TECHNISCHE UNIVERSITÄT WIEN
Vienna University of Technology

bi.ivws

Assessing the fatigue performance of asphalt mastic

Univ. Ass. Dipl.-Ing. Markus Hospodka

Meeting at BASF, Trostberg, June 27th 2017

1. Asphalt Mastic – Basics

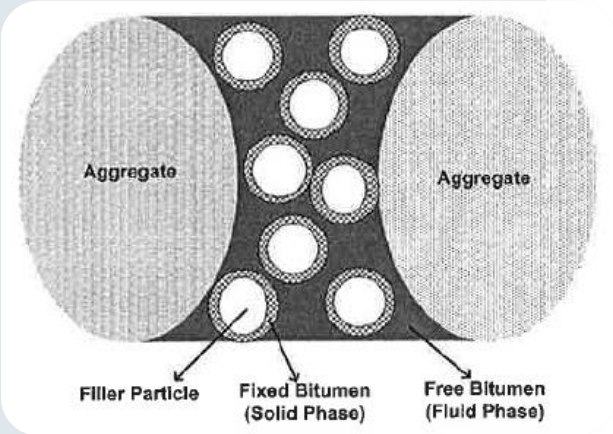
- **Asphalt** as a paving material is a mixture of mineral aggregates and bitumen with a defined void content.

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 $Ca(OH)_2$

1. Asphalt Mastic – Basics

- **Filler – Origin and normative requirements**

Specifications for filler according to ÖNORM B 3130:2016

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

- 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.**

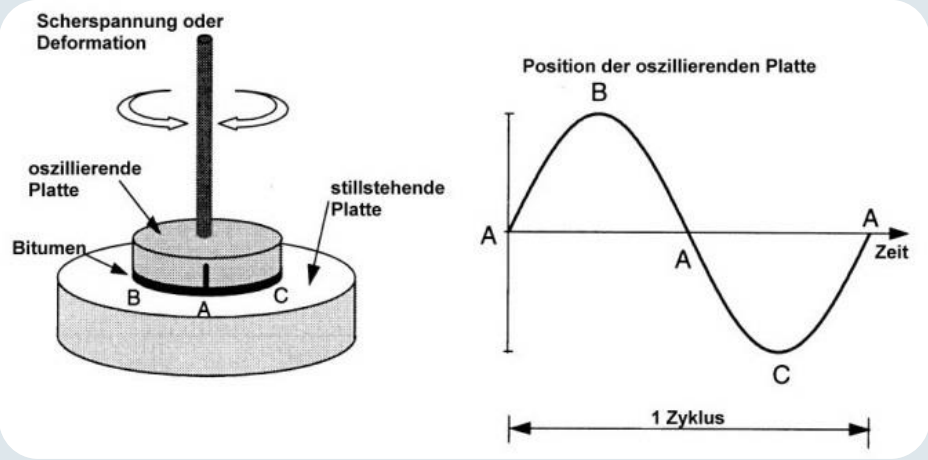
- **Fatigue**: …is the deterioration of a material due to repeatedly applied loads

- 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 δ**
      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]

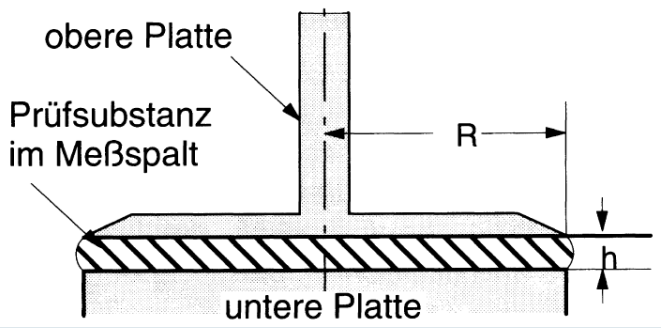
3. Sample Preparation & Testing Parameter

- **Bitumen:** 70/100 → 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 **Ø 8 mm**



[SCHRAMM, Karlsruhe 1995]

Sample height: **3 mm** → Cooling capacity

Test temperature: **10 °C** → Creep (deformation)

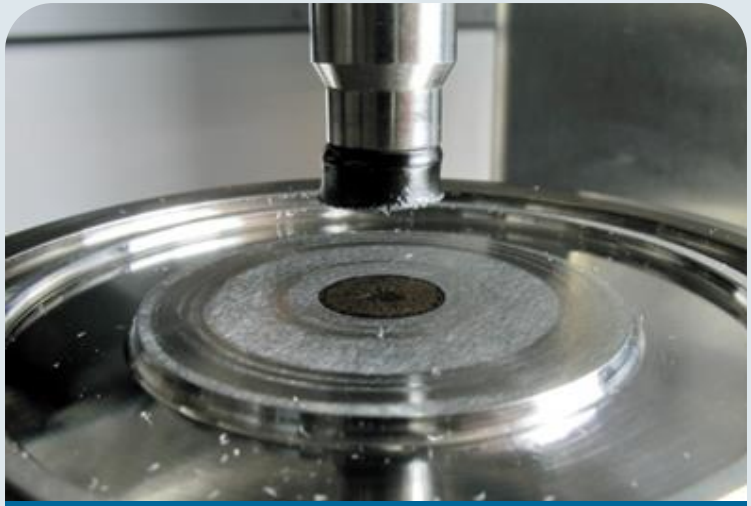
Test frequency: **30 Hz** → Test duration

