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# RESEARCH OF RUT DEPTH IN ASPHALT PAVEMENTS REINFORCED WITH GEOSYNTHETIC MATERIALS

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**Abstract.** Rutting of asphalt pavements is a relevant problem the solution of which has been searched for by the specialists of various fields. This article describes causes of rut initiation and development due to shear strains and presents a theoretical model of the effect of geosynthetic materials on the functioning of asphalt pavements. The article also describes the experimental road section and measurements of the rut depth from the day of the section's construction until now.

**Keywords:** Ruts, asphalt, geosynthetic material, reinforcement, shear strains.

## 1. Introduction

Ruts, otherwise called a wheelpath, are one of the most frequent defects of asphalt pavements. Formation of ruts, having started in the initial stage of pavement operation, increases with the growth of the flow of heavy traffic. Pavement rutting not only increases maintenance costs of road network but also affects driving comfort, creates additional risk to human life. When driving on the road, water accumulated in pavement depressions is an additional cause of slipperiness, and in winter water and the formed ice in pavement depressions increase the braking distance. Thus, the mentioned conditions can cause severe traffic accidents.

Ruts, related to shear deformations in the upper asphalt layer, are the most complicated and dangerous. The main cause of rut initiation is shear strains in asphalt. Those ruts are the accumulation of residual deformations in the upper asphalt layer. Ruts, related to shear strains, are difficult to be calculated and modelled due to the following reasons:

1) the main relations of material characteristics are non-linear, dependent and complicated. Many of the materials of pavement structure under the repetitive and moving loads are difficult to be characterized,

2) changes in the properties of materials under the effect of load and temperature create assumption to study asphalt as a visco-elastic material. Meanwhile, the materials laying in the base courses and frost-blanket courses of pavements and in the subgrade are only slightly dependent on those variables,

3) temperature and moisture of materials differ with each repetition cycle of the load. For this reason, it is necessary to predict the mechanism of rut initiation for various materials, structures, traffic flow and ambient conditions.

There are several causes of such deformations:

1) high ambient temperature,
2) improper components of asphalt mixture,
3) traffic loads.

In 2009 the scientists of Vilnius Gediminas Technical University carried out experimental research aiming to assess the temperature effect of asphalt layer on the stiffness and modulus of elasticity of asphalt layer. The stiffness of asphalt layer depends on material properties, temperature, load size and time of impact, climatic and other factors, therefore, it is recommended to monitor and assess the fatigue of asphalt layers and, having identified it, reassess a temperature correction factor (Motiejūnas *et al.* 2010, Bertuliene *et al.* 2010).

Traffic loads are the main cause since another two are only subsidiary factors determining the time of initiation and development of deformations. It was determined that ruts in asphalt pavements are caused by the following loads:

- standing or stationary (long-duration or static) loads,
- repetitive traffic loads (large number of repetitions),
- braking or acceleration loads.

One of the untraditional measures aimed at reducing ruts, related to shear strains, is the reinforcement of asphalt layers with geosynthetic materials. The early experiments were performed on the experimental section with a purpose to determine the way the geosynthetic materials influence the rheological characteristics of asphalt concrete and changes in the depth of rutting. The article presents the main statistical methods and criteria on the basis of which the statistical data analysis was performed (Bertuliene, Oginskas 2008). However, there are some studies in the world which analyze how geosynthetic materials affect shear strains and rutting of asphalt pavements.

## 2. Factors that determine rut initiation and development

Ruts, related to shear deformations, are formed in a period when the asphalt pavement temperature is high. Those ruts are the accumulation of residual shear deformations (Fig. 3) during a certain period of pavement operation under traffic loads (Huang 1993).

If asphalt is affected by traffic loads the shear strains are formed in pavement.

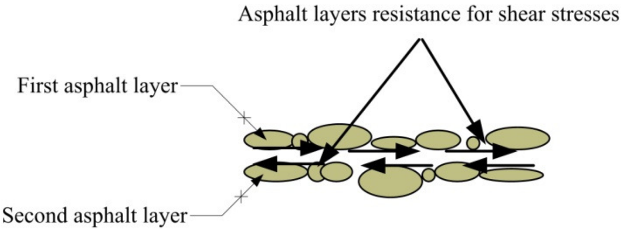


**Fig 1.** Shear strength of asphalt

Share strains force mineral particles of asphalt to move in respect of each other. A binding material of asphalt, i.e. bitumen, resists this movement (Fig. 1). However, bitumen is a material the properties of which are highly dependent on temperature. With the increasing temperature the bitumen stiffness decreases, the strength of relations between mineral particles also decreases.

