



FACULTY
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ENGINEERING

LOW TEMPERATURE CHARACTERISTICS OF BITUMINOUS MIXTURES ACCORDING TO EN 12697-46

Thermal Stress Restrained Specimen Test results

Research report

November 2015, Brno

Introduction

Asphalt mixtures were delivered 7th September 2015 to Road laboratory of Faculty of Civil Engineering in Brno.

Mixtures properties are shown in Table 1. The low temperature characteristics were determined and evaluated according to EN 12697-46 based on contract of Peab Asphalt AB and Brno University of Technology from 14th August 2015.

The low temperature characteristics of delivered mixtures were tested using Thermal Stress Restrained Specimen Test (TSRST). Slab of each mixture with thickness 60 mm was compacted according to EN 12697-35 by a roller compactor running on vertical sliding steel plates (as specified in EN 12697-33). The compaction temperatures of mixtures were 150 °C (ABS 16 70/100 (3516)), 155 °C (ABS 16 50/70 (3506)), 160 °C (ABS 16 SWEBIT 45/80-65 (3595)) and 165 °C (ABS 16 SWEBIT 25/55-80 (3599)) as mentioned in table 1.

The bulk densities of slabs were determined according to EN 12697-6 (Procedure B: Bulk Density – Saturated surface dry – SSD). Properties of compacted slabs are shown in Table 2. Three test specimens (50 mm x 50 mm x 200 mm) were cut from each slab using circular saw. Thicknesses of specimens were reduced by grinding from 60 mm to 50 mm. These specimens were used to determine the low temperature characteristics of the bituminous mixtures.

Table 1: Mixtures properties

Mixture Nr.	Compaction temperature [°C]	Bulk density [Mg/m ³]
ABS 16 70/100 (3516)	150	2,365
ABS 16 50/70 (3506)	155	2,365
ABS 16 SWEBIT 45/80-65 (3595)	160	2,365
ABS 16 SWEBIT 25/55-80 (3599)	165	2,365

Table 2: Properties of slabs compacted in the laboratory

Mixture Nr.	Bulk density [Mg/m ³]	Degree of compaction [%]
ABS 16 70/100 (3516)	2,355	99,5
ABS 16 50/70 (3506)	2,357	99,7
ABS 16 SWEBIT 45/80-65 (3595)	2,368	100,1
ABS 16 SWEBIT 25/55-80 (3599)	2,368	100,1

Laboratory testing device

European standard EN 12697-46 is used for evaluation of low temperature properties. Thermal Stress Restrained Specimen Test (TSRST) was used for determination of low temperature characteristics of compared mixtures.

The aim of the test is to determine the critical temperature (failure temperature, cracking temperature) and the tensile stress of test specimen when the crack occurred (failure stress). The tensile stress increases through cooling of the specimen using constant negative temperature gradient 10 °C per an hour and the shortening of specimen is avoided. The zero deformation of specimen is achieved by heating of the elements of the clamping device which is controlled by computer, based on feedback from sensors mounted on steel pads. The test specimen is glued in these pads.

The testing device (Figure 1) placed in Road laboratory of Brno University of Technology consists of the test chamber (1), rigid frame (2), measurement and control electronics (6) and clamping device – connecting rods with a diameter of 32 mm (3) for connection of the test specimen (4). Force sensor is located at the bottom of the frame (5). The development of the test specimen temperature is determined using the temperature sensor inserted into second specimen placed in cooling chamber. The deformation is measured by three sensors of deformation (7), which are mounted on the pads around the test specimen. The zero longitudinal deformation of the specimen is achieved using procedure of heating of clamping elements which is controlled by the software. The software also captures data during the test procedure and regulates the temperature in the chamber.

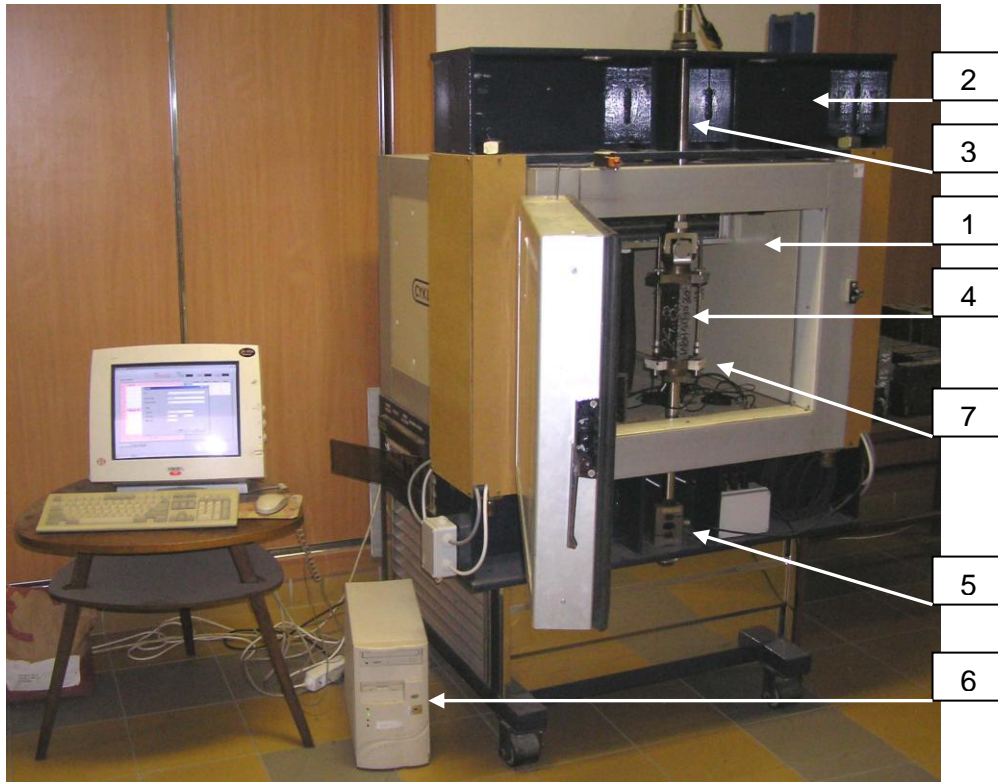


Figure 1: TSRST device

Low temperature characteristic measurement results

The records of increased thermal stress during cooling of test specimens, that cannot be shortened, are presented in Figure 2 to 5 for individual mixtures. Average curves of thermal stresses of individual mixtures are presented in Figure 6 to 9. Overall comparison of thermal stress average curves of all mixtures is given in Figure 10. The overall results are shown in Table 3. Detailed TSRST results for each specimen are presented in Annex A. The Figure 11 shows crack surfaces of evaluated mixtures.

The most important parameter for low temperature characteristics determination is the failure temperature. The failure temperature of compared mixtures was $-15,1\text{ }^{\circ}\text{C}$ to $-20,3\text{ }^{\circ}\text{C}$. The failure stress of compared mixtures was 3,26 MPa to 4,25 MPa. The best low temperature characteristics showed mixture *ABS 16 SWEBIT 25/55-80 (3599)* and the worst low temperature characteristics showed mixture *ABS 16 50/70 (3506)*.

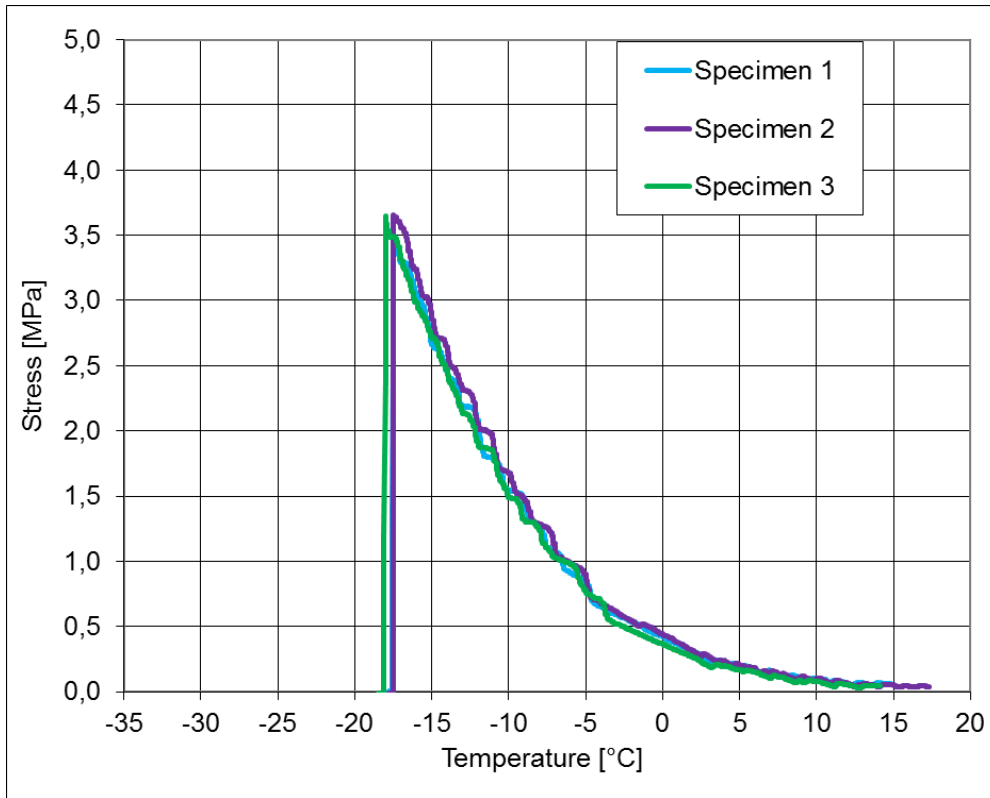


Figure 2: Tensile stress dependence on decreasing temperature of mixture ABS 16 70/100 (3516)

