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THEORETICAL MODELLING OF THE EFFECT OF THERMAL DELAMINATION OF AN ASPHALT CONCRETE PAVEMENT FROM A RIGID FOUNDATION OF A ROAD OR BRIDGE

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Within the framework of the main provisions of the theory of thermoelasticity, a theoretical modeling of the phenomenon of generation of high-gradient fields of tangential thermal stresses in a two-layer structure of an asphalt concrete pavement on a rigid cement concrete or metal base under conditions of a change in the temperature of the system during its seasonal and daily differences was carried out. As is shown, they are the main reason for the occurrence of plastic deformations in the edge zones and subsequent delamination of the structure in them. It is proposed to diminish the concentration and level of generated shear stresses by reducing the thickness of the asphalt concrete layer in these areas.

Key words: asphalt concrete pavement, rigid base, high-gradient shear stresses, local delaminations.

1. Introduction. As the experience of operation of roads and bridges in countries with large temperature fluctuations shows, the most intense manifestations of the effects of cracking, local destruction and general degradation of asphalt concrete materials occur in their structures in winter and summer seasons [1, 5, 8, 11]. Under conditions of frequent temperature changes in heterogeneous asphalt concrete structures with thermomechanical incompatibility of their components, these defects can contribute to their accelerated aging. At the same time, with the thermomechanical compatibility of materials, a more favorable distribution of internal stresses of thermal and mechanical origin is achieved, which excludes premature degradation of the strength of the contacting phases and the entire structure as a whole.

Among the most common phenomena in practice, accompanied by delamination, subsequent cracking and destruction of the asphalt concrete pavement on a rigid (cement concrete or metal) base of a road or bridge, is the effect of concentration of shear thermal stresses between the pavement and the base in the edge zones of the structure [2, 3]. They are caused by the fact that, as a rule, the coefficients of linear thermal expansion (CLTE) of coating 1 and base 2 (Fig. 1) have different values $\alpha^{(1)}$ and $\alpha^{(2)}$, which contributes to the occurrence of incompatible shrinkages and expansions in them [6, 9, 12, 14, 15]. The disadvantage of attempts to strengthen the structure in these places by increasing the thickness of coating 1 or its modulus of elasticity is that, as shown by calculations [1-3], this only leads to negative consequences - a localized increase in shear thermal stresses in the edge zones [1, 15].

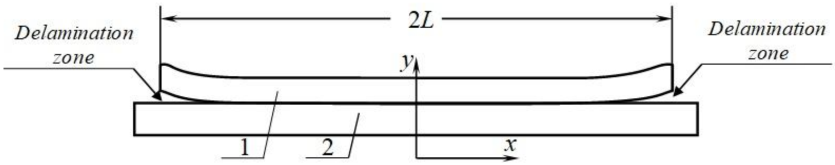
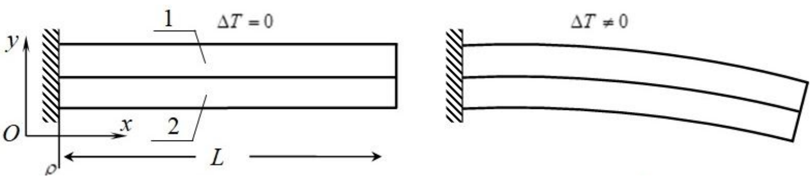


Fig. 1. Cross-sectional diagram of asphalt concrete pavement 1 on rigid base 2 of a road or bridge

It is shown below that a decrease in the concentration of high-gradient tangential thermal stresses and prevention of the delamination effect can be achieved by linearly varying thinning of the upper layer in the peripheral areas.

2. Features of thermoelastic deformation of a two-layer plate with comparable stiffness characteristics of the layers. A clear example of the occurrence of shear thermal stresses in layered structures with a change in temperature *T* is a bimetallic strip of unit width and length *L*, consisting of two connected metal layers 1 and 2 (Fig. 2) with different values of their thermomechanical parameters (coefficients of linear thermal expansion $\alpha^{(1)}$ and $\alpha^{(2)}$ and modulus of elasticity $E^{(1)}$ and $E^{(2)}$), used in various electrical appliances.



