TG5 Rilem
Experience with recycling in the Netherlands

Focus on hot recycling

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December 24, 2007

Road and Railway Engineering
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• Types of recycling
• Recycling in the asphalt plant
• The Dutch situation
• Research CROW (publication 179)
• Developments in the Netherlands
Why Recycling

- Less use of natural resources
- Less use of waste disposals
- Less energy
- Environmental aspects
- Construction cost
Pavement management system
Structural, functional or both

- **Structural condition**
  - unsound
    - structural improvement
      - reconstruction
      - recycling base/subbase
        - conventional
        - cold in-situ
      - overlay
  - sound

- **Functional improvement**
  - surface treatment
  - asphalt overlay
  - mill and replace
  - recycle surface
  - hot in-situ
    - central plant
Why in situ recycling?

- Save on new materials
- Transport benefits, also reduced impact on actual roads
- Reduced construction time means:
  - Reduced delays for road user
  - Lower user cost
  - Better public perception
  - Less equipment and installations needed
Cold In-place recycling: one run. Not discussed further
Hot in situ recycling

- Mostly functional for surface layers

- In the Netherlands (RAW)
  - Repave method
  - Remix method
Remix-plus (Dutch standard RAW)
Since 2000 Re-use of RAP in the Netherlands predominantly via asphalt plant

- RAP = Reclaimed Asphalt Pavement

- Recycling allowed in all asphalt layers (RAW):
  - Surface layer
  - Binder layer
  - Base layer
History of hot recycling in the Netherlands

- Mid 1970 a serious impuls was given to the recycling of old asphalt. Reasons:
  - Oil crisis
  - Environment (scarce materials, no place for waste disposal)
  - Milling machine
  - Only natural aggregate source: gravel from the rivers. Base courses were made with gravel until mid 1970s. Large problems with rutting of the base layers in 1970s (traffic increase, hot summers).
From the early milling area: cold feed

• Cold RAP (mostly in mixing unit): most asphalt plants had the possibility to add into the pugmill (batch plant) or half way drum (drum mix plant).

• Typical amounts:
  • Maximum 20% without any special research for base course mixes.
  • Maximum 10% without special research for surface mixtures.
Important role of the Dutch government to promote RAP re-use

- Two large projects, roads agency together with a group of contractors:
  - 1976: Renofalt (100% re-use)
  - 1980: MARS (re-use up to 100% with micro-wave system)

- Purpose: recycling in the highest possible application and increase of recycling to the highest possible level
Developments in the 1980s and 1990s

• Recycling market becomes a commercial market because the government pushed the market approach with legislation on waste deposits.
• Asphalt plants invested in parallel drums and special handling of RAP
• Since 1990 RAP officially in the Dutch standard (RAW)
• Since 1990: RAP is a building material
Tar

- Tar is not allowed in RAP
- Since 1991 in the Netherlands legally no tar containing products are allowed to use any more (one exception)
- In 2007 almost all RAP can be considered free of tar in the Netherlands
Cold feed of RAP

Cold RAP
Parallel drum (RAP heated to 130 C)
## Hot mix Asphalt plants (partial recycling PR) in the Netherlands (2006)

<table>
<thead>
<tr>
<th>Type of plant</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Batch plant with separate PR drum</td>
<td>38</td>
</tr>
<tr>
<td>Batch plant with cold RAP input</td>
<td>1</td>
</tr>
<tr>
<td>Drum mixer suitable for PR</td>
<td>5</td>
</tr>
<tr>
<td>Installation without PR</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>44</strong></td>
</tr>
</tbody>
</table>
Latest plant (Astec double drum)
HOMOGENEITY of RAP

• See also EN 13108-8

• Adequate Handling of RAP is very important, otherwise things will go wrong.

• In the Netherlands we can recycle so much, because we have organised this well and put requirements in the RAW

• Also in a number of asphalt plants the RAP is stored under a roof (moisture aspect)
The Netherlands: mix types

- GAC = Gravel Asphalt Concrete
- STAC = Stone Asphalt Concrete
- OAC = Open Asphalt Concrete
- DAC = Dense Asphalt Concrete
- SMA = Stone Mastic Asphalt
- PA = Porous Asphalt
The Netherlands

<table>
<thead>
<tr>
<th>Asphalt layer</th>
<th>Asphalt mix</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base layer</td>
<td>GAC (history)</td>
</tr>
<tr>
<td></td>
<td>STAC</td>
</tr>
<tr>
<td>Binder layer</td>
<td>OAC</td>
</tr>
<tr>
<td>Surface layer</td>
<td>DAC</td>
</tr>
<tr>
<td></td>
<td>SMA</td>
</tr>
<tr>
<td></td>
<td>PA</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Layer</th>
<th>% of total production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base layer</td>
<td>56 %</td>
</tr>
<tr>
<td>Binder</td>
<td>7 %</td>
</tr>
<tr>
<td>Surfacing</td>
<td>37 %</td>
</tr>
</tbody>
</table>
Research CROW between 1997-2002 predominantly on STAC

- RAP at the highest possible level
- Higher percentage RAP
- RE-use GAC RAP in STAC
- Check on functional properties:
  - Permanent deformation
  - Tensile strength/crack growth
  - Fatigue
Research CROW

- Gyratory compaction: check on compactability
- Dynamic triaxial test: resistance against permanent deformation
- SCB test: tensile strength (crack growth)
- Four point bending test: stiffness and fatigue
SCB test: monotonic loading (displacement controlled) at 0 °C
Four point bending test: Results CROW research
Some results CROW research (1)

- No problems with determination properties of RAP and mix design.