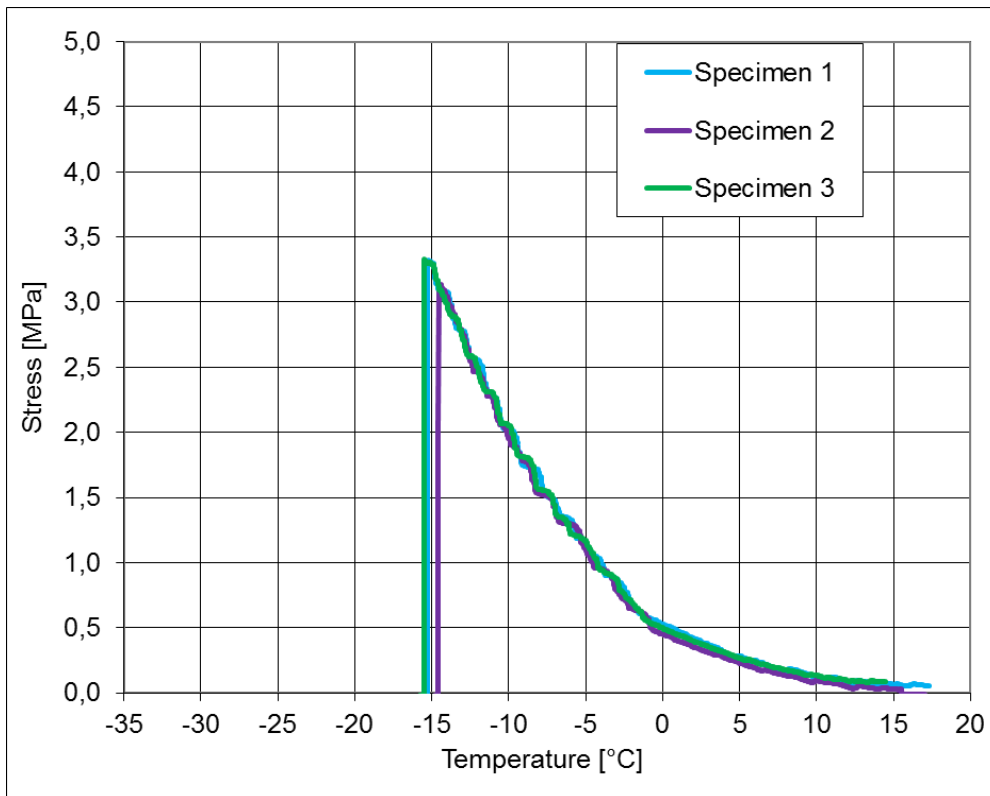


Figure 3: Tensile stress dependence on decreasing temperature of mixture ABS 16 50/70 (3506)

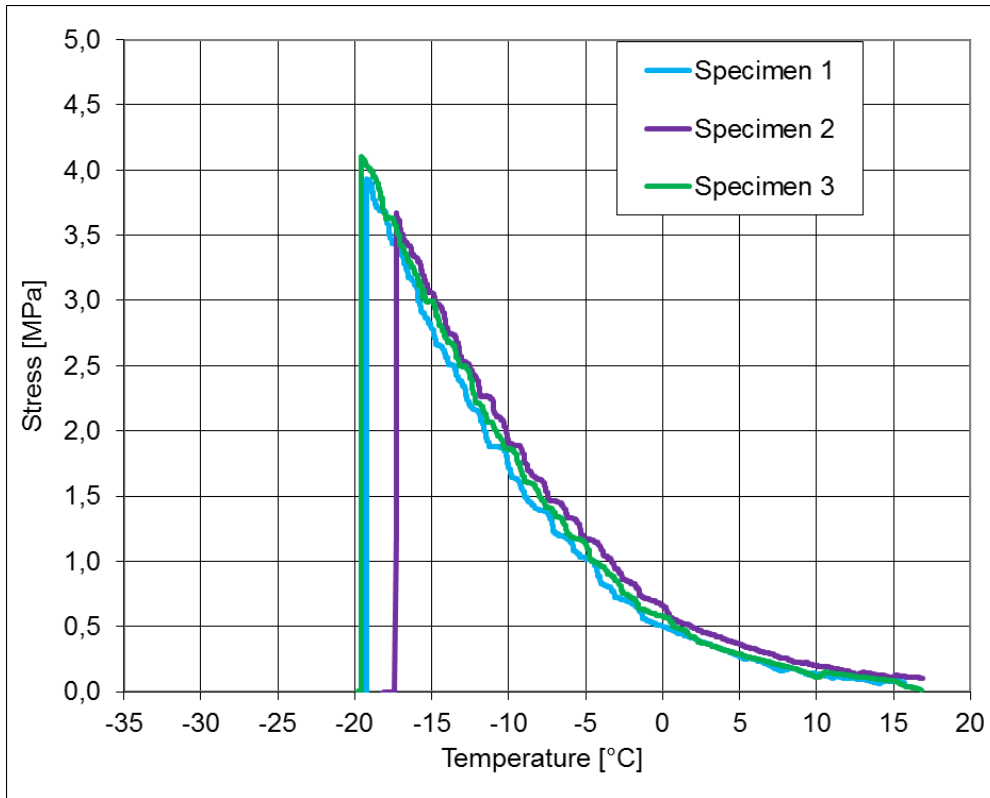


Figure 4: Tensile stress dependence on decreasing temperature of mixture ABS 16 SWEBIT 45/80-65 (3595)

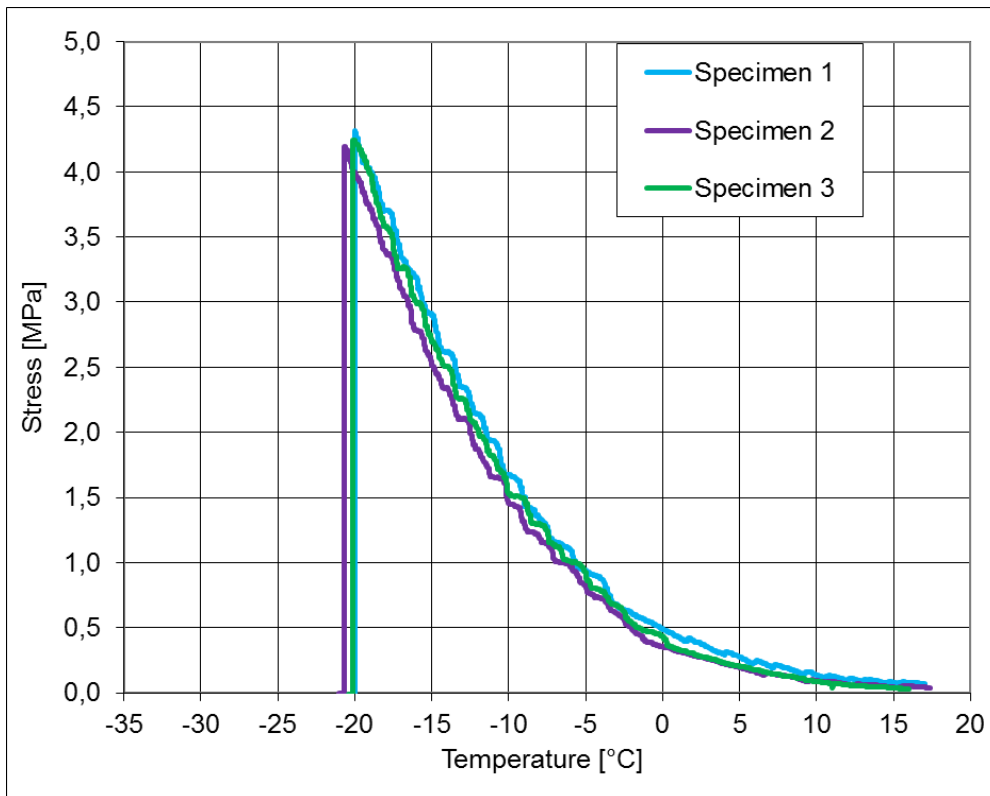


Figure 5: Tensile stress dependence on decreasing temperature of mixture ABS 16 SWEBIT 25/55-80 (3599)

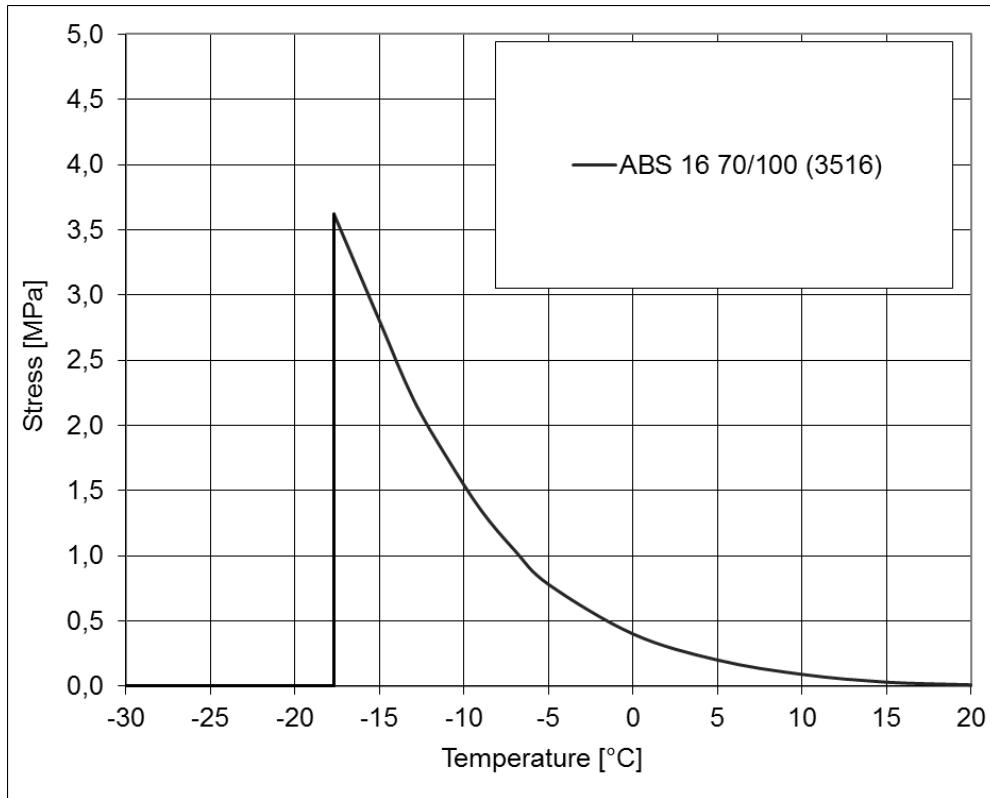


Figure 6: Average tensile stress dependence on temperature of mixture ABS 16 70/100 (3516)

