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

Conférence Européenne des Directeurs des Routes
Conference of European Directors of Roads

AllBack2Pave

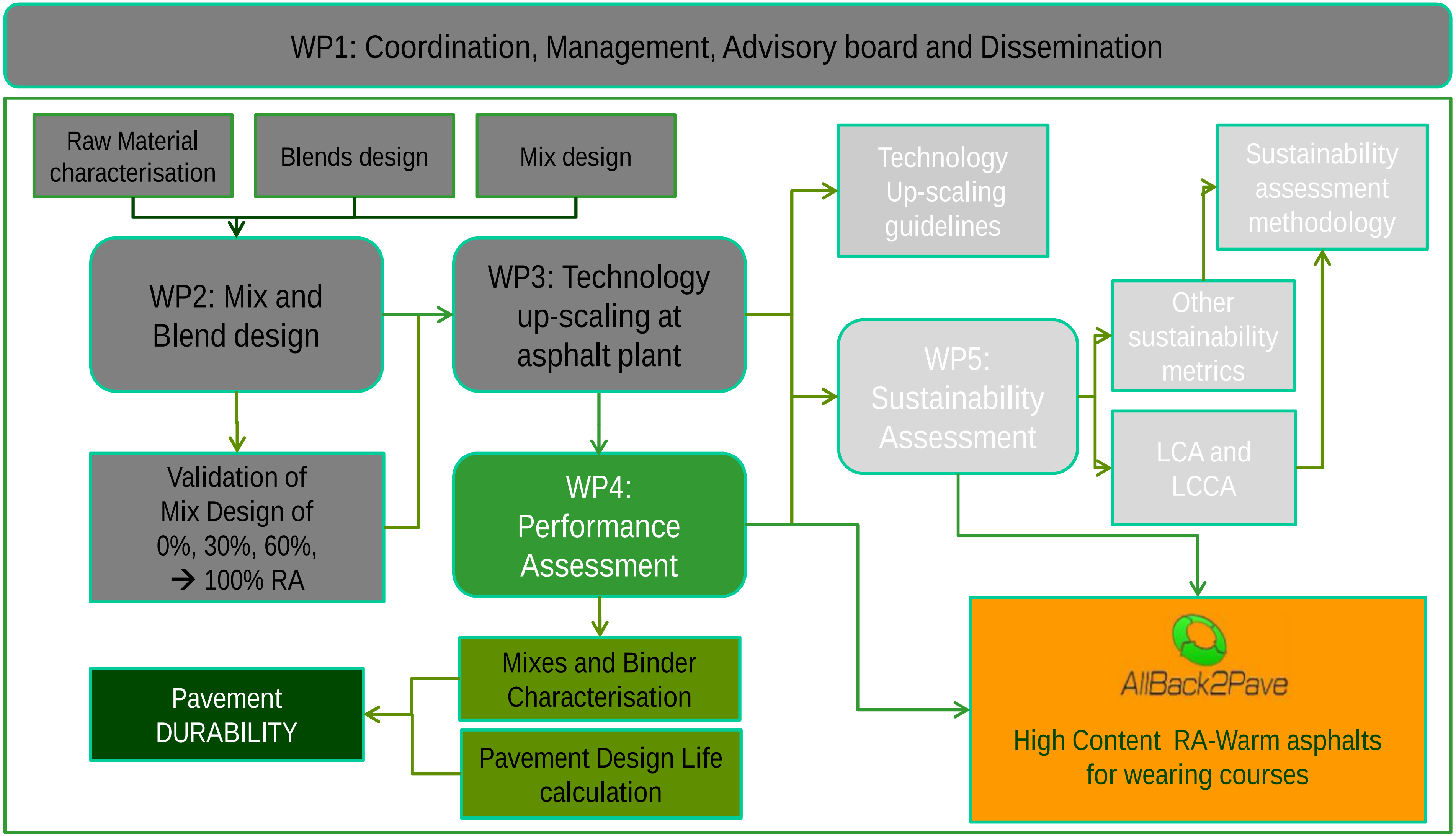
Towards a sustainable 100% recycling of reclaimed asphalt in road pavements

- Material Performance -

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

TECHNISCHE UNIVERSITÄT DRESDEN
The University of Nottingham
UNIVERSITÀ DEGLI STUDI DI PALERMO

Introduction



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

Outline

- **Materials**

- **Material Performance**

  Binder Performance

  Asphalt Performance

Outline

- **Materials**
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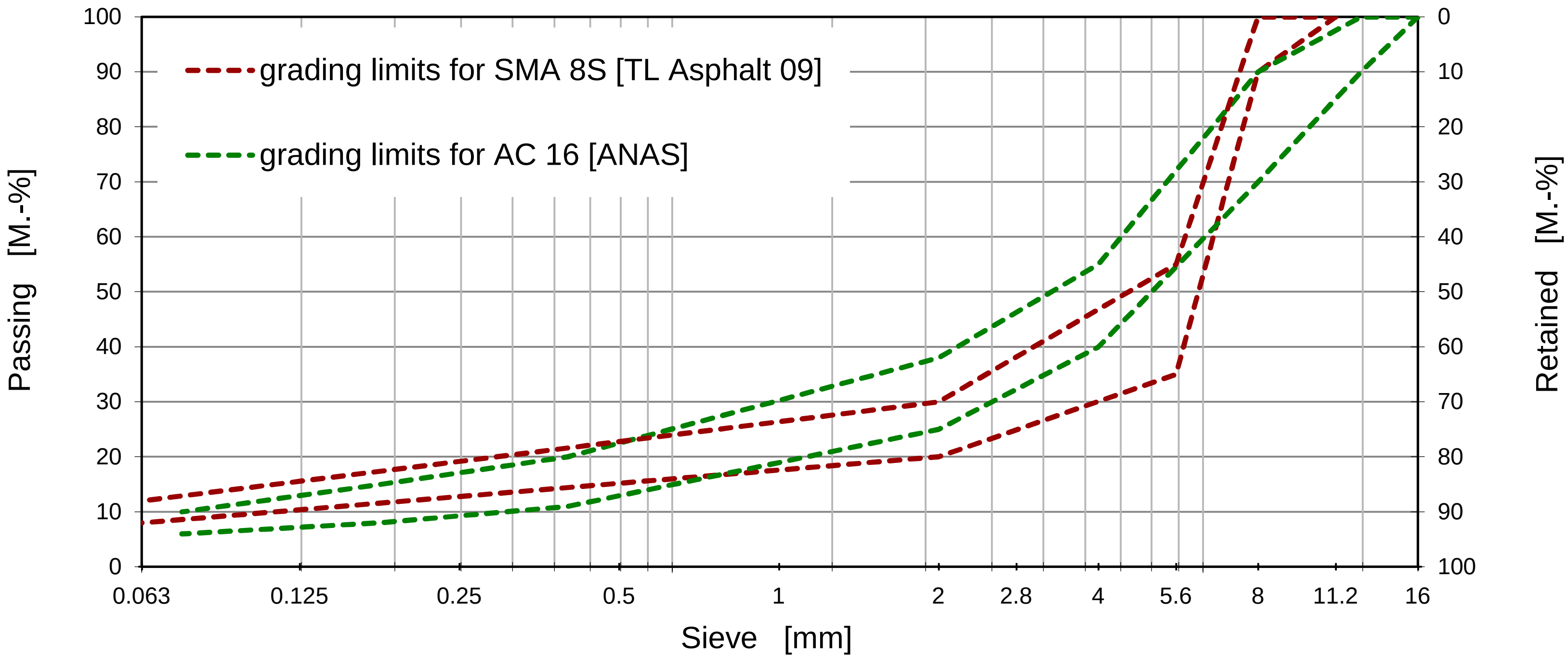
  Asphalt performance

Materials tested

Asphalt Mixes for Wearing Courses

German asphalt mixes	Italian asphalt mixes
Asphalt mix : SMA 8S	Asphalt Mix : "AC 16"
Binder type : Polymer modified bitumen **PmB 25/55-55**	Binder type : Paving bitumen **Bitumen type 50/70**
0% RA 30% RA 60% RA 60% RA + Additives	0% RA 30% RA + Additives 60% RA + Additives 90% RA + Additives
Aggregate type : Gravel and granite sources	Aggregate type : Basaltic and volcanic sources
Mixture of rejuvenator + warm mix additives 'Storbit+' *STORIMPEX*	Mixture of rejuvenator + warm mix additives 'Storbit +' *STORIMPEX*
Fillers : Limestone	Fillers : Limestone
Fibers : Pelletized cellulose fibers	

