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Distribution of temperature, moisture, stress and strain in the highway

Распределение температуры, влажности, напряжений и деформаций в автомобильной дороге

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Ключевыеслова:дорожная одежда; земляное полотно; температура; влажность; холодный период; промерзание; незамерзшая вода; напряжение; деформация

Abstract. The paper analyzes regularities for the distribution of temperature, moisture, stresses and strains in pavement and subgrade of the highway, located in northern part of Kazakhstan, within one year, especially during cold season. Distribution of temperature and moisture has been determined experimentally with the use of special sensors. Stresses and strains have been calculated with the use of elastic multilayer semi-space model. It has been shown that the stiffness (elasticity modulus) of asphalt concrete layers and upper part of subgrade soil increases considerably during cold winter season: up to 18000 MPa and 10000 MPa respectively. All the components of stresses and strains vary considerably in points of pavement and subgrade during the annual cycle. Variations of pavement surface deflection and horizontal stress in the bottom asphalt concrete layer are of quasi harmonic nature, and horizontal strain in this point varies under the quasi bicyclic law. Horizontal stress during the cold season is a tensile one and has the biggest value, and during hot season it changes its sign and becomes the compressive one. Horizontal strain during the whole annual cycle remains only a tensile one. The biggest variations of stresses and strains occur in the upper part of subgrade. During cold season the vertical compressive stresses and strains are the minimal ones, and in the beginning of spring they are the maximal ones.

Аннотация: В работе анализируются закономерности распределения температуры, влажности, напряжений и деформаций в дорожной одежде и земляном полотне автомобильной дороги, расположенной в северной части Казахстана, в течение одного года, в частности в холодный период. Экспериментальным путем с помощью специальных датчиков исследуется распределение температуры и влажности. Расчеты напряжений и деформаций выполняются с использованием математической модели упругого многослойного полупространства. Показано, что жесткость (модуль упругости) асфальтобетонных слоев и верхней части земляного полотна значительно увеличивается в зимний период: до 18000 МПа и 10000 МПа, соответственно. Все компоненты напряжений и деформаций значительно изменяются в точках дорожной одежды и земляного полотна в течение годового цикла. Изменения деформации и горизонтального напряжения в нижнем асфальтобетонном слое дорожной одежды квази-гармонического характера, а горизонтальная деформация в этой точке изменяется по квазибициклическому закону. Горизонтальное напряжение в нижнем асфальтобетонном слое в зимний период является растягивающим и имеет наибольшее значение, а в летний период меняет свой знак, т.е. становится сжимающим. Горизонтальная деформация в этом асфальтобетонном слое в годовом цикле изменяется по сложной зависимости, но остается только растягивающей. Наибольшие изменения напряжений и деформаций возникают в верхней части земляного полотна. В холодный период

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вертикальные напряжения и деформации являются минимальными, а в начале весеннего сезона они максимальные.

1. Introduction

Pavement and subgrade are the main constructive elements, on which the strength and operational life of the highway depend. Mechanical loads of moving vehicles, climatic and hydrological factors affect the highway. The temperature can be considered as one of the most important from climatic factors. For example, depending on temperature, the mechanical and physical characteristics of the asphalt concrete pavement layers vary within the wide range. The more the small-size clay particles in the subgrade soil, the more its mechanical and physical properties depend on moisture. Phase transition of the first order occurs in wet soil at the temperature of approximately 0°C, resulting in the fact that the part of moisture from liquid condition (water) transforms into solid (ice) condition, and in liquid condition remains only the so-called unfrozen water. During winter season with the decrease of negative temperature the amount of unfrozen water in soil gradually decreases, the stiffness of soil in subgrade increases, and it is expected that the increase of the stiffnes for the asphalt concrete layers and soil in winter season should impact greatly on the distribution of stresses and strains in pavement and subgrade.

As it is known, deformability, strength, thermal and physical characteristics of frozen soils differ greatly from unfrozen soils [1–4].

1. Highway specialists of the beginning of the last century understood the importance of temperature impact in subgrade on pavement state. Thus, as the short message of Wiley read [5] they believed in the Illinois University, that concrete highway cracking phenomenon can be explained by limits and rates of temperature variation in pavement and subgrade, and investigations were started. Preliminary results showed that extreme temperatures delay greatly in comparison with the air.

2. Temperature gradient shows the direction of heat flow and causes the effect of thermal diffusion (moisture transfer with availability of temperature difference). For example, it was obtained experimentally in the work Xu et al [6] that formation of water concentration gradient in subgrade soil was based, mainly, on temperature gradient.

3. Tan and Hu [7] obtained experimentally that water transfer in soil under impact of temperature gradient takes a long time. There was no obvious water transfer in the tested samples during first days. It became obvious only after expiring of five days.

4. Essential role of temperature gradient in water transfer in the frozen soil was evaluated experimentally in the work of Mao et al. [8].

5. The paper [9] mentions the practical importance of zero isotherm during construction of subgrade for railway and it is investigated experimentally by testing stand and numerical simulation.