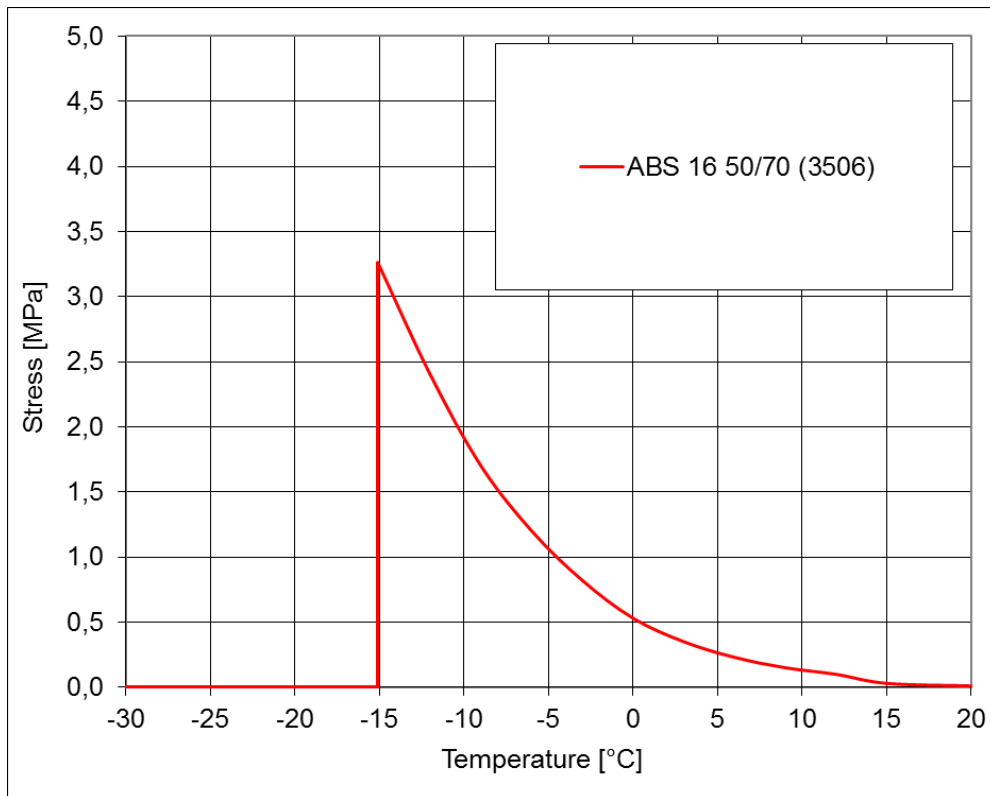


Figure 7: Average tensile stress dependence on temperature of mixture ABS 16 50/70 (3506)

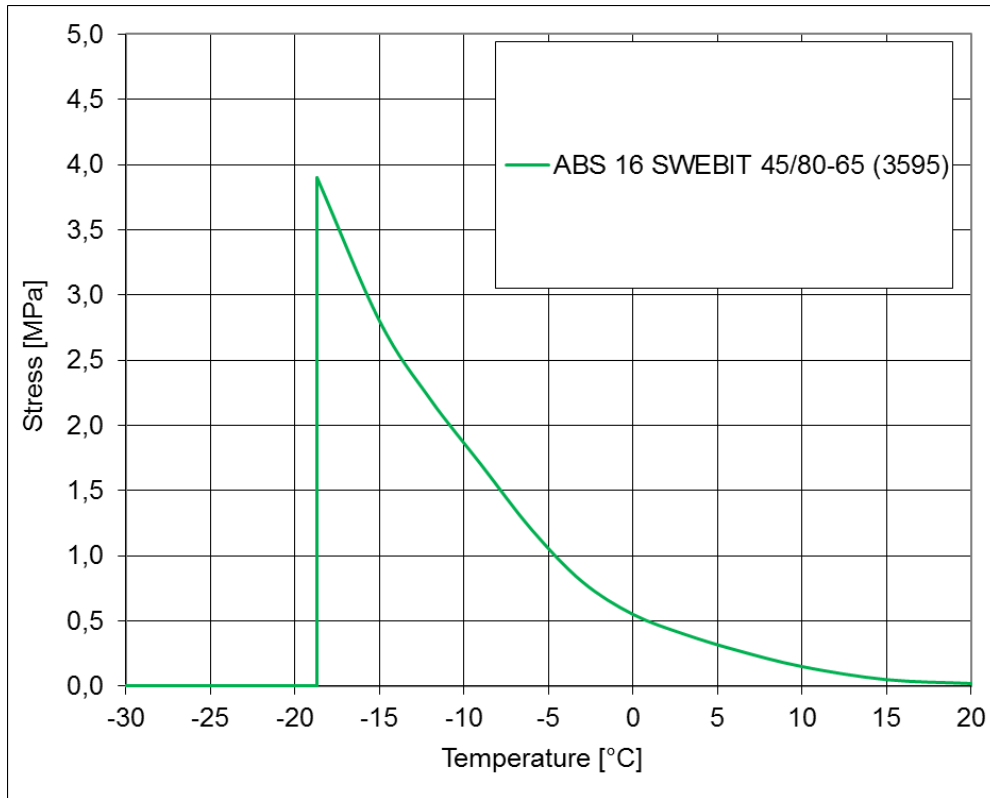


Figure 8: Average tensile stress dependence on temperature of mixture ABS 16 SWEBIT 45/80-65 (3595)

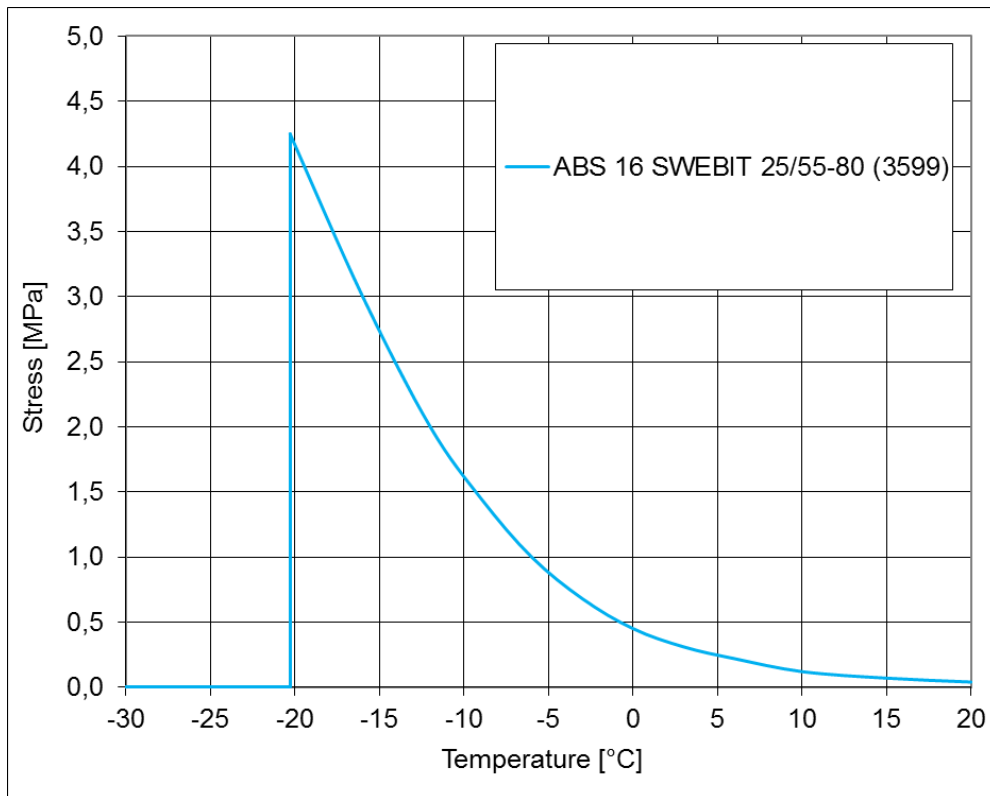


Figure 9: Average tensile stress dependence on temperature of mixture ABS 16 SWEBIT 25/55-80 (3599)