(a) (b)

Fig. 2. Crosssectionsof a bimetallic plate in the initial (a) and thermally deformed (b) states

In the initial state at $T = 0$ bimetallic plate is not deformed and longitudinal strains $\varepsilon_x^{(1)}$ and $\varepsilon_x^{(2)}$ in its layers are equal to zero (Fig. 2(a), Fig. 3(a)). Therefore, the longitudinal forces are also equal to zero

$$N_x^{(1)} = 0\,,\ \ N_x^{(2)} = 0 \tag{1}$$

as well as tangential forces $\tau_{xy}^{(1)}, \tau_{xy}^{(2)}$ between the layers of the plate

$$\tau_{xy}^{(1)} = 0, \quad \tau_{xy}^{(2)} = 0. \tag{2}$$

In equalities (1)

$$N_x^{(1)} = \sigma_x^{(1)} h^{(1)}, \quad N_x^{(2)} = \sigma_x^{(2)} h^{(2)}, \tag{3}$$

where $\sigma_x^{(1)}$, $\sigma_x^{(2)}$ – longitudinal stresses in layers 1 and 2.

However, if the temperature of the entire system has changedby ΔT , then in each of the layers thermal strains of different magnitudes are generated

$$\varepsilon_{x,T}^{(1)} = \alpha_1 \Delta T, \; \varepsilon_{x,T}^{(2)} = \alpha_2 \Delta T, \tag{4}$$

which, due to the difference $\alpha^{(1)}$ and $\alpha^{(2)}$ are incompatible and lead to different thermal elongations of the layers. But since the layers are connected to each other along the line of contact, in order to combine their deformations and displacements, elastic tangential forces $\tau_{xy}^{(1)}, \tau_{xy}^{(2)}$ are generated in them between the layers (Fig. 3), which lead to the occurrence of additional elastic strains $\varepsilon_{x,el}^{(1)}, \varepsilon_{x,el}^{(2)}$.

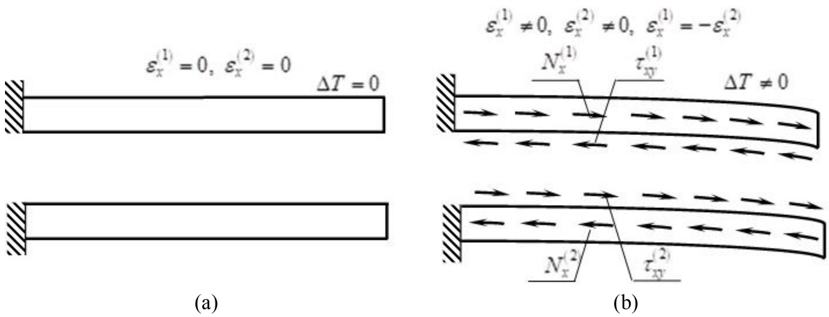


Fig. 3. Conditionally separated layers of a bimetallic plate in the initial (a) and thermally deformed (b) states

In this case,

$$\begin{aligned} \varepsilon_x^{(1)}(x) &= \varepsilon_{x,el}^{(1)}(x) + \varepsilon_{x,T}^{(1)}(x), \\ \varepsilon_x^{(2)}(x) &= \varepsilon_{x,el}^{(2)}(x) + \varepsilon_{x,T}^{(2)}(x), \end{aligned} \tag{5}$$

and the longitudinal forces are determined by the equalities

$$\begin{aligned} N_x^{(1)}(x_i) &= E^{(1)} h^{(1)} \left[\varepsilon_x^{(1)}(x_i) - \alpha^{(1)} \Delta T \right], \\ N_x^{(2)}(x_i) &= E^{(2)} h^{(2)} \left[\varepsilon_x^{(2)}(x_i) - \alpha^{(2)} \Delta T \right] \end{aligned} \tag{6}$$

in every section $x = x_i$ of the system.

