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Stress analysis of asphalt mixture in the indirect tensile strength test

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Abstract. Nowadays asphalt mixture is the most used material in the construction and reconstruction of roads. It is used for its advantages, such as availability of materials, flexibility and no need for dilatation. However, the asphalt mixture has one disadvantage, namely temperature sensitivity. At different temperatures it exhibits different physical-mechanical properties. For a better understanding of the physical-mechanical properties of the asphalt mixture, we can use complex rheological models. Complex rheological models can describe the viscoelastic behaviour of the asphalt mixture with a high prediction. Laboratory tests are required to determine input values for complex rheological models. The article is focused on the analysis of asphalt mixture in the indirect tensile strength test and compare with numerical solution.

1. Introduction

Asphalt mixture is a relatively complex material in terms of determining its physical-mechanical properties. It is a composite that consists of several road materials. These materials which are used in asphalt mixture exhibit different physical-mechanical properties [4]. Therefore, the asphalt mixture is assignment to viscoelastic materials. The filler is aggregate which have low internal damping approaching zero and thus can be classified as a material with high stiffness. Binder is asphalt obtained by crude oil, asphalt lakes or asphalt mines (Gilsonite). Asphalt is a substance that causes the asphalt mixture to be classified as viscoelastic material [1, 2]. Substances in this category are characterized by a change their physical-mechanical properties when the temperature is changed [4, 11]. This results have a change in the physical-mechanical properties of the asphalt mixture as the temperature changes. At minus temperatures it becomes a solid with a high complex modulus [11,12]. At the plus temperatures its physical-mechanical properties changes and the value of the complex module decreases. The asphalt mixture becomes viscoelastic material. Internal damping is higher and closer to value one. Finally, we have additives and admixtures that improve the asphalt mix properties and thus eliminate the negative properties of the asphalt binder.

Because of the composition already mentioned, there is a complication in testing asphalt mixtures. The use of aggregates of uneven shape as fillers results in uneven deposits during compaction. This results in a slight asymmetry in some laboratory tests. The asphalt mixture also changes its physical-mechanical properties mainly due to temperature changes. It is therefore important to carry out a large number of measurements at different temperatures and different types of stress [4]. This article focuses on the static analysis of asphalt mixture in the indirect tensile strength test. On the Marshall sample under laboratory conditions, the decrease of the applied force was observed over time under constant deformation.



2. Materials

Asphalt mixture with label AC16L was used for the test. The mixture was prepared in laboratory conditions with a specified composition (table 1). Aggregate was used from the stone pit Hradova (table 2).

Table 1. Asphalt mixture AC 16L.

Mixture	Max. aggregate fraction	Layer	Type binder	Softening point [°C]	Penetration (25°C, 100g, 5s)/0.1 mm
Asphalt mixture	16	Bounding layer	50/70	49.5	51

Table 2. Aggregate fraction.

Composition of asphalt mixture	Aggregate fraction [mm]				Asphalt binder	Additive
	Stone meal	11 - 8	8 - 4	4 - 0		
Percentage of total quantity [%]	6.6	17.9	19.8	49.9	5.79	0.01

3. Method of laboratory test

Test sample of standard dimensions (figure 1) was subjected to indirect tensile strength stress. The diameter D on the test samples averaged 100.5 mm and the thickness H averaged 68.2 mm.

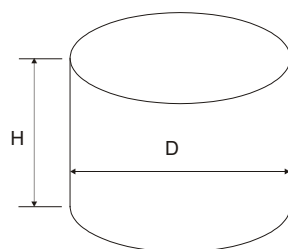


Figure 1. Marshall sample.

The essence of the test is in inducing indirect tension in the test sample. Pressure is applied to the body according to figure 2.

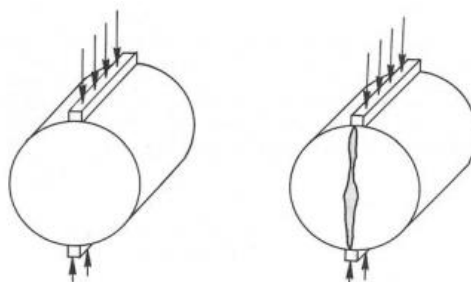


Figure 2. Marshall sample – action force.

For the determination of stress in the middle of the sample was use theoretical relation [7]. The tension intensity is influenced by the dimensions of the loading area. This area is determined by the standard. For the calculation of tensile stress, we can use 1st equation (1) and for the calculation of the compression stress we can use 2nd equation (2):

$$\sigma_{tension} = \frac{2P}{\pi \cdot a \cdot H} \left(\sin 2\alpha - \frac{a}{2R} \right) \quad (1)$$

$$\sigma_{compression} = \frac{6P}{\pi \cdot a \cdot H} \left(\sin 2\alpha - \frac{a}{2R} \right) \quad (2)$$

where

P – Force [kN],

a – Loading area [m],

H – Thickness [m],

R – Radius [m],

The geometrical quantities in equation 1st and 2nd and the theoretical stresses along the sample body cross-section are shown in figure 3.