6. They calculated temperature values in New Hampshire State [10] for the surface of highway subgrade under computer program in each month of the year and they obtained resilient modulus values for subgrade soils at those temperatures in the laboratory.

7. The works [11, 12] show existence of reliable correlation relationship between temperature and subgrade modulus.

8. The works [13, 14], mainly, analyze the impact of temperature of the asphalt concrete layers on the mechanical behavior of pavement. The first paper, measures the deflection of pavement surface, using falling weight deflectometer experimentally at different temperatures, and it is found out that the temperature and the thickness of the asphalt concrete layers impact greatly on dynamic properties of the asphalt concretes. The second paper develops the mathematical model, and with the help of it the distribution of temperature, stresses and strains in pavement has been analyzed in different time of 24 hours in the hot season of the year. It has been shown how greatly the temperature of the asphalt concrete layers impacts on the distribution of stresses and strains in pavement.

9. Some results of theoretical and experimental research for temperature variation in pavement and subgrade of the highways in sharp continental climatic conditions during various seasons of the year have been published in the works [15–18].

This paper experimentally analyzes the distribution of temperature and moisture in pavement and subgrade of the highway, located in the northern part of Kazakhstan, within one year. Using the results obtained, by calculation, the stress and strains in pavement and subgrade have been determined, their variation has been shown during the annual cycle, impact of freezing for the subgrade soil on the values of stresses and strains has been evaluated.

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2. Methods

2.1. Experimental section

The section with asphalt concrete (km 76+30) pavement of “Astana-Burabai” highway was selected for performance of long-term monitoring for temperature and moisture variation in pavement structure layers and points of subgrade of the highway in climatic conditions of northern region of Kazakhstan in November 2010. Highway has 6 lanes with the width of 3.75 m each. It is allowable for car to move with the speed of 140 kph, and for trucks with the speed of 110 kph along this highway. Reconstruction of the highway was completed in November of 2009.

Pavement structure of the section with asphalt concrete (Figure 1) consists of the following layers: 1 – stone mastic asphalt concrete, 6 cm; 2 – dense asphalt concrete, 9 cm; 3 – crushed stone treated with bitumen, 12 cm; 4 – crushed stone and sand mix treated with cement (7%), 18 cm; 5 – crushed stone and sand mix, 15 cm;6 – sand, 20 cm. Subgrade is constructed from heavy sandy clay loam: moisture in the plastic limit WP = 18.7 %; moisture in the liquid limit WT =34.8 %. Underground water is deep (lower than 3.0 m).

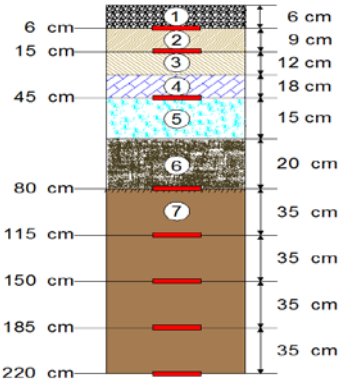

Figure 1. Scheme for location of sensors in pavement structure and subgrade for section with asphalt concrete pavement of “Astana-Burabai” highway: 1…6 – numbers of pavement layers; 7 – subgrade; 🟥– temperature and moisture sensors

2.2. Temperature and moisture sensors

Company “Interpribor” (Chelyabinsk, Russia) produced temperature and moisture sensors on the order of Kazakhstan Highway Research Institute (KazdorNII). Each sensor, produced in the form of metal capsule, contains element for measurement of temperature based on the effect of thermal resistance and element for measurement of moisture through diamagnetic permeability. Such design concept allows performing simultaneously the measurement of temperature and moisture in points of pavement and subgrade.

Figure 2 shows general view of one set of sensors visually. Temperature element of sensors was calibrated by the producer and moisture element was calibrated in the laboratory of KazdorNII. Calibration of sensors was performed with the use of soils, selected from the areas of their installation. Measurement ends of the sensors were put on the surface of the highway and fixed in measurement chamber of land system of the set (Figure 3).

Figure 2. One set of temperature and moisture sensors

Figure 3. Measurement (land) system for setof temperature and moisture sensors

Each set had 8 temperature and moisture sensors, 3 of which were installed in pavement layers, and 5 of them were installed into subgrade of the highway. The depth for their installation, calculated from pavement surface, were equal to: 6, 15, 45, 80, 115, 150, 185 and 220 cm.