When shear strains exceed the limits of bitumen stiffness, mineral particles start moving in respect of each other. Numerical values of shear strains depend on the magnitude and total area of acting load. The largest numerical values of shear strains are at a 5 cm depth and about 10 cm distance from the load application edge in a horizontal direction. Particles from the load impact zone move to those parts of asphalt pavement which are not so intensively affected by loads (Fig. 2).

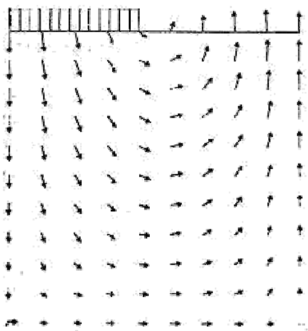

**Fig 2.** Movement of particles subject to acting load

Thus, shear deformations are formed in the upper asphalt layer (Fig. 4).

Theoretically, ruts, related to shear deformations, should be formed in the whole asphalt layer, however, investigations that were carried out in Lithuania showed that ruts, related to shear deformations, are formed only on the upper asphalt layer. This is caused by several reasons:

1) in different period of the year pavement temperature is different,

2) different physical-mechanical indices of separate layers,

3) insufficient bond between separate asphalt layers,

4) quality of asphalt mixtures do not meet the current requirements (production spoilage, improper mix design).

In a hot period of the year pavement temperature in Lithuania rises to +60°C, however, in the lower asphalt layers the temperature is lower – about 10°C. In the Republic of Lithuania for different structural asphalt layers different requirements are set: the upper asphalt layers are more intensively affected by temperature variations, therefore, for those layers asphalt with more universal properties shall be used. Such mixtures must have not only high stability by Marshall, since this determines their resistance to rut initiation in a hot period of the year, but also sufficient plasticity to prevent temperature cracks in a cold period of the year. The lower layers are usually characterized by much higher stability by Marshall. Theoretically, all the asphalt layers should function as one monolithic layer. However, in this system the weak locations are joints between the structural layers. It is obvious, that sufficient bond between separate layers would ensure integrity of the whole system, however, in most cases the bond is too low. In Lithuania thickness of the upper asphalt layer is 5 cm. Namely at this depth the maximum values of shear strains are formed. The bond between the layers being insufficient, the particles of the upper layer start sliding by the surface of preceding layer and moving up.

## 3. Effect of geosynthetic materials on shear deformations

Strengthening of asphalt pavements with geosynthetic materials is associated with the term "reinforcement". Reinforcement is a structural measure giving additional strength. The term "reinforcement" itself is associated with the mobilization of strains in certain layers, concretely – in geosynthetic materials (Fig. 5).

Asphalt concrete is a material characterized by elastic properties. Elasticity is the property of material which allows to resist the acting strains. Though, under different ambient temperatures, elasticity of asphalt concrete varies within very wide limits (Fig. 6).