Materials tested



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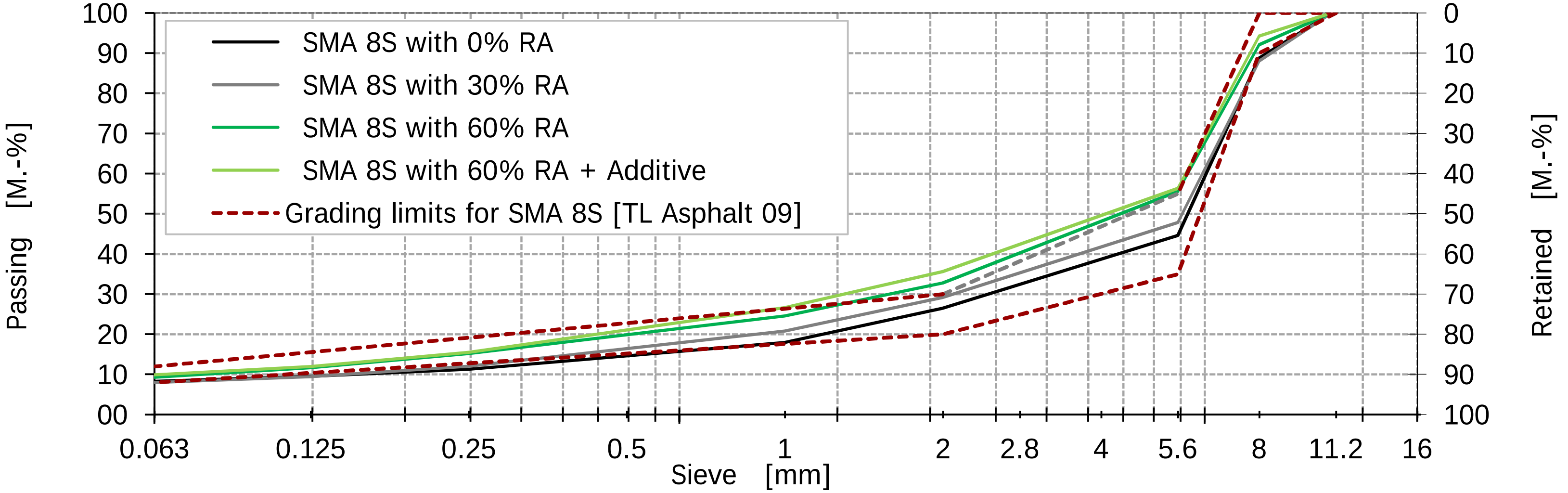
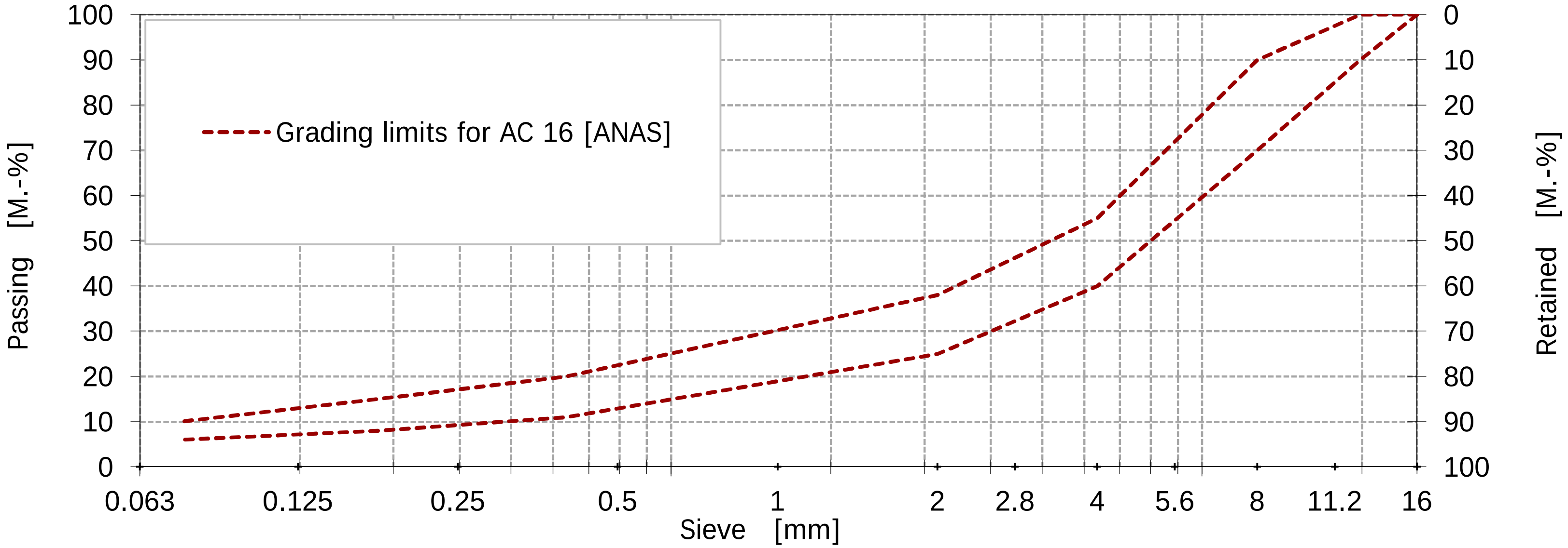
Materials tested





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Materials tested

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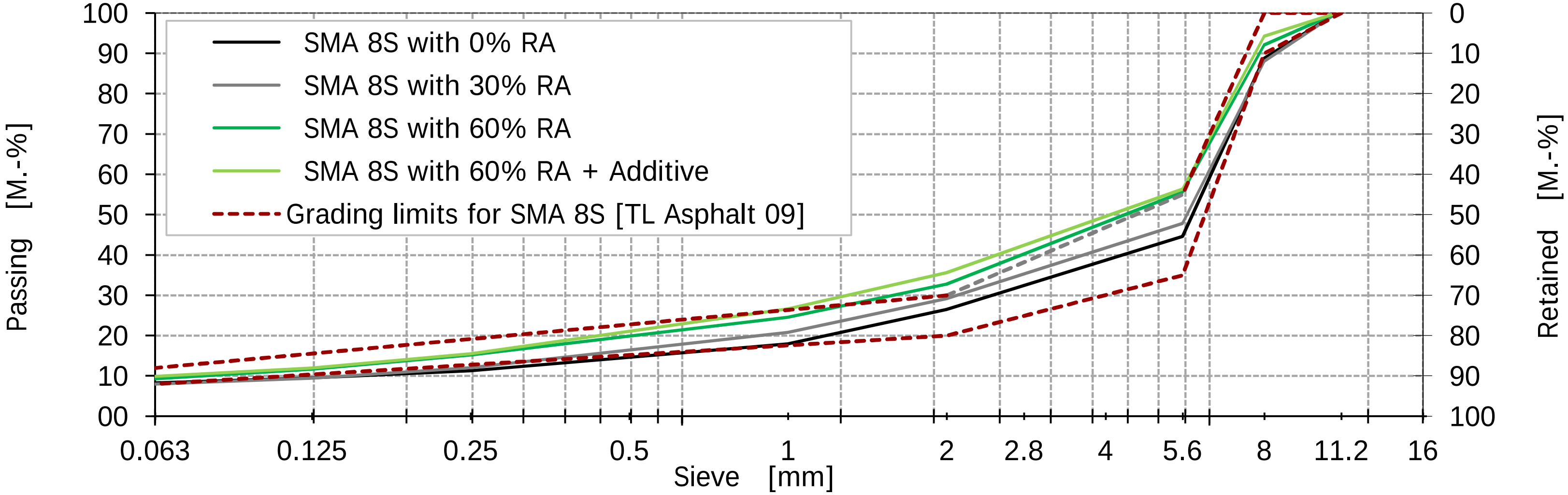

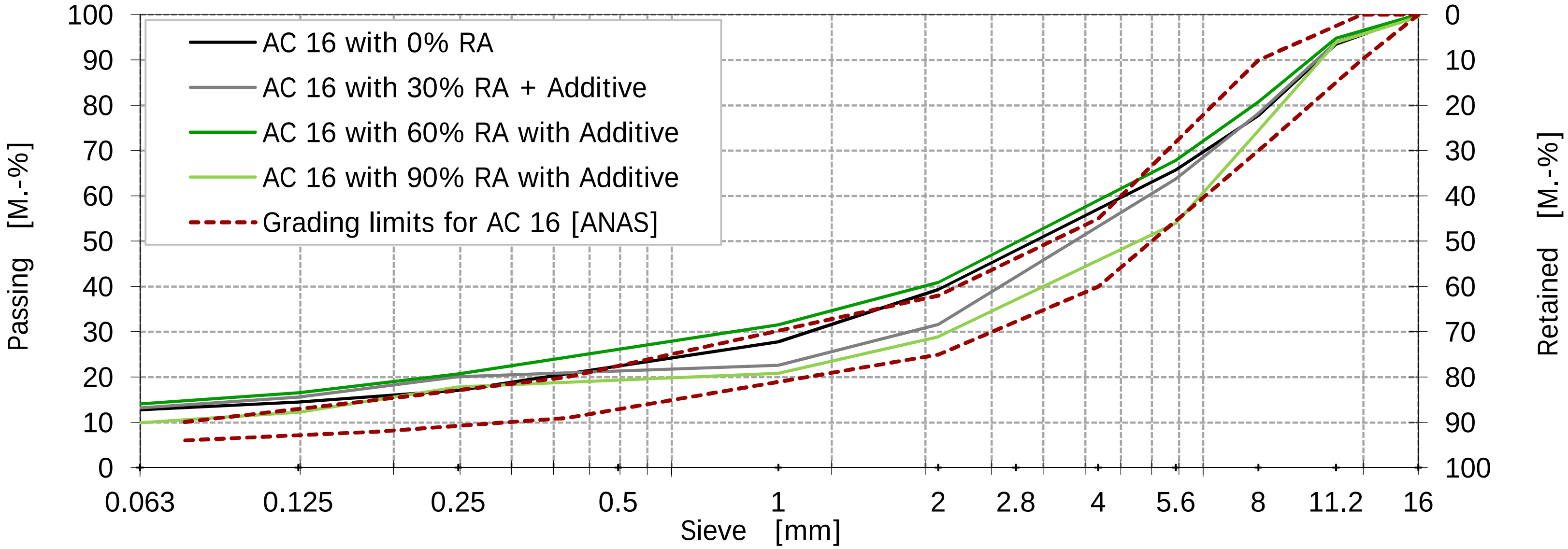

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Outline

- Materials
- Material Performance

  Binder Performance

  Asphalt performance

Material performance

Binders properties characterisation

- **Rutting resistance**
  Multiple Stress Creep recovery test

- **Fatigue resistance**
  Time Sweep test

- **Thermal cracking resistance**

- **Critical temperatures**

Binder performance

Rutting resistance

Multiple Stress Creep Recovery (MSCR) tests [AASHTO T 350-14 2014]

