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3rd International Conference on Road and Rail Infrastructure
28–30 April 2014, Split, Croatia

Road and Rail Infrastructure III

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COMPARISON THE CHARACTERISTICS OF AC 8 SURF AND AC 11 SURF AND RESULTS BETWEEN TREE LABORATORIES AT LOW TEMPERATURES

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Abstract

The first part of this paper presents comparison of the characteristics of asphalt concrete AC 8 surf and AC 11 surf, with bitumen B 50/70, at low temperatures. The second part shows the results of international comparison between three laboratories in EU, who carried out the Tensile Stress Restrained Specimen Test (TSRST) and Uniaxial Tensile Strength Test (UTST) in accordance with standard EN 12697-46. In the first part are presented results of the TSRST and UTST tests as a function of the asphalt mixture characteristic (bitumen content and voids filled with bitumen – VFB) and temperature. The analysis of the results has shown that there are certain differences, especially at the higher temperatures of the test. In the second part, it is shown that there are obvious differences in the results at TSRST and UTST test between compared laboratories. Based on these findings, we believe that it would be necessary to do more extensive inter-laboratory analysis to confirm this hypothesis and that there is need to update the standard EN 12697-46 in some points.

Keywords: asphalt concrete, bitumen, low temperatures, cracks

1 Introduction

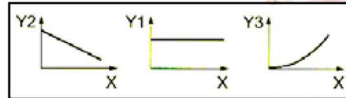
The asphalt samples expand when they are heated and contract when they are cooled. If the contraction due to cooling is prevented with falling temperatures increasing tensile stresses in the asphalt material will be generated, which can lead to fracture (micro-cracking in the binder matrix) if the maximum tensile strength is reached [1]. These damages are primarily due to temperature changes, changes in bituminous binder, excessive traffic load and/or deficiencies in construction and maintenance. So, the knowledge of the behaviour of cracks is essential both for researchers, planners and civil engineers.

This paper presents comparison of the characteristics of asphalt concrete AC 8 surf and AC 11 surf, with bitumen B 50/70, at low temperatures. It shows the results of the Tensile Stress Restrained Specimen Tests (TSRST) and Uniaxial Tensile Strength Test (UTST) as a function of the bitumen content in the asphalt mixture and temperature. In the second part shows the results of international comparison between three laboratories in EU, who carried out the TSRST and UTST in accordance with standard EN 12697-46.

TSRST test simulates the condition of asphalt pavement at low temperatures, where the resulting thermally induced tensile stresses, called cryogenic stress, primarily reflect as transverse cracks spaced at 3 to 5 m (Fig. 1) [2]. UTST test simulates the resistance of asphalt mixtures at low temperatures exposed to traffic loading. The maximum of critical tensile stress does not occur in the wheel track but in a distance of 30 cm to 90 cm from the location of loading (Fig. 2).



Principle:



X ... time

Y1 ... strain

Y2 ... temperature

Y3 ... stress

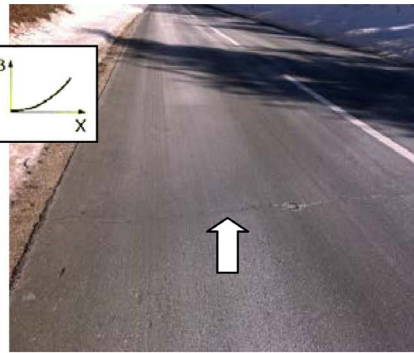
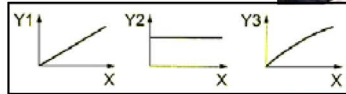


Figure 1 Tensile Stress Restrained specimen Test – TSRST (left) and transversal thermal crack (right) [3]



Principle:



X ... time

Y1 ... strain

Y2 ... temperature

Y3 ... stress

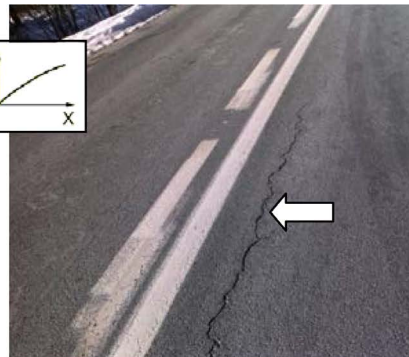


Figure 2 Uniaxial Tensile Strength Test – UTST (left) and longitudinal crack at the wheel tracks (right) [3]

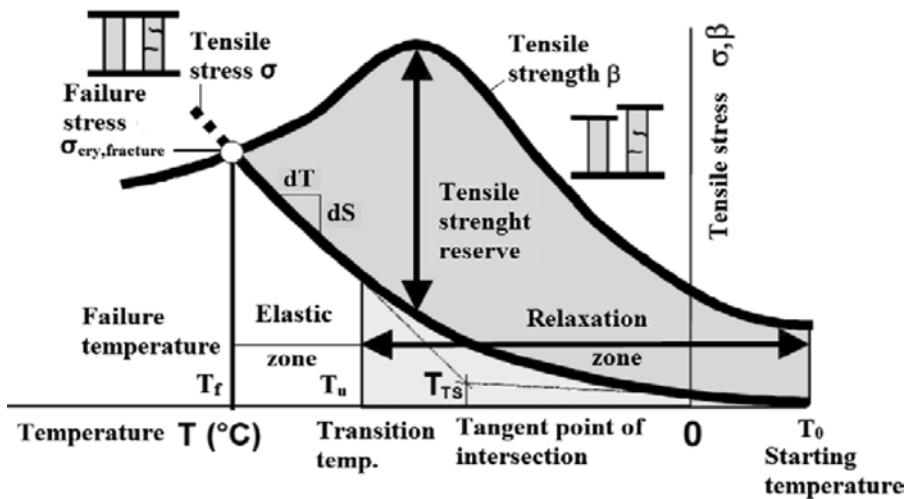


Figure 3 The Arand (1987) concept of tensile stress with relaxation and elastic zone [2, 3, 6]

The [4] concept of tensile stress, tensile strength and tensile strength reserve is shown in Fig. 3. The thermally induced (cryogenic) stress in asphalt specimen gradually increases as temperature decreases, until the specimen fractures [5]. At the break point, the stress reaches its maximum value – the fracture stress $\sigma_{cry,fracture}$ at fracture temperature $T_{failure}$ (hereinafter T_f). At lower temperatures the slope of the stress-temperature curve dS/dT becomes constant, and the curve is linear (elastic behaviour). The transition temperature T_u divides the curve into two parts – relaxation zone and elastic zone (non-relaxation) and tangent point of intersection T_{TS} is intersection between tangent of the stress-temperature curve at elastic zone and relaxation zone. The bitumen in asphalt specimen becomes stiffer when the temperature approaches the transition temperature and the thermally induced stresses are not relaxed below this temperature [6]. The difference between the tensile strength and low temperature stress is known as the tensile strength reserve $\Delta\beta_t(T)$ and it is the reserve that is available to accommodate additional superimposed stresses (traffic induced stress) [5]. Equation for tensile strength reserve is:

