2020 NESMEA

Assessment of Active Filler impact on Cold Recycled Asphalt Mixture Properties

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Special thanks to Beatriz Chagas Silva Gouveia
Contents

- Introduction on Cold Recycling technologies
- Objectives and motivations
- Laboratory campaign
- Experimental results
- Constitutive model
- Summary and ongoing research
Cold Recycling technologies

- Recovering and re-using material from an existing pavement without the addition of heat.
- 100% of the milled material from an existing pavement (RAP) can be recycled.
- No need for transporting the material: the mixture is prepared on site or in mobile plants.

- Saving of resources,
- Reduced costs,
- Reduced emissions,
- Short construction times.
Cold Recycling technologies

**Mixture components:**

- Reclaimed asphalt pavement (RAP)
- Asphalt stabilizing agent (foamed asphalt or emulsified asphalt)
- Mineral filler and/or **active filler** *(cement, lime...)*
- Water (compaction and chemical reactions)

**Technologies:**

- Cold In-Place Recycling (CIR)
- Cold Central Plant Recycling (CCPR)
The obtained product is called **Bituminous Stabilized Material** (BSM)

**Cold Recycling technologies**

PARTIALLY-BONDED MATERIALs
Asphalt stabilizing agents

- Foamed asphalt
- Emulsified asphalt

Adhesive mastic dispersed in the mixture
Asphalt droplets suspended in water
Aggregates fully coated
**Fillers & active fillers**

**Active filler**

The term active filler is used to define fillers that **chemically alter** the mix properties. This includes fillers such as lime, cement and fly ash but excludes natural fillers such as rock flour.

**Purposes of incorporating active fillers:**

- Improve **adhesion** of the binder to the aggregates
- Improve **dispersion** of the binder in the mix
- Increase **stiffness & strength gain** of mix
- Accelerate curing of compacted mix