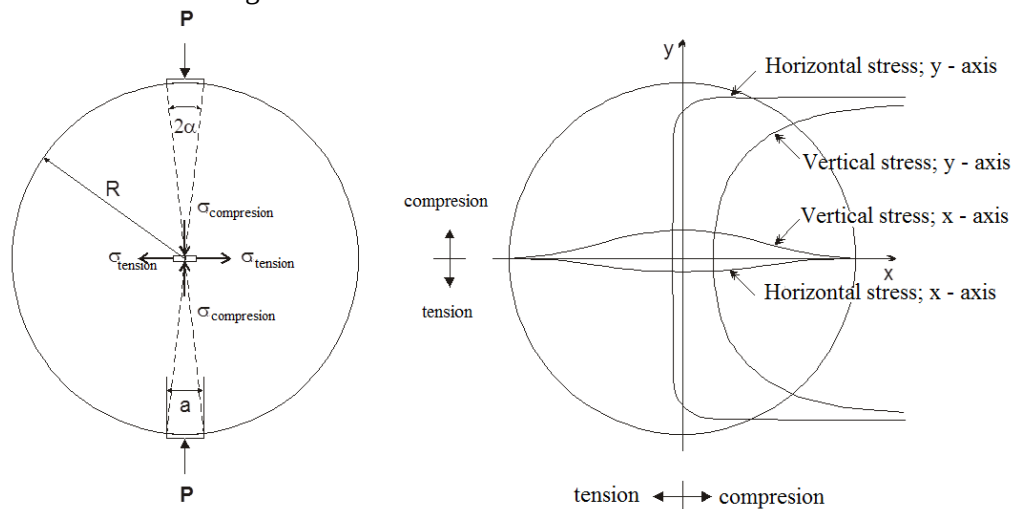


Figure 3. Stresses in the sample body.

4. Procedure of the test

Measurement was realised using hydraulic press device labelled FU160. This hydraulic press has the required sensitivity of the deformation record and allows adjustment of the continuous course of the load intensity. Test sample was measured in one load cycles and consisted of 6 load steps. Figure 4 shows the course of loading of the test sample in a single load cycle. The rate of deformation increase was 0.2 mm/s. Deformation was kept at 0.5 mm for 10 s. Thereafter, the deformation value dropped to 0 mm, which was kept for 20 s.

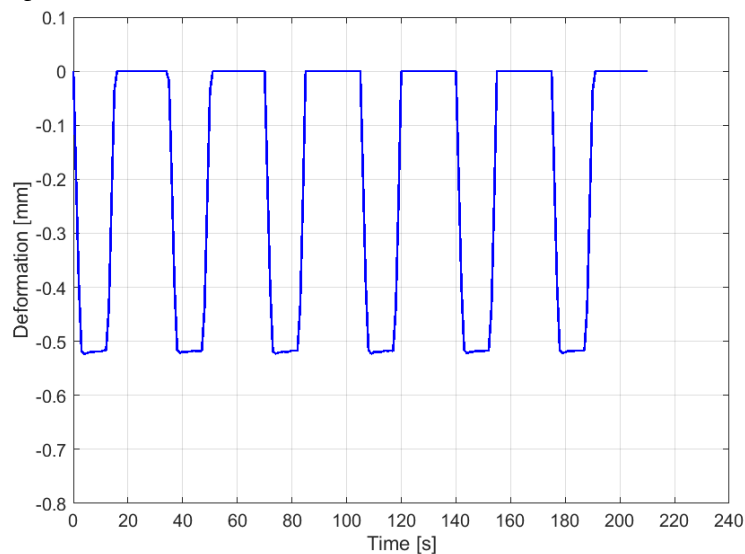


Figure 4. Test run.

5. Results

It is possible to see that force changed (decreasing tendency) during the duration of the selected constant deformation. In the first load step, the highest force was recorded. In the next load steps, force was lower.