$$\Delta\beta_t(T) = \beta_t(T) - \sigma_{cry}(T) \quad (1)$$

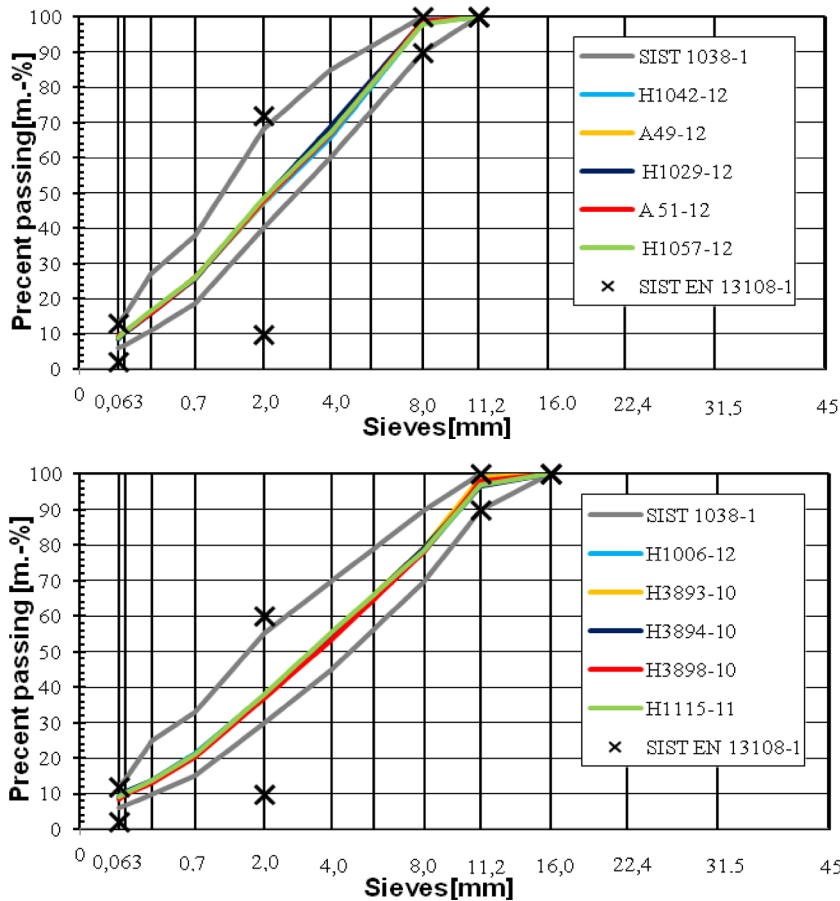


Figure 4 Grain size distribution of AC 8 surf and AC 11 surf

2 Comparison AC 8 surf and AC 11 surf at low temperatures

2.1 Material

The tests were carried out on asphalt concrete 0/8 mm (AC 8 surf) and asphalt concrete 0/11 mm (AC 11 surf). The asphalt mixture and test specimens were prepared in the laboratory ZAG Ljubljana. In the laboratory we prepared five different mixtures with bitumen content of 4.0, 5.0, 5.4, 5.8 and 6.0 (at AC 11 surf), 6.2 (at AC 8 surf) m.-%. Stone fractions used for the stone aggregate mixture are as follows: filler aggregate (grain under 0.125 mm) from Stahovica (limestone), mineral aggregate 0/2, 2/4 and 4/8 mm from Ljubečica (silicate). For binder we used paving grade bitumen 50/70 by MOL (Hungary). Fig. 4 presents grain size distribution for this asphalt mixture AC 8 surf and AC 11 surf. The grain size distributions overlap and it is clear that the filler aggregate was practically constant. For tests we used a rectangular specimen with cross section dimensions 40 x 40 mm² and a length of 160 mm by the EN 12697-46. Table 1 shows properties of used fresh and extracted paving grade bitumen 50/70. Binder was extracted from asphalt with trichloroethylene Infracore Asphalt Analyzer (EN 12697-1). In our research, we decided to try to keep a constant content of filler aggregate in asphalt mixture and to vary air voids. Table 2 presents the results of some basic tests of asphalt mixtures AC 8 surf. Table 3 presents the results of some basic tests of asphalt mixtures AC 11 surf.