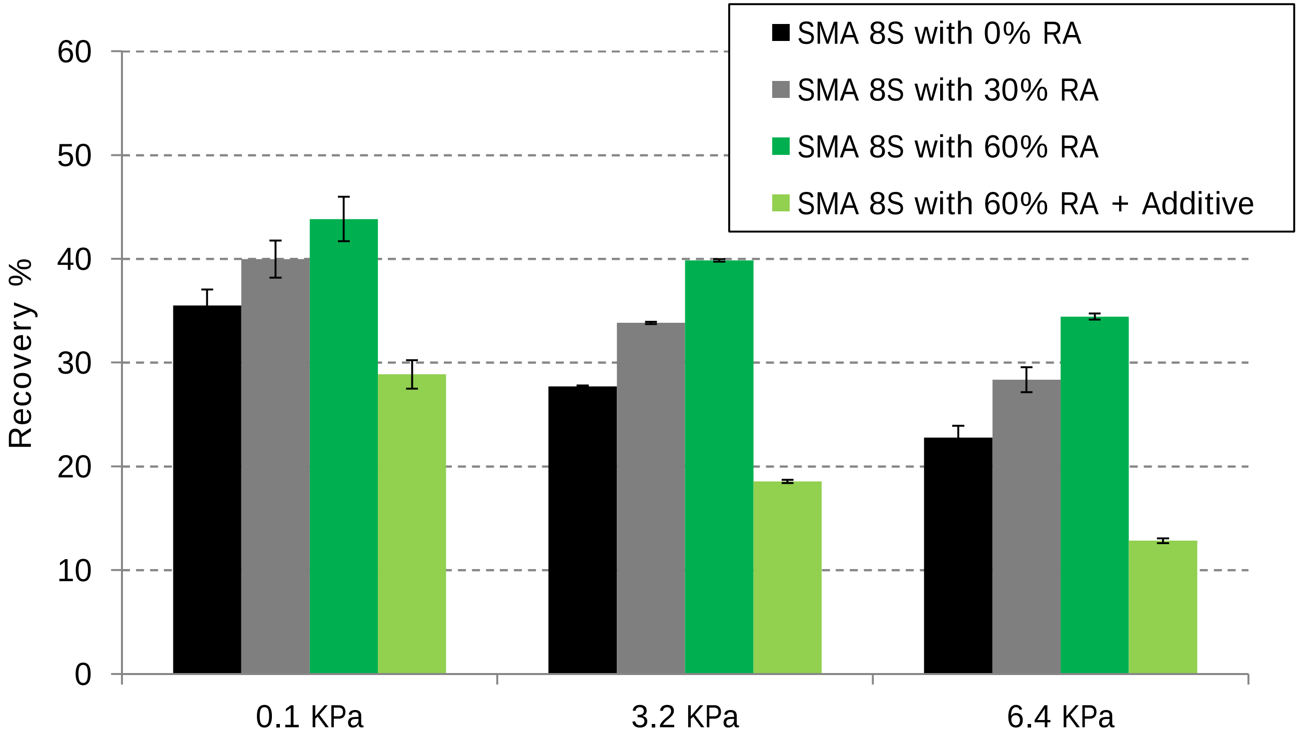
- improvement of the Superpave specification (poor relation authors between Superpave rutting parameter (G*/senδ) and real rutting in mixtures)
- test temperature of 60^{0}C
- 9 stress levels [kPA]: 0.1, 0.2, 0.4, 0.8, 1.6, 3.2, 6.4, 12.8 and 25.6

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

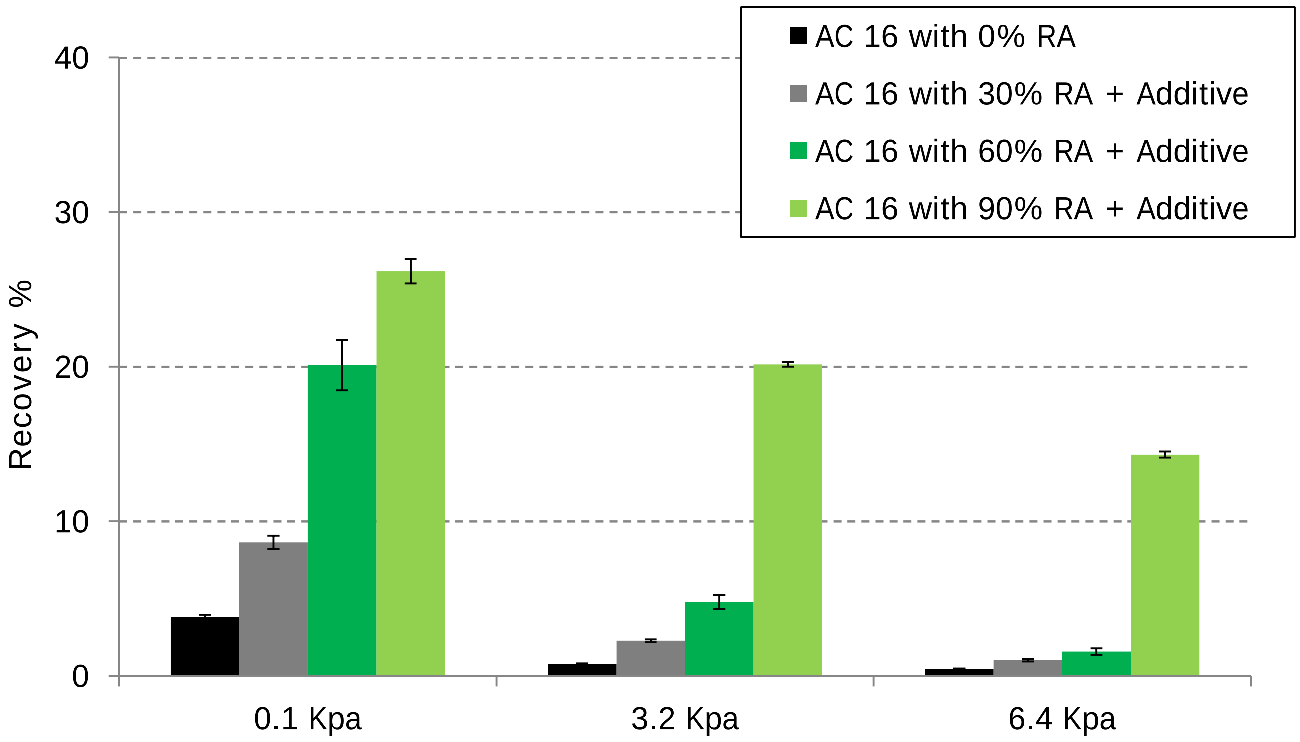


- increased percentage of RA leads to an increase of the percentage of recovered strains, meaning that better resistance to rutting will be provided.

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.

Binder performance

Fatigue resistance

Time Sweep tests

- DSR tests
- test temperature of 20^{o}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

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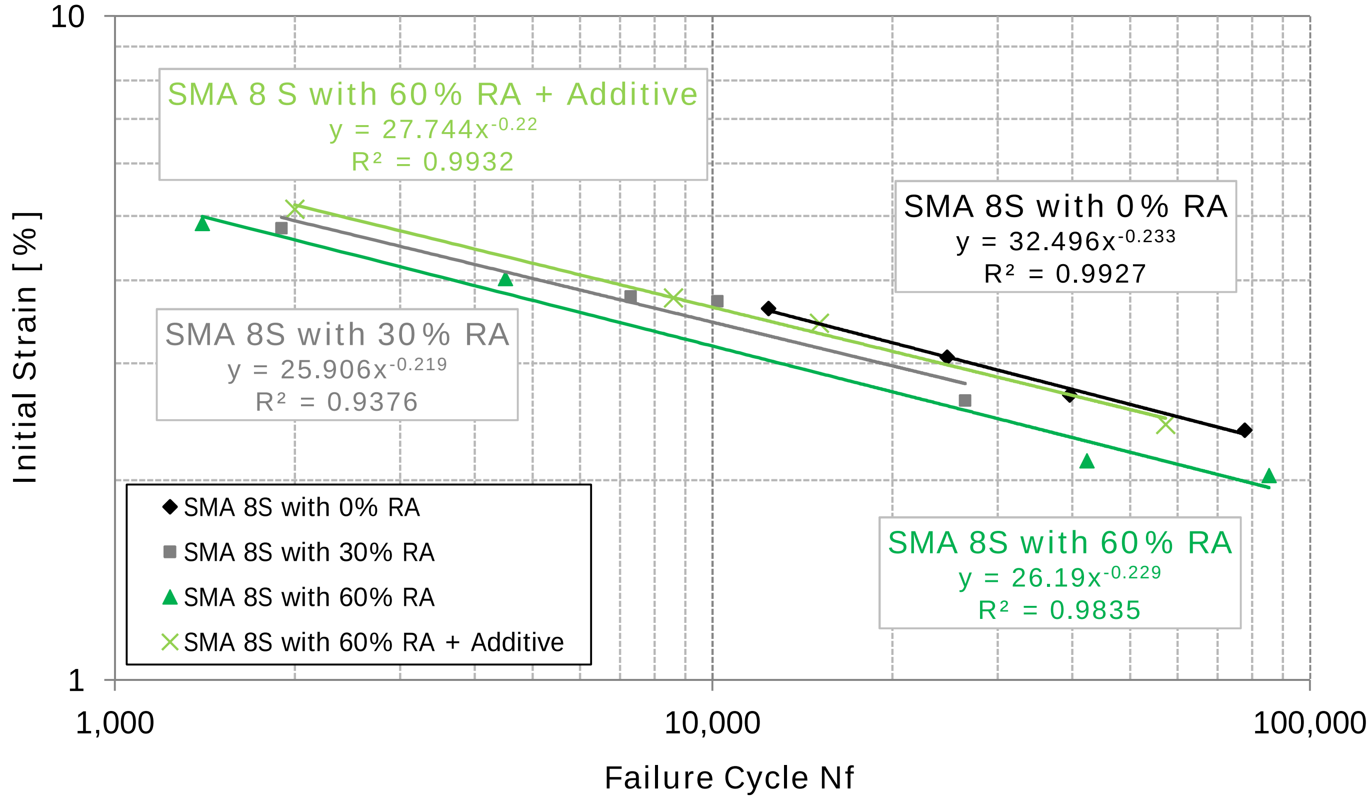
Fatigue resistance

