CEDR Transnational Road Research Programme
Call 2012: Recycling: Road construction in a post-fossil fuel society
funded by Denmark, Finland, Germany, Ireland, Netherlands and Norway

Towards a sustainable 100% recycling of reclaimed asphalt in road pavements

- Material Performance -

International Workshop on Recycling:
Road Construction in a post-fossil fuel Society
**Introduction**

WP1: Coordination, Management, Advisory board and Dissemination

- Raw Material characterisation
- Blends design
- Mix design

WP2: Mix and Blend design

- Validation of Mix Design of 0%, 30%, 60%, \(\rightarrow 100\%\) RA

WP3: Technology up-scaling at asphalt plant

WP4: Performance Assessment

- Mixes and Binder Characterisation
- Pavement Design Life calculation

WP5: Sustainability Assessment

- Technology Up-scaling guidelines
- Sustainability assessment methodology
- Other sustainability metrics
- LCA and LCCA

High Content RA-Warm asphalts for wearing courses

Deliverables available at http://allback2pave.fehrl.org/

Workshop on Recycling
Outline

- Materials
- Material Performance
  - Binder Performance
  - Asphalt Performance

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Materials tested

Asphalt Mixes for Wearing Courses

German asphalt mixes
- Asphalt mix: SMA 8S
- Binder type: Polymer modified bitumen
  - PmB 25/55-55
- Aggregate type: Gravel and granite sources
- Mixture of rejuvenator + warm mix additives
  - ‘Storbit’ STORIMPEX
- Fillers: Limestone
- Fibers: Pelletized cellulose fibers
- 0% RA
- 30% RA
- 60% RA
- 60% RA + Additives

Italian asphalt mixes
- Asphalt Mix: “AC 16”
- Binder type: Paving bitumen
  - Bitumen type 50/70
- Aggregate type: Basaltic and volcanic sources
- Mixture of rejuvenator + warm mix additives
  - ‘Storbit +’ STORIMPEX
- Fillers: Limestone
- 0% RA
- 30% RA + Additives
- 60% RA + Additives
- 90% RA + Additives

Deliverables available at http://allback2pave.fehrl.org/
Materials tested

![Graph showing grading limits for SMA 8S and AC 16 materials](image)

- **grading limits for SMA 8S [TL Asphalt 09]**
- **grading limits for AC 16 [ANAS]**

Materials tested

Grading limits for SMA 8S [TL Asphalt 09]
- SMA 8S with 0% RA
- SMA 8S with 30% RA
- SMA 8S with 60% RA
- SMA 8S with 60% RA + Additive

Grading limits for AC 16 [ANAS]

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Materials tested

Grading limits for AC 16 [ANAS]

Grading limits for SMA 8S [TL Asphalt 09]

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Binders properties characterisation

- Rutting resistance
  Multiple Stress Creep recovery test

- Fatigue resistance
  Time Sweep test

- Thermal cracking resistance

- Critical temperatures
Rutting resistance

Multiple Stress Creep Recovery (MSCR) tests [AASHTO T 350-14 2014]
- improvement of the Superpave specification (poor relation authors between Superpave rutting parameter \( G^*/\text{sen}\) and real rutting in mixtures)
  - test temperature of 60°C
  - 9 stress levels [kPA]: 0.1, 0.2, 0.4, 0.8, 1.6, 3.2, 6.4, 12.8 and 25.6

Result: Recoverable and Non-Recoverable Creep Compliance (Jnr [%]) for each stress level
Binder performance

Rutting resistance

- Recovery [%] of SMA 8S binders at 0.1 kPa, 3.2 kPa and 6.4 kPa

- increased percentage of RA leads to an increase of the percentage of recovered strains, meaning that better resistance to rutting will be provided.

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Binder performance

Rutting resistance

- Recovery [%] of AC 16 binders at 0.1 kPa, 3.2 kPa and 6.4 kPa

- increased percentage of RA leads to an increase of the percentage of recovered strains, meaning that better resistance to rutting will be provided.

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Fatigue resistance

**Time Sweep** tests
- DSR tests
- test temperature of 20°C
- test frequency of 10 Hz
- different strain/stress levels
- failure considered as the decrease of 50% of the initial complex modulus ($G^*$)

**Result:** Fatigue curves for each binder
Binder performance

Fatigue resistance

- Fatigue laws of SMA 8 S binders

- Increased percentage of RA leads to a decrease of fatigue life

Deliverables available at http://allback2pave.fehrl.org/
Binder performance

Fatigue resistance

- Fatigue laws of AC 16 binders

- increased percentage of RA seems to increase the fatigue life

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Asphalt properties characterisation

• **Stiffness behaviour**
  indirect tensile test, four point bending beam test
  EN 12697-26