2.3. Deformation behavior of asphalt concretes

Asphalt concrete is a visco-elastic material [19–21] and its deformation behavior depends on temperature and load duration. At present the experimental, as well as calculation methods are known for determination of elasticity modulus of the asphalt concretes. For example, the so-called model of M.W. Witczak [22], which has been used in the work [23]. In this paper the elasticity modulus of stone-mastic and porous asphalt concretes was calculated under the modified formula of Hirsh, suggested in the paper [24]:

$$E_{ac}(t) = P_c(t) \cdot \left[E_{ag} \cdot (1 - VMA) + E_b(t) \cdot VFA \cdot VMA \right], \tag{1}$$

$$P_c(t) = 0.006 + \frac{0.994}{1 + \exp\left[-\left(0.6628 + 0.5861 \cdot \ell n\left(VFA \cdot \frac{E_b(t)}{3} \right) \right) - 12.87 \cdot VMA - 0.1706 \cdot \ell n(\varepsilon \cdot 10^6) \right]}, \tag{2}$$

where $E_{ac}(t)$ is an elasticity modulus of asphalt concrete at the time moment t, $E_b(t)$ is an elasticity modulus of bitumen at the time moment t, E_{ag} is an elasticity modulus of stone aggregate, set as equal to 26 540 MPa, *VMA* are the air voids of mineral aggregate (as a decimal fraction), *VFA* are the voids, filled with binder (as a decimal fraction, ε is a level of strain, set as equal to $100 \cdot 10^{-6}$ for low and mean temperatures.

Elasticity modulus of bitumen $E_{ac}(t)$ is calculated under formula [25]:

$$E_b(t) = Eg \left[1 + \left(\frac{Eg \cdot t}{3 \cdot \eta} \right)^b \right]^{-\left(1 + \frac{1}{b}\right)} \tag{3}$$

where $E_g$is an instantaneous elasticity modulus, set as equal to 2 460 MPa, η is a coefficient of the viscosity for bitumen, MPa·s.

Coefficient of viscosity η is obtained under the expressions:

$$\begin{cases} \eta = a_{TrAhr}(T) \cdot \eta(T_r) & \mathrm{T} \le \mathrm{T}_{rb} - 10; \\ \eta = a_{Tr\,\mathrm{WLF}}(T) \cdot \eta(T_r) & \mathrm{T} > \mathrm{T}_{rb} - 10, \end{cases} \tag{4}$$

$$\eta(T_r) = 0.00124 \left[1 + 71 \cdot \exp\left[-\frac{12(20 - PI)}{5(10 + PI)} \right] \right] \cdot \exp\left(\frac{0.2011}{0.11 + 0.0077PI} \right), \tag{5}$$

$$a_{TrAhr}(T) = \exp\left[11720 \cdot \frac{3(30 + PI)}{5(10 + PI)} \left[\frac{1}{(T + 273)} - \frac{1}{(T_{rb} + 263)} \right] \right], \tag{6}$$

$$a_{TrWLF}(T) = \exp\left[-\frac{2.303\,(T - T_{rb} + 10)}{(0.11 + 0.0077PI)\,(114.5 + T - T_{rb}} \right]. \tag{7}$$

where *PI*and $T_{rb}$are penetration index and softening point of bitumen.

Parameter b is calculated under the expressions:

$$b = \frac{1}{\frac{1}{\beta} + \frac{\ell n(\pi)}{\ell n(2)} - 2}, \tag{8}$$

$$\beta = \frac{0.1794}{1 + 0.2084\, PI - 0.00524\, PI^2}. \tag{9}$$

In calculations of the values for elasticity modulus of the asphalt concretes the load duration was set as equal to 0.1 of a second. The values of Poisson’s coefficient for asphalt concretes at various temperatures were obtained under formula, recommended by the Guide [26]:

$$\nu = 0.15 + \frac{0.35}{1 + \exp\,(-1.63 + 3.84 \cdot 10^{-6} \cdot E_{ac}(t))}, \tag{10}$$

where $v$is a Poisson’s coefficient of asphalt concrete, $E_{ac}(t)$ is an elasticity modulus of asphalt concrete.

2.4. Deformation behavior of soil

The values of elasticity modulus for the soil of subgrade (heavy sandy clay loam) at the positive temperatures are set under the standard document [27] depending on soil moisture, and at negative temperatures they are obtained according to the data of the Professor N.A. Tsytovich [28] depending on the value of negative temperature and the amount of unfrozen water. The upper part of the subgrade for the highway with thickness of 140 cm (from 80 cm to 220 cm from the asphalt concrete pavement surface) was divided into 7 layers, each of them had the thickness of 20 cm. It was set that for each of those soil layers the temperature and moisture had constant values.

2.5. Deformation behavior of pavement interlayers

Values of elasticity modulus and Poisson’s coefficient of the materials of pavement interlayers (crushed stone, treated with bitumen; crushed stone and sand mix, treated with cement (7 %); crushed stone and sand mix; sand) are fixed under the standard document [27] and shown in the Table 1.