- Fatigue laws of SMA 8 S binders

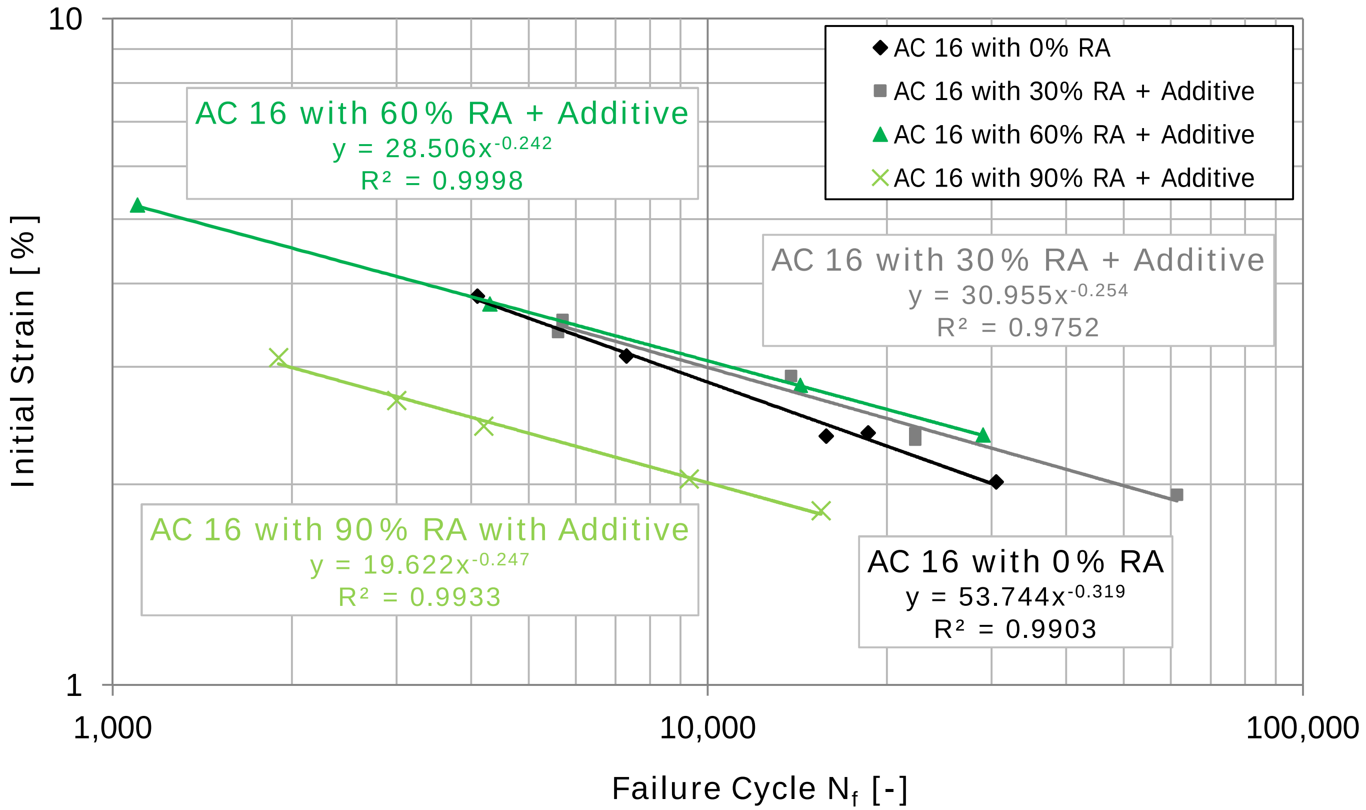


- increased percentage of RA leads to an decrease of fatigue life

Binder performance

Fatigue resistance

- Fatigue laws of AC 16 binders



- increased percentage of RA seems to increase the fatigue life

Outline

- Materials

- Material Performance

  Binder Performance

  Asphalt performance

Material performance

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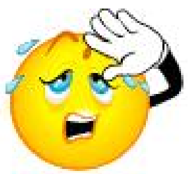
Asphalt properties characterisation

- **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

Asphalt performance

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Stiffness behavior

- Four Point Bending Beam tests
- Indirect Tensile Tests

- specimens produced by roller sector compaction

- test temperature: -10 to 30^{0}C
- test frequency: 0.1Hz to 20Hz

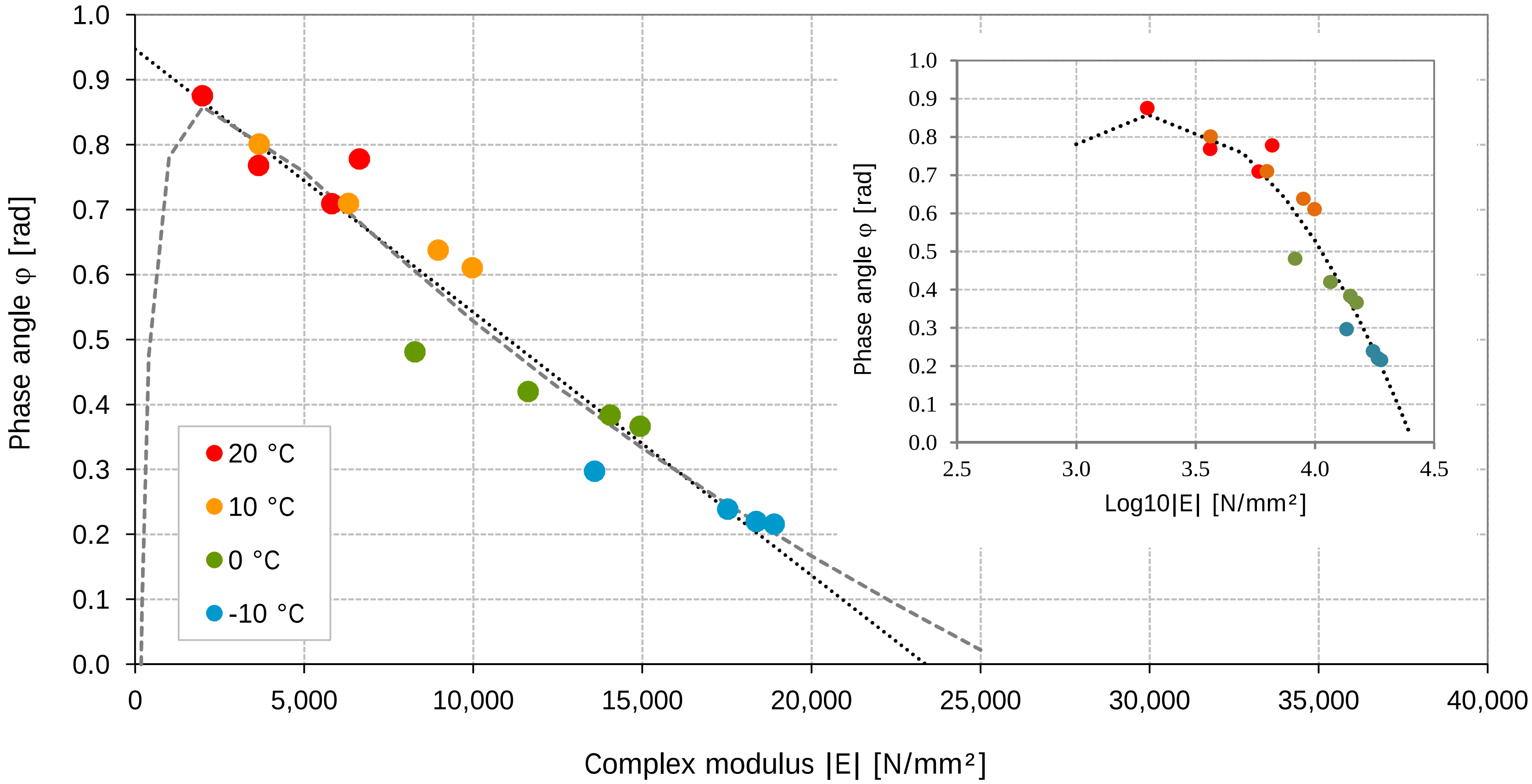
<u>Result:</u> stiffness modulus master curves

- depending on the reduced frequency (α_T) determined by Arrhenius equation

Asphalt performance

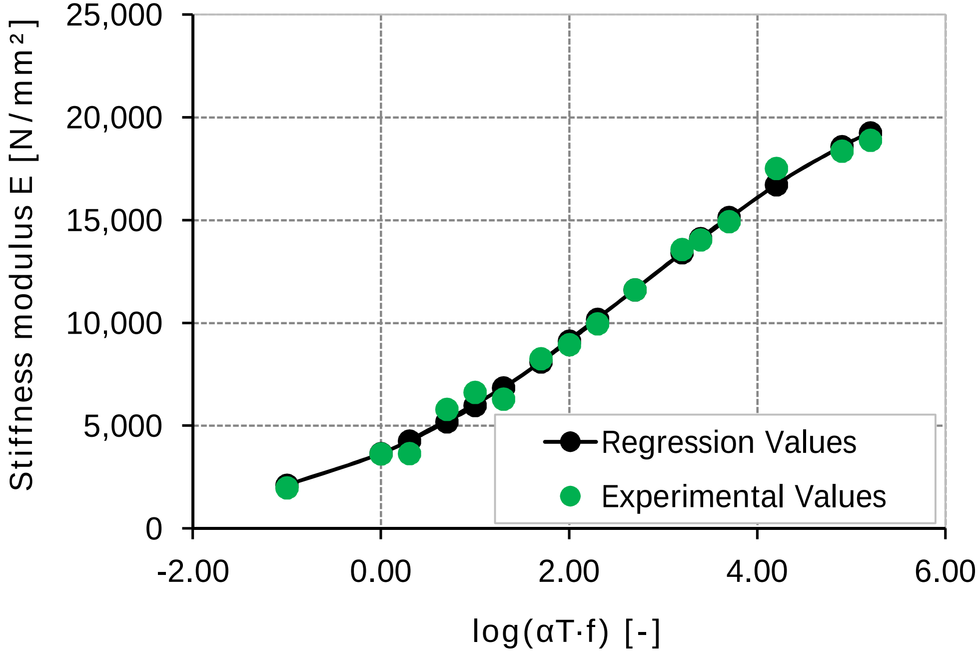
Stiffness behavior

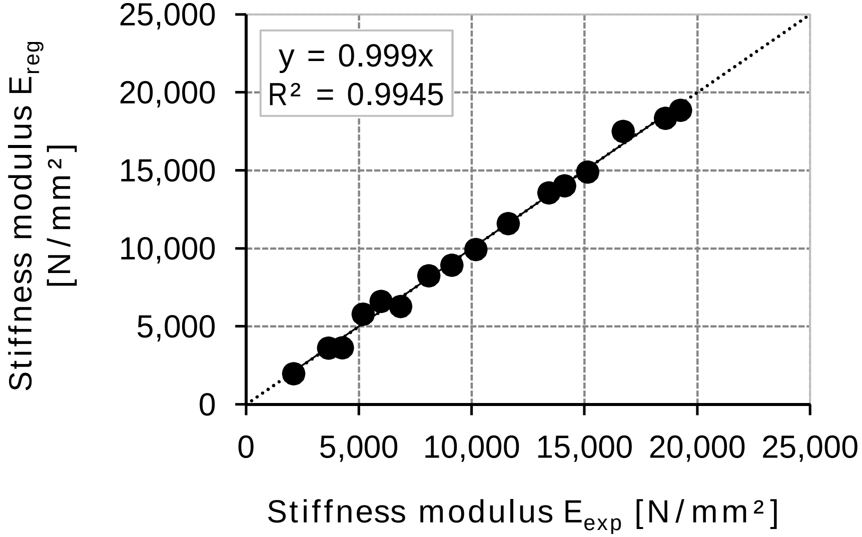
- different approaches to determine the reduced frequency with constant and variable shift factor (determination of E_{min} and E_{max} based on phase angle)