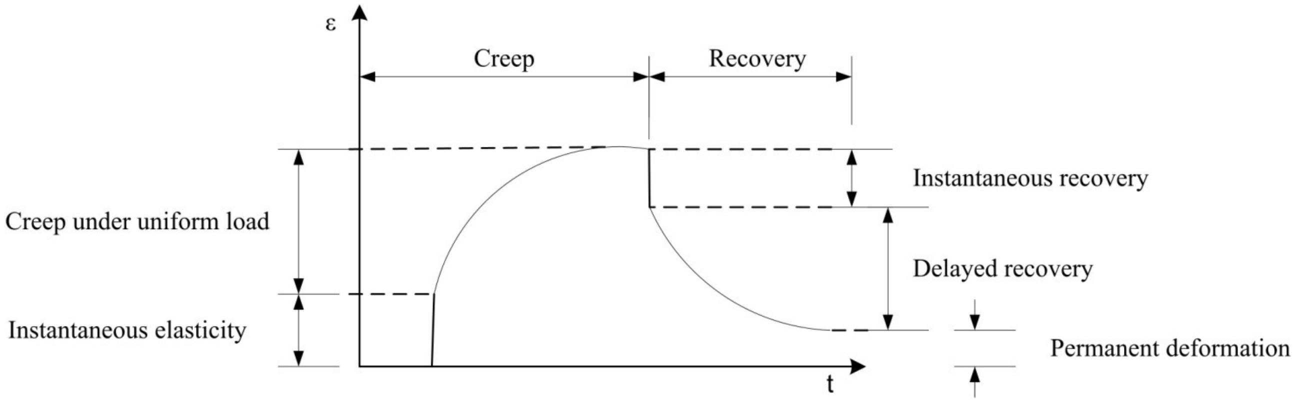


**Fig 3.** Functioning of visco-elastic material

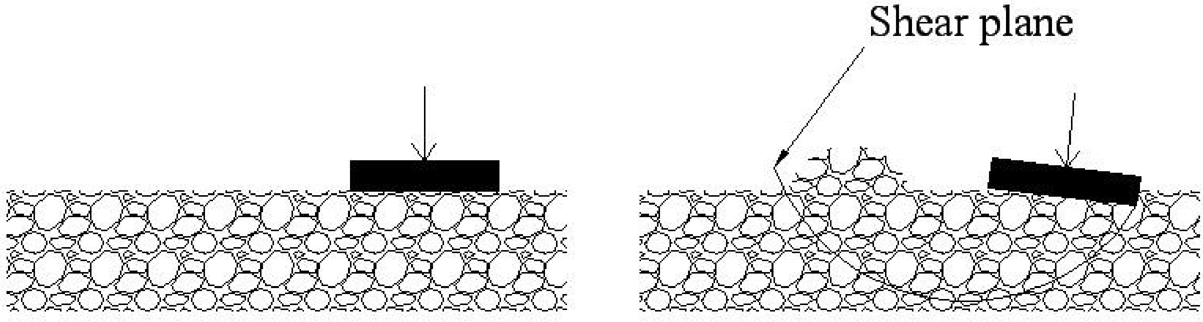


**Fig 4.** Formation of shear deformations in asphalt

In a hot period of the year when pavement temperature varies from +20° C to +50º C the modulus of elasticity varies to approximately three times. A similar variation is also represented by the viscosity values of asphalt concrete.

Under low temperatures and high modulus of elasticity, asphalt concrete is itself able to resist the affecting strains. In such case, share strains are concentrated at the surface of asphalt concrete layer or die away without reaching the deeper layers, thus, geosynthetic materials have no effect on those strains (Fig. 7).

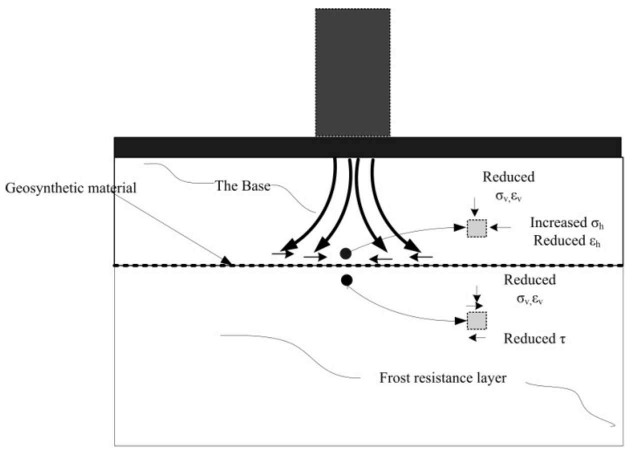


**Fig 5.** Mechanism of the reinforcement of asphalt pavement

In the Republic of Lithuania road pavements in summer heat up to +60° C. Under this temperature asphalt concrete has already lost its ability to resist the mentioned strains. Thus, the values of shear strains increase, move deeper and reach the underpart of asphalt concrete layer. In a way of research the relative value of shear strains was determined, which, under temperature variation from 0° C to +25º C, changes from 2,5 to 16 times.

In that case, geosynthetic materials are involved into the functioning of asphalt concrete (Fig. 8). They take over part of shear strains, thus, reducing the effect of strains on asphalt concrete.