Table 1. Values of elasticity modulus and Poisson’s coefficient of the materials of pavement interlayers

Material	Elasticity modulus E, MPa	Poisson’s coefficient v
Crushed stone treated with bitumen	600	0.25
Crushed stone and sand mix, treated with cement (7%)	500	0.25
Crushed stone and sand mix	230	0.30
Sand	120	0.30

2.6. Calculation scheme for stresses and strains in pavement and subgrade

Calculation scheme of pavement structure and subgrade is shown in Figure 4. As it is seen, the scheme shows 13 layers, out of which the first 6 simulate the pavement layers, and the other 7 layers correspond to the layers of subgrade. The materials of all the layers and soil are considered as elastic one. The lowest soil layer (the 13th layer) is considered as elastic semi-space, which has infinite thickness. Stresses and strains in such multilayer elastic system are determined with the use of the solution of Prof. A.K. Privarnikov [16]. On the surface of the upper layer there is a load q = 0.6 MPa, uniformly distributed within the circle with diameter of D = 42 cm. It corresponds to the axial load of 13 tons.

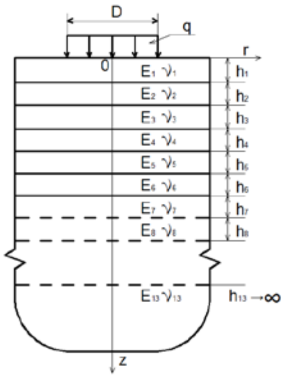

Figure4.Calculation scheme

3. Results and Discussion

3.1. Temperature and moisture in subgrade and pavement

Figure 5 shows the graphs of temperature distribution in the depth of highway during various seasons of the year, constructed under experimental data, which were obtained through the use of sensors. As it is seen, temperature distributions differ greatly from each other during various seasons of the year.

Figures 6 and 7 show the graphs of temperature variation in points of pavement and subgrade in summer and winter 24 hours. As it is seen daily temperature variation occurs only in asphalt concrete layers and up to the depth of 45 cm. Temperature variation does not occur below this depth, therefore, in points of subgrade in daily cycle. Temperature variation in this field is of seasonal character and it is observed in the annual cycle.

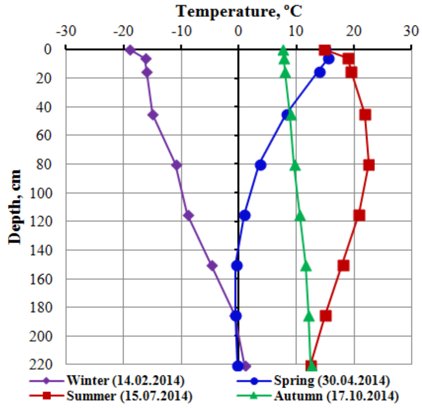

Figure 5. Temperature distribution in the depth of highway during various seasons of the year

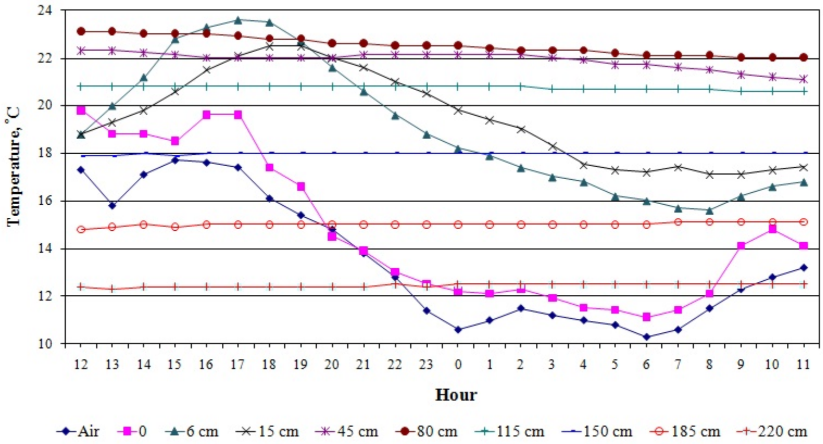

Figure 6. Temperature variation in points of pavement and subgrade in summer (14-15.07. 2014)

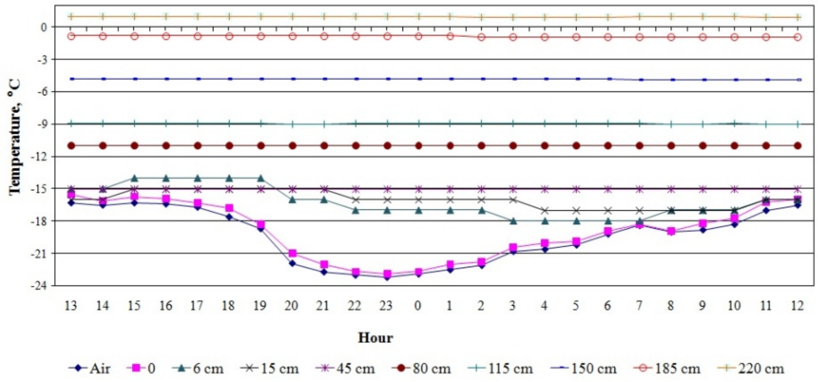

Figure 7.Temperature variation in points of pavement and subgrade in winter (13-14.02. 2014)

As expected, the biggest temperature values occur in summer and with temperature decrease in autumn temperature reduction occurs also in subgrade. Subgrade (1.50 cm) and ground foundation in winter are in frozen condition. Temperature of subgrade surface reduces to -12 °C. Pavement and subgrade start melting in the beginning of spring from top to bottom.

