



RUB

RUHR-UNIVERSITÄT BOCHUM



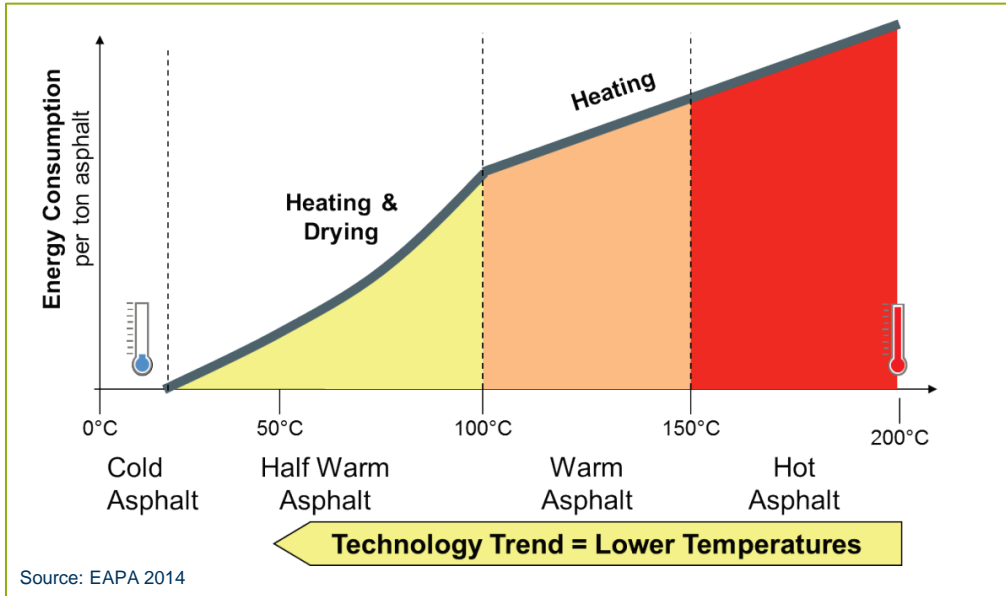
## PRODUCTION OF WARM MIX ASPHALT WITH FOAMED BITUMEN AND HIGH RECYCLING CONTENTS – INSIGHTS FROM RESEARCH AND FIELD APPLICATIONS

2nd International Workshop on **Asphalt Recycling Technologies**

Georg Bus, M.Sc.

# Motivation

- **Asphalt workers benefits:** less emissions and improved working conditions
- **Environmental benefits:** less energy used and lower emissions
- **Manufacturing and paving benefits:** less hardening of the bitumen



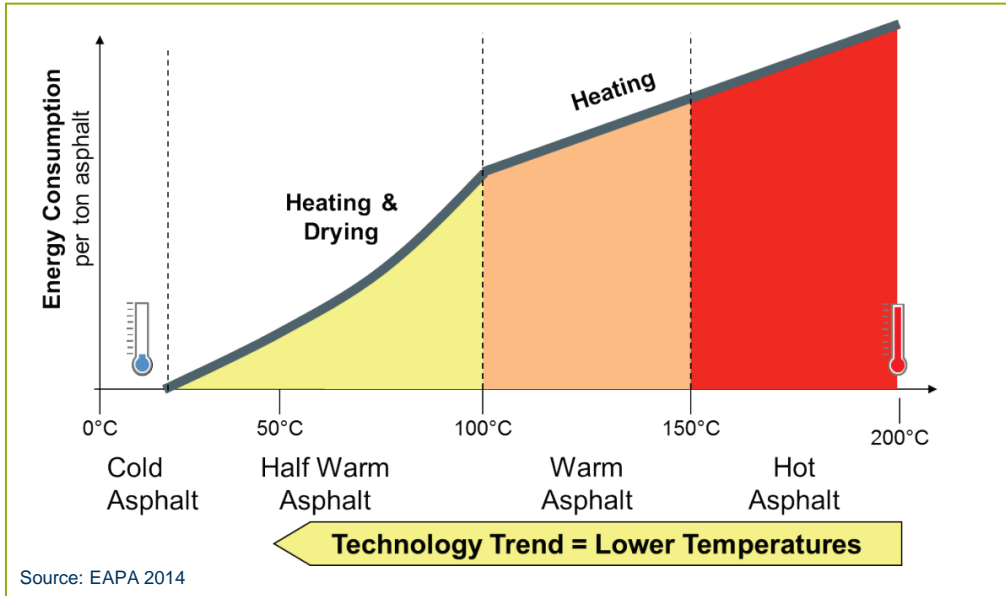
## WMA Additives / Techniques

- Organic Additives
- Chemical Additives
- Foaming techniques



# Motivation

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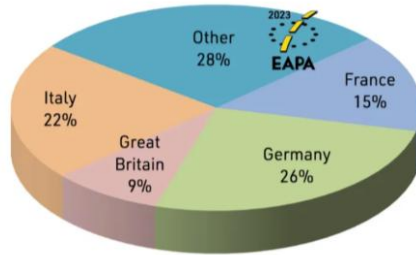