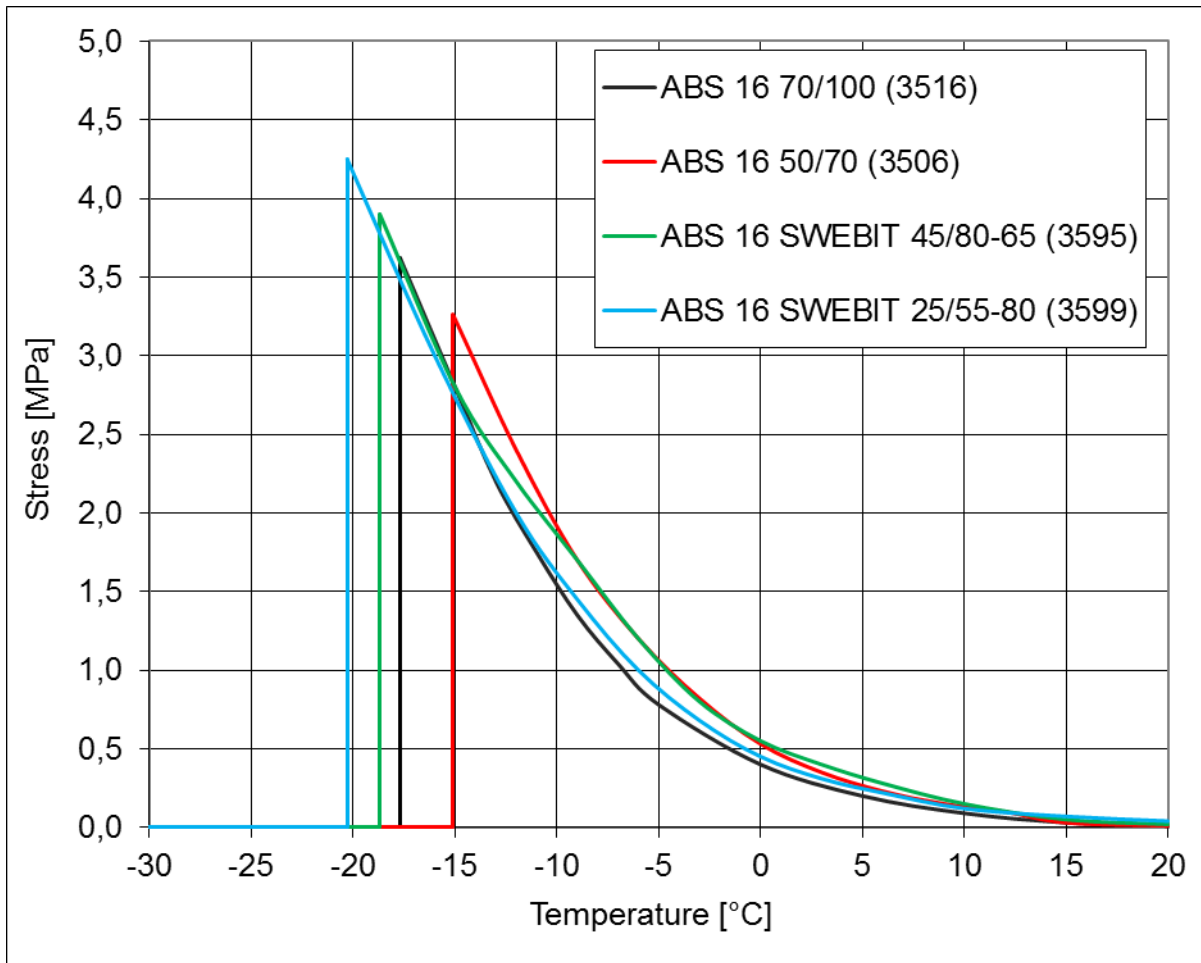


Figure 10: Overall comparison of average curves of all mixtures

Table 3: Tensile stress and the temperature of test specimens at failure

Mixture	Value	Test specimen			Average
		I	II	III	
ABS 16 70/100 (3516)	Failure stress [MPa]	3,56	3,65	3,65	3,62
	Failure temperature [°C]	-17,5	-17,5	-18,0	-17,7
ABS 16 50/70 (3506)	Failure stress [MPa]	3,32	3,14	3,33	3,26
	Failure temperature [°C]	-15,2	-14,5	-15,5	-15,1
ABS 16 SWEBIT 45/80-65 (3595)	Failure stress [MPa]	3,94	3,67	4,10	3,90
	Failure temperature [°C]	-19,2	-17,3	-19,6	-18,7
ABS 16 SWEBIT 25/55-80 (3599)	Failure stress [MPa]	4,31	4,19	4,25	4,25
	Failure temperature [°C]	-20,0	-20,7	-20,1	-20,3

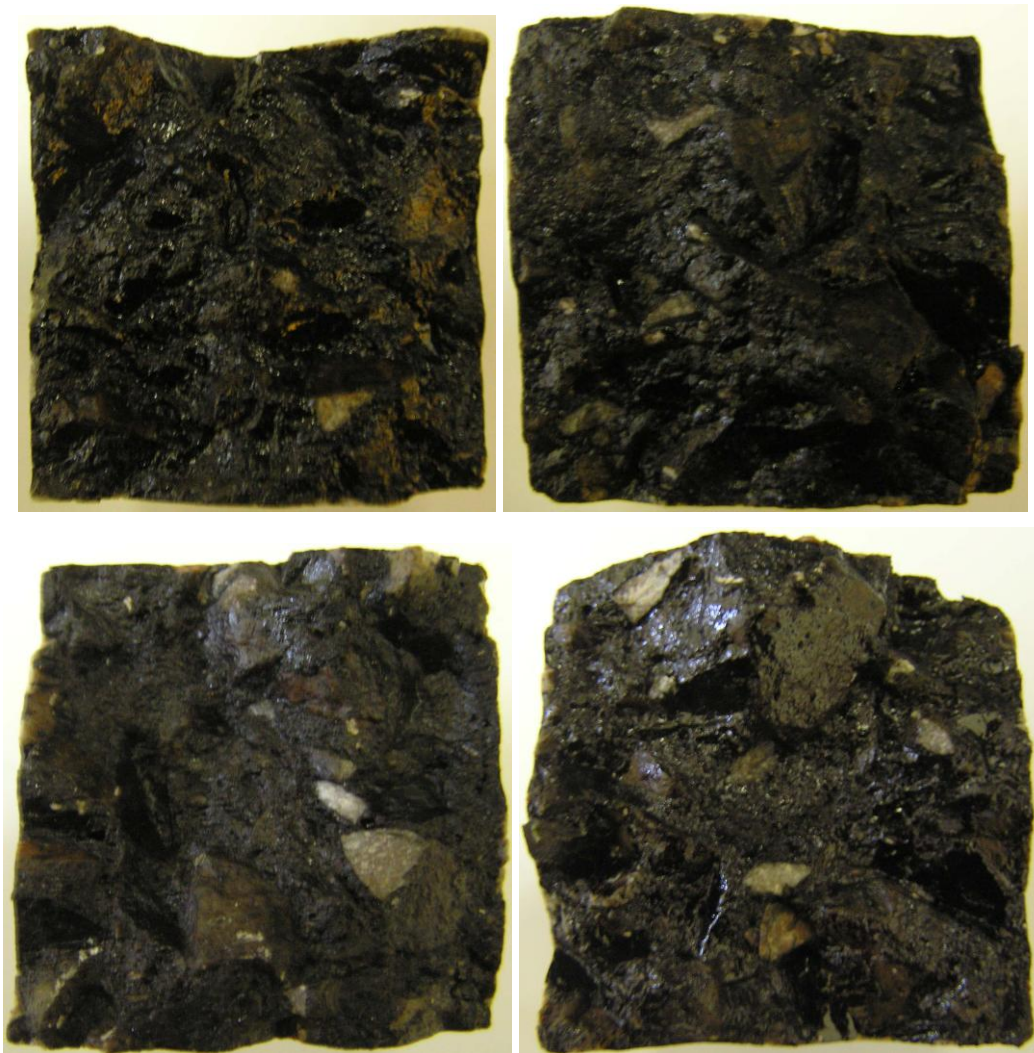


Figure 11: Pictures of crack surfaces of evaluated mixtures (ABS 16 70/100 (3516) – upper left, ABS 16 50/70 (3506) – upper right, ABS 16 SWEBIT 45/80-65 (3595) – lower left, ABS 16 SWEBIT 25/55-80 (3599) – lower right)

Conclusions

The low temperature characteristics of four Peab Asphalt AB mixtures have been tested in Road Laboratory of Faculty of Civil Engineering in Brno.

Bulk density and temperature of compaction are known characteristics of these mixtures. Specimens with very similar bulk density to prescribed bulk density value were prepared in Road laboratory in Brno. All sides of specimens were cut and grinded, the surfaces were smooth.

The low temperature characteristics were determined according to EN 12697-46 in Thermal Stress Restrained Specimen Test device. The rate of cooling of each specimen was 10 °C per hour. The zero elongations of specimens were controlled using three sensors of deformation. Tensile forces resulting from decreasing of the temperature were continuously measured.

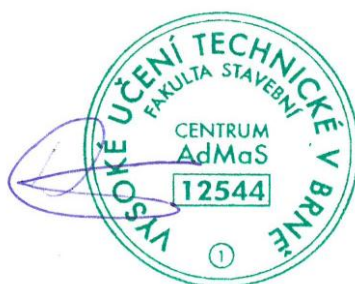
The failure temperature of compared mixtures was -15,1 °C to -20,3 °C. The failure stress of compared mixtures was 3,26 MPa to 4,25 MPa.

The failure temperature of mixture *ABS 16 70/100 (3516)* was $-17,7\text{ }^{\circ}\text{C}$ and failure stress was $3,62\text{ MPa}$. The failure temperature of mixture *ABS 16 50/70 (3506)* was $-15,1\text{ }^{\circ}\text{C}$ and failure stress was $3,26\text{ MPa}$. The failure temperature of mixture *ABS 16 SWEBIT 45/80-65 (3595)* was $-18,7\text{ }^{\circ}\text{C}$ and failure stress was $3,90\text{ MPa}$. The failure temperature of mixture *ABS 16 SWEBIT 25/55-80 (3599)* was $-20,3\text{ }^{\circ}\text{C}$ and failure stress was $4,25\text{ MPa}$.

In Brno, 5.11.2015

Elaborated by:

Ondřej Dašek, Ph.D.