Figures 8–10 show the graphs for moisture distribution in the depth of subgrade during various seasons of the year, where it can be seen that moisture values in points of subgrade are almost the same in summer and autumn seasons of the year. Part of water, contained in points of subgrade, is transferred to ice in winter with negative temperatures occurrence. Continuous line in Figures 9 and 10 shows moisture content in liquid condition (unfrozen water), and dashed line corresponds to initial moisture (before winter). It can be seen that frozen water content (ice) in subgrade decreases during winter period with the depth increase (Figure9). Defrosting of subgrade in spring occurs from top to bottom. It is clearly seen from Figure10 that upper part of subgrade defrosted to 130 cm in the end of April 2014 and the rest part of subgrade is in frozen condition.

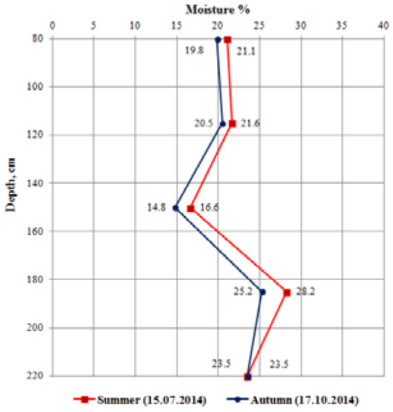

Figure 8. Moisture distribution in the depth of subgrade in summer and autumn periods of the year

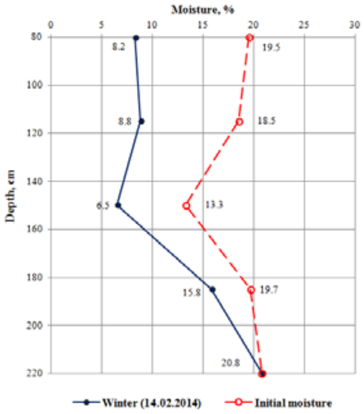

Figure 9. Moisture distribution in the depth of subgrade in winter period of the year

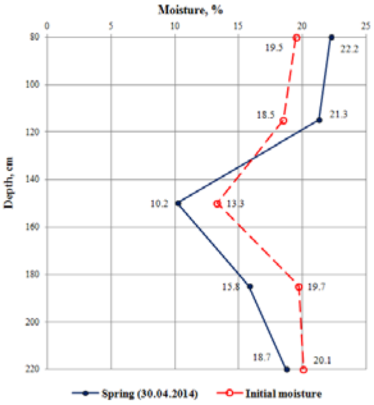

Figure 10. Moisture distribution in the depth of subgrade in spring period of the year

It is clear from the graphs of temperature and moisture variation (Figures 11, 12) on subgrade surface (80 cm) and in the depth of 115 cm, that sharp decrease of moisture occurs in winter approximately at the moment of temperature transition to negative area, and moisture is also decreases with further temperature reduction. And in spring there is intermittent increase of moisture during temperature transition from negative area to positive area. Certainly, these phenomena show phase transitions, which occur at temperature, approximately equal to 0°C.

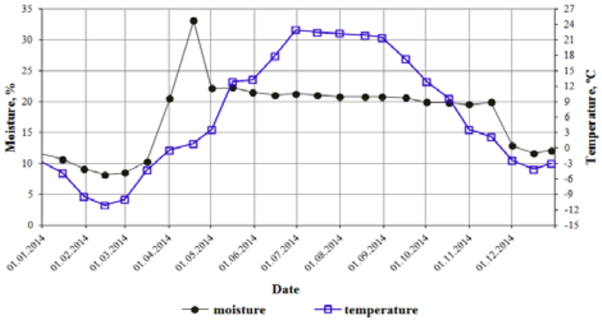

Figure 11.Temperature and moisture variation on subgrade surface (80 cm)

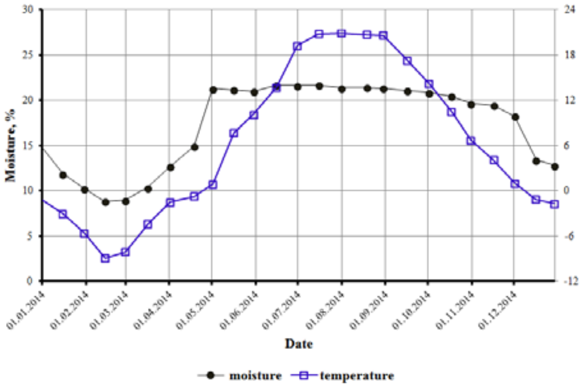

Figure 12. Temperature and moisture variation in subgrade (115 cm)

3.2. Deformation behavior of asphalt concretes

Figure 13 shows the graphs of the mean half-monthly values of temperature for asphalt concrete layers of “Astana-Burabai” highway in the course of the year (December 2013 – December 2014). Figures 14 and 15 show the values of elasticity modulus and Poisson’s coefficient of the asphalt concretes, obtained under the above expressions. It should be noted that the mean half-monthly values of the top and bottom layers for the asphalt concrete of the highway are practically the same.