Test mode: **Controlled stress (CSS)**

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!**

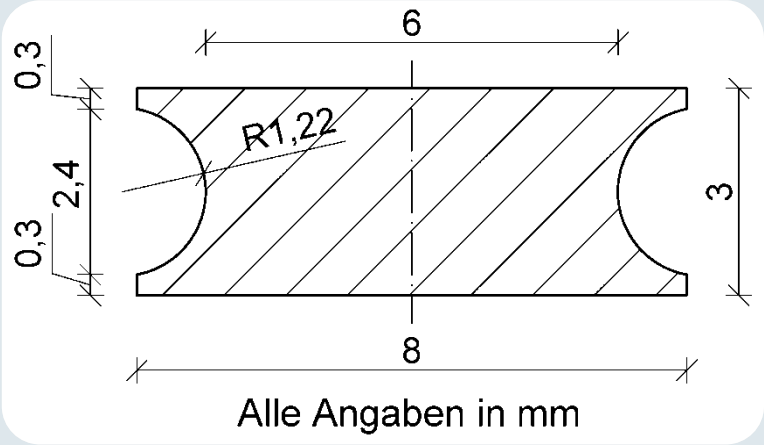


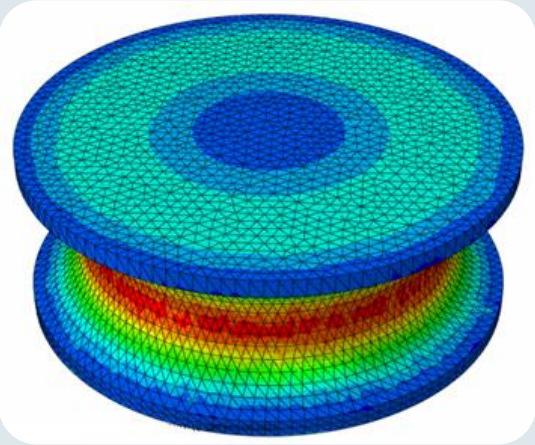
Lower interface / bottom plate

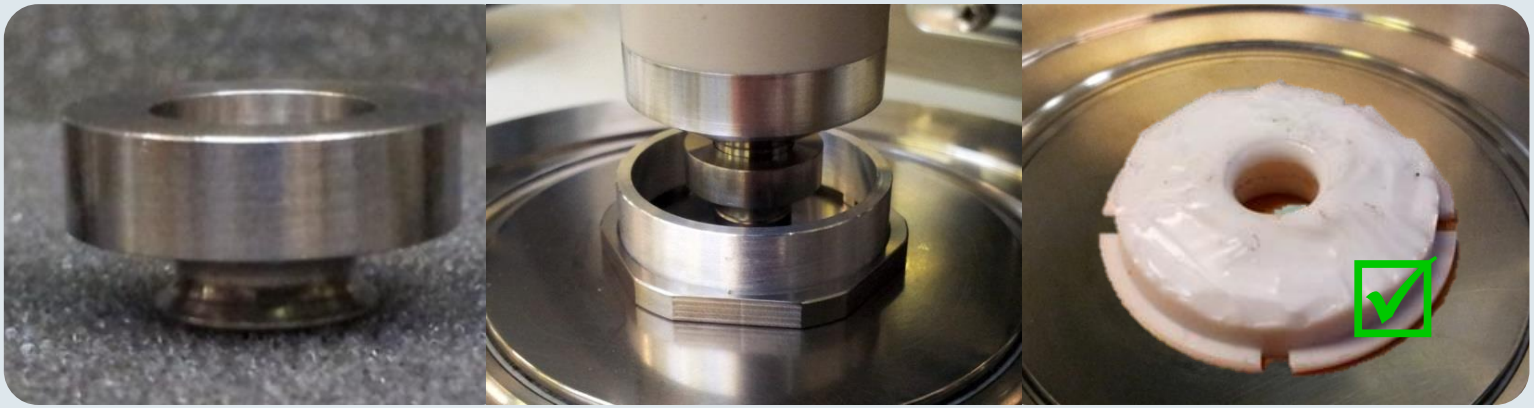
Upper interface / top plate