**Fillers micro-structure:**

- **Mineral Filler** with 32% Air Voids
- **Hydrated Lime** with 65% Air Voids

![Graph showing % Air Voids for Cement, Hyd. Lime, Basalt, Limestone]
**Active filler: Cement**

```
PARTIALLY BOUNDED MATERIAL (BSM) = ASPHALT IS THE BINDER

vs

CEMENT TREATED MATERIAL = CEMENT IS THE BINDER
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Active filler: Hydrated lime

CaO + H₂O → Ca(OH)₂ + 15.5 kCal

- The application rate may be increased with respect to cement
- Less concerns related to loss in flexibility
- A blend of cement and hydrated lime could be used
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Objectives

- Evaluate the **effect of introducing active fillers** in cold recycled mixtures
- Develop a **framework** to experimentally characterize BSMs
- Assess the **influence of temperature and confining pressure** on material mechanical properties
- Create a **constitutive model** for BSMs and incorporate it in pavement design and analysis
Motivations

- No many information are available on active filler influence on cold recycled mixtures mechanical properties

- BSMs are partially-bonded materials (heterogeneous)

**Mechanical properties are simultaneously...**
- temperature dependent (HMA)
- confining pressure dependent (Crushed aggregates)

  need for a specific method of characterization

- Predominant mode of failure is believed to be accumulation of plastic deformation

  need information on material plastic response
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Laboratory equipment

- Asphalt foaming machine
- Laboratory mixer 30 kg capacity
- Vibrating hammer
Tests are performed at 25 deg C. only

Does not provide information on plastic properties of the material

Cracking risk is not the main concern for BSMs

All of the tests were performed after 28 days curing period at room temperature (@25 deg C.)
Triaxial Shear Test

The Mohr–Coulomb (MC) failure criterion

- Confining pressure effect on shear capacity can be evaluated
- Provides information on plastic properties of the material: cohesion and friction angle values can be calculated
- Simple test and easy to run

All of the tests were performed after 28 days curing period at room temperature
## Laboratory campaign

Mix design using **foamed asphalt** and **cement** as active filler

<table>
<thead>
<tr>
<th></th>
<th>Mix 1</th>
<th>Mix 2</th>
<th>Mix 3</th>
<th>Mix 4</th>
<th>Mix 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>RAP</td>
<td>93%</td>
<td>93%</td>
<td>93%</td>
<td>93%</td>
<td>93%</td>
</tr>
<tr>
<td>Mineral Filler</td>
<td>7%</td>
<td>6%</td>
<td>5.5%</td>
<td>5%</td>
<td></td>
</tr>
<tr>
<td>Cement</td>
<td>0%</td>
<td>1%</td>
<td>1.5%</td>
<td>2%</td>
<td></td>
</tr>
<tr>
<td>Foamed Asphalt</td>
<td>3%</td>
<td>3%</td>
<td>3%</td>
<td>3%</td>
<td></td>
</tr>
</tbody>
</table>

Mix design using **asphalt emulsion** and **hydrated lime** as active filler

<table>
<thead>
<tr>
<th></th>
<th>Mix 1</th>
<th>Mix 2</th>
<th>Mix 3</th>
<th>Mix 4</th>
<th>Mix 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>RAP</td>
<td>95%</td>
<td>95%</td>
<td>95%</td>
<td>95%</td>
<td>95%</td>
</tr>
<tr>
<td>Mineral Filler</td>
<td>4%</td>
<td>3%</td>
<td>2%</td>
<td>1%</td>
<td>0%</td>
</tr>
<tr>
<td>Hydrated Lime</td>
<td>1%</td>
<td>2%</td>
<td>3%</td>
<td>4%</td>
<td>5%</td>
</tr>
<tr>
<td>Asphalt Emulsion</td>
<td>3.3%</td>
<td>3.3%</td>
<td>3.3%</td>
<td>3.3%</td>
<td>3.3%</td>
</tr>
<tr>
<td>Residual asphalt binder</td>
<td>2%</td>
<td>2%</td>
<td>2%</td>
<td>2%</td>
<td>2%</td>
</tr>
</tbody>
</table>
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**Indirect Tensile Strength**

- ITS reaches a maximum value when 3% hydrated lime is added to the mix.

- High application rates (> 3%) of hydrated lime seem to have a **negative effect on ITS**.

- ITS reaches high values already at 1% cement application rate.

- ITS wet > ITS dry for the 2% cement content suggests that there was **unreacted cement** in the mix.
**Internal friction angle**

Typical values for BSM are in between 30 and 40°

- Internal friction angle value is **not influenced by the presence of active filler**
- It is believed to be mostly dependent on **RAP gradation**
Cohesion

Typical values for BSM are in between 100 and 250 kPa

- Cohesion is in the BSM boundaries for all hydrated lime application rates
- Lime does not have a major impact on plastic properties

- Cohesion **exponentially increases** for cement application rates higher than 1%
- Cement strongly impacts plastic response
Replicates gave very **consistent results** (repeatability of triaxial test)

- Material does **not give a linear response**

- When **temperature decreases** and **confining pressure increased** the material stiffens

- Importance of considering triaxial test for **analysis and design**
Cohesion is a temperature dependent property

- Internal friction angle is not affected by testing temperature (controlled by particle to particle contact)
**Effect of Temperature on Elastic Properties**

- Resilient Modulus is a **temperature dependent property** in BSMs

Reference mixture: 2% hydrated lime and asphalt emulsion
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3D Elasto-Plastic Finite Element Model for BSM

Paper accepted for publication: RILEM International Symposium on Bituminous Materials – Lyon, France 2020

Tests performed at 25 deg. C

- Confinement: 200 kPa
  - Maximum Load 49 kN
  - E = 299 MPa

- Confinement: 100 kPa
  - Maximum Load 38.8 kN
  - E = 264.5 MPa

- Confinement: 0 kPa
  - Maximum Load 28.8 kN
  - E = 230 MPa

Laboratory test
Simulation
Multilayer 2D Axisymmetric Model

Paper selected for presentation TRB 2021 and accepted for publication TRR 2021

Realistic temperature distribution with depth
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Summary

- **Triaxial shear and resilient modulus tests are better suited** characterization method than ITS for partially-bonded materials like BSMs.

- **Friction angle is controlled by particle to particle contact** in BSMs: the asphalt content is not high enough to contribute to friction.

- **Cement strongly impacts the cohesion** of the material (does not happen with lime).

- Cohesion and elastic modulus in BSMs are **temperature and confining pressure dependent properties**.

- The introduction of BSM plastic properties in the design and analysis of pavement structure can help **predict rutting potential**.
Ongoing research

- Evaluate the influence of curing time on mechanical properties of cold recycled mixtures (MnDOT-LRRB CIR curing project)
- Investigate the use of quick lime as active filler (In collaboration with University of Stellenbosch, South Africa)

\[
CaO + H_2O \rightarrow Ca(OH)_2 + 15.5 \text{ kCal}
\]

1. The reaction produces heat, that could allow to extend the construction season
2. Control of water content (reaction + evaporation)
Thank you for your time!