Table 1 Properties of paving grade bitumen 50/70

Technical characteristics	Unit	Test method	Fresh bitumen	Extracted bitumen
Penetration at 25°C	mm/10	EN 1426:2007	58	37
Softening point, R&B	°C	EN 1427:2007	50	55.6
Penetration Index, PI	–	EN 12591:2004,B4	-0.4	-0.57
Fraass braking point	°C	EN 12593:2007	-8	-7
Density (in water)	kg/m ³	EN ISO 3838	1020	–
BBR – stiffness S60	°C	EN 14771:2005	-15.6	–
BBR – m-value60	°C	EN 14771:2005	-17.8	–

Table 2 Results of some basic tests of asphalt mixtures AC 8 surf

Bitumen content [m.-%]	Grain size <0.063 mm [m.-%]	Bulk density of Marshall spec. [kg/m ³]	Air voids of Marshall spec. [V.-%]	Voids filled with bit. VFB [V.-%]
4.0	9.1	2411	8.4	53.0
4.9	9.0	2420	6.5	56.7
5.4	8.6	2457	4.6	73.4
5.8	9.1	2442	3.0	76.1
6.2	8.7	2483	2.3	86.7

Table 3 Results of some basic tests of asphalt mixtures AC 11 surf

Bitumen content [m.-%]	Grain size <0.063 mm [m.-%]	Bulk density of Marshall spec. [kg/m ³]	Air voids of Marshall spec. [V.-%]	Voids filled with bit. VFB [V.-%]
3.9	9.3	2404	8.0	62.8
4.9	9.1	2441	5.0	79.4
5.3	9.0	2461	3.8	86.1
5.6	8.6	2467	2.6	92.5
6.0	9.0	2484	1.8	97.9

2.2 Results and analysis

TSRST and UTST test results depending on the content of bitumen in asphalt samples are shown in this section. Intentionally other influences on the results (e.g. equipment, preparation ...) were excluded. In Fig. 5 are shown the results of the test TSRST. The samples of asphalt mixture AC 8 surf have higher tensile stress at failure $\sigma_{cry,f}$ than samples of asphalt mixture AC 11 surf. From almost constant tensile stress it can be concluded that the content of bitumen in the asphalt mixture does not significantly effect on tensile stress. As it was expected temperature tensile stress T_f results for asphalt mixture AC 8 surf is lower than for AC 11 surf, due to higher content of grains under 2 mm.

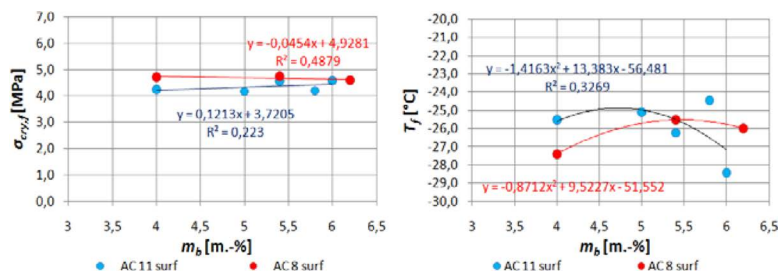


Figure 5 Tensile stress of failure $\sigma_{cry,f}$ (left) and failure temperature T_f (right) results depending of the bitumen content (TSRST test)

Differences between asphalt mixture AC 11 surf and AC 8 surf at UTST test are small when tensile strength β_t is measured (Fig. 6). At test temperature $+20^\circ\text{C}$ the tensile strength β_t of both asphalt mixtures is similar. At lower test temperatures the tensile strength of AC 8 surf samples is becoming higher compared with AC 11 surf. It is assumed that larger grains of aggregate take more strength at higher temperature. From almost constant tensile strength it can be concluded that the increasing of bitumen content in the asphalt mixture does not significantly effect on tensile strength in the zone of optimal bitumen content.

