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ENHANCING THE LABORATORY ASSESSMENT OF THE THERMAL CRACKING RESISTANCE OF ASPHALT MIXTURES

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1. Introduction

Asphalt mixtures as the main construction material for road pavements are a composite of bitumen as the binder and mineral aggregates with a predefined mix design. Bitumen as a viscoelastic material exhibits highly temperature dependent characteristics. The stress relaxation capability of the binder decreases upon cooling and once the tensile strength is reached, the pavement fails by thermal cracking [1]. A common method is the thermal stress restrained specimen test (TSRST) or cooling test. This method has been introduced and improved from the 1960s on [2-4]. In the TSRST, an asphalt mix specimen is mounted within a test device in a thermal chamber. The length of the specimen is kept constant while the thermal chamber cools the specimen down at a constant rate until the specimen fails.

2. Problem Statement and Objectives

Two different devices for TSRST are run in the authors' lab, manufactured in 2003 and 2013. Both devices comply with all requirements given by TSRST standard EN 12697-46. However, a comparative test program discovered that there is a systematic deviation in results obtained from both devices. While the resulting failure stresses are within the repeatability, the failure temperature deviates by more than 3°C. The trend that the 2013 device produces higher failure temperatures was observed for more 10 different asphalt mixtures.

An analysis of the recorded data from the LVDTs (Linear Variable Differential Transformers) that are used for deformation control showed that both devices are controlled with high precision. A significant impact of the deformation control can be omitted. The evolution of cryogenic stresses in TSRST is also affected by the air and specimen temperature. Thus, the present hypothesis is that there is a difference in the air temperature control in the two devices. Preliminary tests revealed that the air cooling rate is within expected range for both devices. However, it was observed that in the 2013 device, the specimen core cools down with the same rate as the air temperature, whereas in the 2003 device, the specimen core cools down significantly slower. This difference between air and specimen temperature can explain why the 2003 device produces better results since the specimen cools down more slowly and therefore, cryogenic stresses are built up at a slower pace. This prolongs the period of stress relaxation in the 2003 device and leads to a later failure. However, since the air temperature rates are comparable in both devices, the larger deviation between air and specimen core temperature in the 2003 device cannot be explained by a significant difference in air cooling temperature. Finding the reason for this temperature deviation is subject of this paper.

3. Materials and Methods

3 dense graded (low air void content) asphalt concrete (AC) samples with different cross sections (5x5 cm and 6x6 cm) were analysed, as well as a binder rich (no air voids) mastic asphalt (MA) and an open graded (high air void content) stone mastic asphalt (SMA).

To record the core temperature, a dummy specimen is prepared for each mixture. The dummy specimen is cut in half and a hole is drilled in the centre of one end plane. The hole is covered with an adhesive aluminium insulation foil and filled with glycerine. A temperature probe is inserted into the hole to record the core temperature. For the presented study, the dummy specimen was placed into the thermal chamber at the position, where the actual test specimen would be mounted in the TSRST. The thermal program that is used for TSRST was run as follows: start at +10°C kept for 60 min, subsequent cooling at a rate of 10°C/h until -40°C air temperature is reached. Air and specimen core temperature are recorded every 4 seconds.

4. Results and Outlook

Main results are shown in Fig. 1. The left diagram shows the temperature lag between air and specimen core temperature for each mix and both devices vs. the TSRST temperature. The right diagram shows the maximum temperature lag. SMA shows the smallest temperature lag (3.6°C max 2003, 8.4°C max 2013). This can be explained with the higher content of larger aggregates and therefore a better temperature conductivity of the material. MA 8 and AC 16 (5x5 cm) both show similar temperature lags. A difference can be found between 5x5 cm and 6x6 cm cross section: the maximum lag increases by 0.8°C to 0.9°C. On average, the 2003 device shows a 4.7°C higher max temperature lag. The essential evidence for explaining this effect was a measurement of air flow velocity. The vane anemometer (vane diameter 2.5 cm) can measure the air velocity continuously. The data show different air velocities on specimen height in vertical direction: The 2003 device exhibits a lower air velocity (0.5 m/s) than the 2013 device (1.4 m/s).

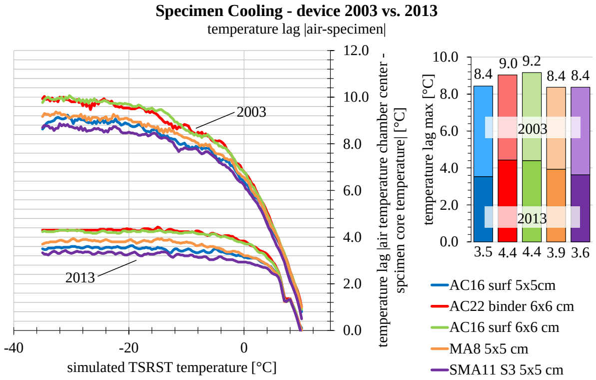

Fig. 1. Temperature lag between specimen core and air temperature for both devices.

To validate the impact of air flow velocity on lag between air and specimen core temperature, an efficient, quick adaption of the 2003 device was set up: Two standard CPU cooling fans were placed on the bottom of the thermal chamber close to the air outlet. The fans' direction was adjusted so that the dummy specimen was in the centre of the air flow. 3 different settings to study the impact of fan power were used: a 12, 20 and 29 Voltage standard PC fan (air flow velocity 12V: 2.9 m/s, 20 V: 5.2 m/s, and 29 V: 7.0 m/s). The thermal program was carried out with one dummy specimen in the 2003 device again, including the supporting fans.

The results of the improved 2003 device are presented in Fig. 2. The left diagram shows the evolution of the temperature lag between air and core temperature vs. TSRST temperature, the right diagram shows the maximum temperature lag. While the initial setup of the 2003 device leads to a temperature lag of 10.0°C, even a low powered fan brings down the temperature lag by 4°C. With the strongest fans, the temperature lag could be brought down to same level as for the 2013 device. These results show that the difference in temperature lag between the two devices is strongly related to the air flow velocity within the temperature chamber and that a higher air flow velocity can be easily and economically realized.

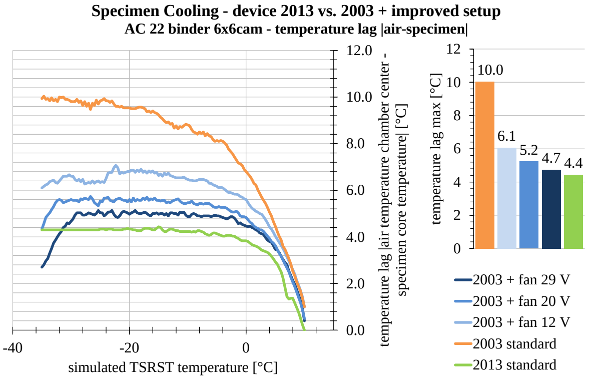

Fig. 2. First improved setup to increase air flow velocity in the 2003 device.

Next steps will be to run TSRST in the enhanced 2003 device and compare results to the 2013 device. It is expected that the improved air flow velocity will lead to more reproducible results. In addition, a larger round robin study should analyse the presented effects in other devices around the world, overcome differences and produce data for reproducibility of standard TSRST according to EN 12697-46.

References

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