Asphalt performance

Stiffness behavior





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Asphalt performance

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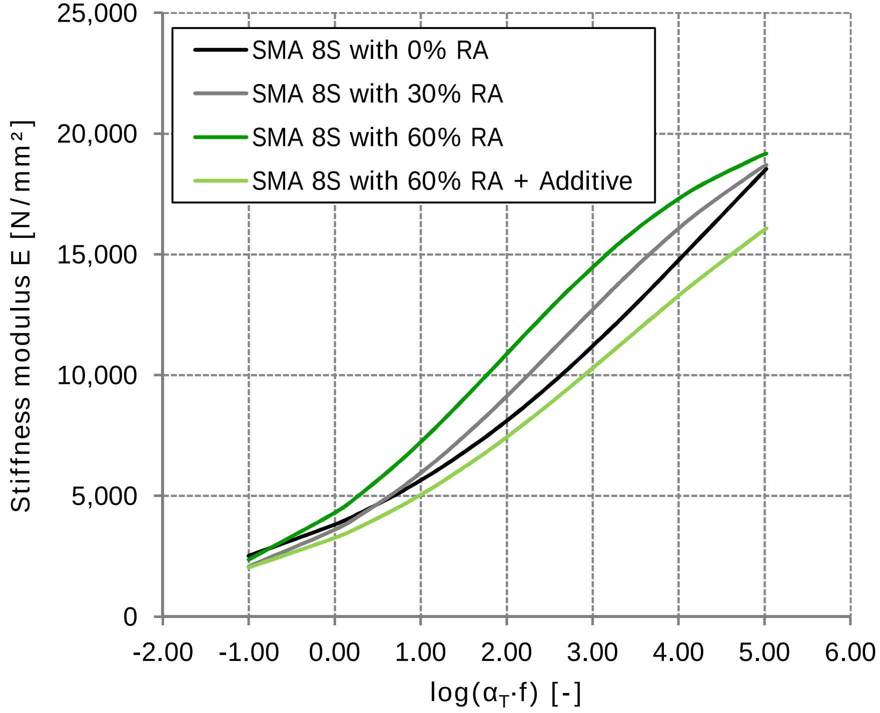
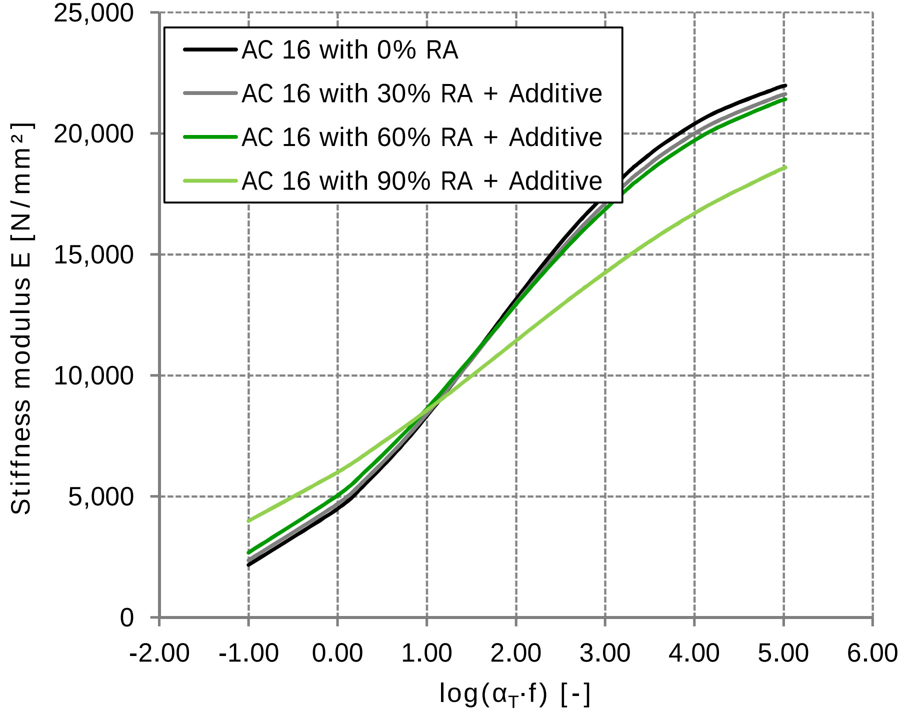
Stiffness behavior

- Master curve of SMA 8 S and AC 16 asphalt mixes @ Ts=20^{0}C
- SMA 8 S: stiffness increases with an increasing amount of RA
- AC 16: almost no difference between temperature related stiffness’s



constant shift factor



constant shift factor

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Asphalt performance

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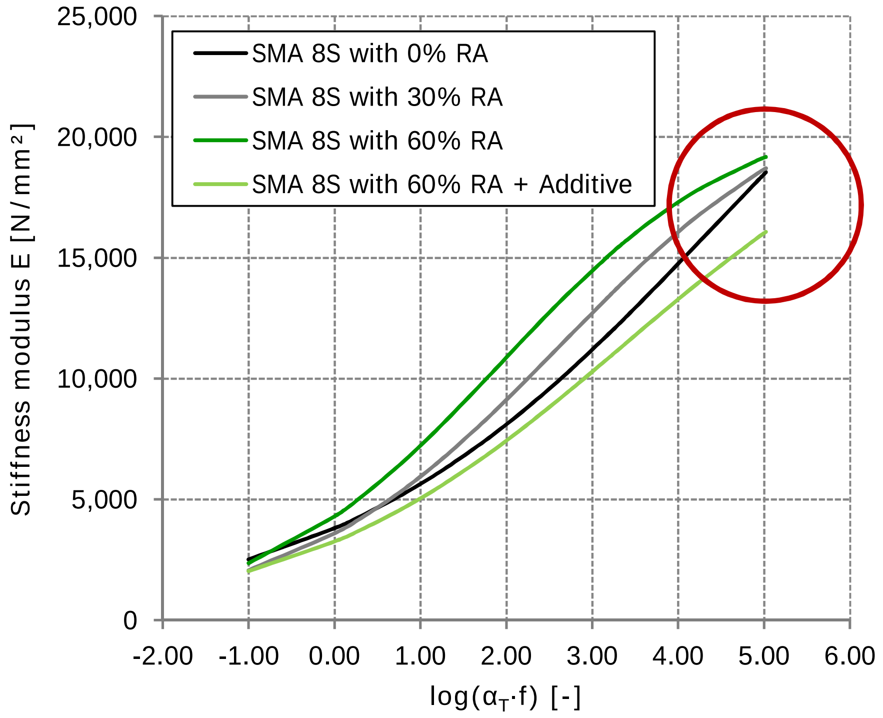
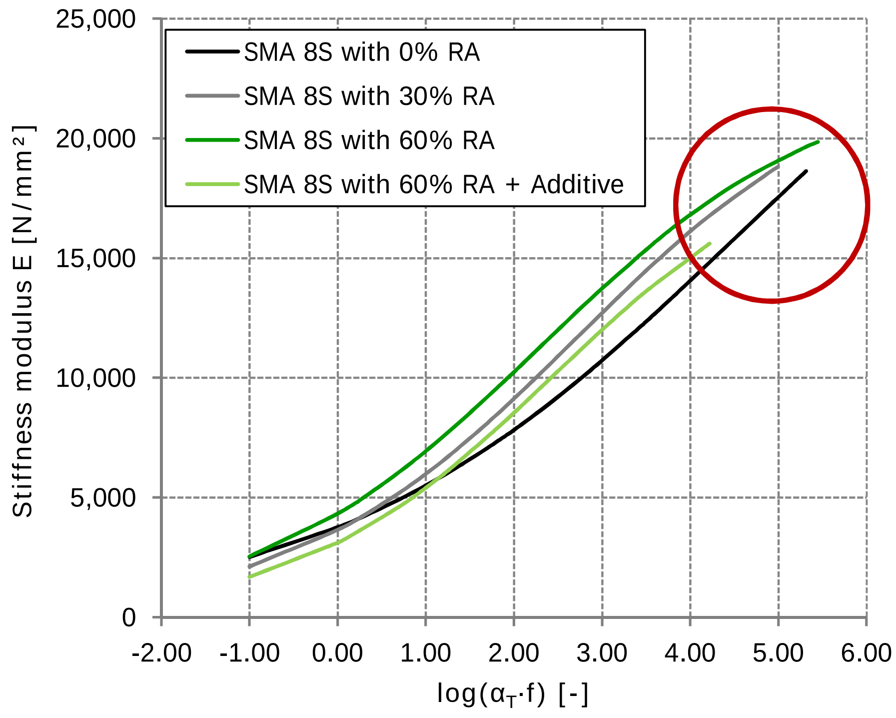
Stiffness behavior