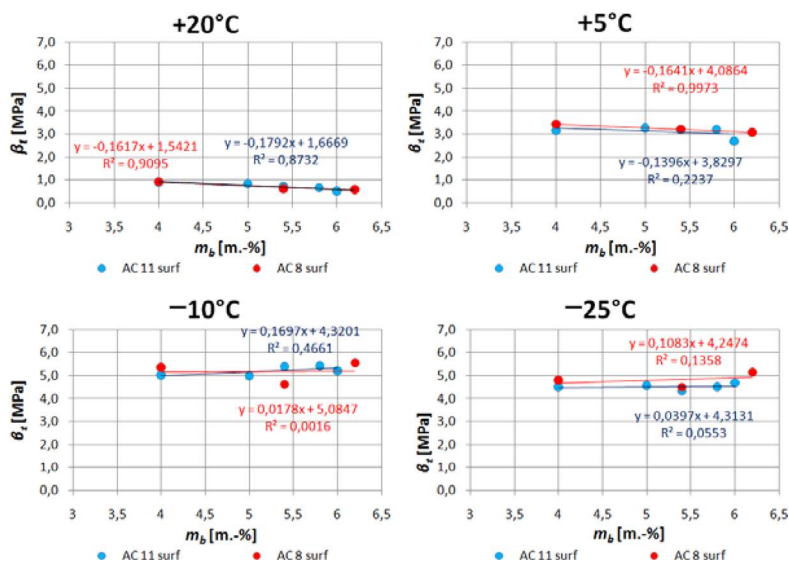


Figure 6 Tensile strength β_t results depending of the bitumen content m_b (UTST test)

There is some dependency between failure strain ϵ_t – and content of bitumen m_b at higher temperatures (Fig. 7). At test temperature +20 °C and +5 °C we see that the content of bitumen has influence on strain. Also the differences between AC 8 surf and AC 11 surf are obvious at these temperatures. The asphalt mixture AC 8 surf has higher strain ϵ_t then AC 11 surf. At test temperature –10 °C and –25 °C the stiffness of both mixtures is a similar and elastic. Failure strain is more related to the properties of material than strength, but in the standard only tensile strength β_t is required.

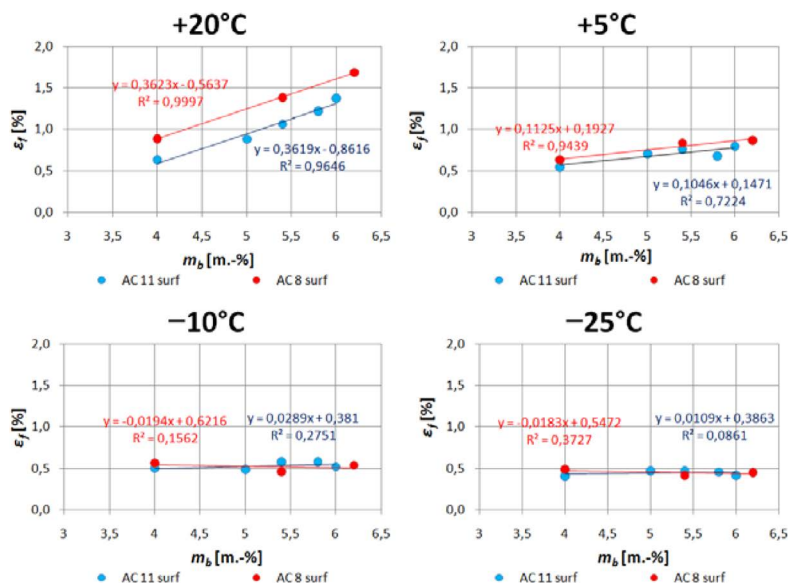


Figure 7 Failure strain depending of the bitumen content between AC 8 surf and AC 11 surf at UTST test

Fig. 8 shows the results of maximum tensile strength reserve $\Delta\beta_{tmax}$ and temperature at maximum tensile strength $T_{\Delta\beta_{tmax}}$. Only temperature at maximum tensile strength $T_{\Delta\beta_{tmax}}$ is significantly different for both asphalt mixtures. The results for asphalt mixture AC 11 surf are better, because of higher values of VFB in the mixture.