3. Sample Preparation & Testing Parameter

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

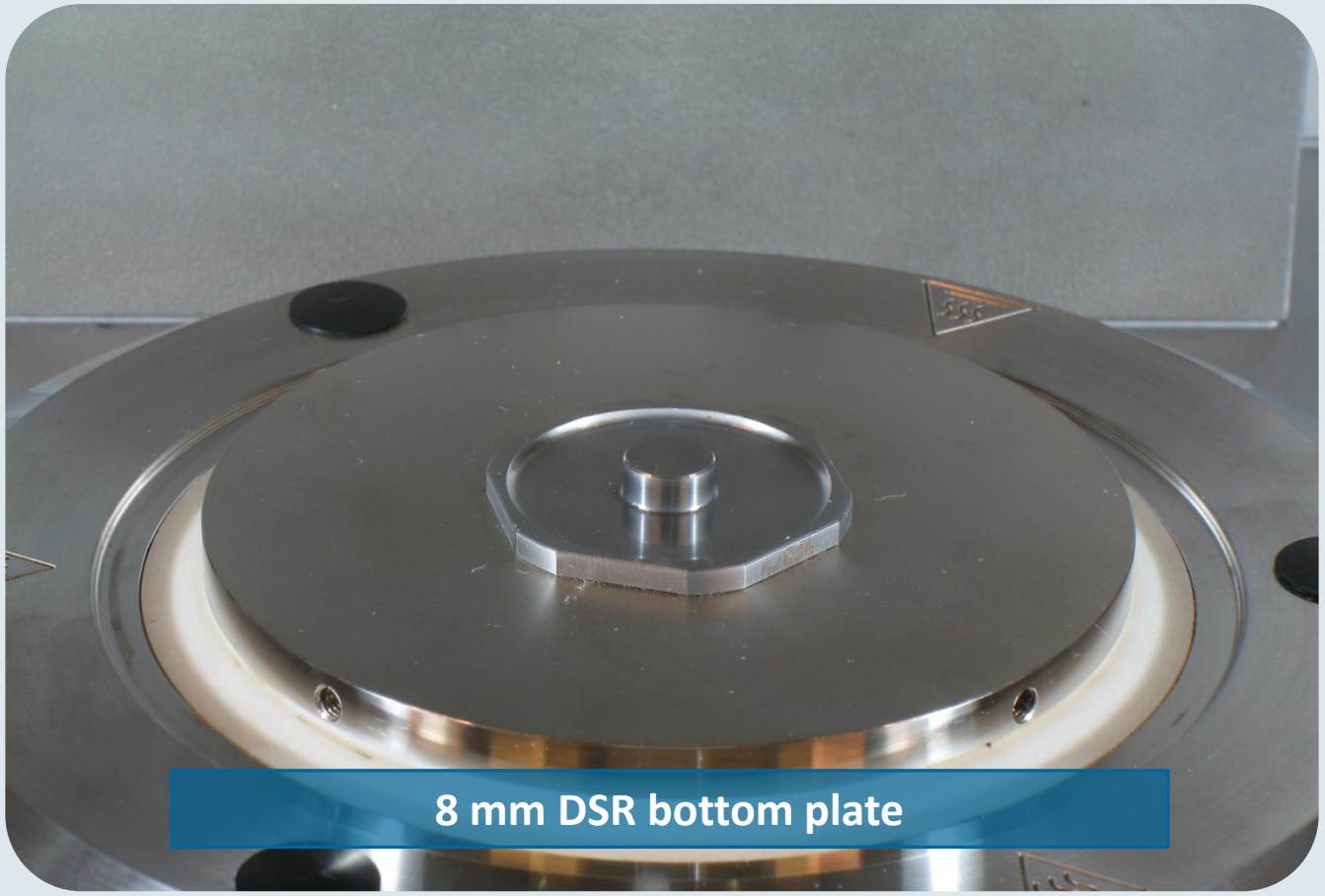






4. DSR Fatigue Test & Results

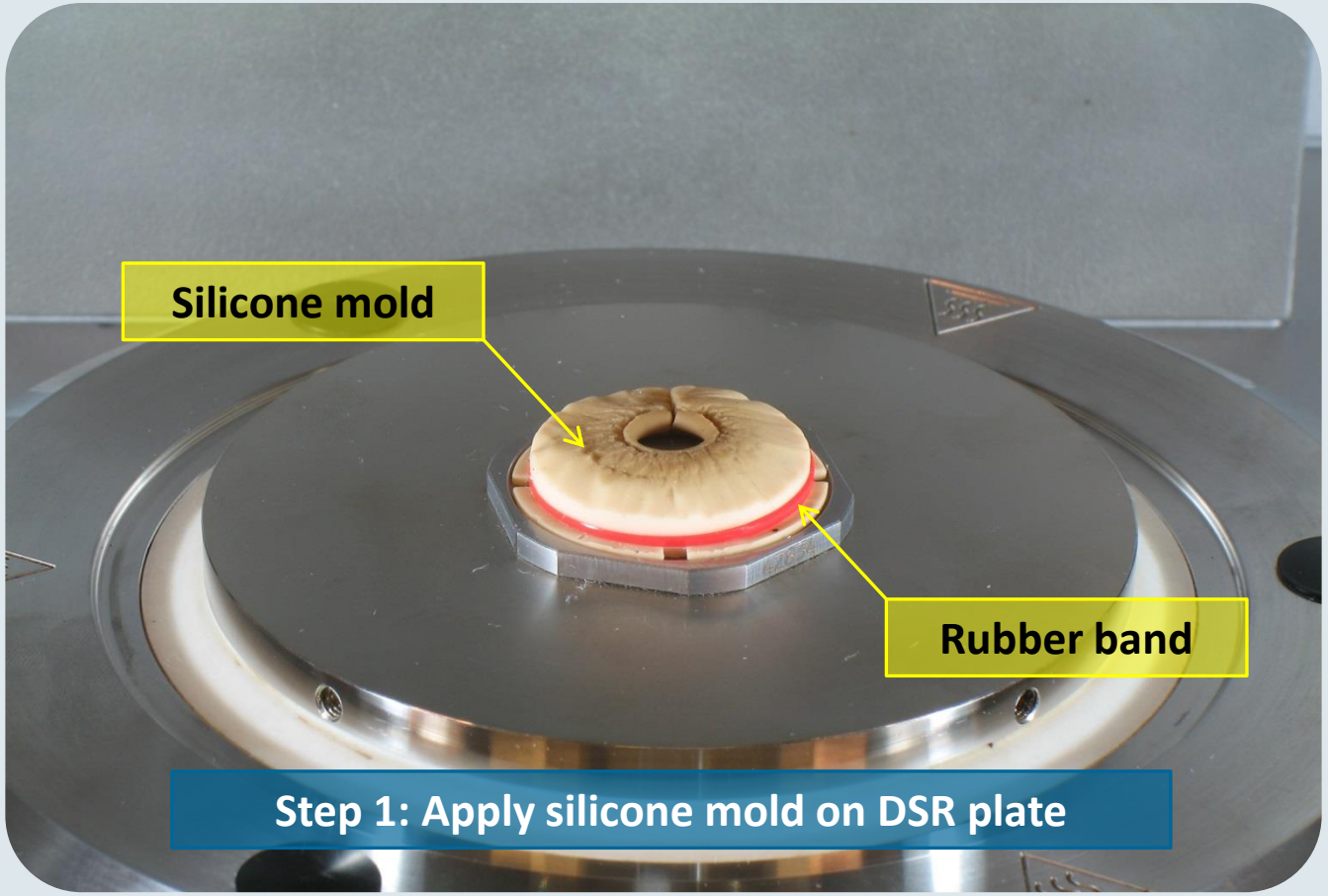
- **Step-by-step sample preparation in the DSR:**