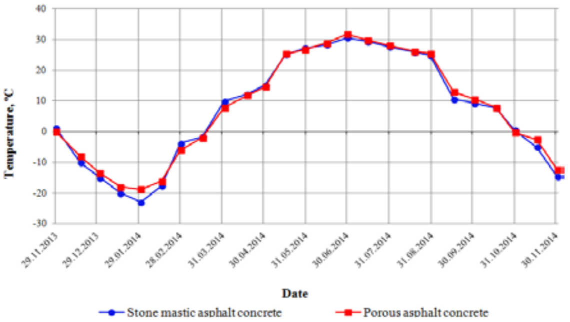

Figure 13. Mean half-monthly values of temperature for asphalt concrete layers

As one should expect, the character of variation for elasticity modulus of the asphalt concretes is fundamentally opposite to the temperature: the higher the temperature, the lower the elasticity modulus, and vice versa, the lower the temperature, the higher the elasticity modulus. And qualitative character of variation of the Poisson's coefficient coincides with the temperature: the higher the temperature, the higher the Poisson's coefficient, and vice versa, the lower the temperature, the lower Poisson's coefficient. At high temperatures (in summer) the values of elasticity modulus for both asphalt concretes are practically the same, but at low temperatures (in winter) they are essentially higher for stone mastic asphalt concrete, than for porous asphalt concrete. At high (in summer) and low (in winter) temperatures the values of Poisson's coefficient for both asphalt concretes are practically the same, but at intermediate temperatures (in spring and autumn) they are somewhat higher for the porous asphalt concrete than for stone mastic asphalt concrete.

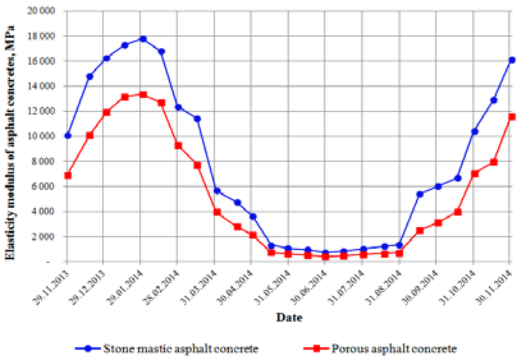

Figure 14. Values of elasticity modulus of asphalt concretes

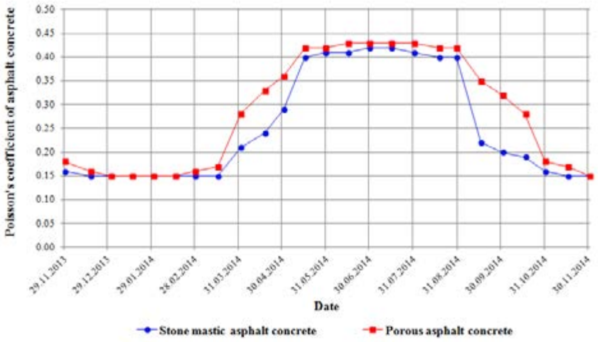

Figure 15. Values of Poisson's coefficient for asphalt concretes

3.3. Deformation behavior of soil

The values of elasticity modulus for the subgrade of the highway, obtained according to the above methods, are shown graphically in Figure 16. As it is seen, freezing in winter season increases essentially the elasticity modulus of the soil. The uppermost layer of the subgrade has the biggest value of elasticity modulus, as the minimum values of negative temperature and the lowest values of unfrozen water occur in the subgrade in winter.

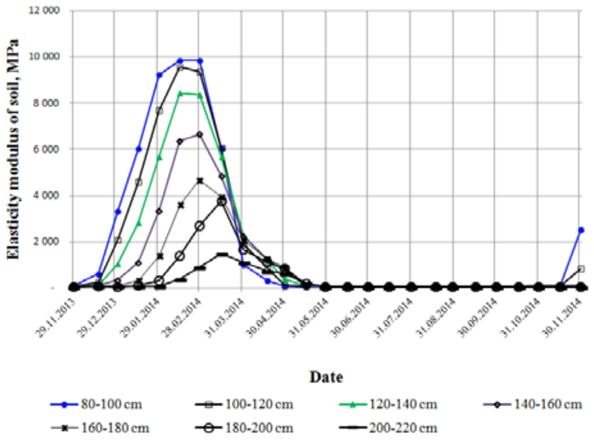

Figure 16. Values of elasticity modulus in subgrade layers of a highway

The values of elasticity modulus decrease with the depth increase. It is explained by the fact that the temperature increase with the depth increase and, therefore, the amount of unfrozen water increases. It should be specially noted that elasticity modulus of upper layers of the soil of the subgrade reaches 8 000-10 000 MPa in winter season, which is 140-180 times more compared with spring and summer seasons. Therefore, we expect that the impact of winter freezing of the soil in the subgrade on stresses and strains in pavement and subgrade layers will be significant. Due to the absence of reliable data, the value of Poisson’s coefficient for the soil of the subgrade is set as constant and it is equal to 0.35.