- Master curve of German (SMA 8 S) and Italian (AC 16) asphalt mixes @ Ts=20^{0}C



constant shift factor



variable shift factor

Asphalt performance

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Fatigue Performance

- Four Point Bending Beam tests
- Indirect Tensile Tests

- specimens produced by roller sector compaction

- test temperature of 20^{0}C
- test frequency of 10Hz

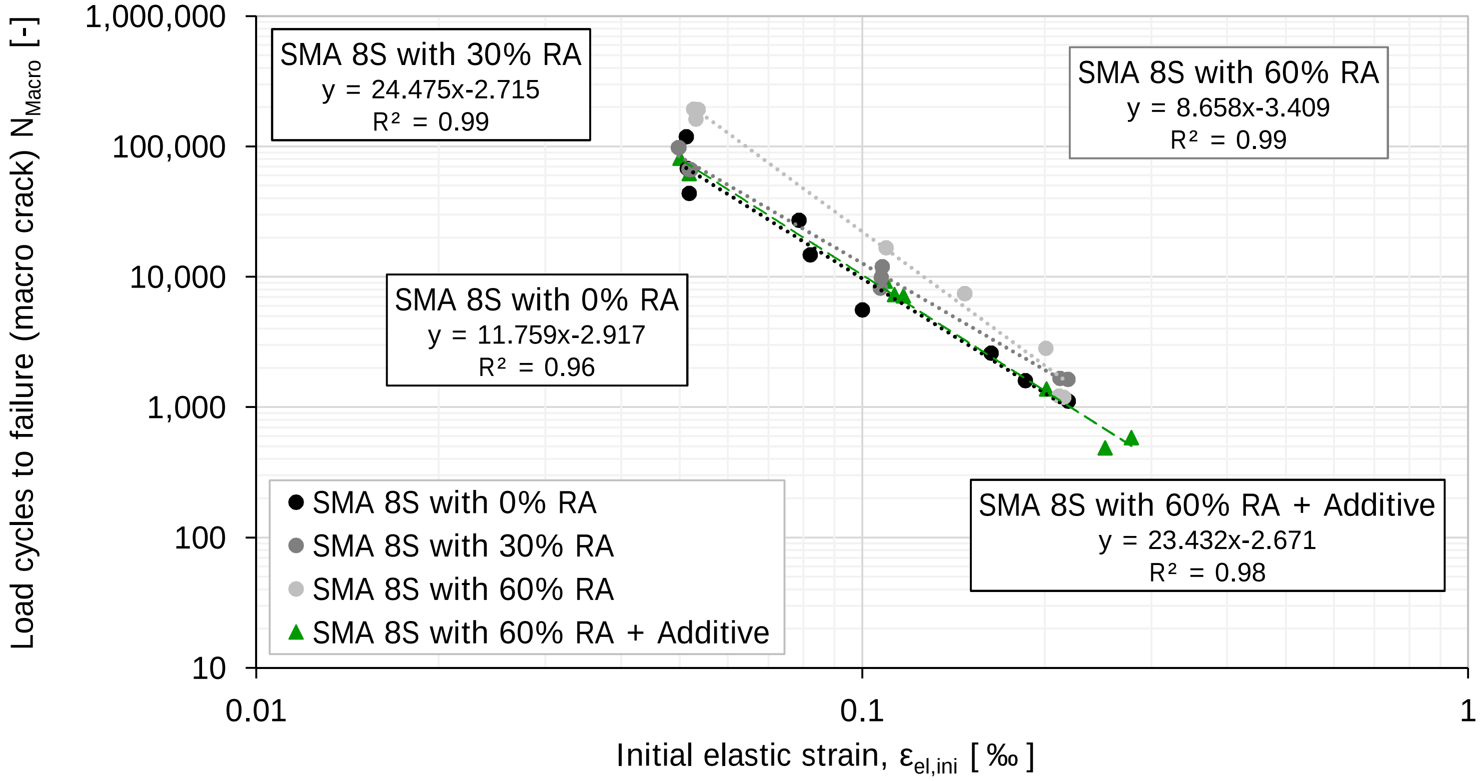
Result: fatigue curves

- different fatigue criteria used to define the failure load cycle:
  moment where the stiffness decrease to its half;
  moment where a macro crack occurs

Asphalt performance

Fatigue resistance

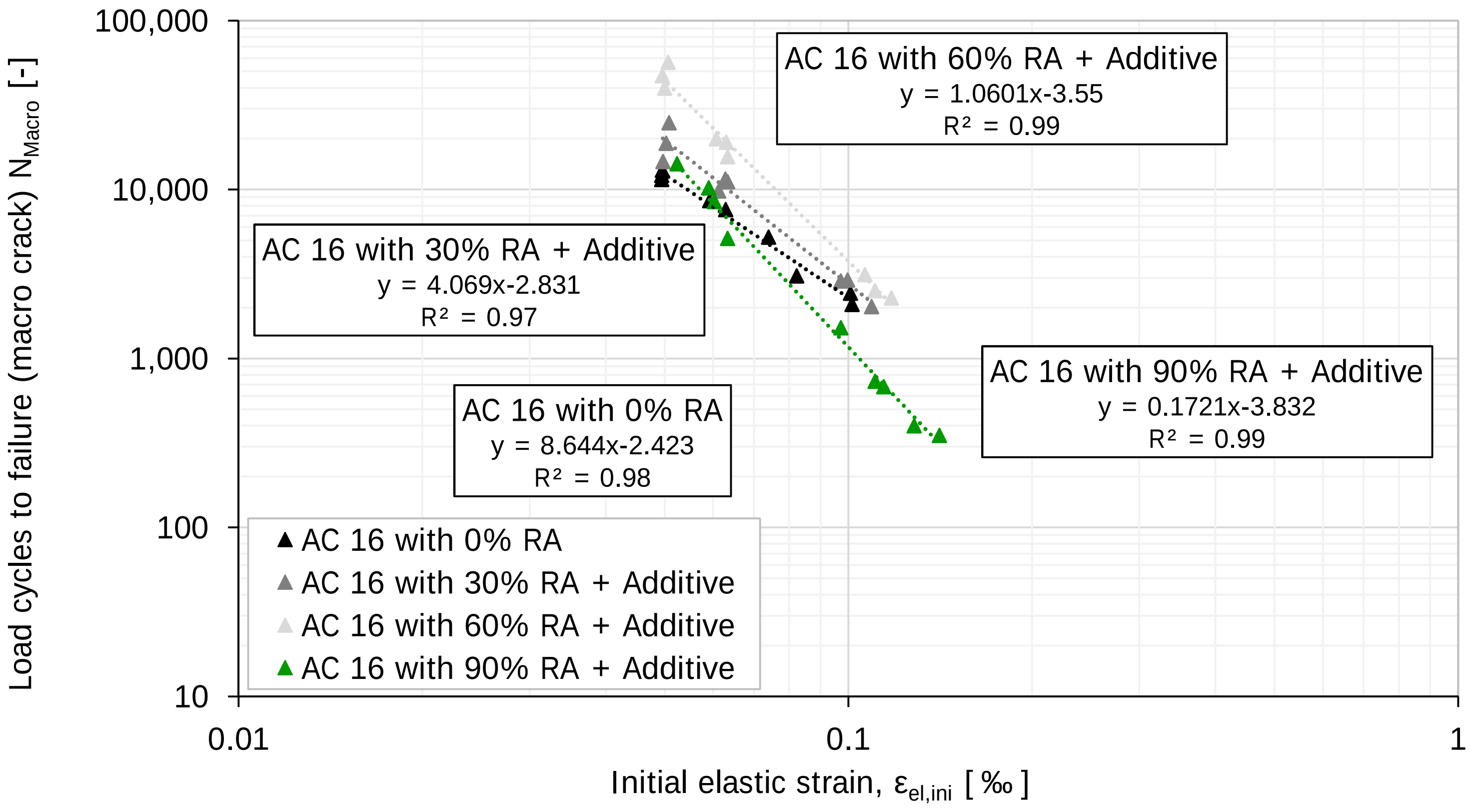
- Fatigue curves for SMA 8 S asphalt mixes
- increasing amount of reclaimed asphalt leads to a better fatigue performance.



Asphalt performance

Fatigue resistance

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



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Asphalt performance

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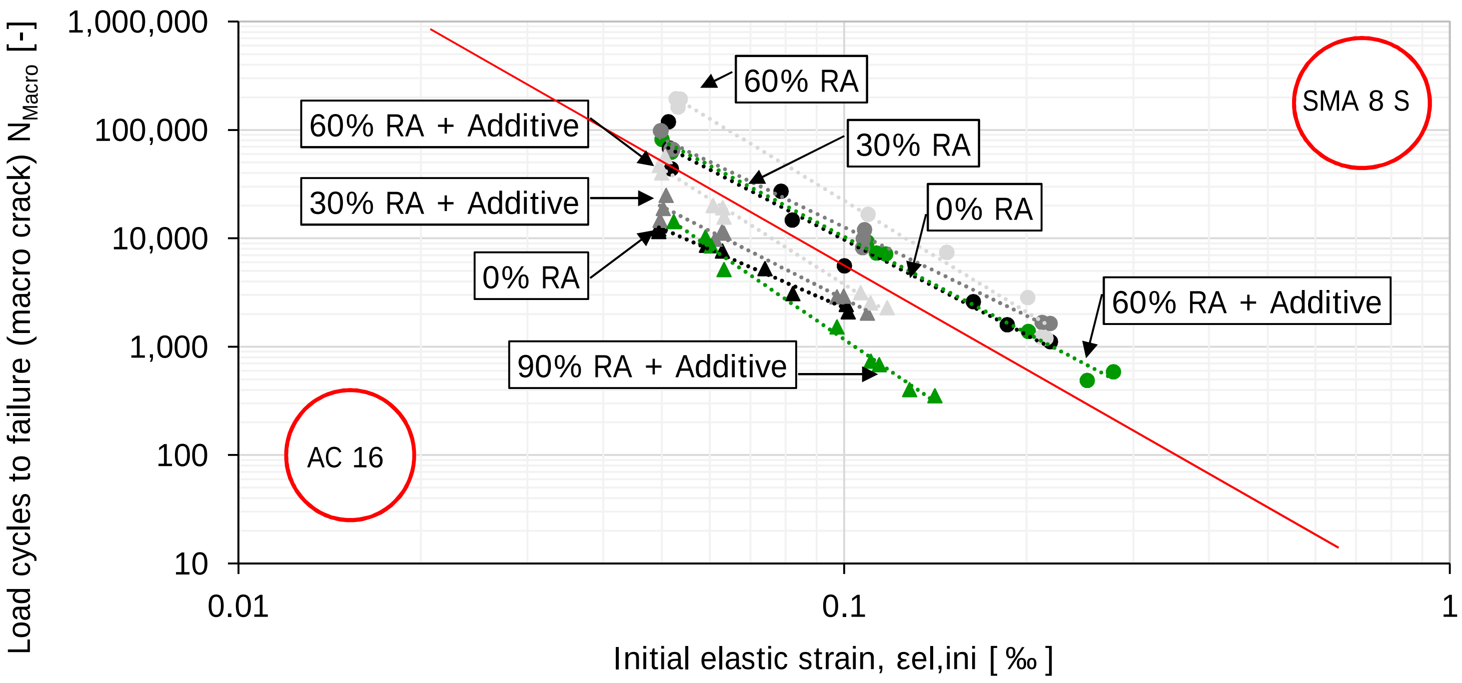
Fatigue resistance