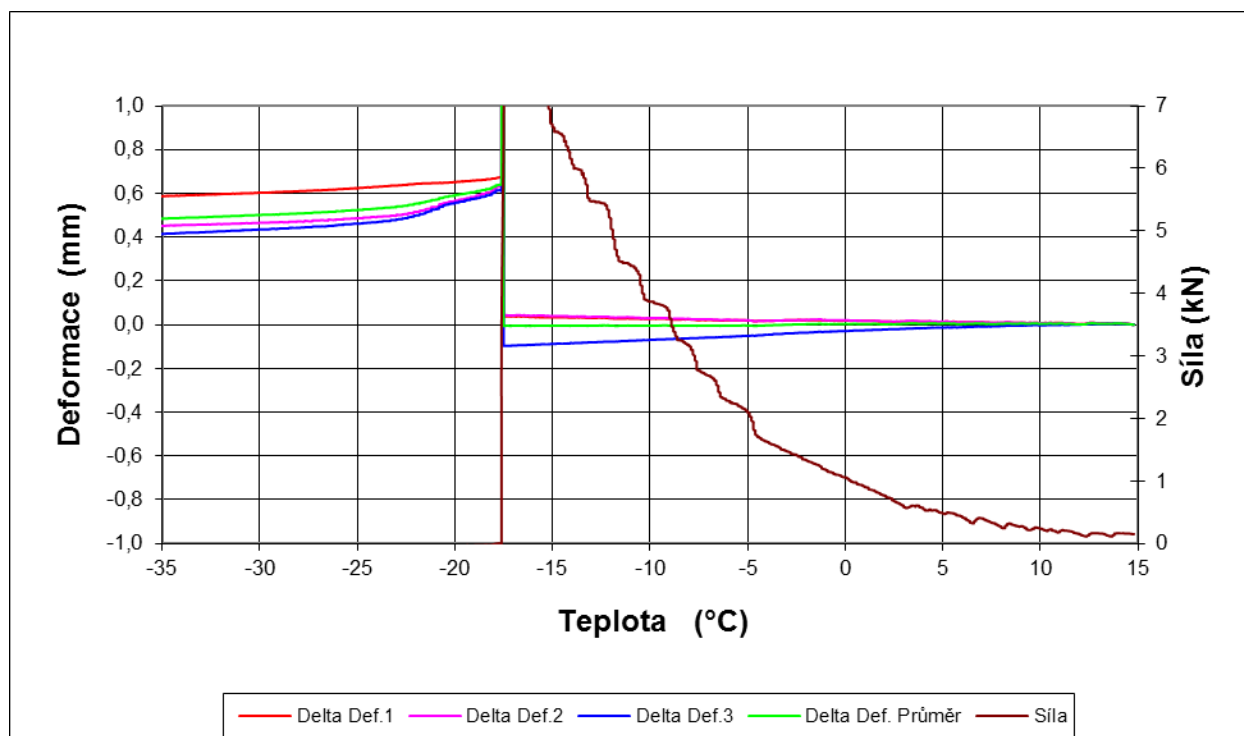


ANNEX A

Detailed results

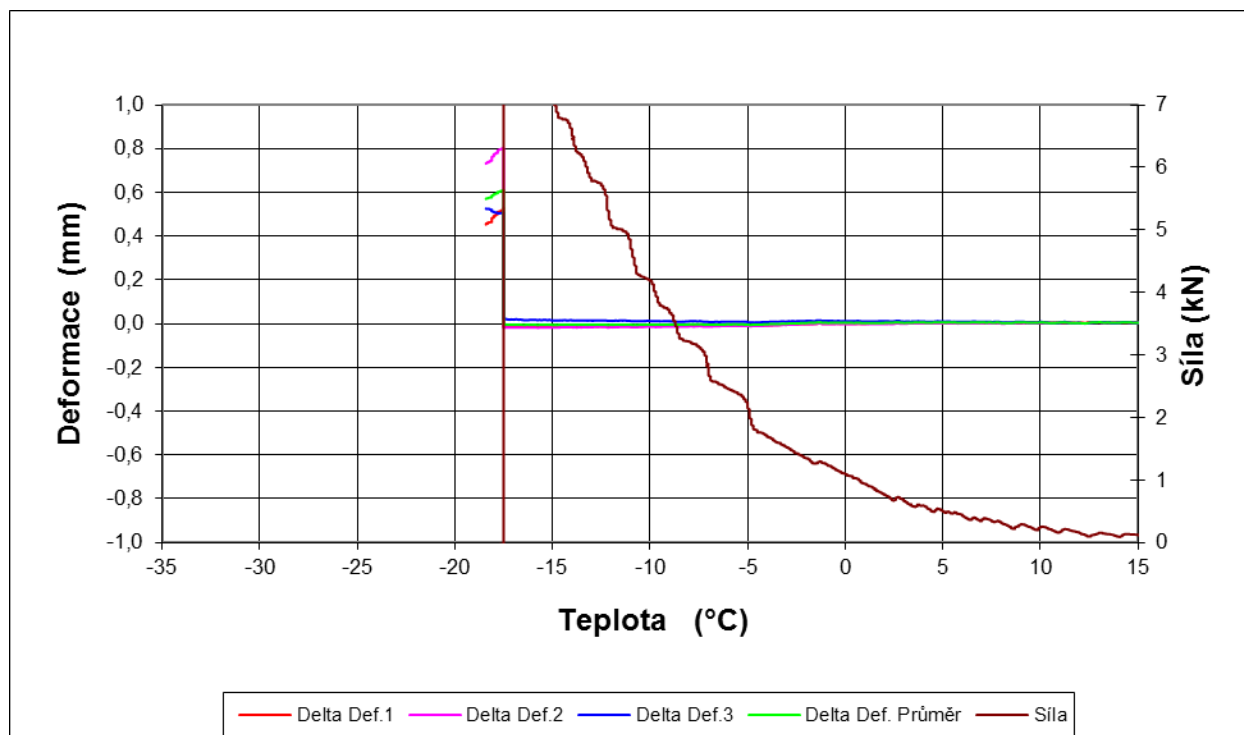
Thermal Stress Restrained Specimen Test

Company:	Peab Asphalt AB
Sample:	3516 I
Dimensions of the specimen - mm:	50 x 50 x 200
Date of the test:	1.10.2015
Testing by:	Šafránek
The set temperature - °C:	10
The period of temperature - min:	15
Cooling rate - °C/hod:	10
Maximum force - kN:	8,89
Maximum stress - MPa:	3,56
Temperature in chamber at crack - °C:	-21,7
Temperature of specimen at crack - °C:	-17,5



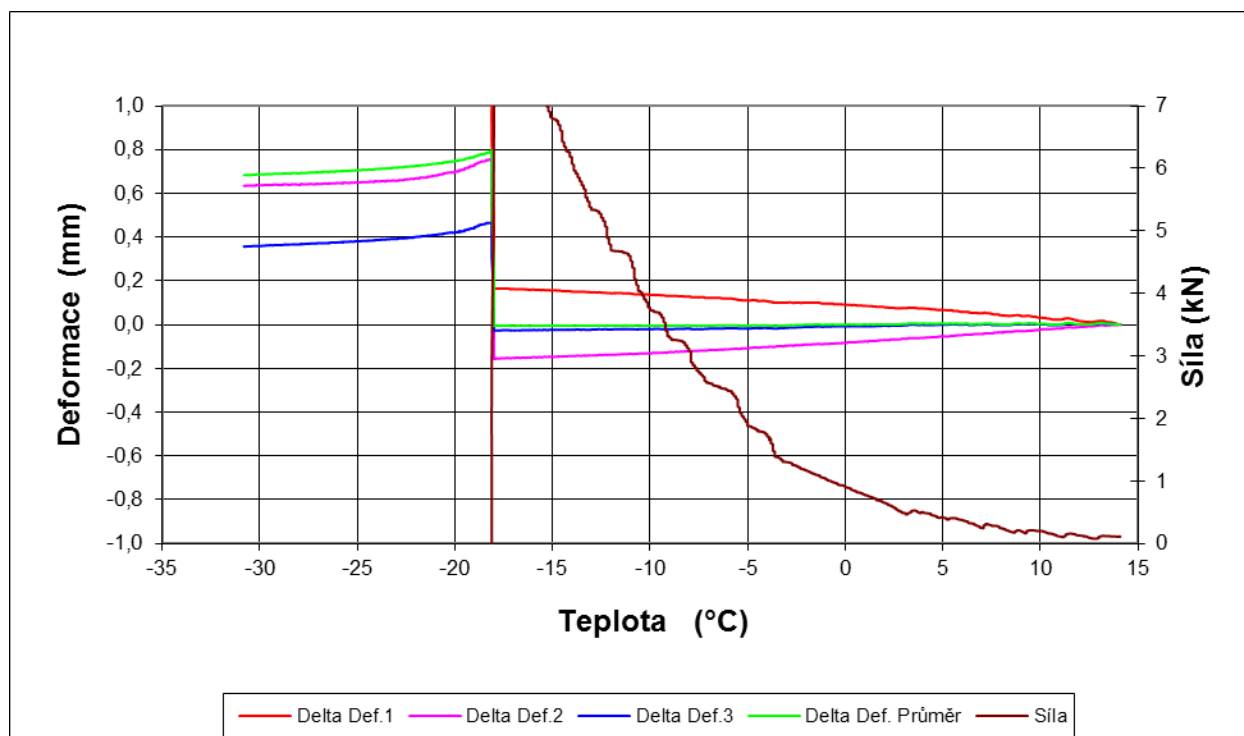
Thermal Stress Restrained Specimen Test

Company:	Peab Asphalt AB
Sample:	3516 II
Dimensions of the specimen - mm:	50 x 50 x 200
Date of the test:	2.10.2015
Testing by:	Šafránek
The set temperature - °C:	10
The period of temperature - min:	15
Cooling rate - °C/hod:	10
Maximum force - kN:	9,13
Maximum stress - MPa:	3,65
Temperature in chamber at crack - °C:	-22,0
Temperature of specimen at crack - °C:	-17,5