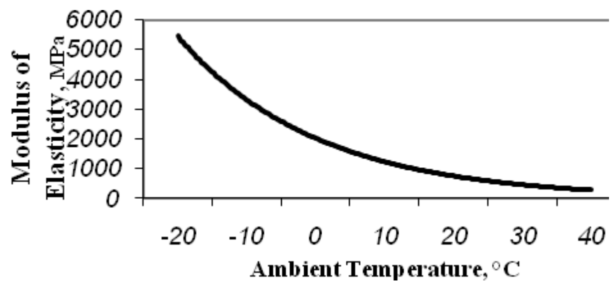


**Fig 6.** Modulus of elasticity of asphalt vs. temperature

Geosynthetic materials are not very sensitive to temperature variations. Materials, most commonly used for reinforcing asphalt concrete, are produced from polyester or polymeric material with fibreglass. Modulus of elasticity of polyester begins to decrease under +220° C, and fibreglass - even +800° C. Under this temperature geosynthetic materials are functioning as elastic bodies. The asphalt concrete layer is being deformed until the limit when the mentioned materials get involved into the operation of the system. Later deformations stop growing.

In order to determine how the geosynthetic materials influence ruts, related to share deformations, the experimental road section was constructed (Laurinavicius, Oginskas 2006).

In the city of Vilnius, there has been a testing road section constructed. Pavement structure of the experimental road section consists of the following layers:

- 4 cm thick wearing course from AC 11 AS asphalt concrete,
- 5 cm thick base course from AC 16 AS asphalt concrete,
- 6 cm thick sub-base from AC 22 PL asphalt concrete,
- 25 cm thick road base from crushed stone,
- 40 cm thick sand layer (frost-blanket course).

The whole pavement structure and the physical and mechanical indices of mixtures used for asphalt concrete layers meet the currently valid normative documents of Lithuania.

Geosynthetic materials were laid under the wearing course.

In order to identify the impact of reinforcement on the reological characteristics and strains of asphalt concrete, a layer of asphalt concrete was reinforced; i. e. geosynthetics was laid between the first and second layer of asphalt concrete. The asphalt concrete layers on the whole testing section were of equal thickness, of the same type and of the same composition. The elasticity modulus of the road base, frost-resistant layers and the embankment was the same on the total length of the asphalt concrete section; therefore, it is taken as a non-variable value. Hence, the variability of different values is associated solely with the reinforcement of asphalt concrete.

On the experimental section, there was the following geosynthetics used: geogrids: HaTelit C 40/17, Bitutex Stargrid Glu 50, Armapal MP-50 and geotextile: Pavemat, Pavegrid G-50, Fibertex AM – 2. On a first stage of experimental research has been measured such parameters: the modulus of elasticity of asphalts concrete *E*, the depth of rutting. The first measurement of the depth of rutting has been accomplished on April 2005, other measurement prosecute an inquiry till now.

Regression analysis (see Fig. 9) shows close contact between the depth of rutting and the modulus of elasticity of asphalt concrete, in a first condition of rutting particularly.