## Mechanical Foaming

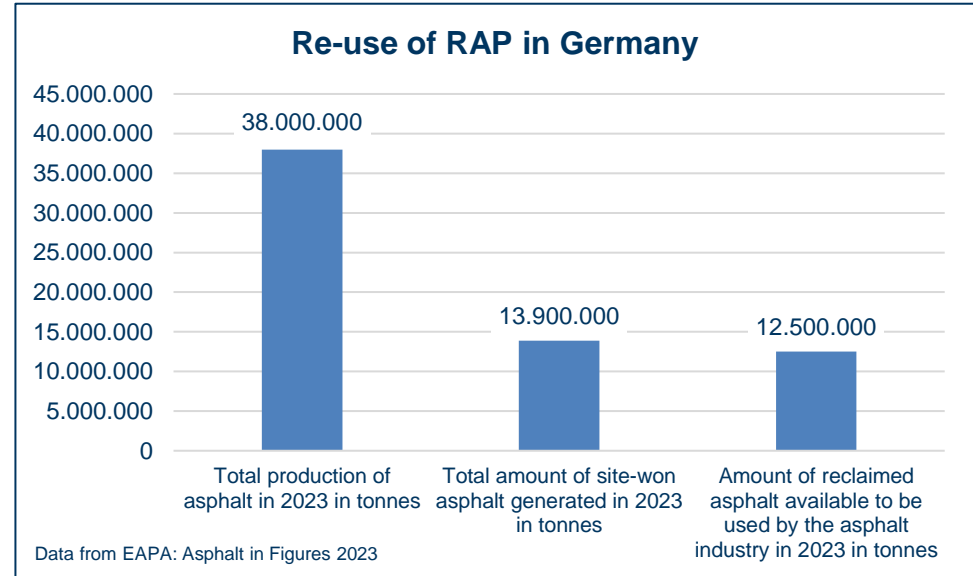


# Motivation

- The use of Reclaimed Asphalt Pavement (RAP) is essential for economical, environmental, and sustainability reasons. ***Is that compatible with foamed bitumen?***



Total amount of reclaimed asphalt available in seventeen European countries providing data in 2023



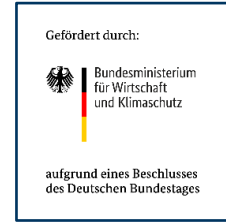
# Research Project (2021 – 2023)

- **Objective:** Suitability of Foamed Bitumen Technology for the production of Warm Mix Asphalt containing Reclaimed Asphalt Pavement

- **Simplified Project Workflow:**



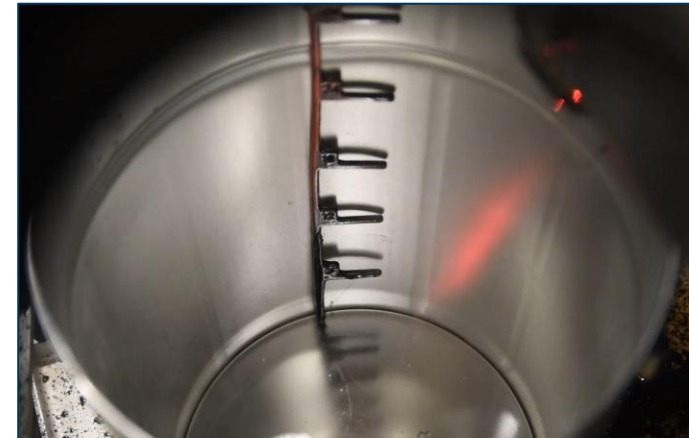
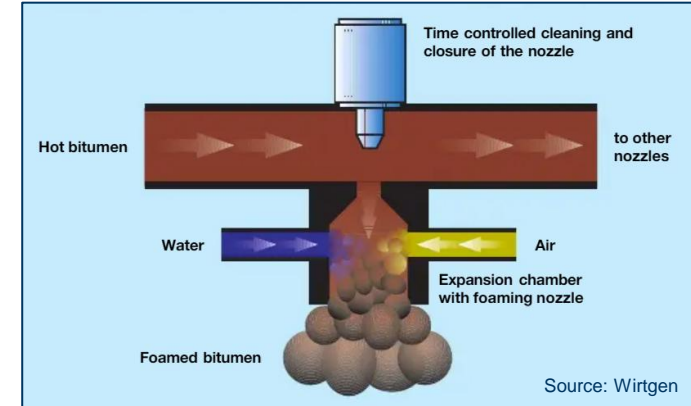
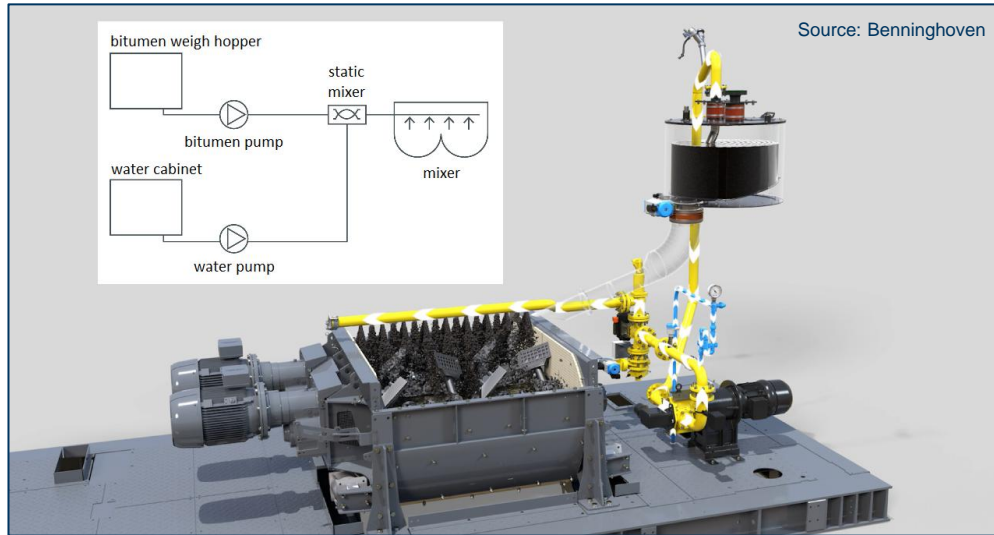
- **Project Partners:**