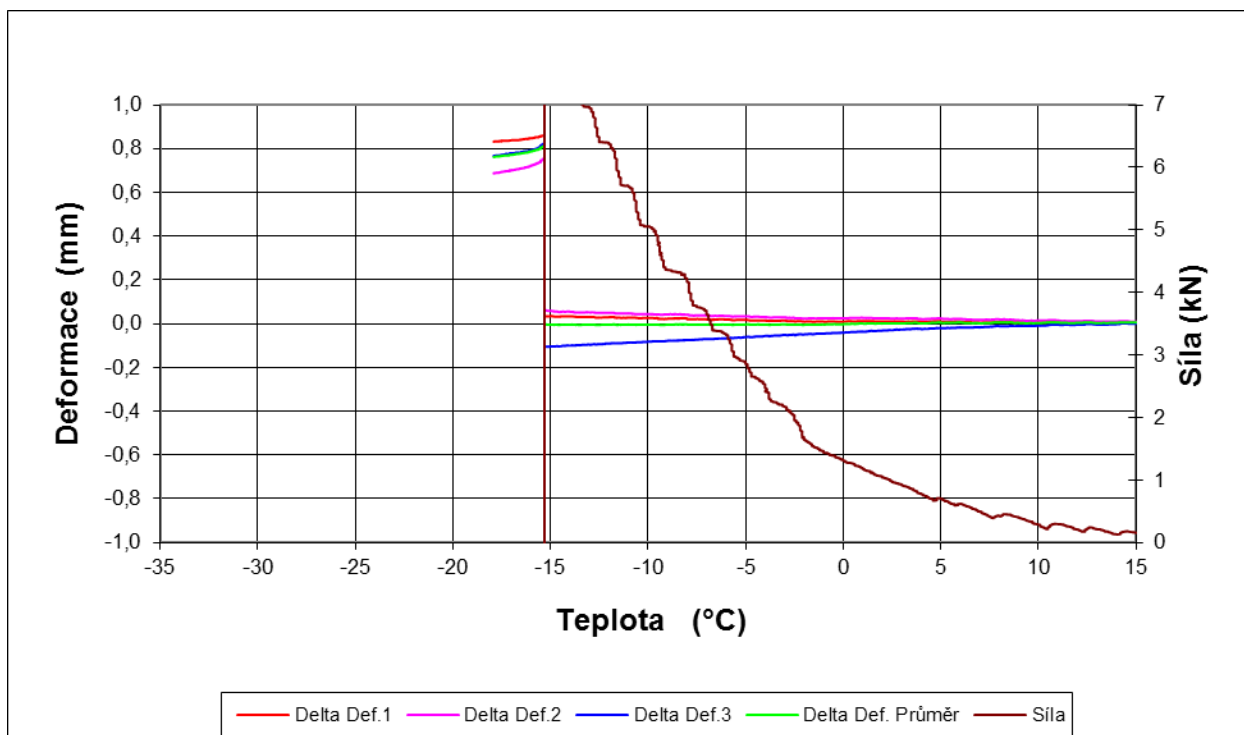
Thermal Stress Restrained Specimen Test

Company:	Peab Asphalt AB
Sample:	3516 III
Dimensions of the specimen - mm:	50 x 50 x 200
Date of the test:	5.10.2015
Testing by:	Šafranek
The set temperature - °C:	10
The period of temperature - min:	15
Cooling rate - °C/hod:	10
Maximum force - kN:	9,12
Maximum stress - MPa:	3,65
Temperature in chamber at crack - °C:	-21,5
Temperature of specimen at crack - °C:	-18,0



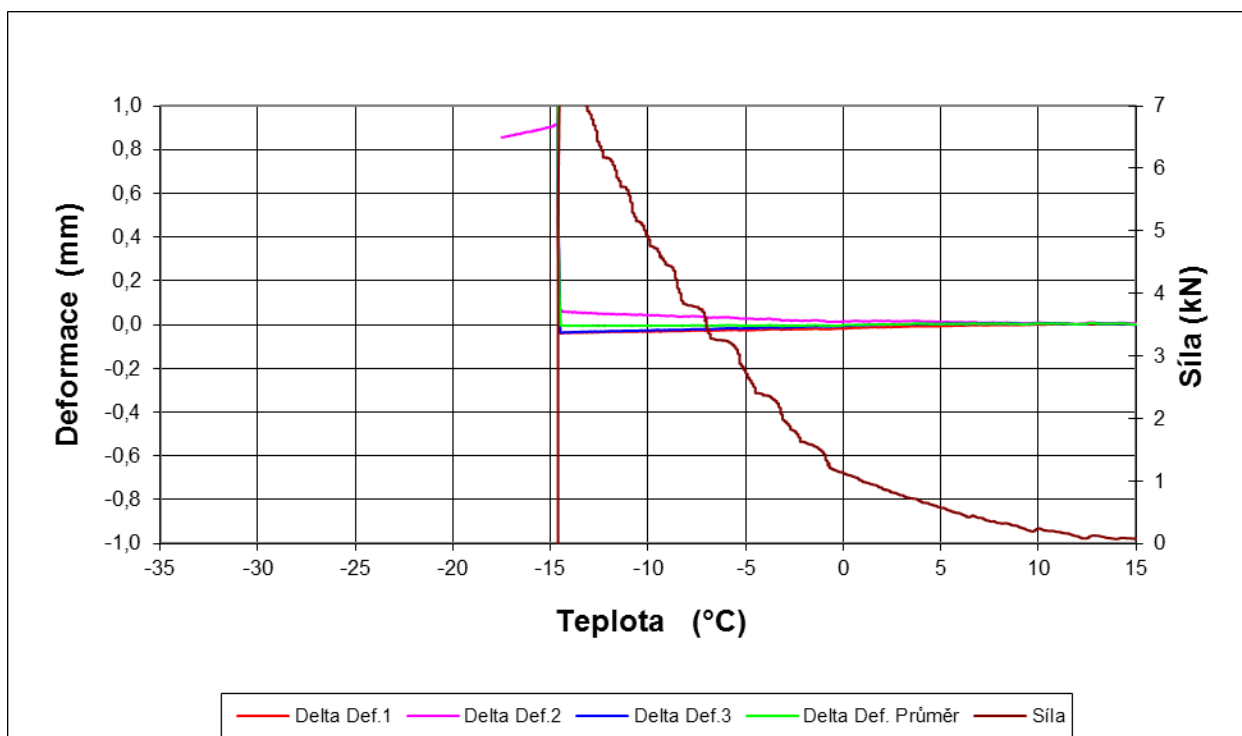
Thermal Stress Restrained Specimen Test

Company:	Peab Asphalt AB
Sample:	3506 I
Dimensions of the specimen - mm:	50 x 50 x 200
Date of the test:	6.10.2015
Testing by:	Šafránek
The set temperature - °C:	10
The period of temperature - min:	15
Cooling rate - °C/hod:	10
Maximum force - kN:	8,30
Maximum stress - MPa:	3,32
Temperature in chamber at crack - °C:	-19,5
Temperature of specimen at crack - °C:	-15,2



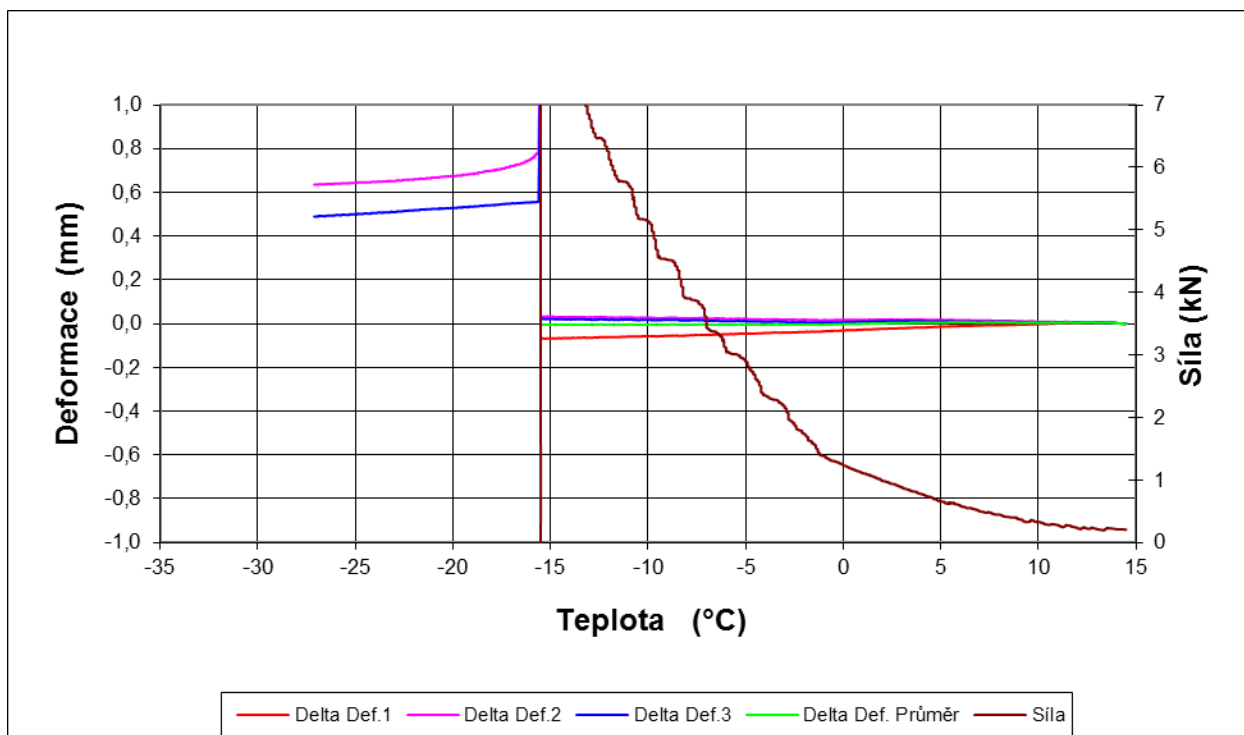
Thermal Stress Restrained Specimen Test

Company:	Peab Asphalt AB
Sample:	3506 II
Dimensions of the specimen - mm:	50 x 50 x 250
Date of the test:	8.10.2015
Testing by:	
The set temperature - °C:	10
The period of temperature - min:	15
Cooling rate - °C/hod:	10
Maximum force - kN:	7,86
Maximum stress - MPa:	3,14
Temperature in chamber at crack - °C:	-19,0
Temperature of specimen at crack - °C:	-14,5