8 mm DSR bottom plate

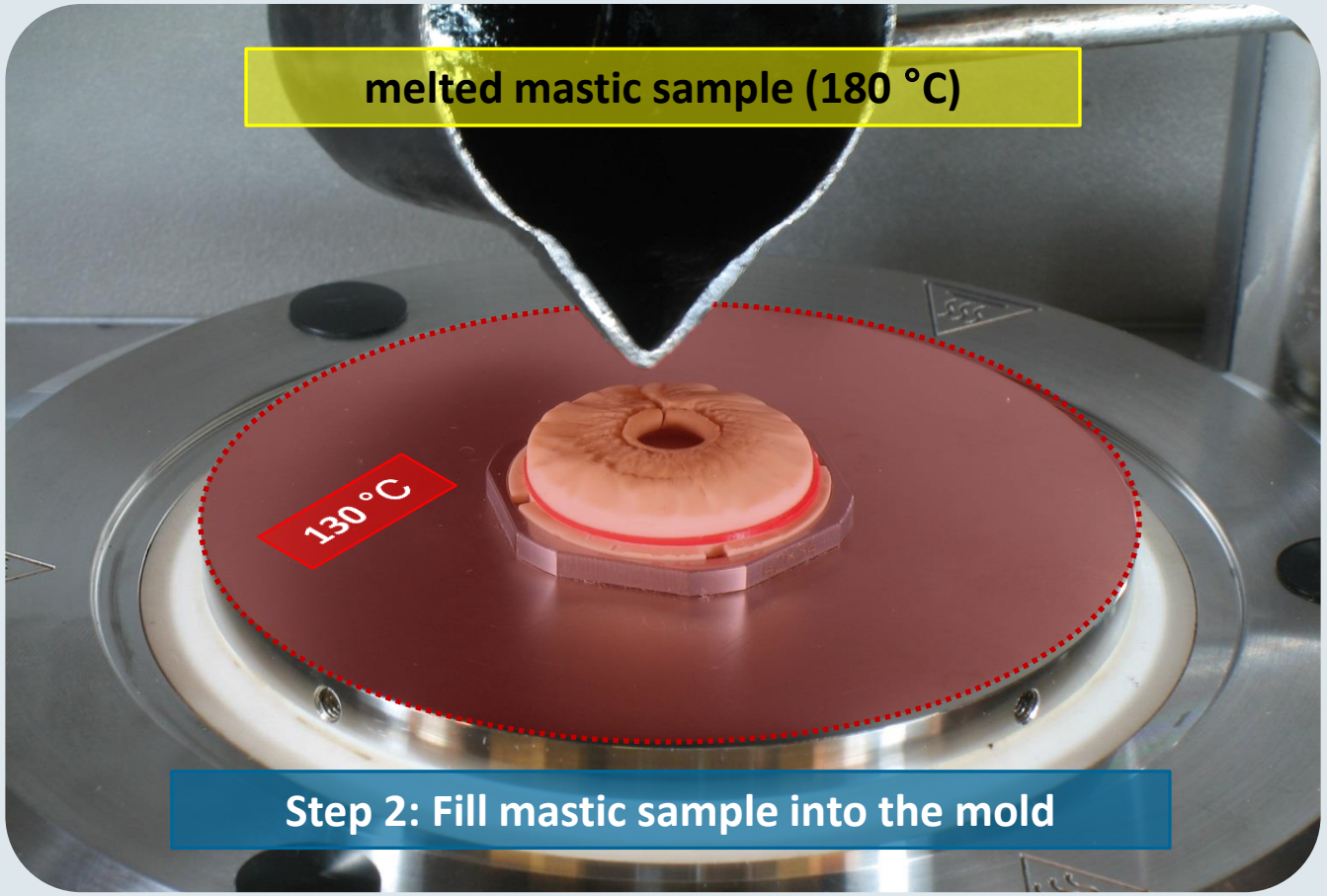
4. DSR Fatigue Test & Results

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



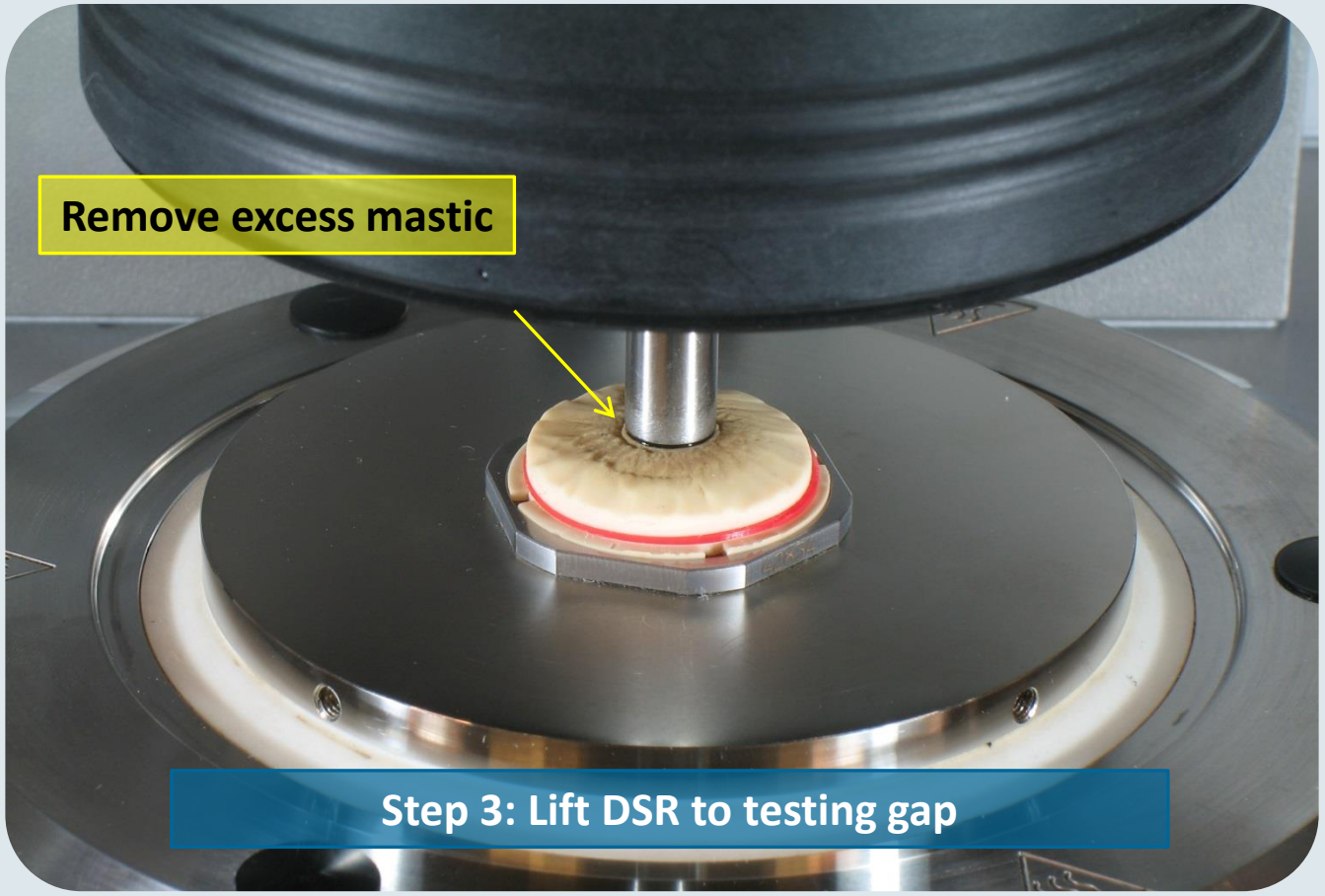
