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ASSESSMENT OF IMPACT OF THE RHEOLOGICAL PARAMETERS CHANGE ON SENSITIVITY OF THE ASPHALT STRAIN BASED ON THE TEST RESULTS

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Abstract

The creep test under the static loading, that allows to determine rheological properties of asphalt based on the creep curve, is the most effective test nowadays. Applied loads are non-destructive and allow to observe the course of the strain after the test load. The test can be carried out on compressing, shearing, bending as well as on triaxial test, that depends on the applied apparatus implementing different intensity [1, 2, 3, 4, 5, 6].
Based on the creep test, the stress of different properties can be specified. Among them there are valuable rheological properties based on selected viscoelascity models [1].
The properties of the viscoelascity models are relevant indexes depicting resistance to deformation. They can be used to forecast the wheel-truck in the accepted rheological model [1]. In this article it is shown the impact of different rheological properties of the viscoelacity model on the wheel-truck as well as the impact of different properties on shape and the course of the creep curve.
The asphalt mixtures presented in this article are characterized by variable rheological properties. It is therefore difficult to determine which property mostly affects the size of the strain. However, the authors of this article attempted to analyse the change of the asphalt strain value of the different variables in particular rheological model, called Bürgers's model.

Keywords: rheological parameters, rheological models, creep test under the static loading, deformation of asphalt mixture

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1. INTRODUCTION

The tested asphalt concrete samples were intended for a wearing course and the traffic category KR 1-2. This kind of asphalt is a bituminous mixture of asphalt and concrete (AC). Analysed creep test with pressing under static load was carried out without side restraint.
The following composition of the asphalt concrete was used to prepare the samples [7]:

- basalt chippings - 41.67%, grading - 0.063/11,2 mm;
- granite chippings - 18.94%, grading - 0.063/2,0 mm;
- Sand - 25.57%, grading - 0.063/2.0 mm;
- stone dust - 8.52%, grading < 0,063 mm;
- asphalt D - 35/50 - 5.30%.

The conditions of the test were in accordance with the recommendations of international colloquium (Zurich, 1977) [8]. One of the assumptions was that the creep with respect to the bodies is characterized by both limited and unlimited strain when there is limited and unlimited load regardless the time of the duration.

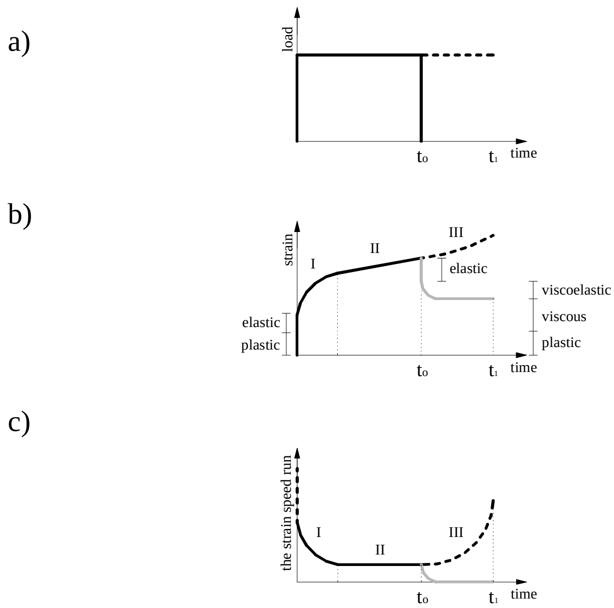


Fig. 1. The strain **course** and the strain speed depending on time [1, 7]:
a) the load course depending on time ; b) the strain course run depending on time;
c) the strain speed course depending on time

Technical conditions adopted in the creep test [9]:

- static load: 0.1 MPa ± 0.3 %,
- duration of load: 3600 s ± 5 s (Nottingham Asphalt Tester),
- duration of relief: 300 s ± 5 s (Nottingham Asphalt Tester),
- test temperature: 40°C ± 0.5°C,
- preload: 2% of static load for 120 seconds,
- dimensions of cylindrical samples: height 100 mm ± 2 mm, diameter 101 mm ± 0.2 mm.