- STAC allows higher fines content with high RAP contents compared to actual RAW requirements.

- Compactability increases with higher RAP contents
Some results CROW research (2)

- Lower angularity milled GAC does not decrease resistance to permanent deformation of STAC
- Increase in content of RAP improves resistance to permanent deformation.
- The strength (SCB) seems to increase with RAP content
- Fatigue at very high RAP contents (above 50%) must be investigated
Recommendations CROW for STAC

- A maximum of 50% RAP (under conditions 70 %)
- RAP as a building material: after milling adequate quality control is required
- If possible only addition of 40/60 or 70/100 Pen bitumen
- Log Penetration rule can be used under certain conditions (see above)
- Requirements per traffic class
State of the art for all mixes in the Netherlands

- Recycling in STAC maximum 50%
- Recycling in OAC maximum 50%;
- Recycling in DAC (0/11 en 0/16) maximum 50%
- Recycling in PA maximum 20%
- No recycling in SMA

- Requirements for the combined Penetration (old – new bitumen) in the mix design for all mixes.
Log Penetration rule

\[ a \cdot \log pen_1 + b \cdot \log pen_2 = (a + b) \cdot \log pen_{\text{mix}} \]

\[ a + b = 1 \]
Asphalt production

Asphalt production The Netherlands

![Bar chart showing asphalt production in The Netherlands from 2001 to 2006. The chart includes data for the years 2001 to 2006, with a peak in 2006.]
Latest developments/ problems are typical Dutch?

- From max 50% to 70% recycling in base layers: very important in the western part of the Netherlands (not enough space for storage of RAP)
- Many PA layers are to be replaced in a first or second maintenance cycle (RAP with extremely hard bitumen). Maybe EME type of approach for base courses???
- Since early 1980 predominantly maintenance. Higher percentages of RAP in higher placed layers. Asphalt production of $9 \times 10^6$ ton/year mostly for binder and surface layers. Increase RAP in these layers?
Latest developments/ problems

• Problem PA-RAP (85% stone and very hard bitumen) must be solved. Black rock approach??
• Not all parallel drums are fit for PA-RAP
• How to keep the temperature of virgin aggregate reasonable at higher RAP content
• PSV stone (> 57): for surface layers requirements are increased. Are base layer RAP stones good enough??
State of the art in the Netherlands: 2007

• Practically all layers below the surface layer are mixes with 50% RAP.
• At the moment 3,5\cdot10^6 ton/year of RAP
• 80% of the RAP is used in hot mix
• 65% of new HMA production contains RAP
• Consumption of bitumen in 2006: 0,37\cdot10^6 ton (on 10.10^6 ton asphalt)
Function and re-use

• Distinction between:
  • Base layers (bearing capacity)
  • Surface layer

• Base layers extremely fit for recycling
• Highest quality, scarcely available, expensive virgin materials only in thin surface layer.
Multiple re-use of RAP

- Regular re-use and higher percentages RAP do not improve the final product:
  - Adhesion
  - healing
  - brittleness
- New techniques cq additions are necessary for durable products
Recycling in future?

- In the Netherlands now already $2.8 \times 10^6$ ton/year RAP in asphalt mixes via asphalt plant (last year $10.1 \times 10^6$ ton asphalt)
- Reduced use of natural resources is very important for the Netherlands
- Recycling can result in good quality mixes
- Interesting challenges, also technological: from single layer to two-layer PA (Dream: PA 0/16 reshape + 2.5 cm PA 5/8 as two-layer PA)
Important Research questions

• Fatigue properties at very high percentages RAP??
• Verification results in practice??
• Use of logPen rule: must be proven
• Healing of mixes with RAP??
• How to recycle with PMB (results in the Nederlands based on Pen bitumen RAP)??
• Re-use of PA RAP (typical Dutch)
• More general: re-use of RAP in the top layers
Holistic approach needed (Porous Asphalt)
The role of GAC in recycling (typical Dutch)

- Gravel was/is the only Dutch (delta of two rivers) natural aggregate source
- In the recent past GAC was the standard baselayer
- GAC replaced as baselayer by STAC on national highways, due to risk of permanent deformation
- Question was can GAC-RAP be used in STAC