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



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Asphalt performance

Rutting resistance

- Wheel Tracking tests

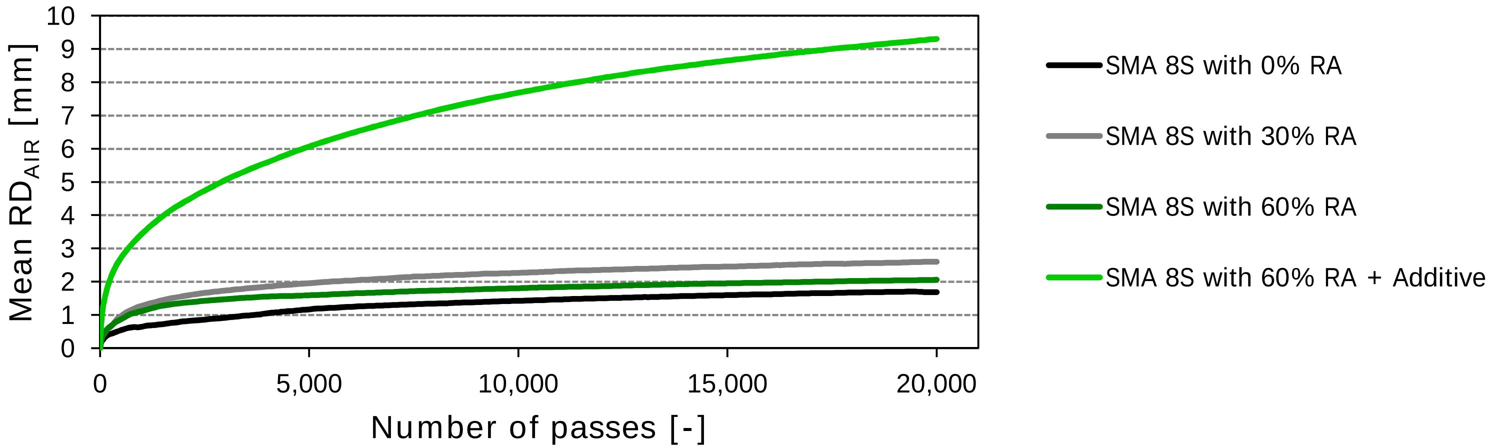
- test temperature of 60^{o}C
- test frequency of 26.5 Hz
- 20,000 passes
- 3 repetitions for each material

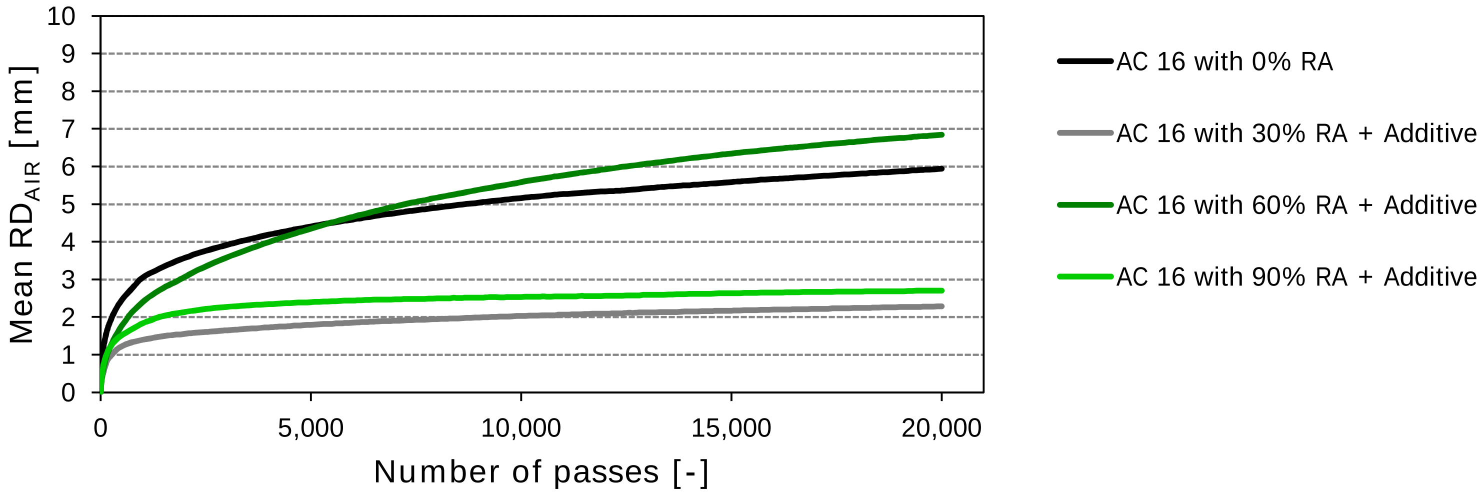
Results: Proportional Rut Depth (PRD_{AIR}) and Wheel-Tracking Slope (WTS_{AIR})

Asphalt performance

Rutting resistance

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





Asphalt performance

Rutting resistance

- Uniaxial Compression Tests

- test temperature of 30^{0}C, 40^{0}C and 50^{0}C
- test frequency of 10 Hz
- different stress levels: minimum 0.050 MPa
  maximum 0.925 MPa (30^{0}C)
  0.900 MPa (40^{0}C)
  0.500 MPa (50^{0}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

Asphalt performance

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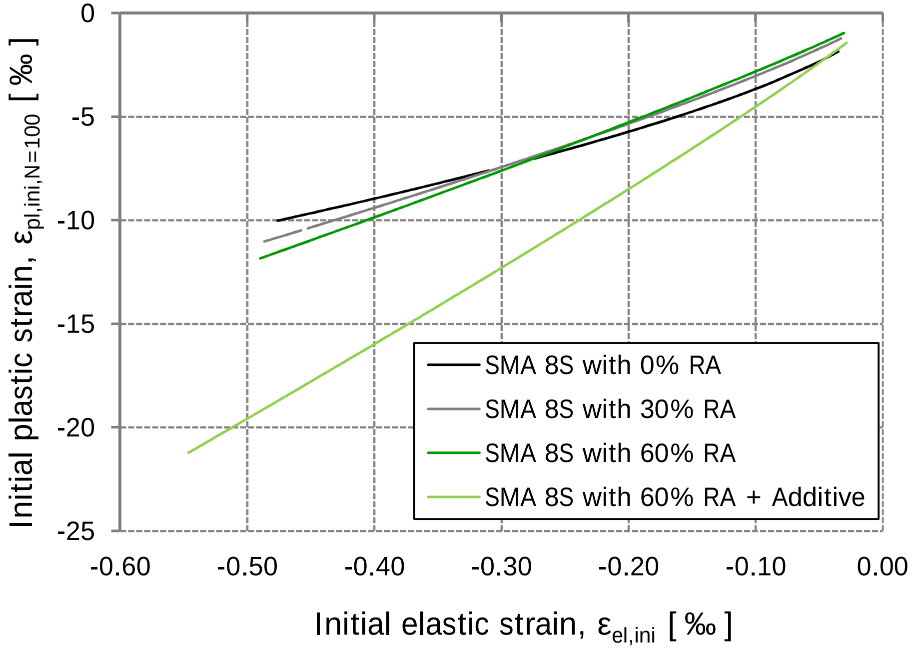
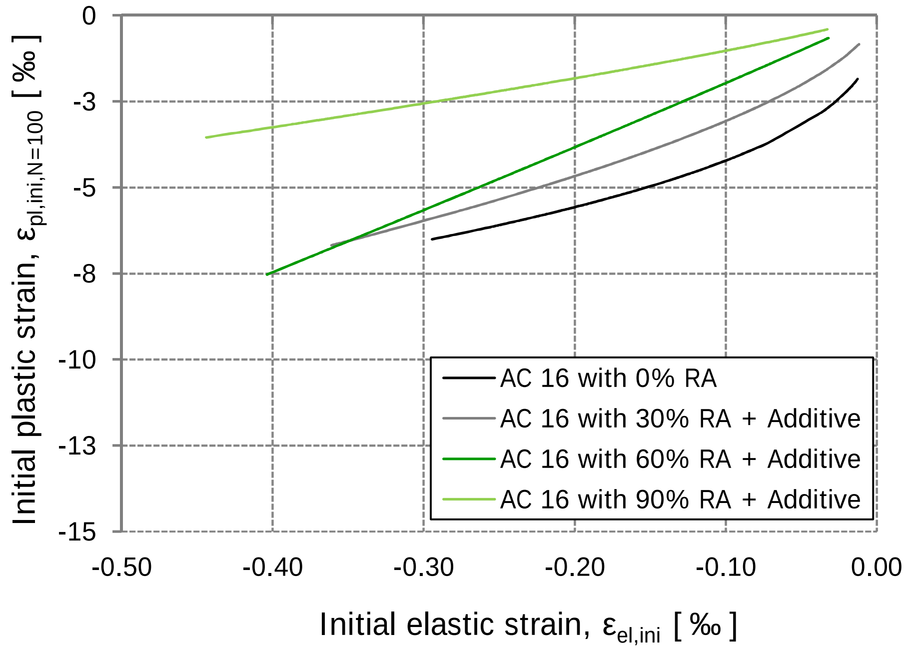
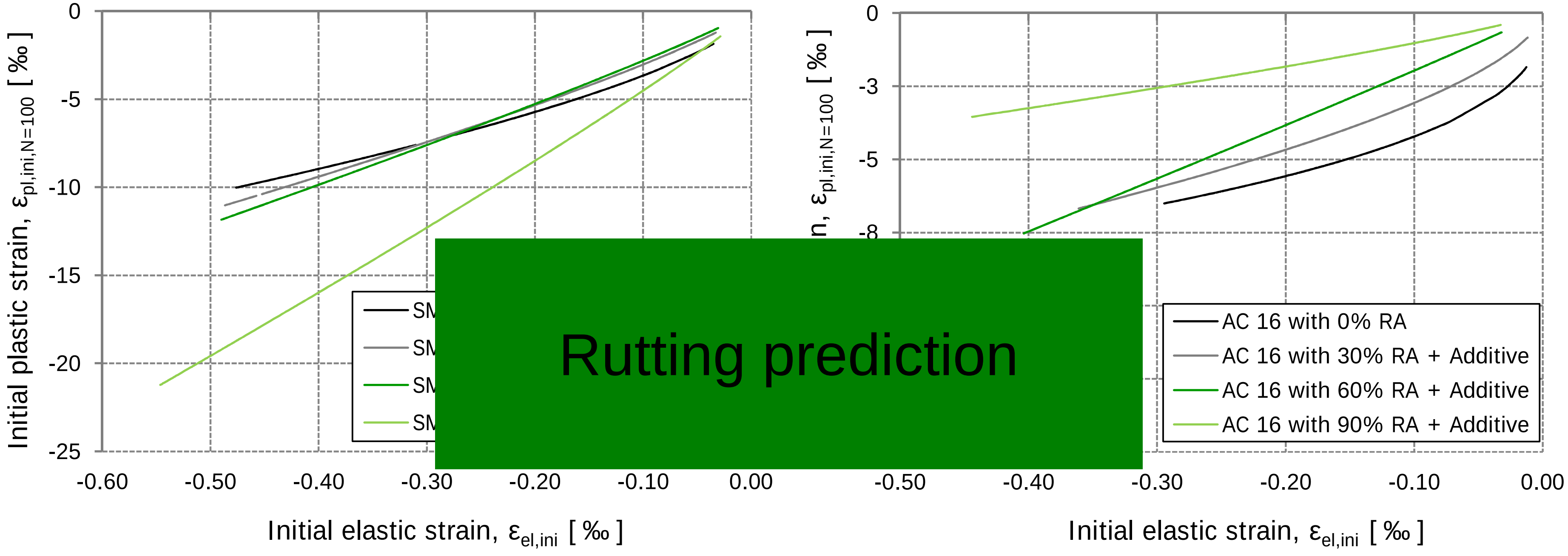




