Cold in-place recycling with emulsion or foamed bitumen
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Cold in place recycling
- milling or crushing the materials of the old pavement
- incorporation of a bituminous binder (bitumen emulsion or foamed bitumen)
- placing and shaping
- compaction
to reconstitute the pavement course on the spot

One way of recycling in place with bitumen emulsion (+ addition of cement)

Production of foamed bitumen
**Objectives and fields of application**

To increase the structural capacity

- Stabilization of granular base course
- Recycle cracked bituminous layers to form a new base or sub-base course

To correct surface layer problems

- Cracking and excessive ageing of the binder
- Separation of interface with semi-rigid pavements

**Advantages of in-place recycling**

*Compared to overlay with hot-mixes*

- Reduction of energy expenditure (no need for drying the materials)
- Reduction of transportation of material
- Limitation of the ancillary works associated with a raising of the road profile

*From a technical standpoint*

- To recycle only one lane if necessary
- To correct the transverse profile
- To put up with certain fluctuations in the composition of the materials
- To reduce the stresses on sub-grades of low-capacity
- To reopen the roadway to traffic at night and during the week-end
**Limits of use**

Unsuitable characteristics of the materials in-place:
- paving stones or blocks
- large heterogeneity
- important content of clayey materials
- Very weak bearing capacity of sub-grade
- Presence of many service exits and manholes
- Climatic conditions (temperature too low, frequent rainfall)
- High level of mechanical performances required

**Preliminary studies**

To establish if CIR is likely to respond to the objectives of maintenance or rehabilitation

- Field investigations
- Characterisation of the materials in-place
- Feasibility of cold in-place recycling?

**Field investigations**

To determine the thickness of pavement layers (transverse and longitudinal profiles)
- borings, trenches

To obtain materials for identification
To check bearing capacity of sub-grade
To locate and record all underground services

**Characterization of the materials in-place**

- Unbound materials
  - grading
  - cleanliness
  - moisture content
Characterization of the materials in-place

Reclaimed bituminous materials
probable grading after pulverization or milling of the pavement
binder content
residual characteristics on the recovered binder (pen., R&B)

Mix design

1. Characterization of the materials to be recycled, in particular:
   - the homogeneity,
   - the grading of the material to recycle to judge if addition of crushed aggregate is necessary for grading correction,
   - the plasticity of the fines,
   - the quality of the aggregate,
   - the content and the nature of the bituminous binder.

2. The selection of the new binder

Mix design

3. Investigation of the compatibility/affinity between the binder and the aggregate (when stabilizing a granular material).

4. Determination of the total fluid content for compaction of the material.

5. Investigation of coating to determine the initial moisture content, to choose the emulsion and the total fluid content.

6. Choice of the residual binder content and determination of mechanical properties

Choice of new binder (bitumen emulsion) (1/2)

<table>
<thead>
<tr>
<th>Properties of the emulsion</th>
<th>Standard</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Binder content</td>
<td>EN 1428</td>
<td>55 - 65%</td>
<td>60 - 65%</td>
<td>60 - 70%</td>
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<tr>
<td>Breaking value</td>
<td>pr EN 13075-1</td>
<td>&gt; 160</td>
<td>120 - 180</td>
<td>80 - 140</td>
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<tr>
<td>Fine time mixing</td>
<td>pr EN 13075-2</td>
<td>&gt; 180</td>
<td>&gt; 180</td>
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<tr>
<td>Mixing stability with cement</td>
<td>pr EN 12848</td>
<td>&gt; 2</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Adhesivity by water immersion test</td>
<td>pr EN 13614</td>
<td>≥ 75%</td>
<td>≥ 75%</td>
<td>≥ 75%</td>
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<tr>
<td>Binder of distillation residue</td>
<td>EN 1426</td>
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<tr>
<td>Penetration</td>
<td>EN 1427</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Softening point</td>
<td>EN 1431</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Viscosity</td>
<td>EN 12595</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volume of flux</td>
<td>EN 1431</td>
<td>0 - 2%</td>
<td>0 - 2%</td>
<td>5 - 10%</td>
</tr>
</tbody>
</table>
**Choice of new binder (bitumen emulsion) (2/2)**

Temperate climates
- 70/100 pen and 180/220 in Scandinavia
- up to 400 pen
- and even softer bitumen MB 6000 to MB 12000

**Choice of new binder (foamed bitumen) (1/2)**

Expansion ratio ER higher than 10
Half-life $\approx$1/2 of 20 to 30s

**Investigation of the compatibility/affinity between the binder and the aggregate**
(when stabilizing a granular material.)