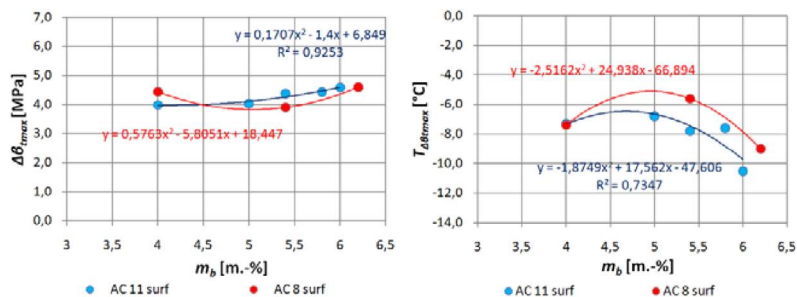


Figure 8 Maximum tensile strength reserve $\Delta\beta_{tmax}$ (left) and temperature at maximum tensile strength $T_{\Delta\beta_{tmax}}$ (right) results depending of the bitumen content m_b

3 Comparison between tree laboratory at low temperatures

In this section is presented inter-laboratory comparison between three independent laboratories in EU. Laboratory 1 is TU WIEN from Austria, Laboratory 2 is ZAG Ljubljana from Slovenia and third Laboratory 3 is RAMTECH from Croatia. All three laboratories carried out low temperature tests according to standard EN 12697-46. All AC 8 asphalt mixtures and test specimens were prepared in Slovene laboratory. The asphalt samples tested in Laboratory 1 had 5.0 m.-%, 5.8 m.-% and 6.2 m.-% of bitumen, asphalt samples tested in Laboratory 2 had 4.0 m.-%, 5.4 m.-% and 6.2 m.-% of bitumen and asphalt samples tested in Laboratory 3 5 m.-% and 5.8 m.-% of bitumen.

In Fig. 9 are presented diagrams of TSRST tests carried out in all three laboratories. The results from Laboratory 1 are presented with red curves, results from Laboratory 2 with blue curves and from Laboratory 3 with green curves. From Fig. 9 two basic shapes of curves can be seen. The first type of curves are coming from Laboratory 2 with 4 m.-%, 5.4 m.-%, 6.2 m.-% and Laboratory 3 with 5.0 m.-% of bitumen content. The second type of curves are coming from Laboratory 1 and one curve from Laboratory 2 with 5.8 m.-%. Common to second type of curves is that they all have temperature of failure T_f under -31 °C, on the contrary first type of curves doesn't reach less then -27 °C. So, the results are out reproducibility limits required by standard EN 12697-46 ($\Delta T_f = 2$ °C). The tension stress (at all curves with equal content of bitumen) are inside reproducibility limits required by standard ($\Delta \sigma_{cry} = 0.5$ MPa). Relaxation zone at second type of curves is longer, representing better behaviour of material at low temperatures.

Results of UTST tests are shown in Fig. 10. The highest maximum of tensile strength β_t and the steepest slope of curves were measured in Laboratory 1 (red curves). On the contrary in Laboratory 3 (green curves) the lowest maximums of tensile strength β_t were measured. The differences between results from these two laboratories are significant due to the fact that they both used the same type of test equipment.

The curves of tension strength reserve for all laboratories are presented in Fig. 11. As it was expected from results of UTST tests the highest maximum of tensile strength reserve $\Delta \beta_{tmax}$ were obtained in Laboratory 1 (red curves) and the lowest in Laboratory 3 (green curves).

In Laboratory 1 were obtained significantly better results for low temperature resistance than in other two laboratories. All samples were prepared in the same way, so influence of the sample preparation on the results was minimized. The only difference we noticed was at gluing samples. All this three laboratories has different procedure of gluing samples. In standard EN 12697-46 procedure of gluing samples is not described precisely enough.