It was adopted in the tests that the asphalt is viscoelastic matter and there are only viscous, elastic and viscoelastic strain. The load time in the creep test, is the time where the speed of strain is constant, the creep is steady, whereas the relief time is the time where the speed of strain equals zero, strain is constant. The identification of the rheological parameters in the Bürgers's model was made on the basis of mentioned test. The identification was conducted for uniavial state with constant load and relief [7].

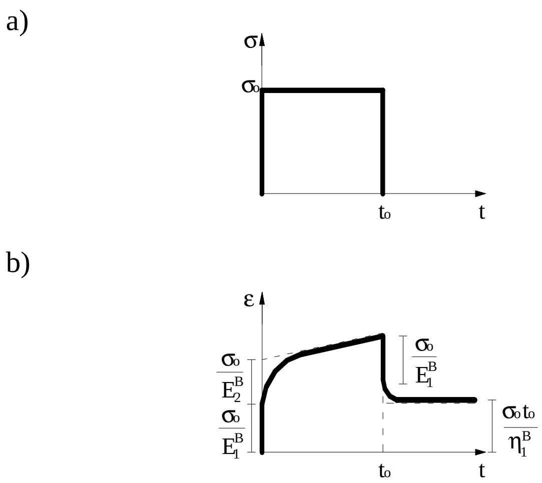


Fig. 2. The creep curve in Bürgers's rheological model [1, 7]:
a) stress course in time ; b) strain course in time (creep curve).

The interpretation of the rheological parameters was based on the best approximation of the creep curve derived from the laboratory test with the curve specified for the viscoelastic model. The following function was used to designate it [1, 7]:

$$\Delta_i^{\,p}=\frac{\sqrt{\dfrac{\sum_{i=1}^{i=l}(\varepsilon_{ti}-\varepsilon_{li})^2}{l}}}{\dfrac{\sum_{i=1}^{i=l}\varepsilon_{li}}{l}}*100\%$$

where:

Δ_i^p is the approximation error of creep [%],

ε_{li} is the strain measured on sample [-],

ε_{ti} is the strain measured for the model [-],

l is the number of measured points.

The approximation of the creep curve in Bürgers's rheological model consisted of minimalization of the above mentioned function and obtaining the smallest error. This determined function was an error for measured points. All the approximation errors were determined by using the supplement to Microsoft Excel - Solver. Detailed description of the study are shown in [7].

2. ANALYSIS OF THE RESULTS OF THE INFLUENCE OF THE RHEOLOGICAL PARAMETERS ON THE STRAIN

Table 1 shows the variability of rheological properties for Bürgers's rheological model. The intervals were used to record and analyse the strain in this particular model when changing the selected properties.

Table 1. The range of the rheological variability for the selected model [7]

model	parameter	range
Bürgers's	E_1^B [Pa]	6,26E+06 - 1,57E+08
	η_1^B [Pas]	6,50E+10 - 1,63E+12
	E_2^B [Pa]	4,86E+07 - 1,22E+09
	η_2^B [Pas]	2,86E+09 - 7,15E+10

Table 2 contains the rheological parameters for the exemplary test that was made for the asphaltic concrete used in wear layers. The average values of individual parameters are selected for this test [7].

Table 2. The rheological parameters for analysed model and exemplary test [7]

model	parameter	value
Bürgers's	E_1^B [Pa]	3,13E+07
	η_1^B [Pas]	3,25E+11
	E_2^B [Pa]	2,43E+08
	η_2^B [Pas]	1,43E+10

2.1. The results of the variation of one parameter

Fig. 3 and 4 show the demands of Bürgers's model for rheological parameters and the strain calculated 1400 seconds later after having changed one parameter. In addition, the approximate strain results are shown by using linear and exponential function. The sensitivity of the parameters to strain value is expressed as a derivative of strain after the consider parameter. The results for the exemplary test is shown in Figure 3.