4. DSR Fatigue Test & Results

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



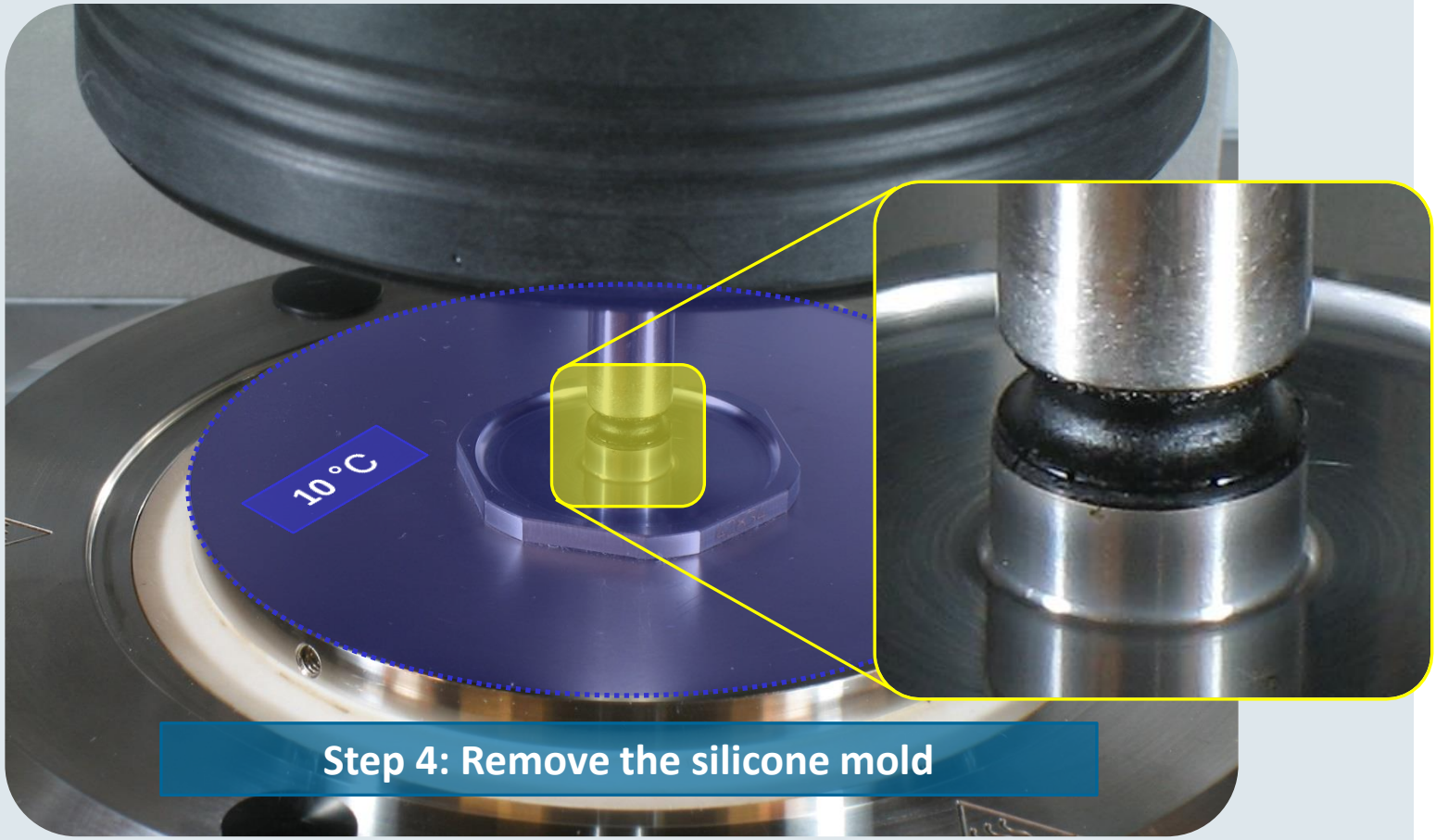
4. DSR Fatigue Test & Results

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