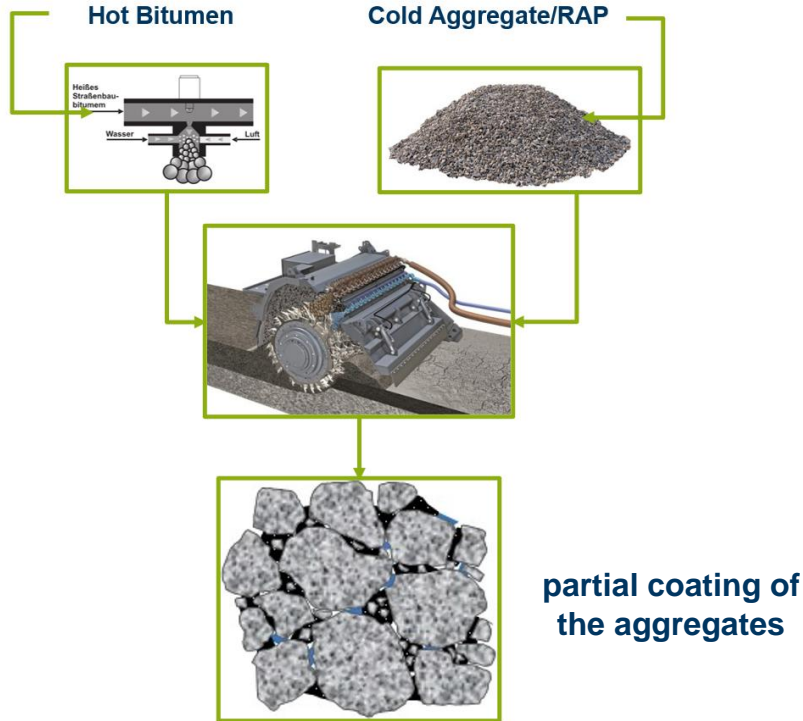
# What is Foamed Bitumen?

- **Foamed Bitumen** is a bitumen that has been expanded by injecting a small amount of water (and air) under pressure, causing it to temporarily foam and increase in volume. This process lowers the bitumen's viscosity, improving its workability and enabling it to coat aggregates at lower temperatures.