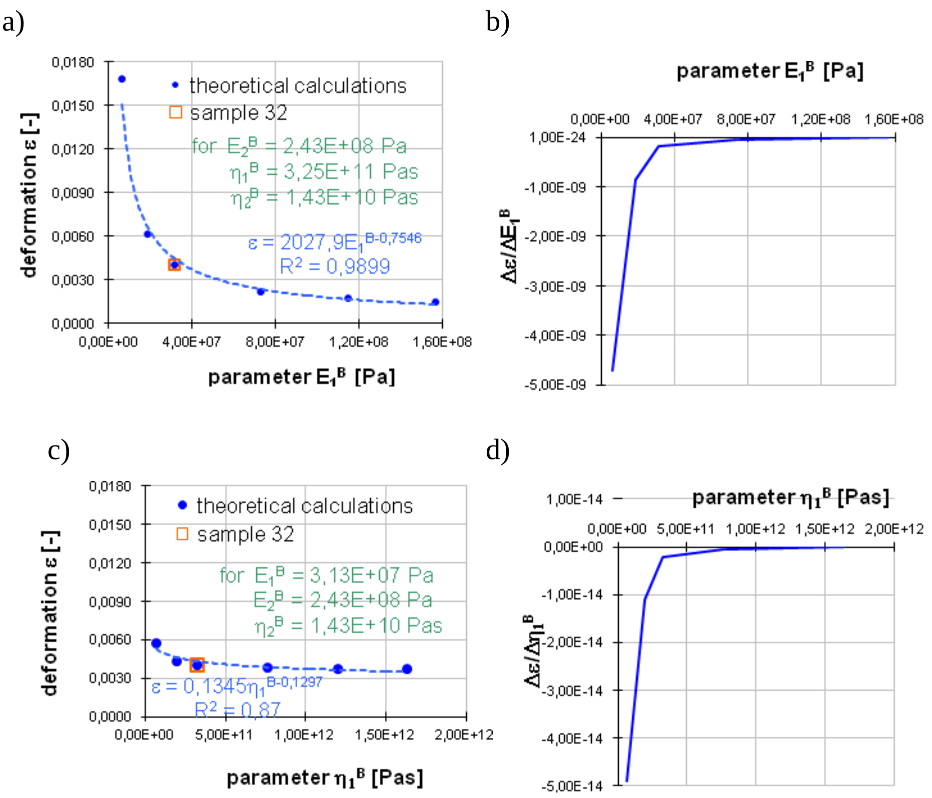


Fig. 3. The dependence of the rheological parameters of the Bürgers's model calculated the strain 1400 seconds after load and sensitivity analysis using the derivative of the approximation function [7]:
a) deformation - parameter E_1^B b) sensitivity analysis for parameter E_1^B
c) deformation - parameter η_1^B d) sensitivity analysis for parameter η_1^B

