Performance assessment of Cold Recycling in Place

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COLD RECYCLING IN PLACE
BENEFITS AND LIMITATIONS OF USE

STRONG ECONOMICAL AND ENVIRONMENTAL INCENTIVES

- Saving of natural resources (virgin aggregates, bitumen)

- Reduction of:
  - Waste (landfill)
  - Transport costs and nuisances
  - Energy costs (transport, heating of aggregates)
  - Emissions (cold technique, transport)

- On average, savings may be estimated as follows:
  - Energy and aggregate costs: up to 20%
  - Gaseous emissions (CO2, SO2): around 20%

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BENEFITS AND LIMITATIONS OF USE

BUT A NUMBER OF LIMITATIONS

- Quality of pavement and materials to be recycled
- Presence of materials or features which rule out milling
- Adverse weather conditions (limited season)
- Mechanical limitations
- Limitations due to the need for a protective layer

⇒ IMPORTANT R&D EFFORTS BY ROAD INDUSTRY

- SCORE project
- Continued field assessment

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THE SCORE PROJECT

- Optimization of existing techniques
- Search for new methods for material assessment and formulation
- Formulation and performance of recycled mixes
  - In-place recycling of 100% bituminous material (RAP)
  - Impact of milling speed and RAP properties
  - Bituminous emulsions and µ-emulsions
  - Foamed bitumen
  - Accelerated curing procedures
  - Mechanical properties

- An important project: 281 man-months over 3 years (2002–2005)
- A diversified partnership of 8 industrial and public research partners

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RECYCLOVIA® PROCESS

- Wirtgen 2200 CR
- Emulsion or foamed bitumen
- Addition of cement or hydr. lime

Single equipment for Milling + Mixing + Laying

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COLD RECYCLING IN-PLACE WITH BITUMINOUS BINDERS IN FRANCE

<table>
<thead>
<tr>
<th></th>
<th>Class I</th>
<th>Class II</th>
<th>Class III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth (cm)</td>
<td>10-15 cm</td>
<td>5-12 cm</td>
<td>5-12 cm</td>
</tr>
<tr>
<td>Objective</td>
<td>Structural Reinforcement</td>
<td>Rehabilitation of the wearing course</td>
<td>Rejuvenating bitumen</td>
</tr>
<tr>
<td>Bitumen Type</td>
<td>Paving grade 70/100 or 160/220</td>
<td>Paving grade or rejuvenating bitumen</td>
<td>Rejuvenating bitumen</td>
</tr>
<tr>
<td>Added Bitumen</td>
<td>3 to 5%</td>
<td>1 to 3%</td>
<td>up to 2%</td>
</tr>
</tbody>
</table>

Assessment of recycled materials is based on gyratory compaction and DURIEZ criteria.

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FURTHER STUDIES AFTER SCORE

5 different jobsites with the following objective:
- Reproduce the recycled material in the laboratory
- Assessment of the mechanical properties after curing
- Comparison between values obtained in situ

<table>
<thead>
<tr>
<th>Class III</th>
<th>Class I</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>D</td>
</tr>
<tr>
<td>9 cm Asph. Concrete</td>
<td>7 cm Asph. Concrete</td>
</tr>
<tr>
<td>~ 11 cm Unbound Gran.</td>
<td>~ 4 cm Surf. Dres.</td>
</tr>
</tbody>
</table>

| B | C |
| ~ 4 cm Surf. Dres. | 8 cm Asph. Concrete |
| ~ 11 cm Unbound Gran. | 8 cm Pouzz. Treated |

- 3 materials of Class III. Two with bitumen emulsion 160/220 (A&D). One with foam 70/100 bitumen (E).
- 2 materials of Class I treated with foam 70/100 bitumen (B&C)

Additional cores from various job sites tested for stiffness
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LAB. STUDIES ON RAP MATERIAL

DURIEZ TEST

- Strong impact of mix formulation and compaction load
- Reduced compaction load should be adopted for DURIEZ testing!

**DURIEZ test - "Dry" Compressive Strength**

![Graph showing the compressive strength of different materials at various compaction loads.]

- Material A
- Material B
- Material C
- Material D
- Material E

**Compaction Load**
- 120 kN
- 40 kN

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ACCELERATED CURING AND STIFFNESS

- On gyratory compacted samples (Φ = 160 mm, h~150 mm)
- Samples compacted at two levels of density
- 7 days in air + 14 days at 35°C-20% RH

Compressive Axial Modulus (CA)

Indirect Tensile Modulus
Sinusoïdal loading (IT-S)
Pulse loading (IT-P)

7d - 18°C - air 14d - 35°C - 20% RH

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STIFFNESS vs CURING TIME

- CA 15°C/10Hz ≈ IT-S 15°C/10Hz ≈ IT-P 10°C/124ms

- Only small differences after 1st period
- Very strong impact of void content
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EVOLUTION OF STIFFNESS IN-SITU

CLASS III MATERIALS

Stiffness Modulus on Class III core samples
( IT-S at 15°C-10Hz or IT-P at 10°C-124ms )

- Material A - Lab. Curing
- Material A  5 months
- Material A  15 months
- Material D - Lab. Curing
- Material D  9 months
- Material E - Lab. Curing
- Material E  15 months
- Material E  24 months
- Material 3-b  7 months
- Material 3-b  17 months
- Material 3-c  5 months
- Material 3-c  12 months
- Material 3-c  32 months
- Material 3-d  18 months

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EVOLUTION OF STIFFNESS IN-SITU

CLASS I & II MATERIALS

Stiffness Modulus on Class I & II core samples
(IT-S at 15°C-10Hz or IT-P at 10°C-124ms)

- Material B - Lab. Curing
- Material B 6 months
- Material B 12 months
- Material C - Lab. Curing
- Material C 6 months
- Material C 12 months
- Material C 26 months
- Material 1-a 9 months
- Material 1-a 17 months
- Material 1-b 39 months
- Material 1-c 16 months
- Material 2-a 13 months
- Material 2-a 24 months
- Material 2-b 8 months

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CONCLUSIONS

MECHANICAL PERFORMANCE

 Very strong incidence of density on mechanical properties, both in laboratory and in-situ

 Laboratory curing & stiffness measurements offer at least an estimate of the ultimate strength likely to be achieved

FACTORS AFFECTING DENSITY AND STIFFNESS IN-SITU

 Bearing capacity of underlying layers, RAP characteristics
 compaction procedures to be improved

 Work condition and climatic factors can affect curing phase
 ensure adequate drainage and avoid autumn

 Adding 0.5 % to 1% of cement boost stiffness at early stage

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