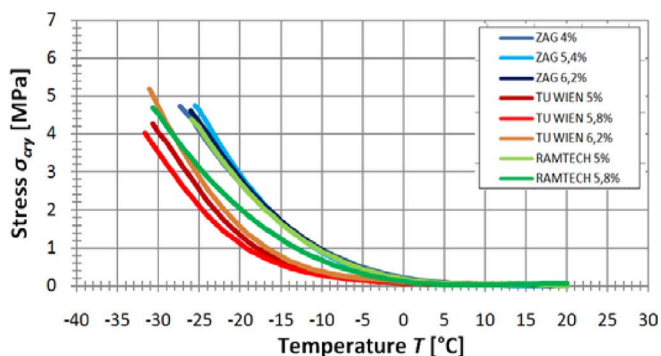


Figure 9 Diagram of a TSRST (tensile stress – temperature) test for AC 8 surf

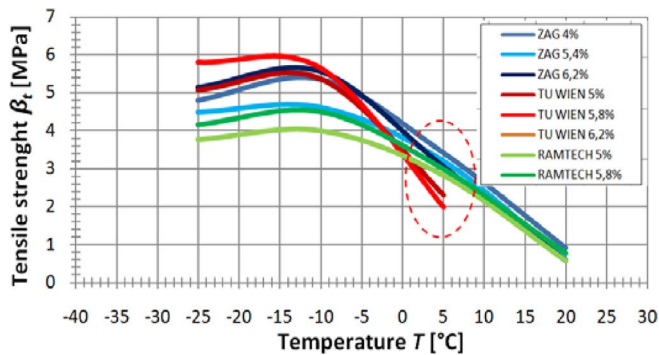


Figure 10 Diagram of a UTST (tensile strength – temperature) for AC 8 surf

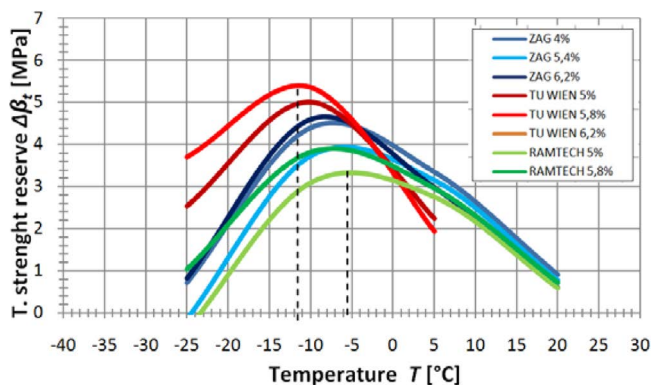


Figure 11 Diagram of a tensile strength reserve – temperature for AC 8 surf

4 Conclusion

The first part of this paper is presented comparison of the characteristics of asphalt concrete AC 8 surf and AC 11 surf, with bitumen B 50/70, at low temperatures. The results of the Tensile Stress Restrained Specimen Tests (TSRST) and Uniaxial Tensile Strength Test (UTST) as a function of the bitumen content in the asphalt mixture and temperature were studied.

With this study mostly insignificant differences between low temperature properties of these two asphalt mixtures were found. Only at test temperature +20 °C (UTST) significant differences between AC 8 surf and AC 11 surf were found. Variation in the bitumen content in the mixture has minor influence on tensile stress or tensile strength in the range of the optimal bitumen content. At test temperature +20 °C and +5 °C it was found that the content of bitumen has influence on strain. Failure strain is more related to the properties of material than strength, but in the standard EN 12697-46 only tensile strength β_t is required.

In this section is presented inter-laboratory comparison between three independent laboratories in EU, where TSRST and UTST tests were carried out. We found out that two laboratories have the same equipment, but different results were obtained. All samples were prepared in the same way, so influence of the sample preparation on the results was minimized. The only difference we noticed was at gluing samples. All this three laboratories has different glue and procedure of gluing samples. At this point standard EN 12697-46 is not precise enough. In the standard it would be necessary to more accurately describe the glue, who have constant properties (coefficient of expansion) in the range of test temperature.

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