

Optimization of Asphalt-concrete Pavement in the Conditions Mountainous Relief

Introduction

Considering everyday heavy traffic and increased caring capacity of vehicles there is a need of construction of stiff and costly asphalt-concrete pavement.

High professional level scientific works and methods of calculation for the optimization of transport capacity of asphalt-concrete pavement are available but there are some important factors having significant impact on pavement that are not considered in the papers.

Particularly, there are factors typical for a hot climate and mountainous relief characteristic for large part of Georgian territory that cause deformation of surface of asphalt-concrete pavement. Namely straight line of pavement is distracted under the influence of propelling and breaking forces transferred from wheels and bent lines of the roadway are affected by the centrifugal force. Existing calculation schemes do not take into account deformations caused by these forces that generate waves and ruts on pavement. The basic effect of these factors is destruction of surface plainness and deterioration of traffic conditions.

With an aim to resolve the issue of optimization of transport capacity of asphalt-concrete pavement considering its strained and deformed state due to real effect of motor transport calculation schemes should consider strong influence of horizontal pressure of transport and deformations caused by it.

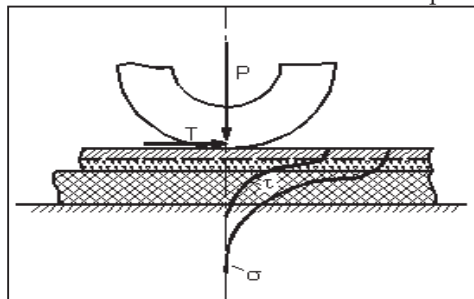
The Body Of The Article

Plainness of pavement surface created applying to organic matrix are destructed after certain period of time due to plastic and shear deformation revealed through waves and ruts. As a rule waves on pavement do not turn up all of a sudden but appear after 2-3 years after its construction. That is why composition of cement concrete should be selected the way that waves do not appear during pavement service life.

Horizontal component of transport pressure between wheels and pavement surface is generated by propelling and breaking forces on straight line of pavement while its bent lines are affected by centrifugal force.

Tangent force generating horizontal component of transport pressure is highest at the top lift of pavement and is damped at the bottom of asphalt road (Drawing № 1). Thus they should be considered only while working out measures to guarantee skid resistance of pavement with materials based on organic matrix.

According to existing methods of pavement calculation, during selection of asphalt-concrete the main attention is paid to stiffness indicators, while there are not considered factors characteristic of a hot climate and intensive pressure of horizontal forces transferred from motor transport. The influence of these factors is the most intensive in the areas with high grade slopes, curve roads, close to cross-roads and stops of transport facilities with high axial load and etcetera. Plastic and shear deformation are the main reasons of appearance of waves on pavement.



Drawing №1: Distribution of normal (σ) and tangent (τ) pressure on pavement under the influence of vertical (P) and horizontal (T) forces

In the conditions of hot and humid climate, especially in mountainous relief, shear deformation should be considered as the main criteria for stiffness of pavement. Thus for selecting pavement stiffness criteria working conditions like influence mode of vertical and horizontal forces, climatic and hydro geological factors should be taken into account. In the conditions of contemporary traffic rebound deflection as well as shear deformation of asphalt concrete pavement should be considered as stiffness criteria but modern normative-technical literature does not properly reflect it.

Georgian territory is mountainous that is why influence of horizontal, tangent forces transferred on pavement from the movement of vehicle wheels at the areas with high grade slopes and curves, is intensive enough. It is especially dangerous at slopes under solar radiation while calculated temperature for slopes in different regions vary in between 50-60°C. In this conditions asphalt concrete pavement turns soft, plastic, easy to deform. That is why expurgations, waves and other kind of destructions generated from shear deformations appear on pavement.

Limit state of asphalt concrete pavement primarily should be defined taking into account pressure of dynamic influence of rolling stock.

The limit state is formed at certain areas of roads. This is the case when part of pavement is subject to plastic deformations, namely plastic layer is formed that after certain period of time in the

form of cylindrical surface creates interior skid contact area (Drawing №2).