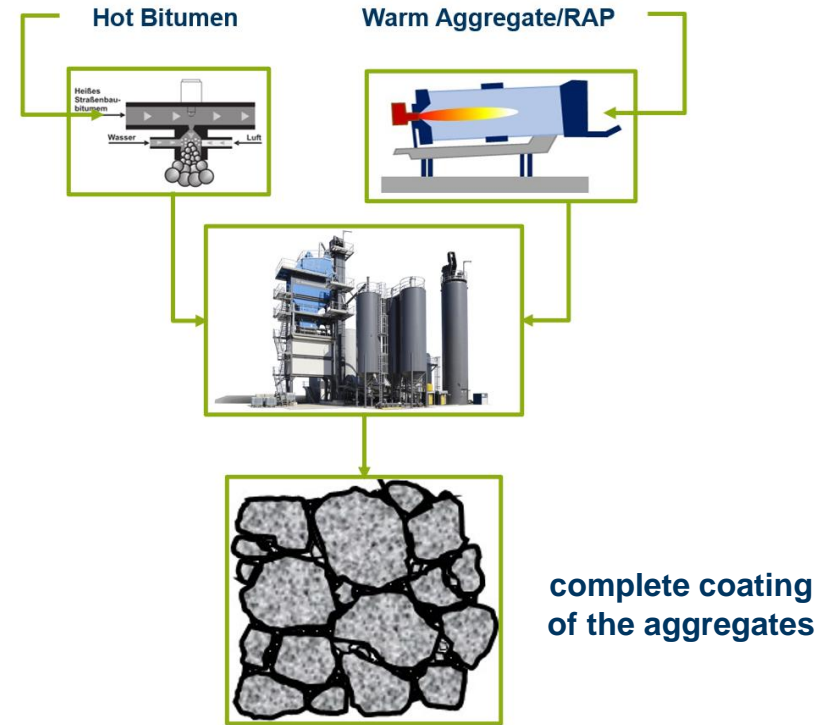


# Applications of Foamed Bitumen

## Cold Mix / Bitumen Stabilised Material

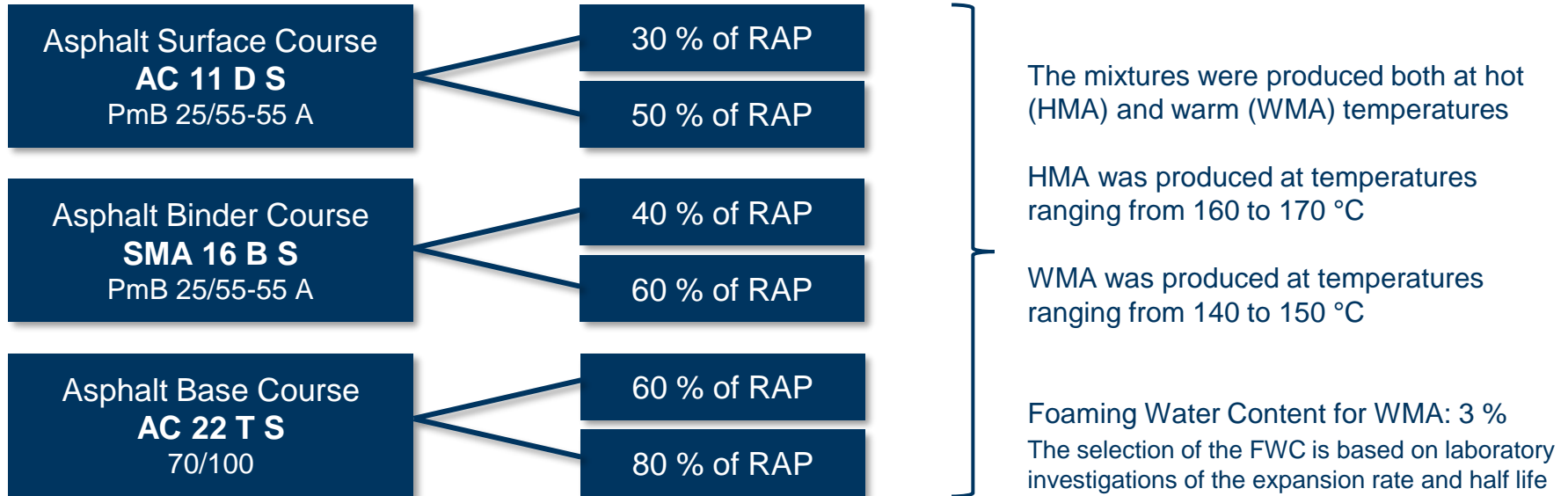


## Warm Mix Asphalt



# Research Project (2021 – 2023)

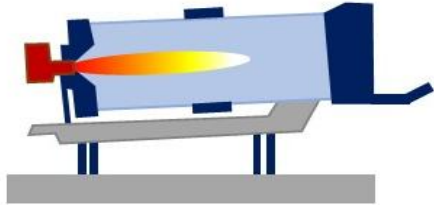
## ■ Mixtures Investigated





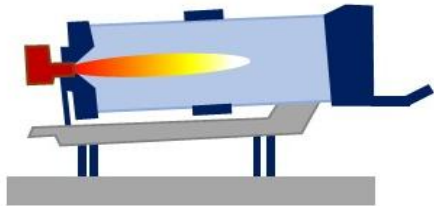
# Research Project – Production of WMA on the Industrial Scale

## Parallel Drum of Asphalt Mixing Plant A and B



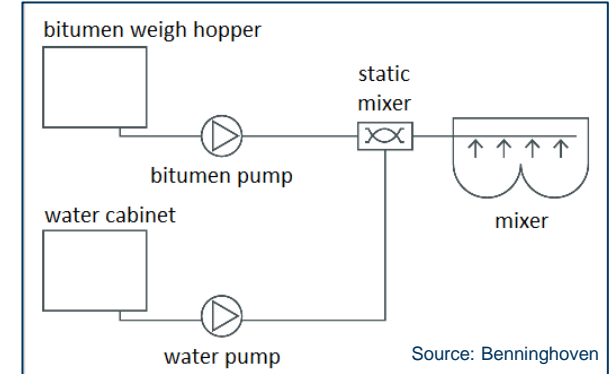
- indirect heating of the RAP
- counterflow principle
- RAP temperatures  $\approx 155\text{ }^{\circ}\text{C}$