Conditionally separate by section $x = x_i$ from the system its right side $x_i \le x \le L$ (Fig. 4). Since only forces $N_x^{(1)}(x_i)$ and $N_x^{(2)}(x_i)$ act on itand it is in balance, so

$$N_x^{(1)}(x_i) + N_x^{(2)}(x_i) = 0\,. \tag{7}$$

Therefore, the forces $N_x^{(1)}(x_i)$ and $N_x^{(2)}(x_i)$ are equal in modulus and differ in signs, i.e.

$$N_x^{(1)}(x_i) = -N_x^{(2)}(x_i). \qquad (8)$$

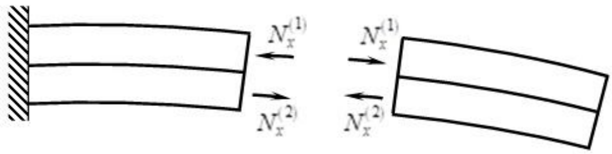
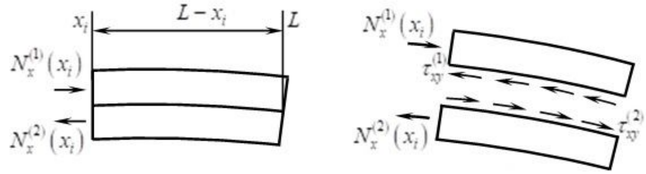


Fig. 4. Equilibrium of separated parts of the plate

In this case, one of the layers is compressed (it shortens), the other is stretched (it lengthens). In order to combine the short part of the system with the long one, it is necessary to bend them and attach the short part to the long part from its inner side (Fig. 5). These curvatures are achieved due to variable tangential forces $\tau_{xy}^{(1)}(x) = -\tau_{xy}^{(2)}(x)$ (Fig. 5b) acting on the contact surfaces of the layers.



(a) (b)

Fig. 5. Scheme of the action of internal forces on the separated part of the biplate with conditionally unseparated (a) and separated (b) layers

From the condition of equilibrium of the separated layers it follows:

$$\begin{aligned} N_x^{(1)}(x_i) &= -\int_{x_i}^{L} \tau_{xy}^{(1)}(x)d\tau, \\ N_x^{(2)}(x_i) &= -\int_{x_i}^{L} \tau_{xy}^{(2)}(x)d\tau. \end{aligned} \qquad (9)$$

Taking into account expressions (5)-(8), we obtain the equality

$$E^{(1)}\left[\varepsilon_x^{(1)}(x) - \alpha^{(1)}T\right]\cdot h^{(1)} = -E^{(2)}\left[\varepsilon_x^{(2)}(x) - \alpha^{(2)}T\right]\cdot h^{(2)}, \qquad (10)$$

which relates the total and temperature deformations of layers 1 and 2. Here it is necessary to take into account that both layers are metallic, therefore, the values of their elastic moduli can have the same orders, although in this case the coefficients $\alpha^{(1)}$ and $\alpha^{(2)}$ should be significantly different.

3. Thermoelasticdeformation ofrigid asphalt concrete pavement. The mode of thermoelastic deformation of a two-layer structure undergoes significant changes if the stiffness characteristics of one layer are much higher than those of the other layer. An example of such a design can be a system of asphalt concrete pavement 1 laid on a rigid (cement concrete or metal) base 2 of a road or bridge (Fig. 1). As in this case

$$E^{(1)} \ll E^{(2)} \tag{11}$$

and the rigidity of base 2 is much greater than the rigidity of layer 1, it can be assumed that the force and deformation effect of layer 1 on base 2 is negligible and when temperature T changes, base 2 is freely deformed along axis x, without experiencing thermomechanical influence of deformations from layer 1 on it and remaining rectilinear. In this case, the total strains ofbase 2 areequaltoitsthermalstrains $\varepsilon_{x,T}^{(2)} = \alpha^{(2)}\Delta T$, and total strains $\varepsilon_x^{(1)}$ of layer 1 and $\varepsilon_x^{(2)}$ of base 2 are the same, i.e.

$$\varepsilon_x^{(1)} = \varepsilon_{x,T}^{(1)} + \varepsilon_{x,el}^{(1)} = \varepsilon_x^{(2)} = \varepsilon_{x,T}^{(2)}. \tag{12}$$

To analyze the thermomechanics of this design, single out a two-layer strip of this structure bythe cross sections $z = z_k$ and $z = z_{k+1}$ and consider its deformation.