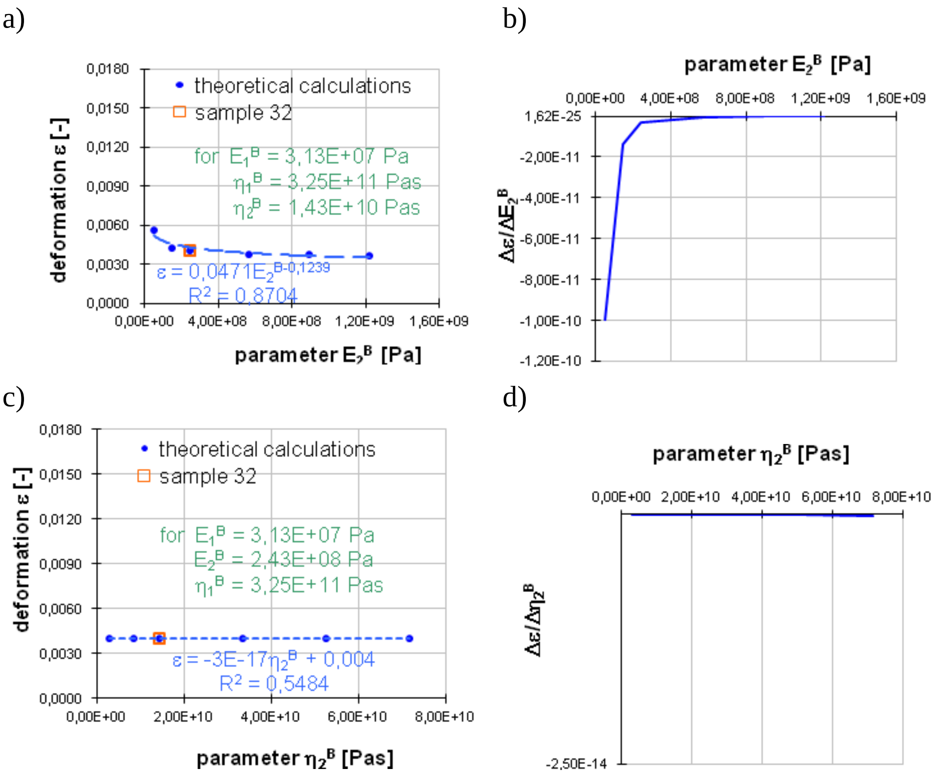


Fig. 4. The dependence of the rheological parameters of the Bürgers's model calculated strain 1400 seconds after load and sensitivity analysis using the derivative of the approximation function [7].

a) deformation - parameter E_2^B b) sensitivity analysis for parameter E_2^B

c) deformation - parameter η_2^B d) sensitivity analysis for parameter η_2^B

During the analysis of the above results, it can be seen that the parameter E_1^B has the greatest impact on the strain in Bürgers's model. The value change of this particular parameter in considering interval (6.26E+06 - 1.57E+08) caused the change of strain of 91.21 %. The parameters η_1^B i E_2^B have the similar effect on the strain (35.92 % and 34.58 %). Whereas the parameter η_2^B does not have any effect on the strain after 1400 seconds.

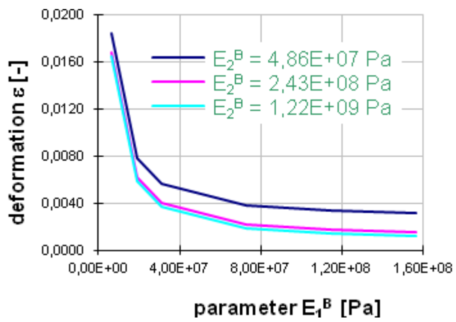
Considering the graphs of the sensitivity, it can be seen that the derivative of the function takes the greatest values for the same parameters in the same intervals, in which their values changes caused the biggest strain.

2.2. The results of the variation of the two parameters

Fig. 5 and 6 show the dependence of the rheological parameters of the Bürgers's model calculated stain after 1400 seconds of load while changing two parameters. These calculations allowed to obtain a complete picture of the impact of the parameters on the strain.

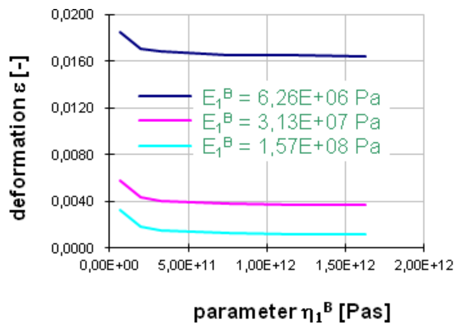
a)

for η_1^B = 3.25E+11 Pas, η_2^B = 1.43E+10 Pas



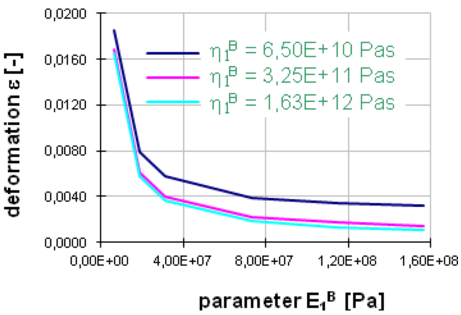
b)

for E_2^B = 2.43E+08 Pa, η_2^B = 1.43E+10 Pas



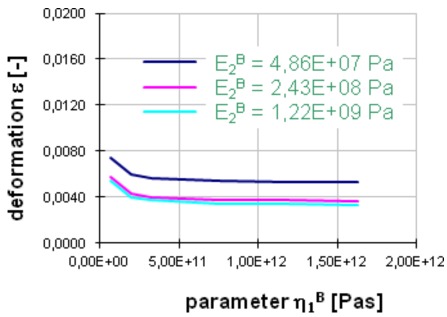
c)