## Parallel Drum of Asphalt Mixing Plant C

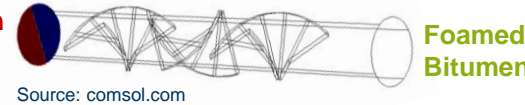


- direct heating of the RAP
- co-flow principle
- RAP temperatures  $\approx 135\text{ }^{\circ}\text{C}$

## Foam Bitumen Module



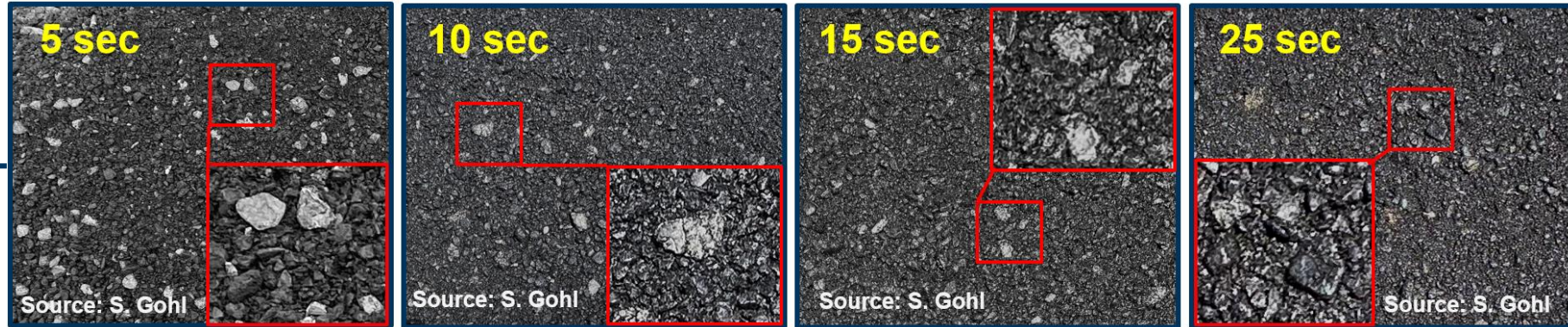
Bitumen  
Water



# Research Project – Production of WMA on the Industrial Scale

## Findings

- At asphalt mixing plants A and B, the resulting asphalt mix temperature ( $\approx 150\text{ }^{\circ}\text{C}$ ) had to be achieved through a combined addition of cold and hot RAP (40 % cold RAP / 60 % hot RAP).
- At asphalt mixing plant C, due to the RAP temperature of approximately  $135\text{ }^{\circ}\text{C}$ , no addition of cold RAP was necessary to adjust the final mix temperature.
- At all three asphalt mixing plants, full coating of the aggregates with binder was successfully achieved.
- Depending on the type of asphalt mix, the mixing time needs be adjusted.



Pre-tests to determine the dry mixing time for binder transfer between RAP and virgin aggregate