In this case, the longitudinal force in layer 1 is equal to

$$N_x^{(1)}(x) = E^{(1)}h^{(1)}\left[\varepsilon_x^{(1)} - \alpha^{(1)}\Delta T\right] = E^{(1)}h^{(1)}\left(\alpha^{(2)} - \alpha^{(1)}\right)\Delta T = \text{const}, \tag{13}$$

idest, it does not depend on x and does not change along this axis.

If so, then the integrals on the right-hand sides of equalities (9) do not depend on the lower limit and remain constant. This can happen,only if on most part of the segment of the contact interaction of layer 1 and base 2 of length $L - \Delta x$ of the roadway (Fig. 6), tangential forces $\tau_{xy}(x)$ in integrands are equal to zero and only on small segments of length Δx at the edges of the system, these forces are concentrated and take on such large values that the integrals of them are equal to the constant longitudinal force $N_x^{(1)}$:

$$\int_{L-\Delta x}^{L} \tau_{xy}^{(1)}(x)dx = N_x^{(1)} = E^{(1)}h^{(1)}\left(\alpha^{(2)} - \alpha^{(1)}\right)\Delta T. \tag{14}$$

These forces are proportional to the modulus of elasticity $E^{(1)}$, coefficient differences $\alpha^{(2)} - \alpha^{(1)}$ and, importantly, the thickness of the coating $h^{(1)}$, i.e. increase with its increase. Very often they cause delamination of the coating 1 from the base 2 observed in practice at the edges of roads and bridges. Conversely, a decrease in tangential friction stresses $\tau_{xy}^{(1)}, \tau_{xy}^{(2)}$ and the resulting friction forces corresponding to them, contributing to the delamination of the system at the edges of the contact plane of coating 1 and base 2, can be achieved, in accordance with formula (14), by reducing thickness $h^{(1)}$. However, it is not necessary to reduce $h^{(1)}$ across the entire width $2L$ of theroadway coverage. It is enough to do this on small edge sections of the road or bridge with a width of l, decreasing the thickness according to a linear law (Fig. 7).

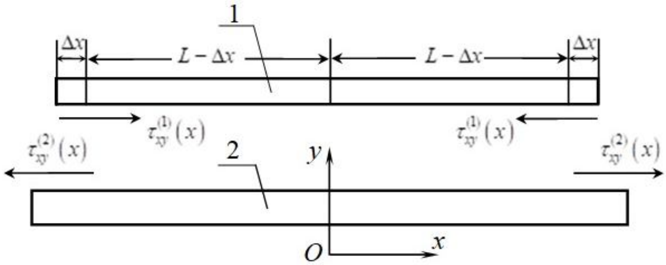


Fig. 6. Diagram of the concentration of tangential forces $\tau_{xy}^{(1)}(x)$, $\tau_{xy}^{(2)}(x)$ at the edges of the road

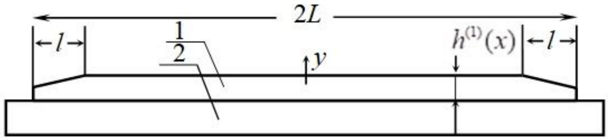


Fig. 7. Cross-sectional diagram of an asphalt concrete pavement with variable thickness $h^{(1)}(x)$

In this case, on the inner segment of constant thickness $h^{(1)}$ size accordingtoformula (14) force $N_x^{(1)} = E^{(1)}h^{(1)}\left(\alpha^{(2)} - \alpha^{(1)}\right)\Delta T$ remains constant, shear stresses $\tau_{xy}^{(1)}(x)$, $\tau_{xy}^{(2)}(x)$ will be equal to zero, and in areas of variable thickness $h^{(1)}(x)$ they will be smoothly distributed due to the change $h^{(1)}(x)$, remaining smaller in absolute value in accordance with the form of the right side in equality (14) (Fig. 8).