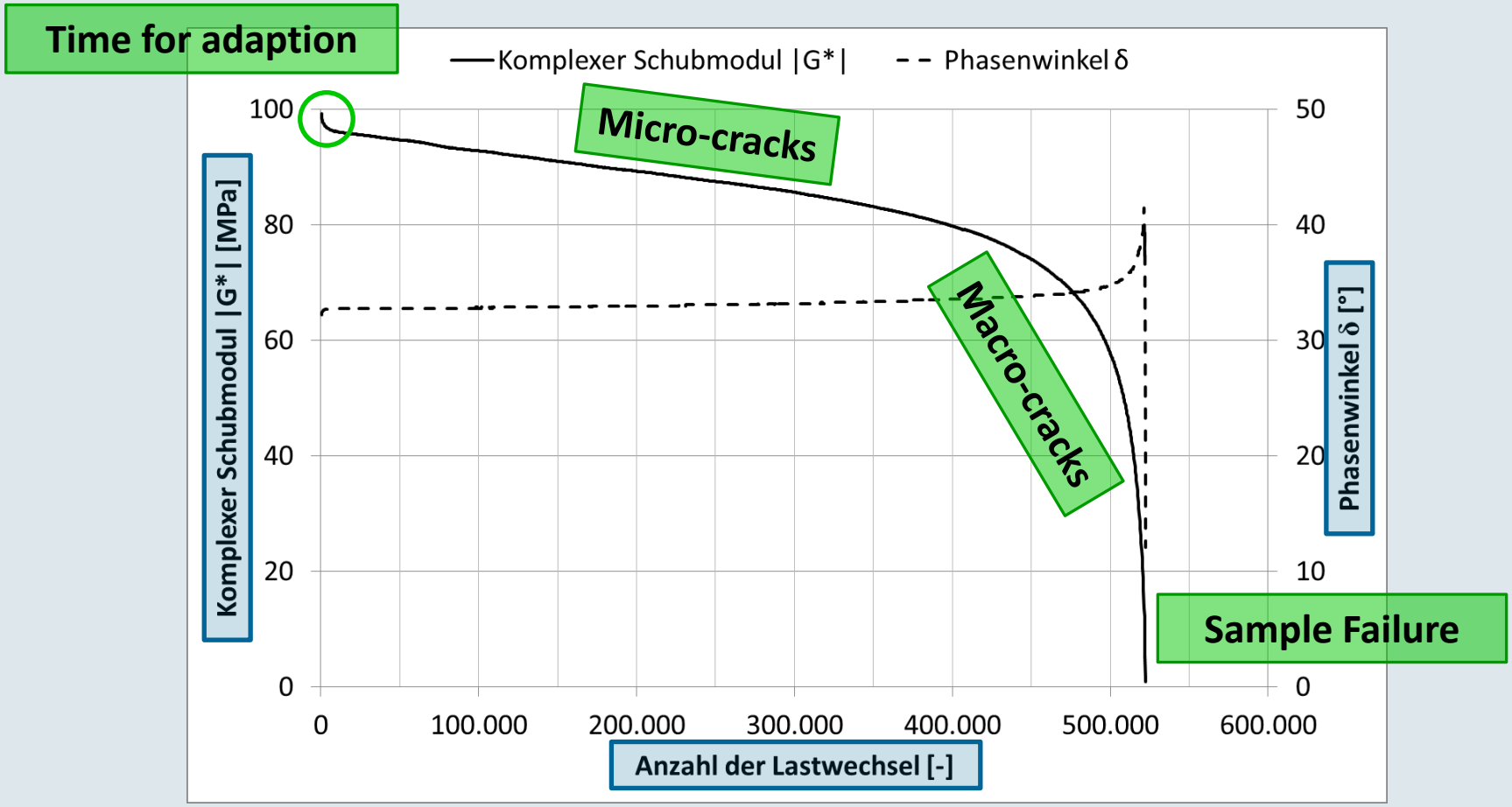
4. DSR Fatigue Test & Results

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



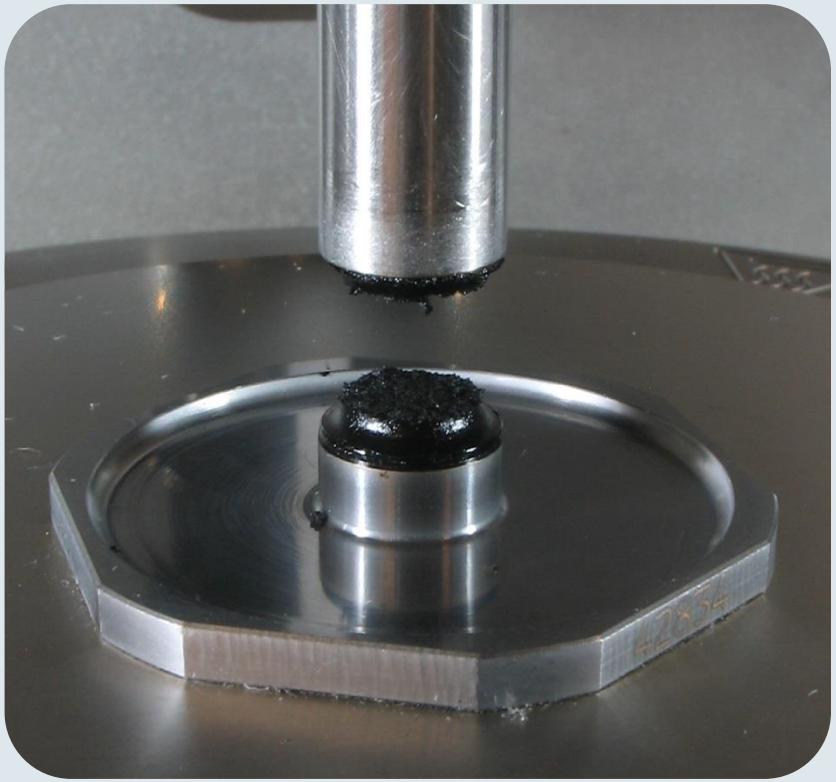
4. DSR Fatigue Test & Results