- mixture with 60% RA + Add. is likely to develop the deepest rut death what was also observed in the wheel tracking test as in the binder characterisation
- clear relation between plastic deformation behaviour & amount of RA
- an increasing amount of RA in combination with the use of additives leads to a lower risk of rutting

Asphalt performance



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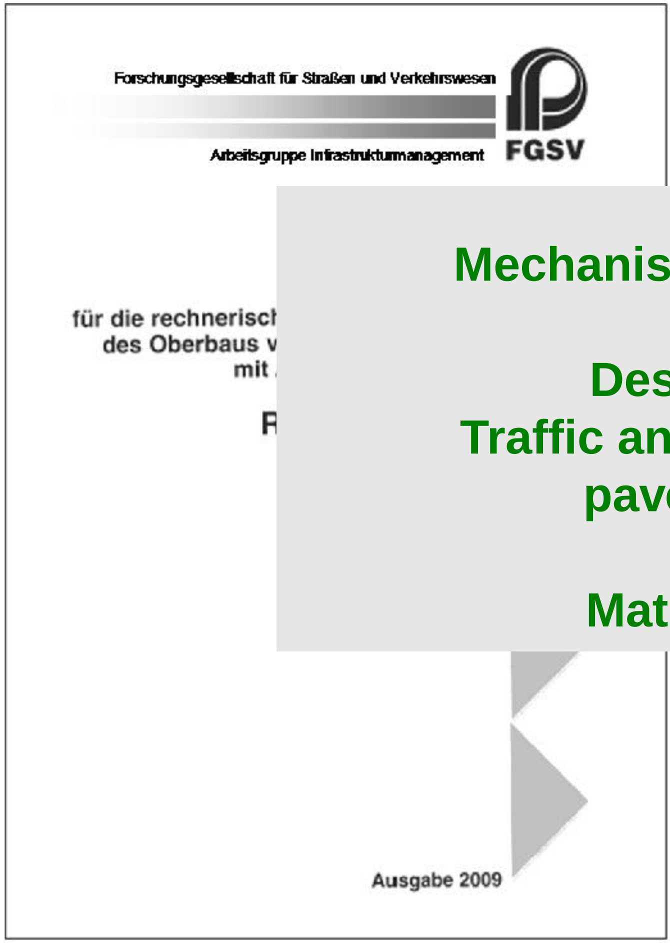
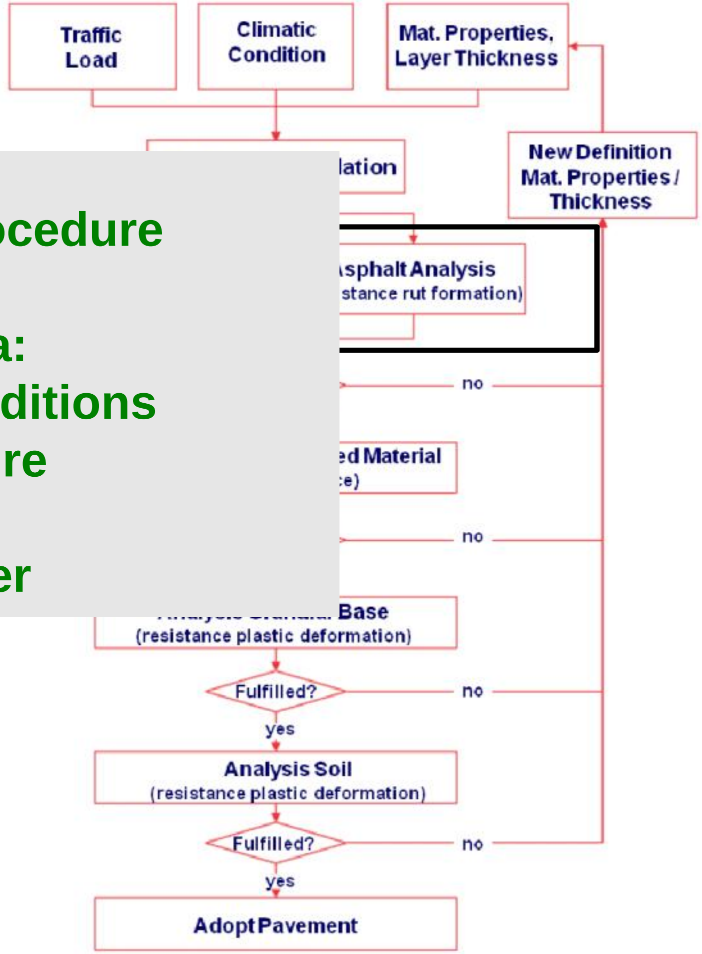
Pavement performance



Mechanistic design procedure

Design input data:
Traffic and climate conditions
pavement structure

Material parameter



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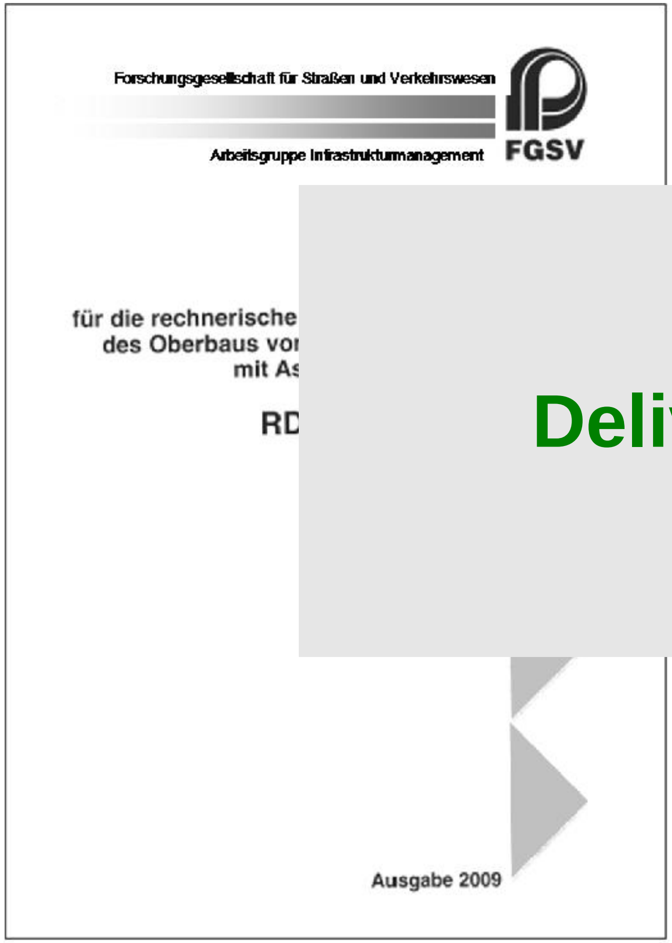
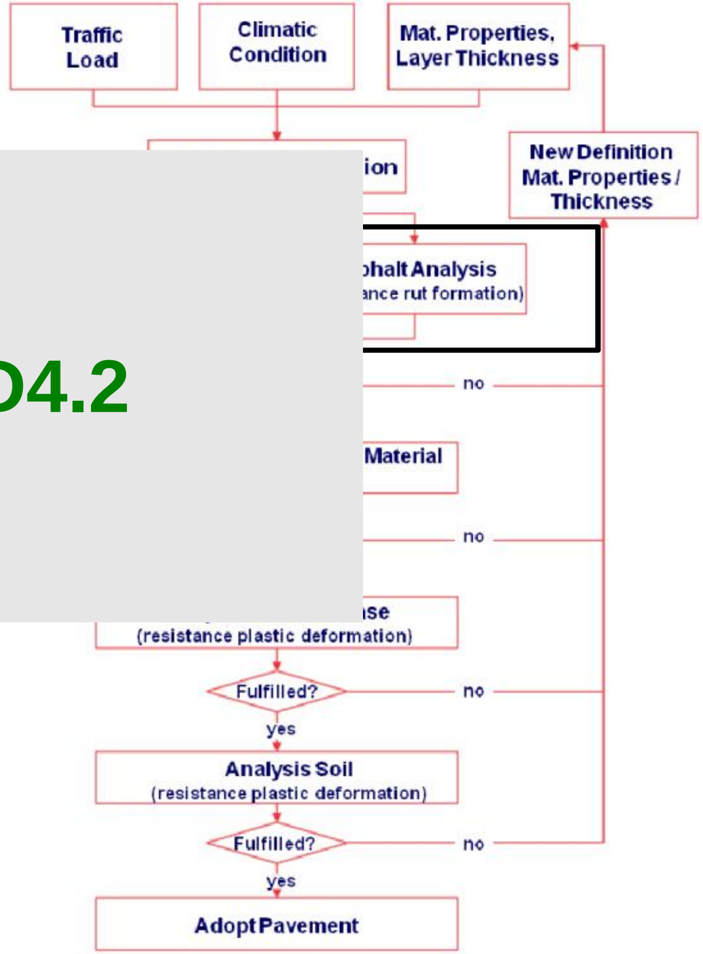
Pavement performance

AllBack2Pave



Deliverable D4.2



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  Binder Performance

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- **Pavement Performance**

Deliverable D4.1

Deliverable D4.2

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