# Research Project – Construction of Trial Sections

**Country Road A**  
**L 1141**  
≈ 18,000 m<sup>2</sup>

Surface Course  
AC 11 D S  
50 % of RAP

Surface Course  
AC 11 D S  
50 % of RAP

**Temperatures**

HMA  
≈  
170 °C

**Country Road B**  
**L 548**  
≈ 18,000 m<sup>2</sup>

Surface Course  
AC 11 D S  
30 % of RAP

Surface Course  
AC 11 D S  
50 % of RAP

Surface Course  
AC 11 D S  
30 % of RAP

Surface Course  
AC 11 D S  
50 % of RAP

Binder Course  
SMA 16 B S  
40 % of RAP

Binder Course  
SMA 16 B S  
60 % of RAP

Binder Course  
AC 11 D S  
40 % of RAP

Binder Course  
AC 11 D S  
60 % of RAP

WMA  
≈  
140 °C

**Road A**



**Road B**



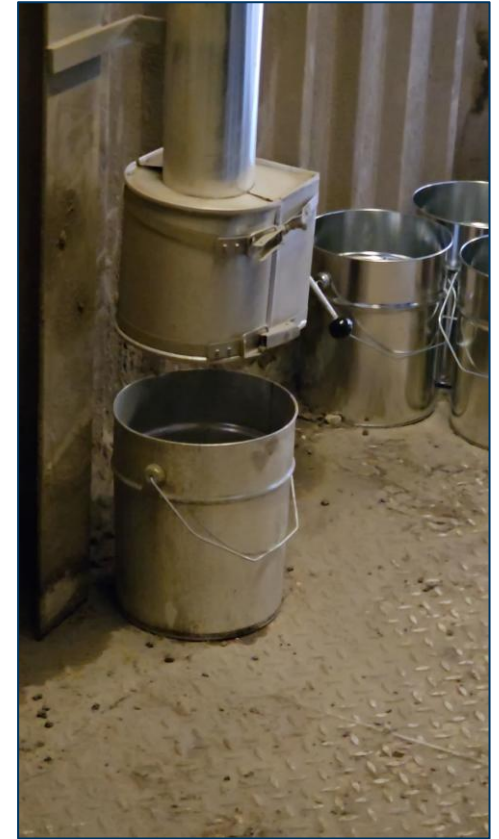
**Road B**





# Research Project – Construction of Trial Sections

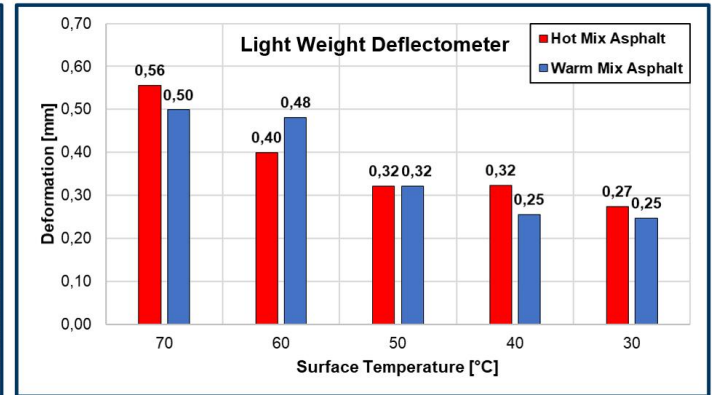
## Collection of foamed bitumen samples at the asphalt mixing plant



# Research Project – Construction of Trial Sections

## Findings

- The compaction of WMA required approximately the same number of roller passes as HMA.
- Due to the lower mix temperature, the compaction window for WMA was shorter than that of HMA, requiring optimized rolling logistics and minimized roller travel distances.
- The compaction success was monitored using a non-destructive density measurement device.
- Light Weight Deflectometer measurements indicate similar deformation behavior for HMA and WMA.

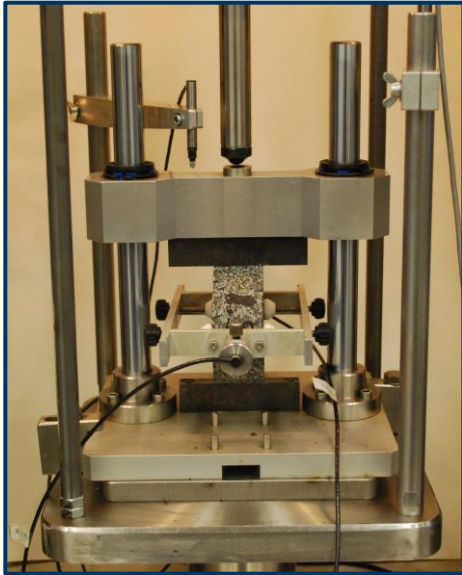




# Research Project – Construction of Trial Sections

## Performance Investigation

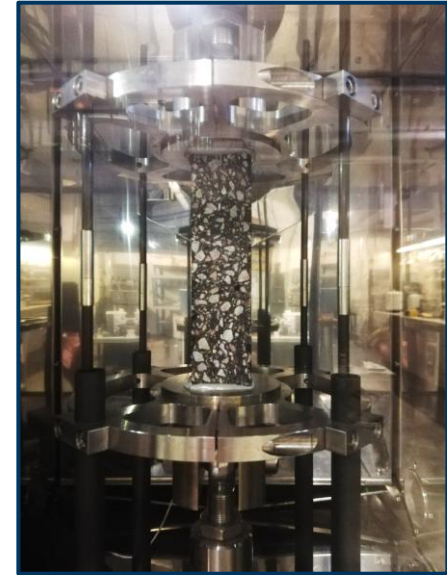
Dynamic Stiffness  
at -10 °C, 0 °C, 10 °C, 20 °C