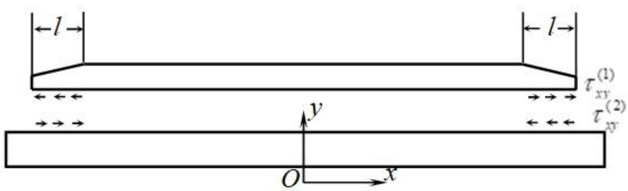


Fig. 8. Scheme of uniform distribution of tangential forces $\tau_{xy}^{(1)}(x)$, $\tau_{xy}^{(2)}(x)$ in sections of length l of contact coating of variable thickness $h^{(1)}(x)$ on rigid base 2

If length l is chosen such that forces $\tau_{xy}^{(1)}(x)$ are less than the ultimate tensile strength $\left[\tau_{xy}^{(1)}\right]$ of the asphalt concrete material under shear, then the delamination of layer 1 from base 2 will not occur under the given thermal effect.

4. Finite element verification of thermal deformation features of a two-layer structure. The above results of the analysis of thermoelastic deformation of an elastic layer on a rigid basis were obtained by methods of strength of materials and are of a qualitative nature. To confirm them, it is advisable to carry out numerical calculations of the test problem based on the theory of thermoelasticity [7, 10, 13], for example, using the finite element method [4]. For this purpose, a simplified design scheme of the cross section of the Southern Bridge across the Dnieper in the city of Kyiv was chosen. On it, with some regularity, an emergency situation is observed associated with intense cracking and delamination of the asphalt concrete pavement from the metal sheet of the bridge structure as a result of seasonal and daily temperature changes in winter and spring.

For the calculation, a flat cross section of the bridge deck was selected, consisting of a fine-grained asphalt concrete layer 1 with a thickness $h^{(1)} = 0.07\ \text{m}$, laid on a steel ribbed plate 2 (rigid base) with a thickness $h^{(2)} = 0.014\ \text{m}$. The values of thermomechanical characteristics for asphalt concrete amounted to $E^{(1)} = 5 \cdot 10^9\,\text{Pa}$, $\nu^{(1)} = 0.2$, $\alpha^{(1)} = 2.46 \cdot 10^{-5}\,\text{K}^{-1}$; for steel $E^{(2)} = 2.1 \cdot 10^{11}\,\text{Pa}$, $\nu^{(2)} = 0.3$, $\alpha^{(2)} = 1.3 \cdot 10^{-5}\ \text{K}^{-1}$. Insofar as $E^{(2)}$ is essentially larger $E^{(1)}$ and besides, the metal plate is reinforced from below with ribs, it can be considered that for the top coating it is a rigid base.

With finite element discretization of the area of the cross section of the structure selected for calculation, it was divided in the plane Oxy into rectangular finite elements of size $0.001875 \times 0.001444\ \text{m}^2$. With this discretization, the number of all finite elements was 201344, the number of all nodes was 311787, and the number of all required variables was 726941.

The study of the thermally stressed state of the system was carried out taking into account the fact that the structure is extended ($2L \approx 15\ \text{m}$), but has a relatively small thickness ($h = h^{(1)} + h^{(2)} = 0.07 + 0.014 = 0.084\ \text{m}$). Therefore, it turned out to be appropriate to use additional assumptions and simplifications. Due to the fact that the structure is freely blown by the wind and we can assume that the effect of radiative solar heating in winter (and even at night) can be neglected, we assume that with daily changes in air temperature, the temperaturesof the upper (asphalt-concrete) and lower (metal) layers have time to level off and take the same temperature T over the entire thickness of the package.Due to this, in this case, there is no need to solve the heat conduction problem and one can immediately use the finite element model ofthermoelasticity equations [1, 4], in which the initial temperature T_0 is zero, and its current value $T(t)$ is equal to the ambient temperature. Therefore, the initial and current temperatures of the entire array were taken equal to $T_0 = 0$, $\Delta T = -25^\circ\text{C}$. At the same time, on all horizontal boundary planes of the structure, the boundary conditions for the equality to zero of the normal (σ_{yy}) and tangents (σ_{xy}) stresses, on the extreme vertical planes of the layered web, the conditions were used $\sigma_{xx} = 0$, $\sigma_{xy} = 0$, on the plane of contact of the layers, the conditions of equality of normal and tangential displacements were accepted. In addition, constraints were imposed on the system, excluding its free movement, but not preventing its thermal deformation. Therefore, thermal stresses in the system can only occur due to the difference in the values of the thermal expansion coefficients of asphalt concrete ($\alpha^{(1)}$) and steel ($\alpha^{(2)}$).