• **Fatigue resistance**
  indirect tensile test, four point bending beam test
  EN 12697-24

• **Rutting resistance**
  wheel tracking test, uniaxial cyclic compression tests
  EN 12697-22/ EN 12697-25

• **Moisture damage resistance**
  indirect tensile test
  EN 12697-23/12

Deliverables available at http://allback2pave.fehrl.org/
Asphalt performance

Stiffness behavior

- Four Point Bending Beam tests
- Indirect Tensile Tests
- specimens produced by roller sector compaction
- test temperature: -10 to 30°C
- test frequency: 0.1Hz to 20Hz

Result: stiffness modulus master curves

- depending on the reduced frequency ($\alpha_T$) determined by Arrhenius equation
Asphalt performance

Stiffness behavior

- different approaches to determine the reduced frequency with constant and variable shift factor
  (determination of \( E_{\text{min}} \) and \( E_{\text{max}} \) based on phase angle)
Asphalt performance

Stiffness behavior

\[
\log(\alpha T_f) [-] \quad \text{Stiffness modulus } E_{\text{reg}} [N/mm^2]
\]

Regression Values
Experimental Values

\[
y = 0.999x \\
R^2 = 0.9945
\]
Asphalt performance

Stiffness behavior
- Master curve of SMA 8S and AC 16 asphalt mixes @ Ts=20°C
- SMA 8S: stiffness increases with an increasing amount of RA
- AC 16: almost no difference between temperature related stiffness’s

![Graph showing stiffness modulus E vs log(\(\alpha_T f\))]
Asphalt performance

Stiffness behavior
- Master curve of German (SMA 8 S) and Italian (AC 16) asphalt mixes @ Ts=20°C

**constant shift factor**

**variable shift factor**

Deliverables available at http://allback2pave.fehrl.org/
Asphalt performance

Fatigue Performance

- Four Point Bending Beam tests
- Indirect Tensile Tests
- Specimens produced by roller sector compaction
- Test temperature of 20°C
- Test frequency of 10Hz

Result: fatigue curves

- Different fatigue criteria used to define the failure load cycle:
  - Moment where the stiffness decreases to its half;
  - Moment where a macro crack occurs
Fatigue resistance

- Fatigue curves for SMA 8 S asphalt mixes
- Increasing amount of reclaimed asphalt leads to a better fatigue performance.
Asphalt performance

Fatigue resistance

- Fatigue curves for AC 16 asphalt mixes
- Increasing amount of reclaimed asphalt leads to a better fatigue performance.

![Graph showing fatigue performance for different asphalt mixes]
Asphalt performance

Fatigue resistance
- Fatigue curves for SMA 8 S and AC 16 asphalt mixes

![Graph showing fatigue resistance for SMA 8 S and AC 16 asphalt mixes with different RA percentages and additives.](image-url)
Asphalt performance

Rutting resistance

- Wheel Tracking tests
- test temperature of 60°C
- test frequency of 26.5 Hz
- 20,000 passes
- 3 repetitions for each material

Results: Proportional Rut Depth (PRD_{AIR}) and Wheel-Tracking Slope (WTS_{AIR})
Asphalt performance

Rutting resistance

- Wheel Tracking Test for SMA 8 S and AC 16 asphalt mixes

![Graph showing Mean RD vs Number of passes for SMA 8S and AC 16 asphalt mixes with different percentages of RA and Additive.](http://allback2pave.fehrl.org/)

Deliverables available at http://allback2pave.fehrl.org/
Asphalt performance

Rutting resistance

- Uniaxial Compression Tests
- test temperature of 30°C, 40°C and 50°C
- test frequency of 10 Hz
- different stress levels: minimum 0.050 MPa
  - maximum 0.925 MPa (30°C)
  - 0.900 MPa (40°C)
  - 0.500 MPa (50°C)
- 30,000 load cycles for each stress level

Results: accumulated plastic strains at a desired load cycle as well as the corresponding initial elastic strain
mixture with 60% RA + Add. is likely to develop the deepest rut death what was also observed in the wheel tracking test as in the binder characterisation

- clear relation between plastic deformation behaviour & amount of RA
- an increasing amount of RA in combination with the use of additives leads to a lower risk of rutting

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Workshop on Recycling
Asphalt performance

- mixture with 60% RA + Add. is likely to develop the deepest rut death what was also observed in the wheel tracking test as in the binder characterisation.

- clear relation between plastic deformation behaviour an amount of RA

- an increasing amount of RA in combination with the use of additives leads to a lower risk of rutting
Pavement performance

Mechanistic design procedure

Design input data:
Traffic and climate conditions
pavement structure

Material parameter
Deliverable D4.2
Outline

- Materials

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- Pavement Performance

Deliverable D4.1

Deliverable D4.2
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