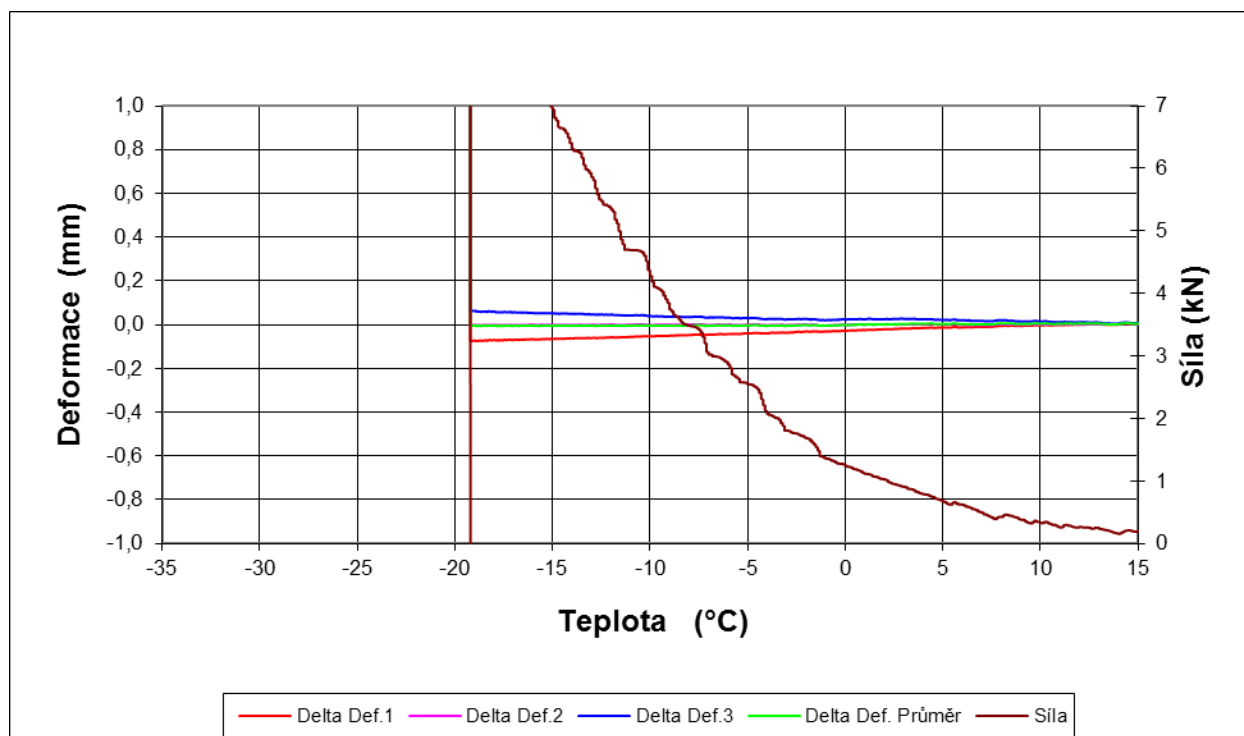
Thermal Stress Restrained Specimen Test

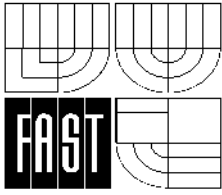
Company:	Peab Asphalt AB
Sample:	3506 III
Dimensions of the specimen - mm:	50 x 50 x 200
Date of the test:	9.10.2015
Testing by:	Šafránek
The set temperature - °C:	10
The period of temperature - min:	15
Cooling rate - °C/hod:	10
Maximum force - kN:	8,33
Maximum stress - MPa:	3,33
Temperature in chamber at crack - °C:	-18,4
Temperature of specimen at crack - °C:	-15,5



Thermal Stress Restrained Specimen Test

Company:	Peab Asphalt AB
Sample:	3595 I
Dimensions of the specimen - mm:	50 x 50 x 200
Date of the test:	19.10.2015
Testing by:	Šafránek
The set temperature - °C:	10
The period of temperature - min:	15
Cooling rate - °C/hod:	10
Maximum force - kN:	9,84
Maximum stress - MPa:	3,94
Temperature in chamber at crack - °C:	-22,1
Temperature of specimen at crack - °C:	-19,2





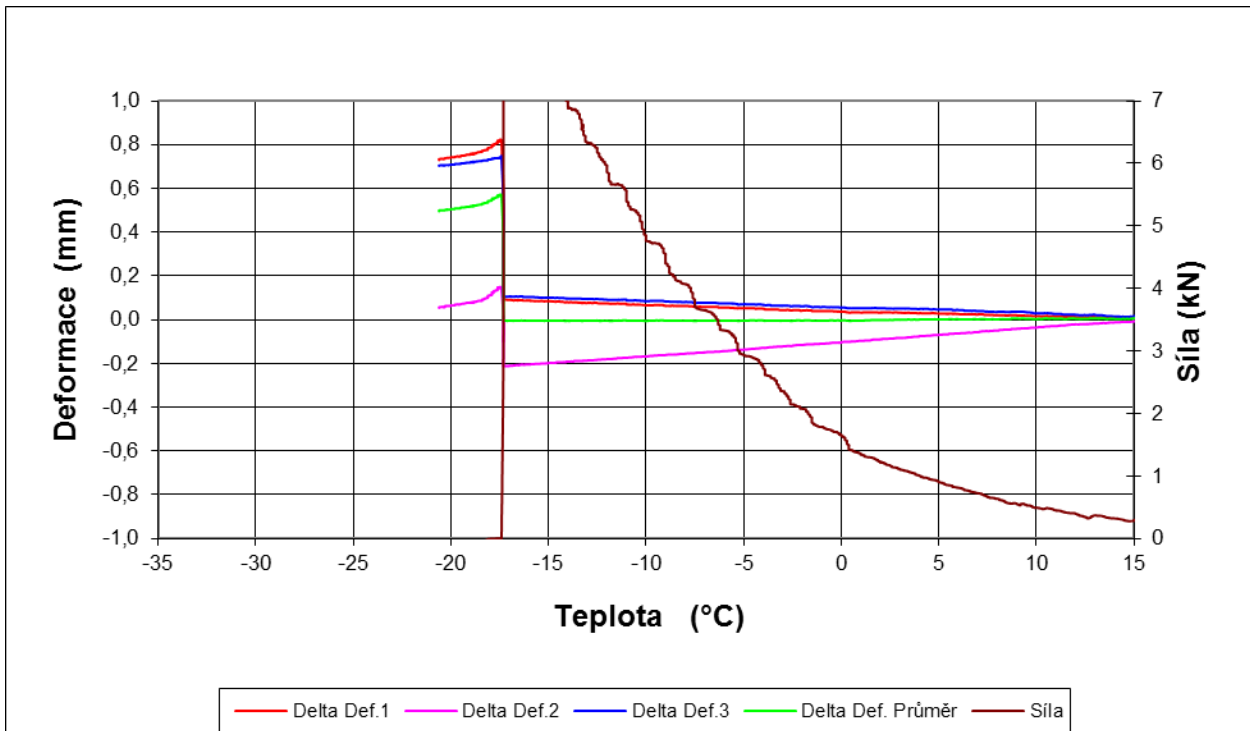
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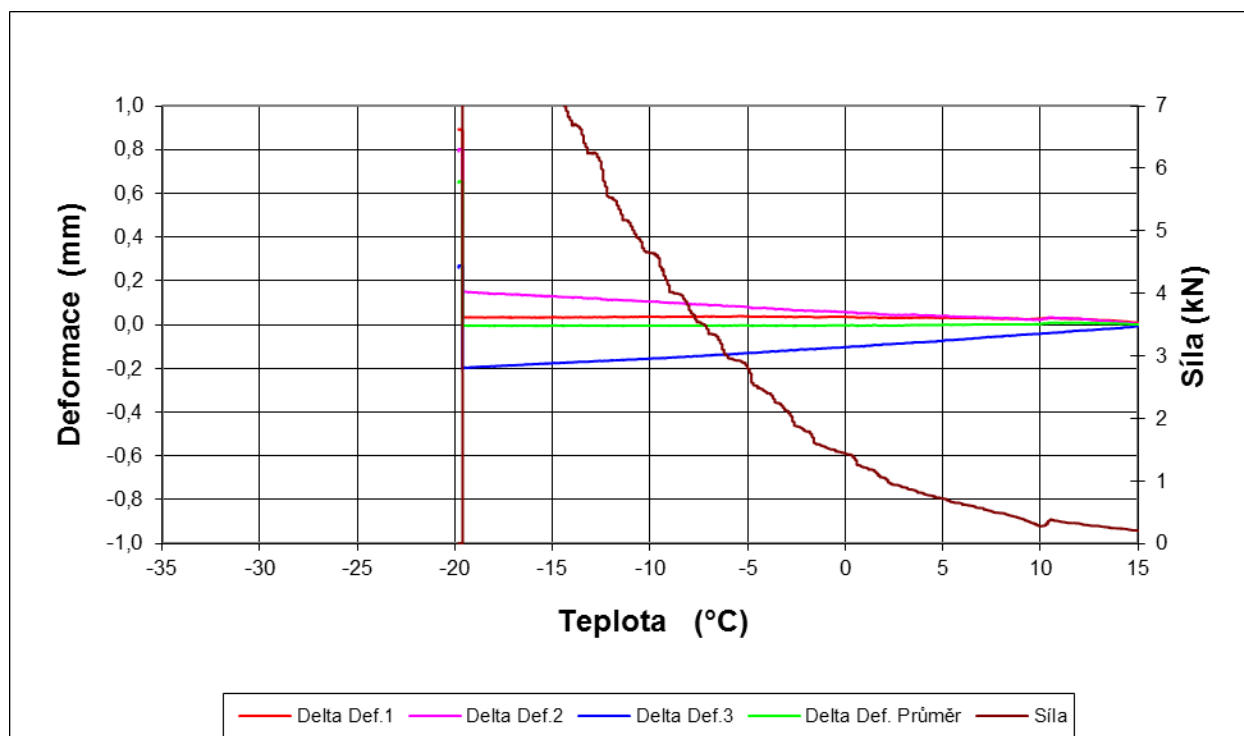
Thermal Stress Restrained Specimen Test