As expected, the calculations showed that the areas of the most inhomogeneous strain and stress fields occur in the edge zones of the structure. Noteworthy is the function $\tau_{xy}(x, y)$ distribution field in section $z = \text{const}$. In Fig. 9, a fragment of the stress $\tau_{xy}(x, y)$ field is shown in coloron the left section of the structure with a length $\Delta x \approx 0.2$ m along the axis Ox. To the right of the field, there is a color scale of stress values corresponding to each color shade on the main field.

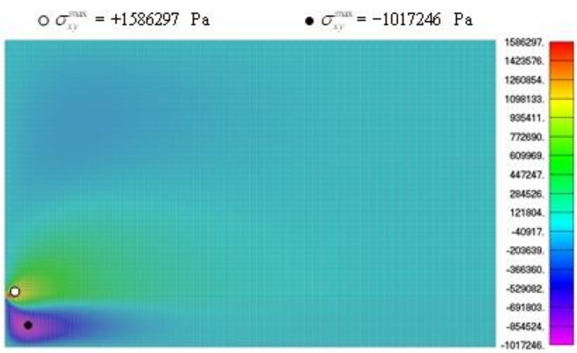


Fig. 9. Shear stress τ_{xy} field in cross section $z = \text{const}$ of the double layer construction

In this figure, the maximum value of the function $\tau_{xy}^{(1)}(x, y) = 1.586$ MPa in asphalt pavement 1 is marked with a light circle, the highest stress $\tau_{xy}^{(2)}(x, y) = 1.017$ MPa in the steel base is indicated by a dark circle. As can be seen, these stresses are concentrated at the nodes of the edge zone $\Delta x \le 0.03$ m and then rapidly decrease with distance from it along the coordinate x. It should be noted that here $\tau_{xy}^{(1)} \ne \tau_{xy}^{(2)}$. This is due to the fact that when using the finite element method, the stresses are calculated not at the nodal points, but at the internal points of the elements, i.e. at some distance from the contact plane, where these stresses coincide in absolute value. Since this function has large gradients in this zone, even a small distance from the plane of contact between layers 1 and 2 leads to noticeable changes and discrepancies in the values $\tau_{xy}^{(1)}$ and $\tau_{xy}^{(2)}$.

Thus, the conducted finite element analysis confirmed the conclusions obtained by the methods of strength of materials that in a two-layer structure consisting of an asphalt concrete pavement layer laid on a rigid foundation of a road or bridge, the largest tangential thermal stresses occur in a narrow section of the layer contact plane, within which these stresses have high gradients and practically tend to zero with distance from this zone. These stresses in this zone can be the reason for the beginning of delamination of the structure in the plane of contact between the layers.

Conclusions

1. On the basis of the theory of thermoelasticity, the problem of the concentration of thermal stresses in a two-layer structure, consisting of the upper asphalt concrete layer of the road surface, laid on a rigid cement concrete or metal foundation of a road or bridge, was posed.

2. In order to determine the reasons for the delamination of this structure observed in practice under thermal influences on it under conditions of seasonal and daily temperature changes, the dependences of internal normal and tangential thermal stresses on the thermomechanical characteristics of the system and its geometric parameters were found using the strength of materials methods.

3. The connection of this problem with the problem of elastic deformation of a bimetallic plate is considered. It is shown that, in contrast to this case, thermoelastic deformation of the upper layer on a rigid base is accompanied by a high-gradient concentration of tangential thermal stresses in the edge zones of the layer contact plane. These stresses can be the main reason for the beginning of the delamination of the asphalt concrete layer from the lower base and its further destruction. Manifestations of the established effect become more noticeable with an increase in the elastic modulus of the upper layer, its thickness and the difference in the coefficients of linear thermal expansion. The finite element testing of the performed calculations confirmed their reliability.

