Cold recycling of bituminous mixtures

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Cold recycling of bituminous mixtures

Self introduction
Cold recycling of bituminous mixtures
Guidelines for presentation

• Give general overview of the topic
• Highlight interest/problems of society, users, road owners, designers and contractors

• Give some examples about specific solutions or problems

• Point out main key players in research

SPECIFIC AND OPEN QUESTIONS
RESEARCH NEEDS
Cold recycling of bituminous mixtures

Presentation structure

• General description
• Critical issues derived from research experience
  – Materials
  – Testing
  – Modelling
• Closure = Questions
Cold recycling of bituminous mixtures
General description

• RAP (reclaimed asphalt pavement)
  – bulk structure
• Bituminous emulsion
  – binder
• Filler (usually Portland cement)
  – filler and stiffening enhancement
• Added water
  – Workability and emulsion dispersion
• Virgin aggregates
  – integration to bulk structure
Cold recycling of bituminous mixtures
General description

In-field recycling (single or multiple unit)

In-plant recycling
Cold recycling of bituminous mixtures
General description

• Advantages:
  – Reduced use of raw materials
  – Reduction of disposal volumes
  – Lower environmental impact
  – Lower energy consumption
  – Reduced impact on labour health and safety
  – Cost reduction

• Disadvantages:
  – Reduced structural performance
  – **Problems in mix design, testing and modelling**

However, based on engineering experience, there are guidelines and specifications!
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Critical issues derived from research experience

- Rehabilitation of motorway A4 Torino-Milano (1999-2001)
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Critical issues derived from research experience

- Rehabilitation of motorway A4 Torino-Milano (1999-2001)
  - Production homogeneity

![Graph showing measured vs expected total binder content and water content over 7 days of monitoring.](image-url)
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Critical issues derived from research experience

- Rehabilitation of motorway A4 Torino-Milano (1999-2001)
  - Production homogeneity
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Critical issues derived from research experience

- Rehabilitation of motorway A4 Torino-Milano (1999-2001)
  - Compaction
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Critical issues derived from research experience

• Load spreading function

EVALUATION OF STIFFNESS AND STRENGTH
Cold recycling of bituminous mixtures
Critical issues derived from research experience

• Problems to solve:
  – Testing technique
  – Sample preparation / coring

Selection of practical characterization techniques
Development of equipment and procedures
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Critical issues derived from research experience

• Field compaction (static)
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Critical issues derived from research experience

• Field compaction (static)
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Critical issues derived from research experience

- Laboratory compaction (gyratory)
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Critical issues derived from research experience

- Elastic stiffness testing (RLIT)

![Graph showing elastic modulus (E) vs. curing time (t) for two binder course mixes: 60/70 and 80/100. The graph includes data points for standard preparation and 150 kN - 5 min.]
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Critical issues derived from research experience

- Indirect tensile strength (ITS) testing (static)
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Critical issues derived from research experience

• Fatigue testing

\[ y = 1371.5x^{-0.2153} \]
\[ R^2 = 0.8657 \]
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Critical issues derived from research experience

E = E₁ + k \cdot \log_{10}(\text{days})

Short term

Long term

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Critical issues derived from research experience

- Elastic stiffness parameters ($E_1$ and $k$) extremely sensitive to variations of:
  - Size distribution
  - Emulsion type
  - Compaction

<table>
<thead>
<tr>
<th></th>
<th>1999</th>
<th>2000</th>
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<tbody>
<tr>
<td>$E_1$</td>
<td>1429</td>
<td>569</td>
<td>1256</td>
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<tr>
<td>$k_E$</td>
<td>1388</td>
<td>921</td>
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<tr>
<td>$E_{60}$</td>
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Lower binder content, coarser RAP, higher air voids
Cold recycling of bituminous mixtures
Critical issues derived from research experience

\[ ITS = 0.467 + 0.281 \log t \]

\[ ITS = 0.238 + 0.290 \log t \]
Cold recycling of bituminous mixtures
Critical issues derived from research experience

- ITS parameters \((RTI_1 \text{ and } k_{RTI})\) extremely sensitive to variations of:
  - Size distribution
  - Emulsion type
  - Compaction

Lower binder content, coarser RAP, higher air voids
Cold recycling of bituminous mixtures
Critical issues derived from research experience

• Evolution of water content
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Critical issues derived from research experience

- Evolution of water content
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Critical issues derived from research experience

- Effect of curing temperature
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Critical issues derived from research experience

- Effect of emulsion type and quantity
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Critical issues derived from research experience

• Effect of filler type (cement vs quicklime)

\[ E_{\text{quicklime}} = 53,615 \times \text{(days)} + 530.51 \]

Filler: 2%
Emulsion: 4%
Water: 1%
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Critical issues derived from research experience

- Compaction properties (from gyratory equipment)
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Critical issues derived from research experience

- Compaction properties (from gyratory equipment)
Cold recycling of bituminous mixtures
Critical issues derived from research experience

- Mix design

![Graph showing the relationship between water content and dry density](image-url)
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Critical issues derived from research experience

- Mix design

![Chart showing workability vs. water content](image-url)
Cold recycling of bituminous mixtures
Critical issues derived from research experience

• Mix design

\[
%FF_{\text{optimum}} = %w_{\text{added}} + (a+Kb) \cdot %E
\]

Indirect tensile strength, ITS (N/mm²)

Dry density, G_{dry} (g/cm³)
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Critical issues derived from research experience

- Short term characterization
  - UNBOUND?

- Resilient modulus $M_R$
- Failure (p-q) criteria
Cold recycling of bituminous mixtures
Critical issues derived from research experience

• Short term characterization
  – UNBOUND?

![Graph showing Mr (Modello) vs. θ [kPa]]
Cold recycling of bituminous mixtures
Critical issues derived from research experience

• Short term characterization
  – UNBOUND?
Cold recycling of bituminous mixtures
Critical issues derived from research experience

- Characterization of the emulsion-filler system

Interconnected binding matrix
  High modulus, high strength

Porous binding matrix
  Low modulus, low strength
Cold recycling of bituminous mixtures
Closure - Questions

- Can production plants be improved?
- Can compaction techniques be improved?
- Should RAP be separated in fractions to control gradation?
- Are rejuvenators needed?
- Are modified emulsions needed?
- What type of filler should be used?
- How much stiffness is needed?
- Options to mix design?
- Options to performance testing?
- Coring?
- Field testing?
Thanks for your attention

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