for E_2^B = 2.43E+08 Pa, η_2^B = 1.43E+10 Pas



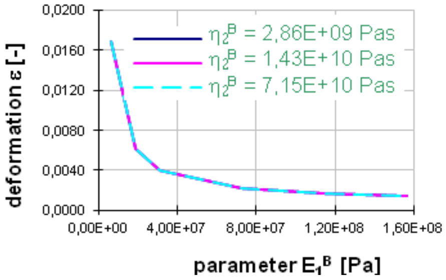
d)

for E_1^B = 3.13E+07 Pa, η_2^B = 1.43E+10 Pas



e)

for η_1^B = 3.25E+11 Pas, E_2^B = 2.43E+08 Pa



f)

for E_1^B = 3.13E+07 Pa, E_2^B = 2.43E+08 Pa

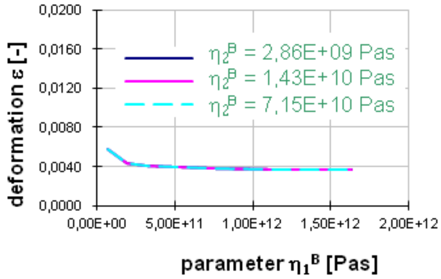
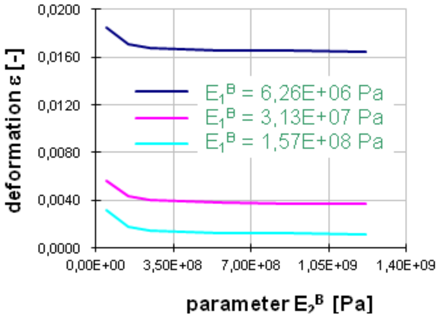


Fig. 5. The dependence of the rheological parameters of the Bürgers's model calculated strain after 1400 seconds of load when changing two [7]:

a) deformation - parameters E_1^B and E_2^B b) deformation - parameters η_1^B and E_1^B
c) deformation - parameters E_1^B and η_1^B d) deformation - parameters η_1^B and E_2^B
e) deformation - parameters E_1^B and η_2^B f) deformation - parameters η_1^B and η_2^B

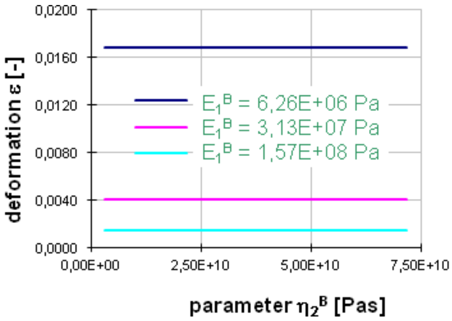
a)

for η_1^B = 3.25E+11 Pas, η_2^B = 1.43E+10 Pas



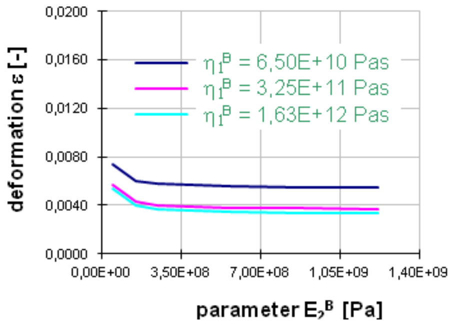
b)

for η_1^B = 3.25E+11 Pas, E_2^B = 2.43E+08 Pa



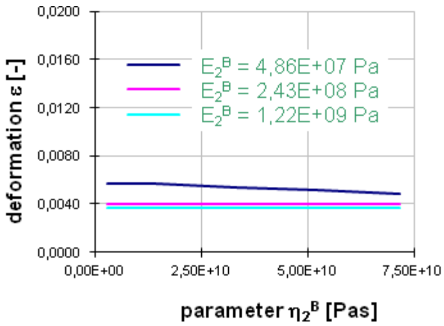
c)

for E_1^B = 3.13E+07 Pa, η_2^B = 1.43E+10 Pas



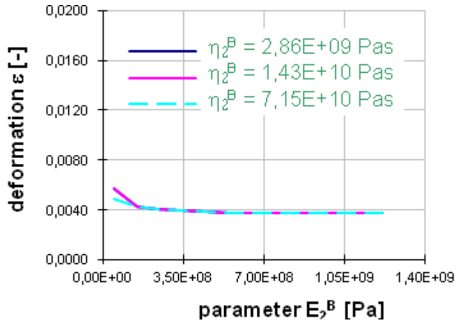
d)