Company:	Peab Asphalt AB
Sample:	3595 II
Dimensions of the specimen - mm:	50 x 50 x 200
Date of the test:	20.10.2015
Testing by:	Šafránek
The set temperature - °C:	10
The period of temperature - min:	15
Cooling rate - °C/hod:	10
Maximum force - kN:	9,19
Maximum stress - MPa:	3,67
Temperature in chamber at crack - °C:	-20,1
Temperature of specimen at crack - °C:	-17,3



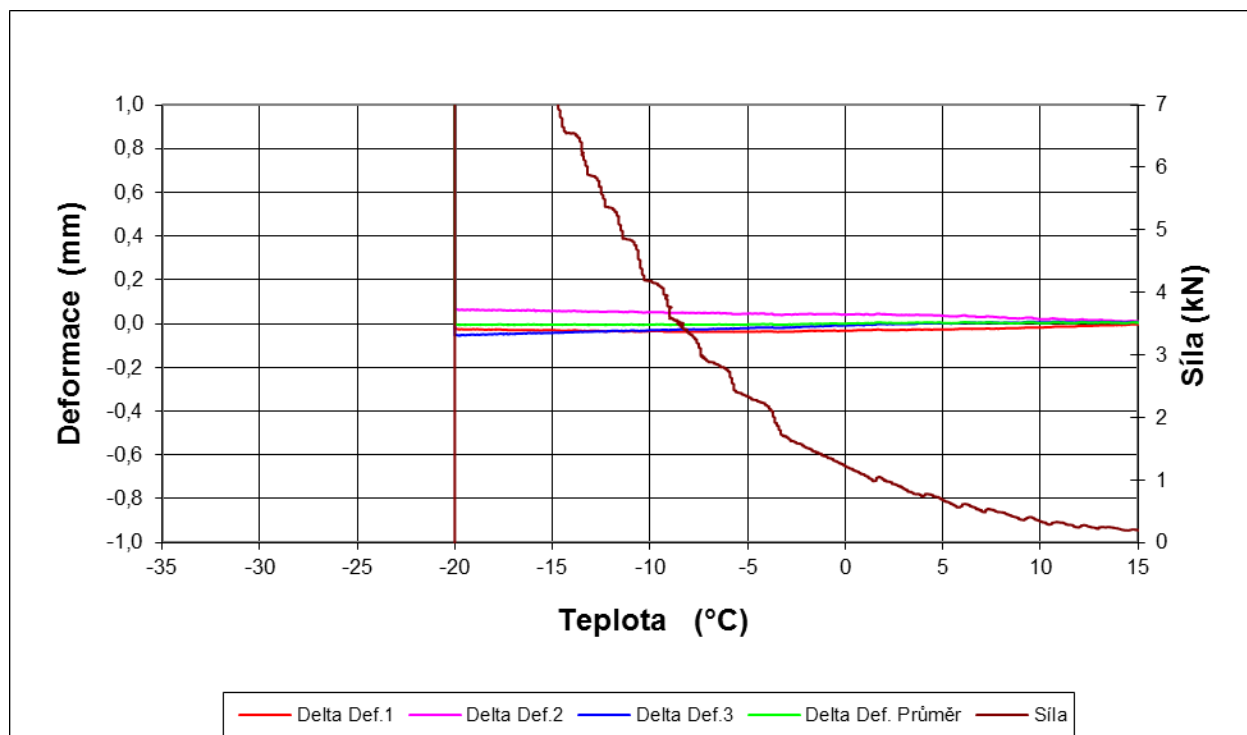
Thermal Stress Restrained Specimen Test

Company:	Peab Asphalt AB
Sample:	3595 III
Dimensions of the specimen - mm:	50 x 50 x 250
Date of the test:	21.10.2015
Testing by:	
The set temperature - °C:	10
The period of temperature - min:	15
Cooling rate - °C/hod:	10
Maximum force - kN:	10,26
Maximum stress - MPa:	4,10
Temperature in chamber at crack - °C:	-22,6
Temperature of specimen at crack - °C:	-19,6



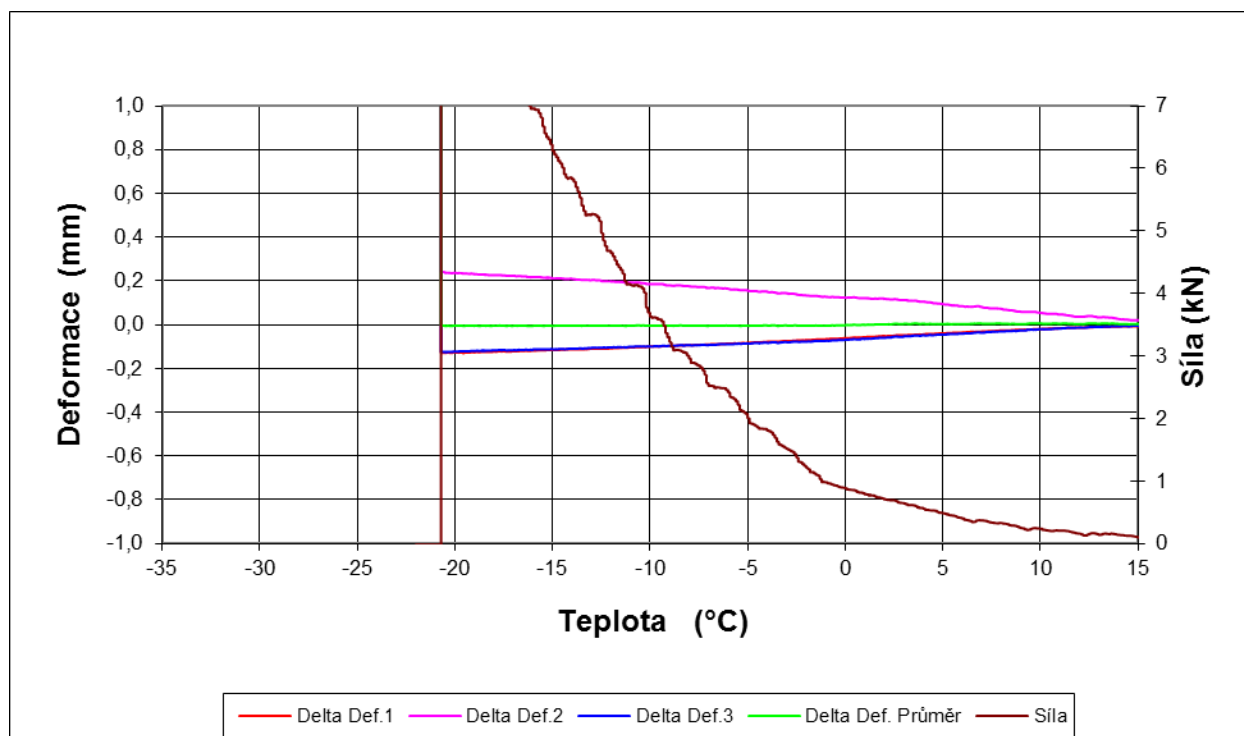
Thermal Stress Restrained Specimen Test

Company:	Peab Asphalt AB
Sample:	3599 I
Dimensions of the specimen - mm:	50 x 50 x 200
Date of the test:	22.10.2015
Testing by:	Šafránek
The set temperature - °C:	10
The period of temperature - min:	15
Cooling rate - °C/hod:	10
Maximum force - kN:	10,78
Maximum stress - MPa:	4,31
Temperature in chamber at crack - °C:	-23,6
Temperature of specimen at crack - °C:	-20,0



Thermal Stress Restrained Specimen Test

Company:	Peab Asphalt AB
Sample:	3599 II
Dimensions of the specimen - mm:	50 x 50 x 250
Date of the test:	23.10.2015
Testing by:	
The set temperature - °C:	10
The period of temperature - min:	15
Cooling rate - °C/hod:	10
Maximum force - kN:	10,48
Maximum stress - MPa:	4,19
Temperature in chamber at crack - °C:	-24,9
Temperature of specimen at crack - °C:	-20,7



Thermal Stress Restrained Specimen Test

Company:	Peab Asphalt AB
Sample:	3599 III
Dimensions of the specimen - mm:	50 x 50 x 250
Date of the test:	24.10.2015
Testing by:	
The set temperature - °C:	10
The period of temperature - min:	15
Cooling rate - °C/hod:	10
Maximum force - kN:	10,61
Maximum stress - MPa:	4,25
Temperature in chamber at crack - °C:	-22,6
Temperature of specimen at crack - °C:	-20,1