- Determination of the capacity of water absorption
- Determination of the reaction of the aggregate in an acid environment (for cationic emulsions)
- Determination of cations in solution
- Determination of the distribution of the bitumen particles diameters
  $\Rightarrow$ composition of the emulsion
Specific aspects of mix design for CIR

Determination of:
- the total fluid content to insure adequate compaction of the mix, for in-place recycling of bituminous mixtures or of "white" materials,
- the quantity of added water at the time of milling to produce later on good coating by the emulsion or the foamed bitumen,
- the binder content to obtain the required mechanical properties.

Determination of the total fluid content for compaction

Most common method:
total fluid content at optimum of Modified Proctor test

(Initial moisture of the recycled materials + added water + bitumen emulsion before breaking)

Study of coating (1/2)

Good coating by the bitumen emulsion supposes certain initial moisture (about)
1.5 to 2.5% for CIR of bituminous mixes
3 to 5% for CIR recycling of "white" + bituminous materials
moisture content increases with the quantity of fines
determine the quantity of water which can be absorbed by the untreated material

Study of coating (2/2)

Percentage of added water is lowest quantity to obtain a minimum percentage of aggregate covered with binder
quality of coating estimated visually
**Selection of the binder content**

Empirical approaches with criteria based on:
- resistance to water and mechanical performances (stability or modulus)

Methodology derived from tests on hot mixes
(Marshall, Hveem, Duriez)

Various methods for preparation of samples:
- compaction (static, impact)
- curing before testing

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**Mechanical characteristics of the recycled material**

Unconfined compression
Recycling of bituminous mixes
(increases with % of reclaimed bituminous material) from < 2 to > 4 MPa
Stabilization of unbound material from > 1 to 3 MPa

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**In-place recycling with foamed bitumen**

- Determination of the optimum moisture content of untreated aggregate using modified Proctor test
- Determination of a binder content based on the aggregate grading curve (cf. Table 6)
- Optimization of the moisture content for mixing (OMMC) from indirect tensile strength
- Optimization of the fluid content for compaction (OFC) from the maximum dry density
- Determination of the bitumen content from the results of mechanical tests on specimens prepared at the total fluid content (OFC)

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**Mechanical characteristics of the recycled material**

Stiffness modulus (around 15°C)
Recycling of bituminous mixes
(increases with % of reclaimed bituminous material) from 2000 to 4000 MPa
Stabilization of unbound material from a few hundred Mpa to 1 Mpa and more
Design of pavements using recycled materials

(see guidelines)

In-place recycling works

Sequence of elementary tasks

One example

Preparatory works
- drainage
- removal of obstacles
- repairing of large localised defects
- cleaning of the pavement...
- correction of the longitudinal or transverse profiles (milling or addition of aggregate)
**Sequence of elementary tasks**

- Addition of aggregate
- Addition of lime or Portland cement
- Milling
- Screening and Crushing
- Mixing
- Placing
- Compaction
- Surface treatment
- Wearing course

**Sealing of the surface**

When risks of deterioration of the surface (weather conditions, traffic)
- Spraying of a diluted rapid-setting emulsion (residual binder content 250 to 350 g/sqm)
- Light chipping (2 to 3 l/sqm of 4/6 or 2/4) if surface opened to traffic

**Laying of the final surfacing**

Necessary to protect the pavement (ingress of water and traffic abrasion) and to provide adequate surface texture

- Type and thickness (depend on traffic and weather conditions and pavement design)
  - from surface dressing to thick hot mix
- Delay application to facilitate curing
  - from a few days to a few weeks depending on the climatic conditions

**Equipment for in-place recycling**
Single-pass recycling train

Milling machine  Crusher + screen  Mixer  Emulsion tank

Portable crusher

Integrated milling + screening + crushing + Mixing machine
Paving behind the recycling machine
Single machine concept
Compaction

Quality control
Specifications and QC/QA
- Characteristics of additives and binder recycling agent
- Top size of the reclaimed pavement materials
- Pulverization depth and recycling depth if they are different
- The pre-mix water content and the binder content
- The density of the compacted material (The use of theoretical maximum density is recommended over the use of laboratory density)
- Equipment calibration

QC/QA

Before the works
- Check of equipment characteristics
- Trial sections
  - Influence of forward speed on particle size distribution and quality of coating
  - Effective depth of pulverization
  - Compaction requirements (optimal moisture content, numbers of passes of the rollers...)
- Calibration of proportioning devices

During the works
- Demonstration section
- Regular checks of
  - Proportioning of water and binder
  - Max size of reclaimed material
  - Moisture content of material in-place
  - Depth of recycling

Thank you for your attention