for E_1^B = 3.13E+07 Pa, η_1^B = 3.25E+11 Pas



e)

for E_1^B = 3.13E+07 Pa, η_1^B = 3.25E+11 Pas



f)

for E_1^B = 3.13E+07 Pa, E_2^B = 2.43E+08 Pa

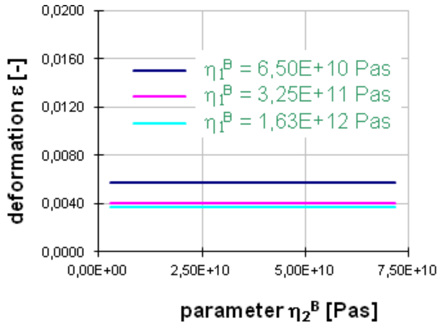


Fig. 6. The dependence of the rheological parameters of the Bürgers's model calculated strain after 1400 seconds of load when changing two parameters[7].
a) deformation - parameters E_2^B and E_1^B b) deformation - parameters η_2^B and E_1^B
c) deformation - parameters E_2^B and η_1^B d) deformation - parameters η_2^B and E_2^B
e) deformation - parameters E_2^B and η_2^B f) deformation - parameters η_2^B and η_1^B

As shown in Fig. 5 and 6, parameter E_1^B has significant effect on strain when changing two parameters in different configurations. At the same time, changing any other parameter causes a significant change in strain. The parameter is E_2^B is the second parameter that has an effect on the strain size. A similar effect on the strain has the parameter η_1^B. It was also found that the parameter η_2^B does not affect the strain value regardless of the configuration of the other parameters.

3. ANALYSIS OF THE RESULTS OF THE INFLUENCE OF THE RHEOLOGICAL PARAMETERS ON THE CREEP CURVE

The shape and the course of the creep curve was analysed using the rheological parameters form the range in Table 1. The course of the creep curve according to changing parameters of Bürgers's model are shown in fig. 7.
The range of variation of rheological parameters were taken from Table 1. Elastic change was observed for E_1^B parameter in Bürgers's model, whereas changing parameter E_2^B, the strain value changed as well. The change of parameter η_1^B in Bürgers's model causes the permanent strain change. The influence of parameter η_2^B is not so significant, the convexity has been noticed.