3.4. Stresses and strains in asphalt concrete layers

Figure 17 represents the graph, showing deflection variation for the surface of the first layer of pavement from stone mastic asphalt concrete. As it is seen, variation of mechanical characteristics for asphalt concrete layers and soil impacts greatly on the deflection value of the pavement surface. Qualitative change of the deflection is of quasi-cyclic nature. It is found that the least deflection values occur from the middle of February to the middle of March, and the biggest ones occur in the beginning of July. The biggest deflection is approximately 5 times more than the least one. Deflection of pavement surface is the only characteristics, which can be measured by non-destructive method. Therefore it is currently used in many countries, including Kazakhstan, for evaluation of strength for the pavement structure [27]. It is considered that during spring defreezing of subgrade the pavement structure has the lease strength and the biggest deflection value of the pavement surface. But the graph of deflection shows that the biggest deflection of the pavement surface occurs in the beginning of July, i.e. in summer, but not in spring. It is seen from the Figure 12 that in the beginning of July the asphalt concrete layers have the highest temperature. Therefore, it becomes clear that the biggest pavement deflection in summer season is specified by essential decrease of stiffness (moduli of stiffness) of the asphalt concrete layers due to the highest temperatures.

The next important characteristics for mechanical behavior of pavement are horizontal stress σ_r^2 and strain ε_r^2 in the bottom surface of the second asphalt concrete layer. Stress σ_r^2 and strain ε_r^2 are considered during evaluation of fatigue strength of the asphalt concrete layers. The USA [26] and many other countries include strain ε_r^2 into relevant calculations, but in the countries of the former USSR – the stress σ_r^2. It is found out (Figure 18), the qualitative character of variation for these factors is different. Graph for variation of stress σ_r^2 is identical to the graph for variation of the mean half-monthly temperature of the asphalt concrete layers (Figure 12): the lower the temperature the higher the stress. In hot period (in summer), when the stiffness (elasticity moduli) of the asphalt concretes becomes low, the stress changes its sign, i.e. transforms from tension into compression.

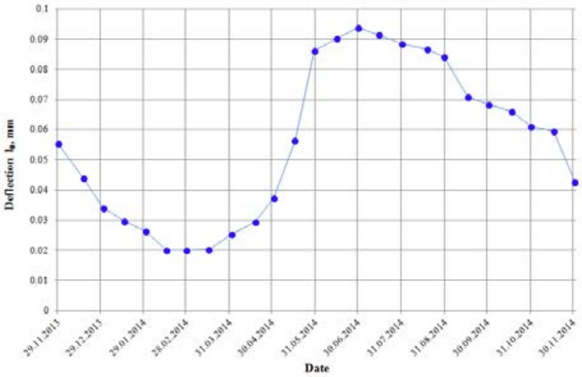

Figure 17. Deflection of the surface for the first pavement layer from stone mastic asphalt concrete

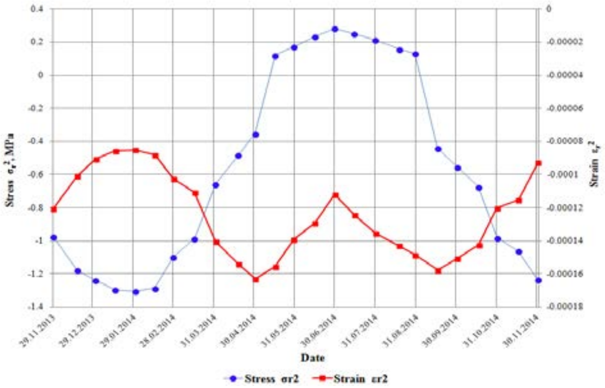

Figure 18. Horizontal stress and strain in the bottom surface of the second asphalt concrete layer

The biggest value of the tensile strength σ_r^2 occurs in the end of January and it is equal to 1.32 MPa, and the biggest value of the compressive strength occurs in the beginning of July and it is equal to 0.28 MPa. The strain ε_r^2 is changed in a more complicated way during annual cycle, but, contrary to the stress σ_r^2, it remains only tensile. Its lowest value, equal to 0.000085 occurs in the end of January, and the biggest values, equal to 0.00016 approximately, occur in the beginning of May and in the middle of September.

