ASSESSING THE FATIGUE PERFORMANCE OF ASPHALT MASTIC

Univ. Ass. Dipl.-Ing. Markus Hospodka

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1. Asphalt Mastic – Basics

- **Asphalt** as a paving material is a mixture of **mineral aggregates** and **bitumen** with a defined void content.

  - Coarse and fine aggregates, **fines („Filler“)**

  *Filler is the aggregate, which most of it passes a 0.063 mm sieve.*
  
  [ÖNORM EN 13043:2014]

- **Asphalt mastic**

  - ...coats the coarse and fine aggregates and works as an adhesive

  - **Poor quality leads to premature deterioration by loss of aggregates at the surface and decreased fatigue life of the base layer**

  - There is no state-of-the-art testing method available to assess the fatigue performance of asphalt mastic

  [RIGDEN, 1947]
1. Asphalt Mastic – Basics

- Filler – Origin and normative requirements

**Added Filler**  ➔  Filler aggregate of mineral origin, that has been produced separately for asphalt paving

**Fines**  ➔  Particle size fraction smaller 0.063 mm of coarse and fine aggregates (over- and undersized particles)

**Mixed Filler**  ➔  Filler aggregate of mineral origin, that has been mixed with calcium hydroxide $\text{Ca(OH)}_2$
1. Asphalt Mastic – Basics

- **Filler – Origin and normative requirements**

  Specifications for filler according to ÖNORM B 3130:2016

<table>
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<th>Test Description</th>
<th>Standard</th>
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<td>Grading of filler aggregates</td>
<td>ÖNORM EN 933-10</td>
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<td>Methylene blue test</td>
<td>ÖNORM EN 933-9</td>
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<td>Particle density of filler</td>
<td>ÖNORM EN 1097-7</td>
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<td>Voids of dry compacted filler (Rigden)</td>
<td>ÖNORM EN 1097-4</td>
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<td>Delta ring and ball test</td>
<td>ÖNORM EN 13179-1</td>
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<td>Water susceptibility of fillers</td>
<td>ÖNORM EN 1744-4</td>
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<td>Chemical analysis</td>
<td>ÖNORM EN 1744-1</td>
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<td>Content of calcium carbonate in added fillers</td>
<td>ÖNORM EN 196-21</td>
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<td>Content of calcium hydroxide in mixed fillers</td>
<td>ÖNORM EN 459-1</td>
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<tr>
<td>Bitumen number</td>
<td>ÖNORM EN 13179-2</td>
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</table>

- Requirements to the fines of the fine and coarse aggregates (applicable when mass fraction is at least 10 %) → quality requirements sufficient?

- Mineralogy, aggregate geometry, chemical weathering, surface chemistry (chemical affinity) and bitumen compatibility are not addressed.
2. Scientific Approach

- **Aim:** Development of a performance criterion for asphalt mastic based on fatigue life.

- **Fatigue:** ...is the deterioration of a material due to repeatedly applied loads

- Fatigue test is already standardized for asphalt mixture
  → 4-Point Bending Beam Test (ÖNORM EN 12697-24)

- **Challenge:** Tests are time-intense and material-consuming

- **Wanted:** Suitable testing device and setup for asphalt mastic
2. Scientific Approach

- **Dynamic Shear-Rheometer (DSR):**
  - Fatigue failure caused by *oscillatory shear stress*
  - **Device is highly available** due to the use for binder testing
  - Only a small sample volume is needed for DSR tests
  - **Please note:** The device has to meet minimum requirements in terms of electrical torque.

[ASPHALT INSTITUTE, Lexington 1994]
2. Scientific Approach

- Dynamic Shear-Rheometer (DSR):
  - Results:
    - Complex shear modulus $|G^*|$
      Ratio of peak stress to the peak strain in harmonic sinusoidal oscillation
    - Phase lag $\delta$
      Phase difference (time lag) between stress and strain to characterize a material regarding to
      elasticity (e.g. rubber band) and viscosity (e.g. play doh).

[TechGalerie GmbH, Düsseldorf 2016] [Lemerg.com, Uploaded by A_Arina, 2015]
3. Sample Preparation & Testing Parameter

- **Bitumen:** 70/100 \[\rightarrow\] rheologically simple material

- **Sample type:** Mixing ration of mass fraction bitumen:filler = 1:1.5
  
  Manually mixing of preheated bitumen and filler with a stirring rod

- **DSR testing parameter:**
  
  Plate-Plate testing system with \(\varnothing 8\ mm\)
  
  - Sample height: 3 mm \[\rightarrow\] Cooling capacity
  - Test temperature: 10 °C \[\rightarrow\] Creep (deformation)
  - Test frequency: 30 Hz \[\rightarrow\] Test duration
  - Test mode: Controlled stress (CSS)

[SCHRAMM, Karlsruhe 1995]
3. Sample Preparation & Testing Parameter

- First attempt, first failure:
  - Failure at the lower interface / bottom plate
  - Partially adhesion / cohesion failure at the upper interface / top plate
  - Aim: pure cohesion failure within the mastic specimen

→ Cylindrical specimen shape is not suitable for fatigue testing!
3. Sample Preparation & Testing Parameter

- **Solution:** Sample geometry with predetermined point of failure

Alle Angaben in mm
4. DSR Fatigue Test & Results

- Step-by-step sample preparation in the DSR:

8 mm DSR bottom plate
4. DSR Fatigue Test & Results

- **Step-by-step sample preparation in the DSR:**

  Step 1: Apply silicone mold on DSR plate
4. DSR Fatigue Test & Results

- Step-by-step sample preparation in the DSR:

  Step 2: Fill mastic sample into the mold

  melted mastic sample (180 °C)
4. DSR Fatigue Test & Results

- Step-by-step sample preparation in the DSR:

Step 3: Lift DSR to testing gap

Remove excess mastic
4. DSR Fatigue Test & Results

- Step-by-step sample preparation in the DSR:

Step 4: Remove the silicone mold
4. DSR Fatigue Test & Results

- Fatigue curve – Crack propagation till fatigue failure

**Time for adaption**

![Graph showing fatigue curve and crack propagation](image-url)
4. DSR Fatigue Test & Results

- **Mastic sample after successful fatigue test**
  - Cohesion failure at the predetermined point of failure
4. DSR Fatigue Test & Results

- Results – Comparing two different asphalt mastic mixtures

Mastic mixture B is capable of 2.8-times the number of load cycles till failure comparing to mastic mixture A.
5. Summary & Conclusions

• High performance demands to asphalt pavements need high quality components:
  – Bitumen
  – Aggregates (Filler / Fines!)

• Assessment of the fatigue performance of asphalt mastic by DSR

• Correlation analysis of various filler parameters and results of fatigue tests:
  – No significant impact of filler mineralogy
  – Significant impact of filler grading curve
  – Impact of filler morphology highly likely

• Additional filler analysis
• Impact of water exposure on fatigue performance
Questions?