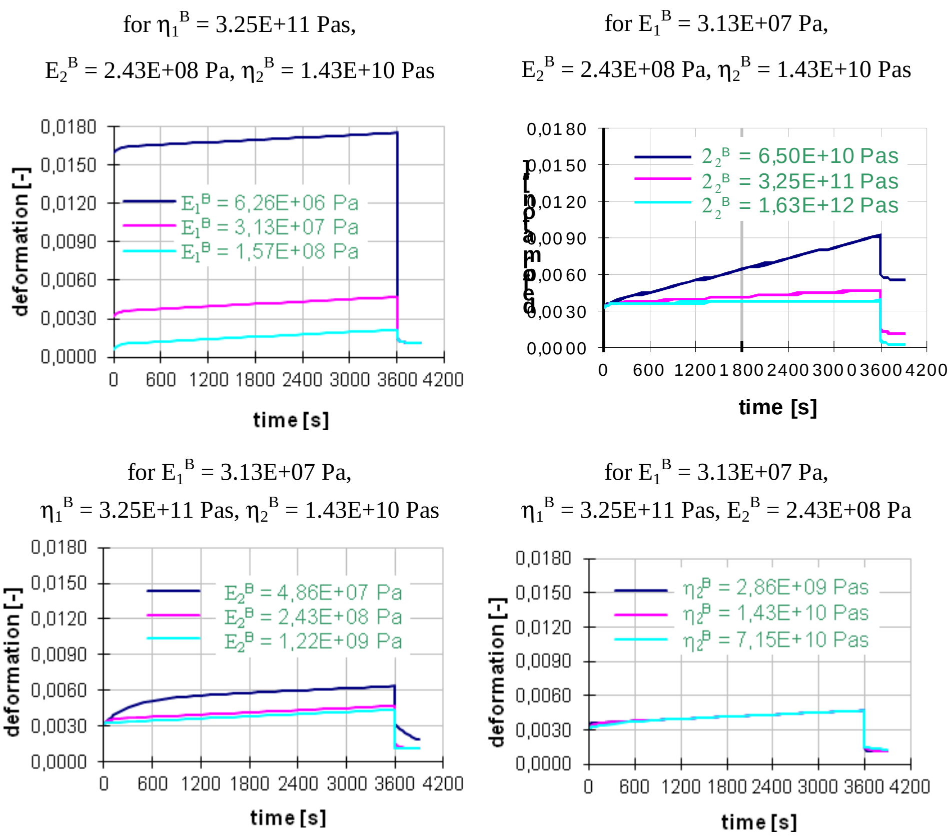


Fig. 7. The course of the creep curve according to change of the Bürgers's model parameters [7].

4. SUMMARY

This article attempted to analyse the results of the influence of rheological parameters on the value of the strain when changing one and two rheological parameters in selected viscoelasticity model that is Bürgers's model. The second part of the article contains the information about the analysis of the results of research on the influence of rheological parameters on the static creep curve.

The analysis allows to identify which rheological model parameters have a significant influence on the size of the permanent deformation. The range of a variation of rheological parameters in the analysis came from a range of parameter values characterizing the asphalt test.

It can be seen from the graphs presented in this article that the strain and the course of creep of changes in the depth of the rheological parameters depend on the value of elastic modulus and coefficient of viscosity.
The greatest influence on the strain size have parameter E_1^B (immediate modulus, in range 6.26E+06 - 7.30E+07 Pa) and η_1^B (viscosity coefficient, in range 6.50E+10 - 3.25E+11 Pas).
When analysing the strain of asphalt (permanent deformations), the above parameters need to be taken into account, because they provide the sensitivity of asphalt to the strain.

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OCENA WPŁYWU ZMIANY PARAMETRÓW REOLOGICZNYCH NA WRAŻLIWOŚĆ DEFORMACJI MIESZANEK MINERALNO - ASFALTOWYCH NA PODSTAWIE WYNIKÓW BADAŃ

S t r e s z c z e n i e

Badanie pełzania pod obciążeniem statycznym jest obecnie najbardziej efektywnym badaniem pozwalającym na określenie reologicznych parametrów mieszanek mineralno - asfaltowych na podstawie krzywej pełzania. Stosowane obciążenia mają poziom nieniszczący i pozwalają na obserwację przebiegu odkształceń w czasie również po odciążeniu. Badanie może być realizowane przy ściskaniu, ścinaniu, rozciąganiu i zginaniu, a także w zakresie trójosiowym, w zależności od stosowanego aparatu realizującego zadany schemat naprężeń [1, 2, 3, 4, 5, 6].
Na podstawie badania pełzania można określić parametry oparte o różne teorie pełzania a szczególnie cenne parametry reologiczne w oparciu o wybrane modele lepkosprężyste [1].
Parametry z modeli lepkosprężystych są miarodajnymi wskaźnikami obrazującymi odporność mieszanek na deformacje. Można za ich pomocą prognozować głębokości koleiny w przyjętym modelu reologicznym [1]. W niniejszym artykule przedstawiono jaki wpływ na głębokość koleiny mają różne wartości parametrów reologicznych z analizowanego modelu lepkosprężystego oraz wpływ parametrów na kształt i przebieg krzywej pełzania.
Przedstawione w artykule mieszanki mineralno - asfaltowe charakteryzują się zmiennymi parametrami reologicznymi, zatem trudno jest określić, który parametr decyduje o wielkości odkształcenia danej mieszanki. Mając na uwadze powyższe, w artykule podjęto próbę analizy zmiany wartości odkształcenia mieszanki mineralno – asfaltowej przy zmianie jednego oraz dwóch parametrów w danym modelu reologicznym – w tym przypadku - Bürgersa.

Słowa kluczowe: parametry reologiczne, modele reologiczne, badanie pełzania pod obciążeniem statycznym, deformacje mieszanek mineralno-asfaltowych

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