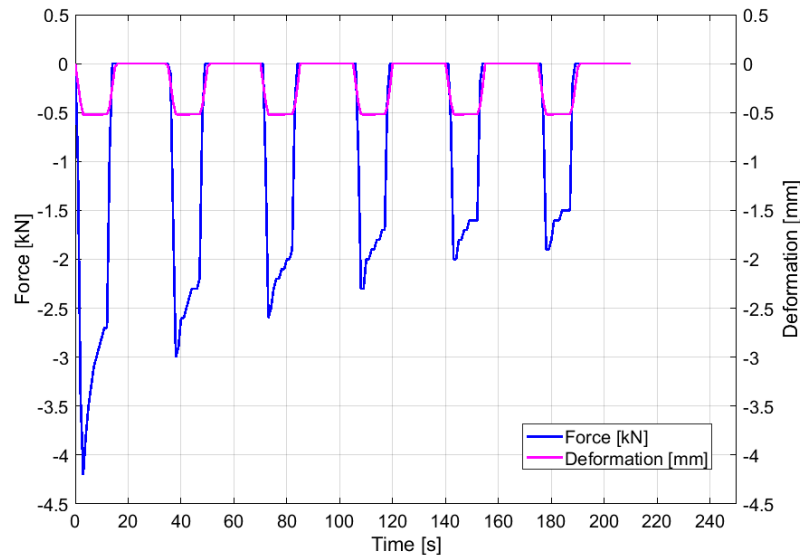


Figure 5. The force changes over time.

The force observed in the test was used to calculate the stress in the center of the sample. Tensile strength stress was calculated with 1st equation and compressive stress was calculated with 2nd equation. Software Abaqus was used to calculate and the results. The results were compared to those obtained by analytical solution. The test and numerical model with basic parameters was made in the program [9, 10]. The values in technical regulation were used as material properties [3]. Figure 6 shows the results from the 1st load cycle. In the plot stress values calculated using 1st and 2nd equation and software Abaqus are compared. At tensile stress there are smaller deviations between the calculated values with equation and the values from Abaqus. On the contrary, at compression stress the value is almost identical.

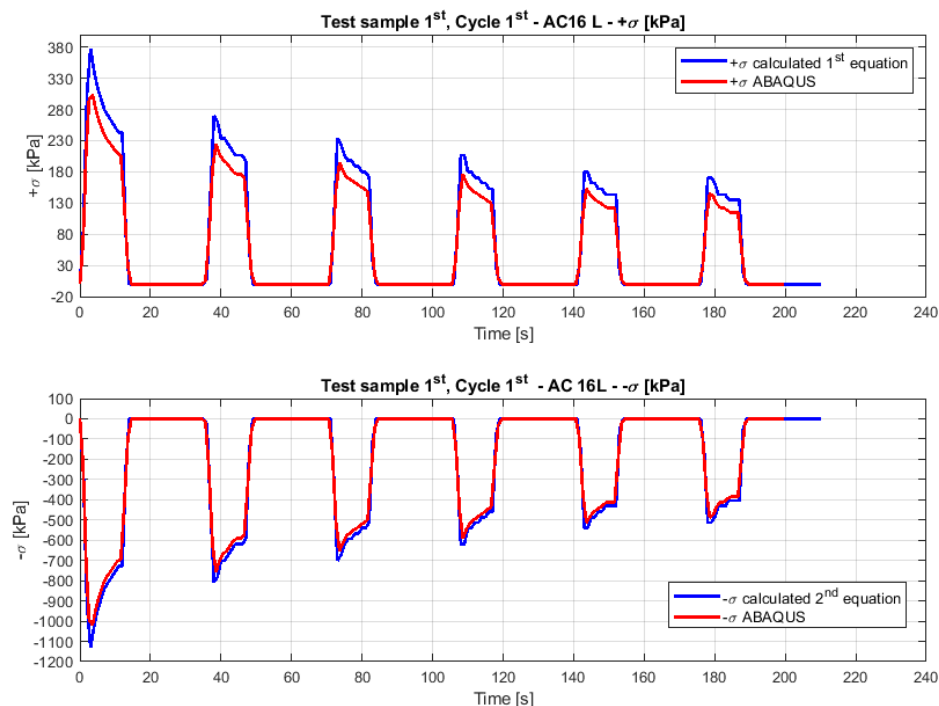


Figure 6. 1st cycle – compare stress.

6. Conclusion

From the results obtained in this study of the asphalt mixture subjected to indirect tensile stress we can conclude that:

1. For the tested sample subjected to indirect tensile loading, the load force decreased at the selected permanent deformation. This points to the fact that the asphalt mixture does not behave as a linear elastic material and Hook's law cannot be applied [15].
2. The observed non-linear material behaviour leads to rheological models.
3. Comparison of the stress results obtained from laboratory measurements and theoretical models shows the non-linear behaviour of road asphalt mixtures [10,13].

By evaluating given results from numerical and experimental measurements on asphalt mixture stressed by indirect tensile, it leads to the opinion that a rheological model that describes more accurately the behaviour of the material is more suitable for describing the physical-mechanical properties of the asphalt mixture [10,13,14].

7. References

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