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ТЕОРЕТИЧНЕ МОДЕЛЮВАННЯ ЕФЕКТУ ТЕРМОСИЛОВОГО ВІДШАРУВАННЯ АСФАЛЬТОБЕТОННОГО ПОКРИТТЯ ВІД ЖОРСТКОЇ ОСНОВИ ДОРОГИ ЧИ МОСТУ

У практиці дорожнього будівництва до одного з найпоширеніших явищ, що супроводжується відшаруванням, подальшим тріщиноутворенням та руйнуванням асфальтобетонного покриття на жорсткій (цементобетонній чи металевій) основі автомобільної дороги або мосту, відноситься ефект концентрації зсувних термонапружень між покриттям і основою в крайових зонах конструкції. Вони викликаються тим, що, як правило, коефіцієнти лінійного температурного розширення фаз системи мають різні значення, що сприяє виникненню в них несумісних усадок та розширень. В умовах частих змін значень температури в неоднорідних асфальтобетонних конструкціях з термомеханічною несумісністю їх компонентів ці ефекти можуть сприяти їх прискореному старінню. У той же час при термомеханічній сумісності матеріалів досягається більш сприятливий розподіл внутрішньої напруги термічного і механічного походження, що виключає передчасну деградацію міцності контактуючих фаз і всього компонента в цілому. Методами опору матеріалів і методом скінченних елементів встановлено, що в умовах зміни температури системи при її сезонних та добових перепадах найбільшої концентрації піддаються дотичні напруги. Вони локалізуються в крайовій зоні площини контакту шарів, зростають із збільшенням товщини та модуля пружності верхнього шару. Ці напруження є основною причиною виникнення пластичних деформацій у цих зонах та подальшого розшарування в них конструкції. Запропоновано знижувати концентрацію та рівень високоградієнтних дотичних напружень, що генеруються, за рахунок зменшення товщин асфальтобетонного шару на цих ділянках.

Ключові слова: асфальтобетонне покриття, тверда основа, високоградієнтні зсувні напруження, локальні відшарування.

Gaidaichuk V.V., Shlyun N.V. ,Shevchuk L.V., Bilobrytska O.I.

THEORETICAL MODELLING OF THE EFFECT OF THERMAL DELAMINATION OF AN ASPHALT CONCRETE PAVEMENT FROM A RIGID FOUNDATION OF A ROAD OR BRIDGE

In the practice of road construction, one of the most common phenomena accompanied by delamination, subsequent cracking and destruction of the asphalt concrete pavement on a rigid (cement concrete or metal) base of a road or bridge is the effect of concentration of shear thermal stresses between the pavement and the base in the edge zones of the structure. They are caused by the fact that, as a rule, the coefficients of linear thermal expansion of the phases of the system have different values, which contributes to the occurrence of incompatible shrinkages and expansions in them. Under conditions of frequent temperature changes in heterogeneous asphalt concrete structures with thermomechanical incompatibility of their components, these effects can contribute to their accelerated aging. At the same time, with the thermomechanical compatibility of materials, a more favorable distribution of internal stresses of thermal and mechanical origin is achieved, which excludes premature degradation of the strength of the contacting phases and the entire system as a whole. Using the methods of strengthof materials and the finite element method, it has been established that under the conditions of a change in the temperature of the system during its seasonal and daily fluctuations, shear stresses are subjected to the highest concentration. They are localized in the edge zone of the plane of contact between the layers and increase with an increase in the thickness and modulus of elasticity of the upper layer. These stresses are the main reason for the occurrence of plastic deformations in these zones and subsequent delamination of the structure in them. It is proposed to reduce the concentration and level of generated high-gradient shear stresses by reducing the thickness of the asphalt concrete layer in these areas.

Keywords: asphalt concrete pavement, rigid base, high-gradient shear stresses, local delaminations.

Гайдайчук В.В., Шлюнь Н.В., Шевчук Л.В., Билобрыцька Е.И.