Permanent Deformation  
at 50 °C

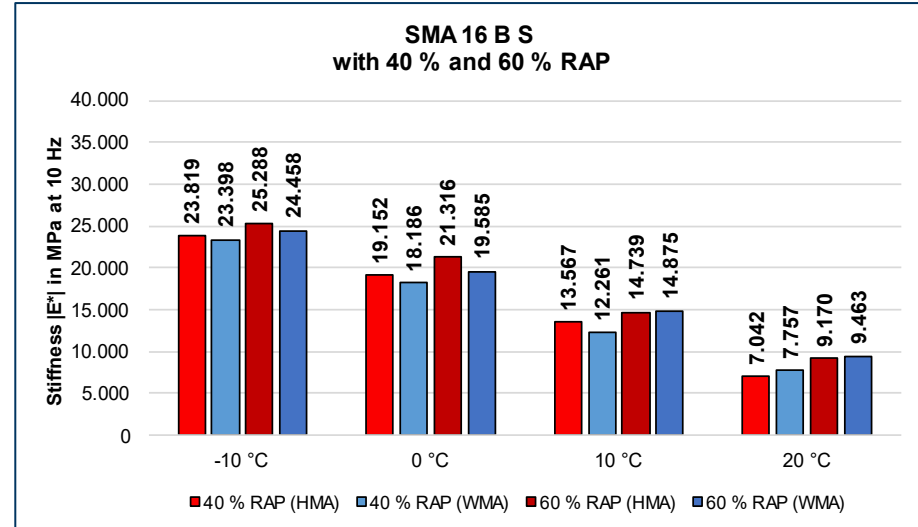
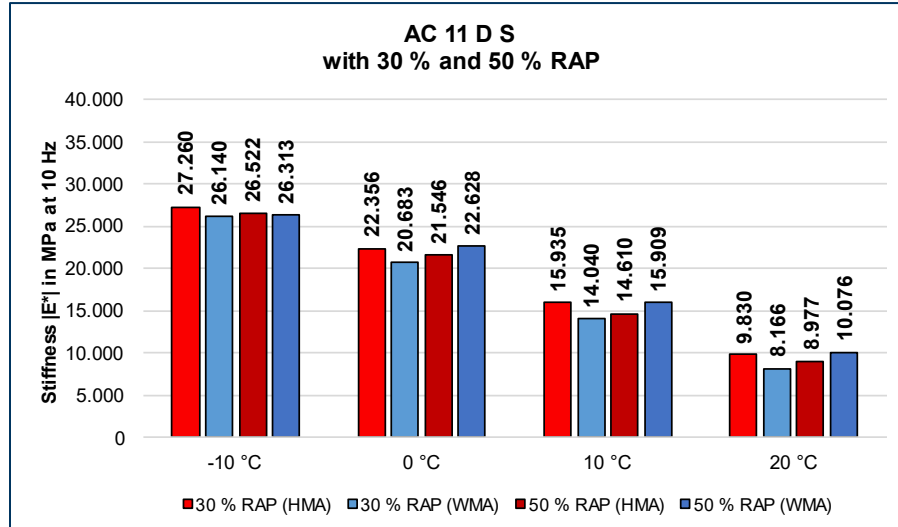


Low-Temperature Behavior  
TSRS-Test



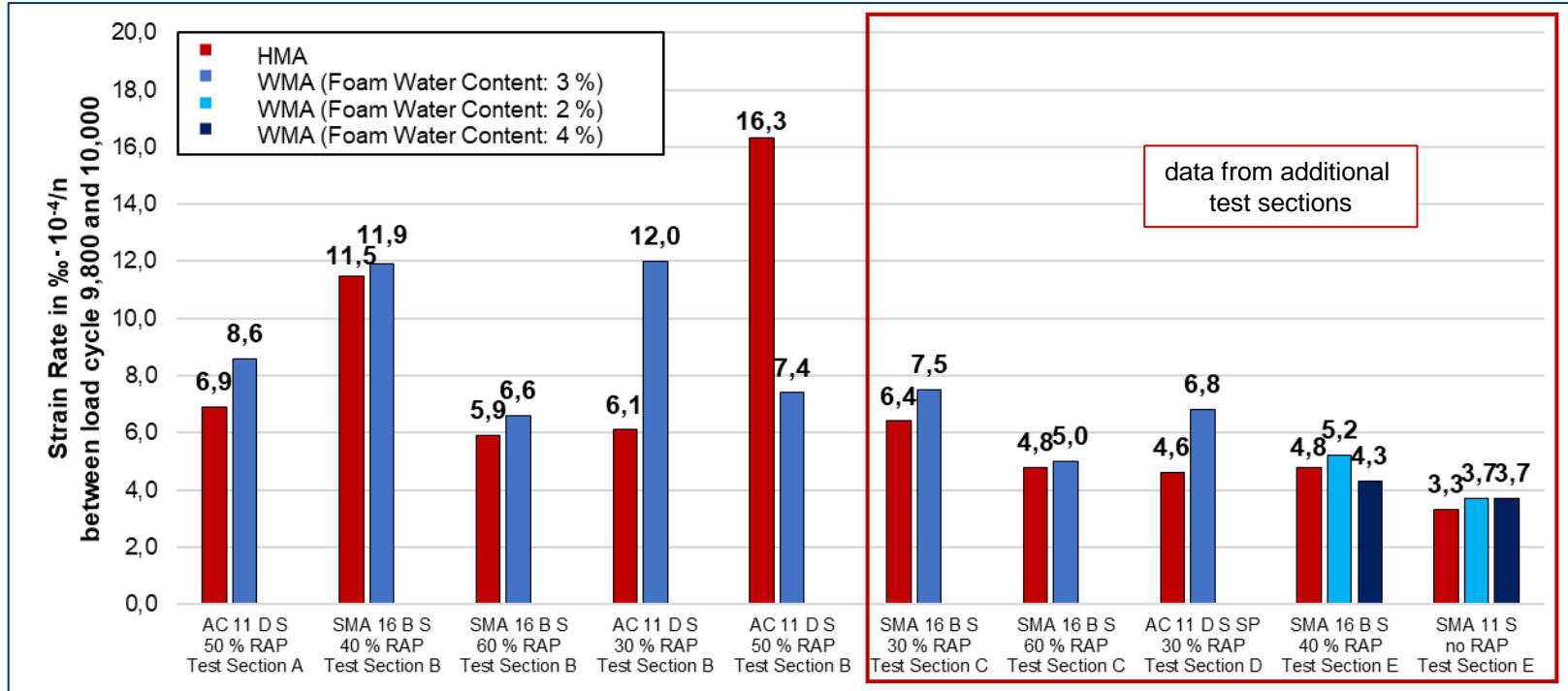
# Research Project – Construction of Trial Sections