3.5. Stresses and strains in subgrade

The graphs of variation for vertical stress σ_z^{sg} and strain ε_z^{sg} in points of subgrade, located in three different depths (0, 60, 120 cm), are shown in the Figures 19 and 20. It is seen that freezing of soil of the subgrade impacts greatly on stress and strain in subgrade. The largest variation of stress and strain during annual cycle occurs on the surface of subgrade and with the increase of the depth the impact of freezing decreases. For example, on the surface of subgrade the biggest vertical stress σ_z^{sg} in the end of winter season (in the beginning of April) reaches 0.045 MPa, and in the beginning of winter season (in the middle of November) it decreases to 0.018 MPa. As it could be expected, during freezing the soil becomes stiff and the strain decreases sharply. And with the beginning of defreezing the stiffness of soil decreases sharply, which causes sharp increase of the strain. In the case considered the biggest vertical strain, equal to 0.00043, was registered on the surface of subgrade in the middle of May and it decreases gradually in time before freezing starts.

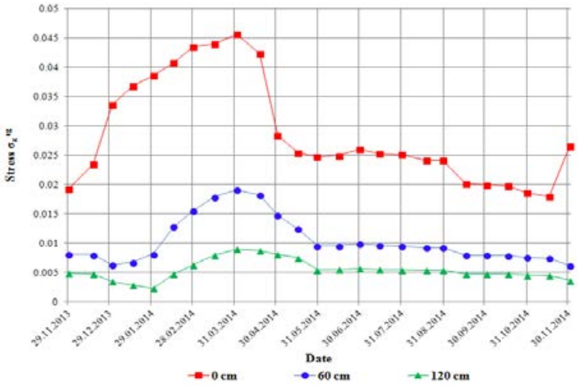

Figure 19. Vertical stress in subgrade

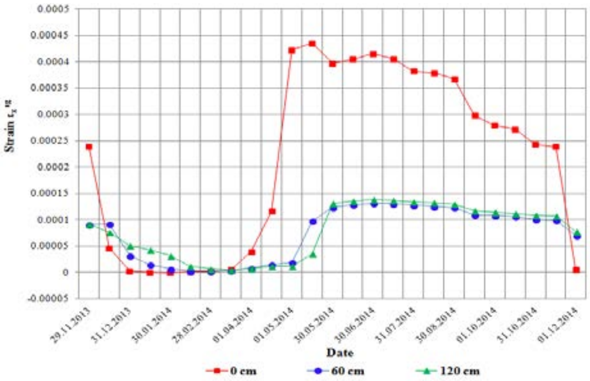

Figure 20. Vertical strain in subgrade

4. Conclusions

The results of experimental analysis for temperature and moisture variations and calculation of stresses and strains in points of pavement and subgrade in this paper allow drawing the following conclusions:

1. Daily temperature variation causes similar daily temperature variation in upper (asphalt concrete) pavement layers. Amplitude of daily temperature variations is decreased with the depth increase and in the depth, equal approximately to 45–50 cm, it is practically equal to zero. Temperature and moisture in points of subgrade do not vary within 24 hours, as the time, required for their sensible variation, is much more than the duration of 24 hours. Their variation is of seasonal nature, and it is clearly seen during annual cycle. Temperature and moisture are distributed in different ways in the depth of subgrade during various year seasons. In winter the temperature of the subgrade surface decreases to -12°C and it increases in the depth. Maximum freezing depth can reach 254 cm.

2. Deformation characteristics of the asphalt concrete pavement layers vary greatly depending on temperature. Elasticity modulus of stone mastic and porous asphalt concretes during cold winter season reaches 17 800 MPa and 13 400 MPA respectively, whereas during hot summer season they can decrease to 740 MPa and 400 MPa respectively. Transition of the part of water, contained in the subgrade soil, from liquid condition into solid one (ice) at the temperatures, which are lower than 0 ºC, also increases the stiffness (elasticity modulus) of soil. During winter season the elasticity modulus of soil for top layers of the subgrade reaches 8 000–10 000 MPa, which 140–180 times more than in spring and summer.

3. Substantial variation of mechanical characteristics of the asphalt concrete layers for pavement and the subgrade soil, caused by temperature and moisture variations during annual cycle, determines the substantial variation of stresses and strains in points of pavement and subgrade as well. For example, the deflection of the pavement surface and horizontal strain in the bottom asphalt concrete layer vary during annual cycle under quasi harmonic law. Together with it, the deflection varies in 5 times.

4. Horizontal stress in the bottom asphalt concrete layer during winter season is a tensile one and it has the biggest value, and in summer season it changes its sign, i.e. it becomes the compressive one. Horizontal strain in this asphalt concrete layer during annual cycle varies under the more complicated quasi bicyclic dependence, but remains only tensile one.

5. The most considerable variations of stresses and strains during annual cycle occur in the top part of the subgrade. For example, the least value of vertical compressive stress was recorded on the surface of subgrade in the beginning of winter season (in the middle of November), and in the end of winter season (in the beginning of April) it increases up to the maximal one.

6. The least vertical compressive strain, close to zero, as it has been expected, occurs in winter, when the top part of subgrade is in frozen condition. When defreezing starts, the stiffness of the soil decreases and, therefore, vertical compressive strain increases, and its biggest value on the subgrade surface occurs in the middle of May.

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