ТЕОРЕТИЧЕСКОЕ МОДЕЛИРОВАНИЕ ЭФФЕКТА ТЕРМОСИЛОВОГО ОТСЛОЕНИЯ АСФАЛЬТОБЕТОННОГО ПОКРЫТИЯ ОТ ЖЕСТКОЙ ОСНОВЫ ДОРОГИ ИЛИ МОСТА

В практике дорожного строительства к одному из наиболее часто встречающихся явлений, сопровождающихся отслоением, последующим трещинообразованием и разрушением асфальтобетонного покрытия на жесткой (цементобетонной или металлической) основе автомобильной дороги или моста относится эффект концентрации сдвиговых термонапряжений между покрытием и основой в краевых зонах конструкции. Они вызываются тем, что, как правило, коэффициенты линейного температурного расширения фаз системы имеют разные значения, что способствует возникновению в них несовместных усадок и расширений. В условиях частых смен значений температуры в неоднородных асфальтобетонных конструкциях с термомеханической несовместимостью их компонент эти эффекты могут способствовать их ускоренному старению. В тоже время при термомеханической совместимости материалов достигается более благоприятное распределение внутренних напряжений термического и механического происхождения, исключающее преждевременную деградацию прочности контактирующих фаз и всейсистемы в целом. Методами сопротивления материалов и методом конечных элементов установлено, что в условиях изменения температуры системы при ее сезонных и суточных перепадах, наибольшей концентрации подвергаются касательные напряжения. Они локализуются в краевой зоне плоскости контакта слоев, возрастают с увеличением толщины и модуля упругости верхнего слоя. Эти напряжения являются основной причиной возникновения пластических деформаций в этих зонах и последующего расслоения в них конструкции. Предложено снижать концентрацию и уровень генерируемых высокоградиентных касательных напряжений за счет уменьшения толщин асфальтобетонного слоя на этих участках.

Ключевые слова: асфальтобетонное покрытие, твердая основа, высокоградиентные сдвиговые напряжения, локальные отслоения.

УДК 539.3

Гайдайчук В.В., Шлюнь Н.В., Шевчук Л.В., Білобрицька О.І. **Теоретичне моделювання ефекту термосилового відшарування асфальтобетонного покриття від жорсткої основи дороги чи мосту** // Опір матеріалів і теорія споруд: наук.-тех. збірн. – К.: КНУБА, 2022. – Вип. 109. – С. 38-49.

У статті наведено результати теоретичного моделювання явища генерування високоградієнтних полів дотичних термонапруг у двошаровій конструкції асфальтобетонного покриття на жорсткій цементобетонній або металевій основі в умовах зміни температури системи при її сезонних та добових перепадах.

Іл. 9. Бібліогр. 15 назв.

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Gaidaichuk V.V., Shlyun N.V., Shevchuk L.V., Bilobrytska O.I. **Theoretical modelling of the effect of thermal delamination of an asphalt concrete pavement from a rigid foundation of a road or bridge** // Strength of Materials and Theory of Structures: Scientific-&-Technical collected articles – Kyiv: KNUBA, 2022. – Issue 109. – P. 38-49.
The article presents the results of theoretical modeling of the phenomenon of generation of high-gradient fields of tangential thermal stresses in a two-layer structure of an asphalt concrete pavementon a rigid cement concrete or metalbase in conditions of changing system temperature during its seasonal and daily differences.
Fig. 9. Ref. 15.

УДК 539.3
Гайдайчук В.В., Шлюнь Н.В., Шевчук Л.В., Билобрыцька Е.И. **Теоретическое моделирование эффекта термосилового отслоения асфальтобетонного покрытия от жесткой основы дороги или моста** // Сопротивление материалов и теория сооружений: науч.-тех. сборн. – К.: КНУСА, 2022. – Вып. 109. – С. 19-30.
В статье приведены результаты теоретического моделирование явления генерирования высокоградиентных полей касательных термонапряжений в двухслойной конструкции асфальтобетонного покрытия на жесткой цементобетонной или металлической основе в условиях изменения температуры системы при ее сезонных и суточных перепадах.
Ил. 9. Библиогр. 15 назв.

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