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

- Hot Bitumen
- Cold Water and Air
- Expansion Chamber
- Spray Nozzle
- 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
Objectives and fields of application

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
Advantages of in-place recycling

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>Case</th>
</tr>
</thead>
<tbody>
<tr>
<td>Binder content</td>
<td>EN 1428</td>
<td>55 - 65%</td>
<td>60 - 65%</td>
</tr>
<tr>
<td>Breaking value</td>
<td>pr EN 13075-1</td>
<td>&gt; 160</td>
<td>120 - 180</td>
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<tr>
<td>Fines time mixing</td>
<td>pr EN 13075-2</td>
<td>&gt; 180</td>
<td>&gt; 180</td>
</tr>
<tr>
<td>Mixing stability with cement</td>
<td>Pr EN 12848</td>
<td>≤ 2</td>
<td>---</td>
</tr>
<tr>
<td>Adhesivity by water immersion test</td>
<td>Pr EN 13614</td>
<td>≥ 75%</td>
<td>≥ 75%</td>
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<tr>
<td>Binder of distillation residue</td>
<td>Penetration</td>
<td>EN 1426</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Softening point</td>
<td>EN 1427</td>
<td></td>
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<tr>
<td></td>
<td>Viscosity</td>
<td>EN 12595</td>
<td></td>
</tr>
<tr>
<td>Volume of flux</td>
<td>EN 1431</td>
<td>0 - 2%</td>
<td>0 - 2%</td>
</tr>
</tbody>
</table>

Adapted to traffic and climatic conditions, and to the viscosity of the aged binder to recycle.
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)

![Graph showing the relationship between half-life (seconds) and expansion ratio for different water content percentages at various bitumen temperatures.](image)

- **Water content for foaming**
  - 5% at 180°C
  - 4% at 170°C
  - 3% at 160°C
  - 2% at 180°C
  - 1% at 170°C

**Bitumen temperature**
- 180°C
- 170°C
- 160°C

**Legend**
- Blue line: 180°C
- Pink dashed line: 170°C
- Green dashed line: 160°C
Choice of new binder (foamed bitumen) (2/2)

Expansion ratio ER higher than 10
Half-life $\tau_{1/2}$ 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
- 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
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)
- Optimisation of the moisture content for mixing (OMMC) from indirect tensile strength
- Optimisation 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)
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
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

- Compacting the profiled mixture
- Profiling the treated material
- WR 2500: milling and admixing
- WM 400: mixing and injecting slurry
- Infeed of emulsion
- Levelling the additional aggregate
- Spreading the additional aggregate
Sequence of elementary tasks

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
Single-pass recycling train
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
QC/QA

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