, Melisle)  
Exp. Agg. 6.3 mm, Age ~2 years  

101.7 dBA  
On-Board Sound Intensity (OBSI)  

Mean Profile Depth (MPD)
Conclusion

- The selection of the best type of pavement and surface texture for a given location is a complex problem that requires consideration of several factors that are often competing:
  - Safety
  - Comfort and noise
  - Durability (of structure and surface)
  - (Life-cycle) Cost,…

- Adequate design and skilful construction offer the best chances for a high quality surface.

- Today’s concrete surfaces, mainly EAC, provide excellent solutions for the combination of all the technical requirements and are applicable for all types of pavements (motorways, trunk roads, secondary roads, tunnel pavements,…)

Portorož, Slovenia
Thank you for your kind attention