## Performance Investigation – Stiffness (E-Modulus)



# Research Project – Construction of Trial Sections

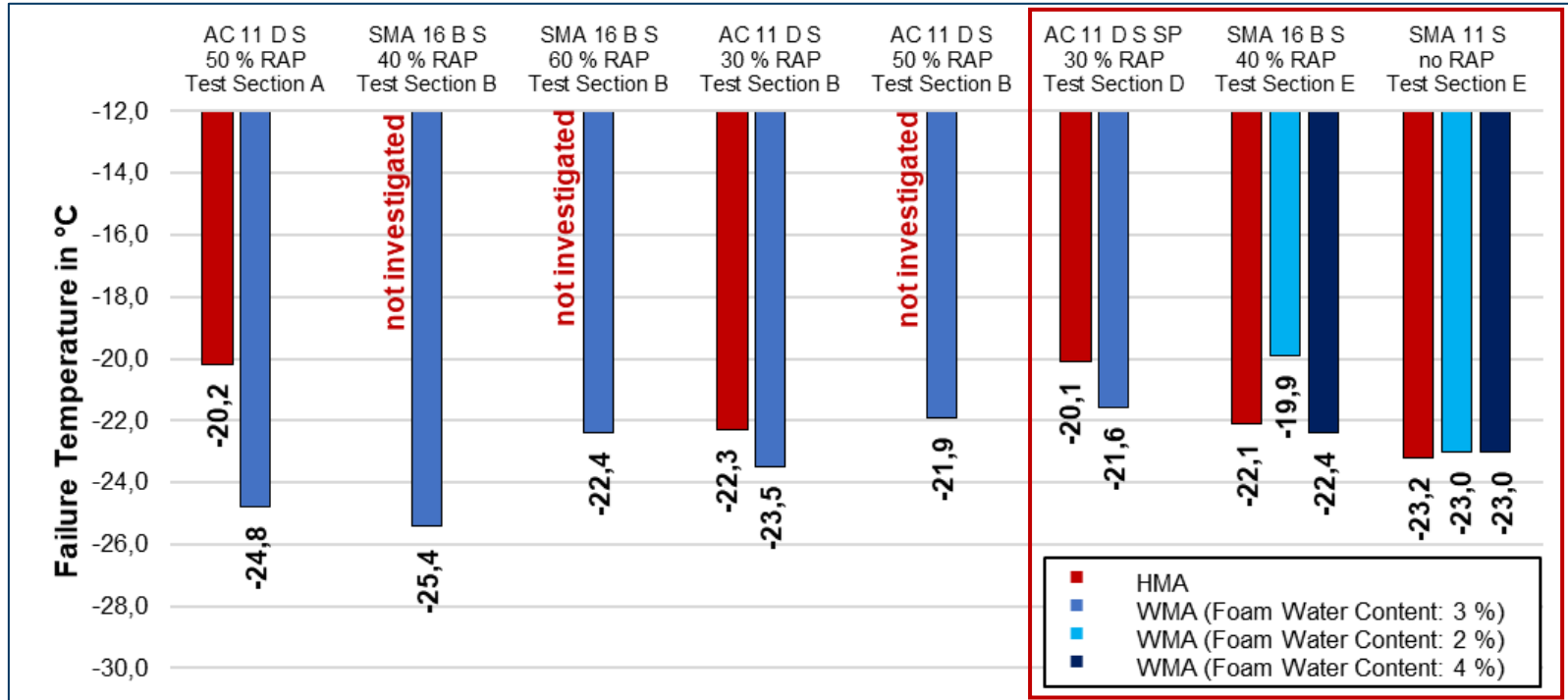
## Performance Investigation – Permanent Deformation at 50 °C



# Research Project – Construction of Trial Sections

## Performance Investigation – Low-Temperature Behavior (TSRS-Test)

data from additional  
test sections



# Conclusions

- The findings from the research project, along with the additionally examined test sections, confirm that WMA can be successfully produced using foamed bitumen as well as high contents of RAP. There is no concrete evidence that the reduction in temperature in combination with the use of foamed bitumen negatively impacts permanent deformation or low-temperature behavior.

# Outlook

- Within the scope of the research project, no fatigue behavior was investigated. This should be addressed in future research projects.



# Thank you for your attention!