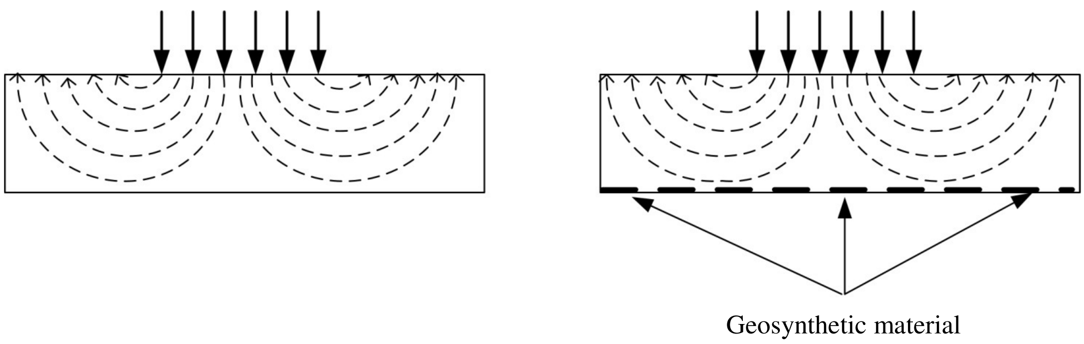


**Fig 7.** Distribution of shear strains when asphalt concrete functions as elastic body

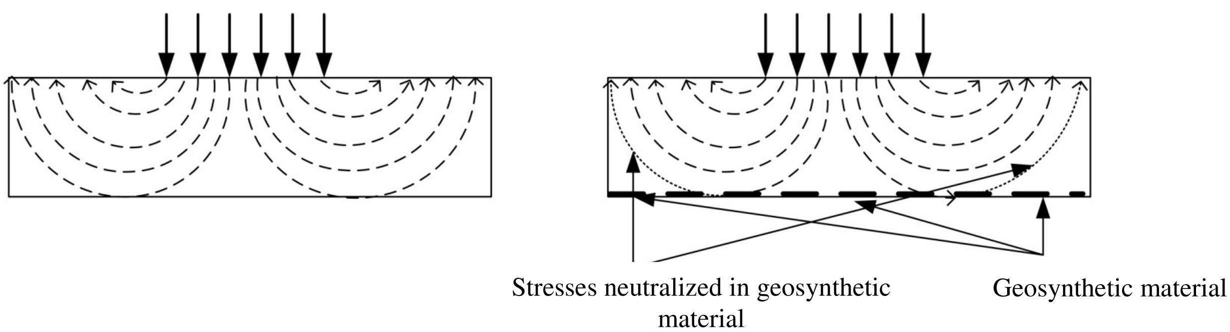


**Fig 8.** Distribution of shear strains when asphalt concrete functions as non-elastic body

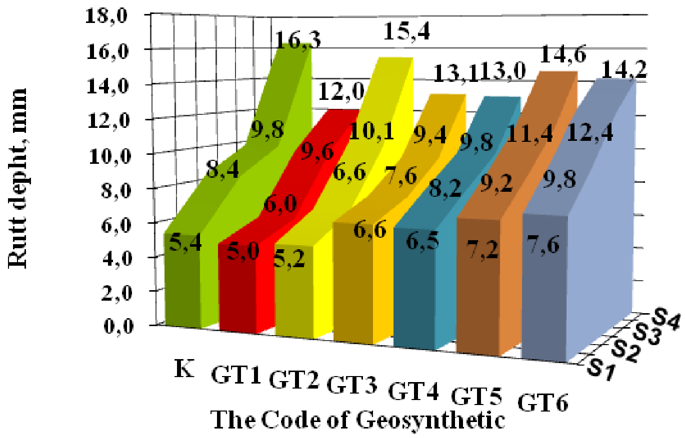


**Fig 9.** Measurements of the depth of ruts

## 4. Analysis of the results of rut depth measurements

Results of the measurements (Fig. 9) showed that geosynthetic materials have the effect on the depth of ruts. The first measurement, indicated as $S_1$ in the above figure, was carried out after the first winter of road operation. Measurement showed that on some sections with geosynthetic materials the rut depth was larger than that on the reference section, i.e. the section without geosynthetic materials. The second measurement $S_2$, carried out after the first summer, showed that the effect of geosynthetic materials on the development of ruts is significant. Though the final rut depth varied within large limits, the largest increase in rut depth was measured on the reference section. The third measurement $S_3$ and the increase in rut depth over this period showed no specific tendencies. When studying the final result the stable tendencies could be noticed, though, the increase in rut depth over this period varied highly. Results of the last measurement $S_4$ emphasize the tendencies of the effect of geosynthetic materials on the rut depth. Both, the final rut depth and the increase in rut depth were the largest on the section without any geosynthetic material. However, not all geosynthetic materials give obvious benefit. In a more detail analysis using statistical analysis methods it would be also difficult to decide is there any difference between the rut depth on the section reinforced with geosynthetic materials GT2, GT5, GT6 and on the reference section. For this purpose, it is necessary to carry out longer observations of the experimental road section and measurements of the rut depth.

## 5. Conclusions

1. Theoretical research showed that geosynthetic materials can affect pavement ruts, related to shear deformations in asphalt pavements. The increase of ruts depth in control section during hot period is 1.6 times and this is the biggest value, between all sections.
2. Experimental research showed a positive effect of geosynthetic materials on the formation and development of ruts, i.e. rut depth on the road sections reinforced with geosynthetic materials is lower than that on the reference section 1.4 times. In order to more comprehensively study the effect of geosynthetic materials on the rut depth, it is necessary to use statistical analysis methods allowing a comparison of different samples.
3. It is necessary to continue measurements and observations of the experimental road section in order to identify another defects and deformations of this section and to determine cost-efficiency of the use of geosynthetic materials.

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