- **Fatigue curve – Crack propagation till fatigue failure**



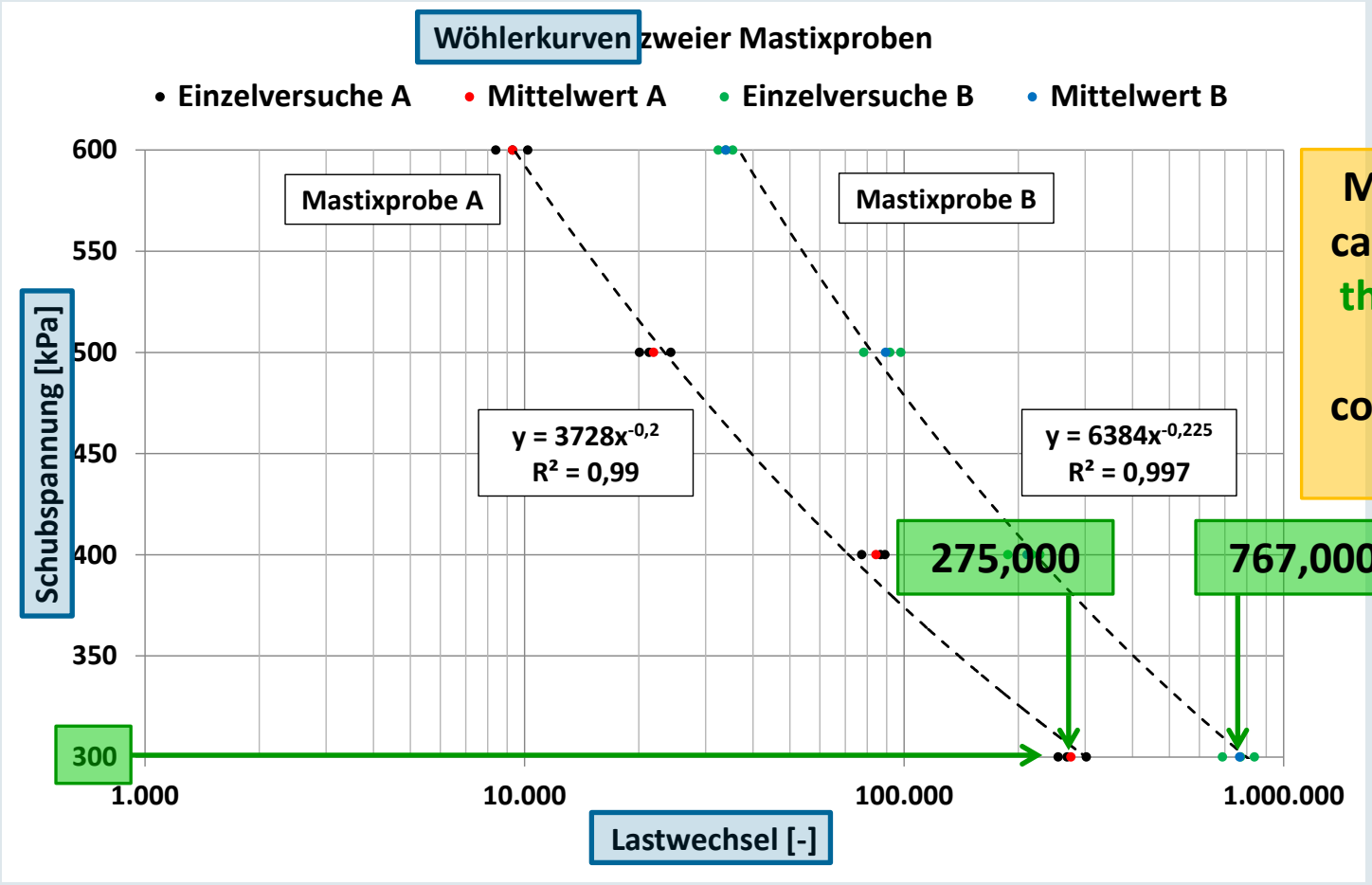
4. DSR Fatigue Test & Results

- **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!)**

[dpa/Picture Alliance, Deutschland 2013]

- **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**

TECHNISCHE UNIVERSITÄT WIEN
Vienna University of Technology

bi.ivws

Questions?