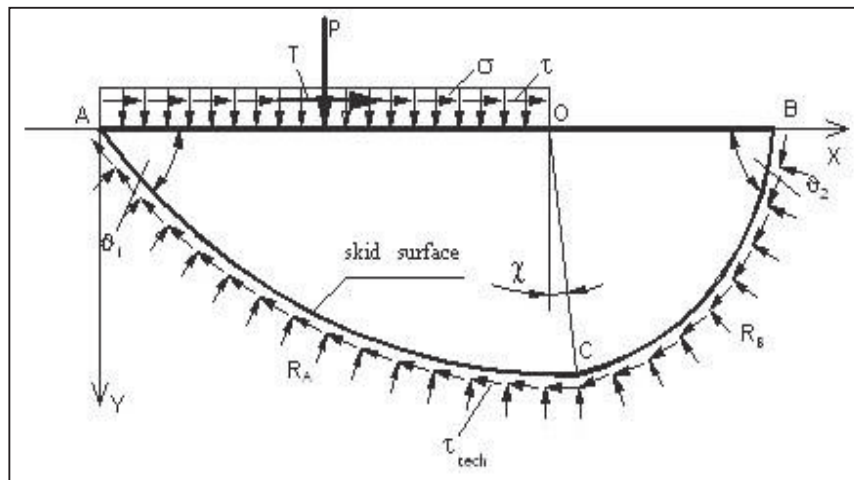
Skid surface separates part of the pavement AOB from the other body. In the limit state at ACB surface emerges reactive normal pressure of RA and RB intensity and reactive limited tangent pressure $\tau_{tech} = \tau_{xy}$.

These reactive forces balance affect of motor transport pressure. While defining limit state of pavement having single width generated reactive σ_z transverse normal pressure, perpendicular planes ABC (in the direction of Z wasp) and τ_{boc} tangent pressure of parallel planes ACB should be taken into account.

Schemes of force and pressure distribution (Drawing 2) are confirmed by laboratory experiments and measured in real working conditions of pavement.

This kind of calculation scheme of pavement can be considered as the plane problem in the theory of elasticity and plasticity. Particularly during plane deformation that in general is different from common strained state of plane problem so that none of the three normal pressures σ_x , σ_y , σ_z is equal to nil (in the other case $\sigma_z = 0$.)

Equation of shear surface is applied according the limiting state of the theory of elasticity (by Ilyushin) together with theoretical and experimental results. This equation is suitable for limit state: $y = ax^3 - bx^4$.



Drawing №2: Interior skid contact surface; P - vertical pressure; T - horizontal pressure; σ_z - normal pressure; τ - tangent pressure; RA and RB normal reactive pressure; τ_{tech} - reactive limited tangent pressure spots of generated curve.

Considering plasticity criteria calculating $\sigma_x, \sigma_y, \sigma_z$ pressure components for the generated curve areas gives opportunity to identify final value of P and T forces.

Pressure components are identified applying to the following formulas:

1. when $\sigma_0 = \text{const}$ and σ_0 - vertical pressure is normal strain

$$\sigma_x = -\frac{\sigma_0}{\pi} \left(\vartheta_2 - \vartheta_1 - \frac{1}{2} \sin 2\vartheta_2 + \frac{1}{2} \sin 2\vartheta_1 \right);$$

$$\sigma_y = -\frac{\sigma_0}{\pi} \left(\vartheta_2 - \vartheta_1 + \frac{1}{2} \sin 2\vartheta_2 - \frac{1}{2} \sin 2\vartheta_1 \right);$$

Tangent pressure $\tau_{xy} = -\frac{\sigma_0}{\pi} (\sin^2 \vartheta_2 - \sin^2 \vartheta_1)$

2. when $\tau_0 = \text{const}$ and τ_0 - horizontal pressure is normal strain

$$\sigma_x = -\frac{2\tau_0}{\pi} \left(\ln \frac{\cos \vartheta_2}{\cos \vartheta_1} + \frac{\sin^2 \vartheta_2 - \sin^2 \vartheta_1}{2} \right);$$

$$\sigma_y = -\frac{\tau_0}{\pi} (\sin^2 \vartheta_2 - \sin^2 \vartheta_1);$$

Tangent pressure $\tau_{xy} = -\frac{\tau_0}{\pi} \left(\vartheta_2 - \vartheta_1 - \frac{1}{2} \sin 2\vartheta_2 + \frac{1}{2} \sin 2\vartheta_1 \right)$

Our case when both kind of pressures affect the pavement gives opportunity to apply to superposition principle.

$$\sigma_x = \sigma_x(\sigma_0) + \sigma_x(\tau_0);$$

$$\sigma_y = \sigma_y(\sigma_0) + \sigma_y(\tau_0);$$

$$\tau_{xy} = \tau_{xy}(\sigma_0) + \tau_{xy}(\tau_0).$$

Shear lines due to main (σ_1, σ_2) pressure creates angles that in our case equals to $\pi/4$ radian.

Thus shear lines are characteristic. With equation of characteristics, change of sum ($\sigma_x + \sigma_y$) as well as sum ($\sigma_1 + \sigma_2$) in the line is proportional to spin of curve slide. Besides, proportional coefficient is equal to $4K$.

This is how effect of main pressure and angle of its decline is identified at the slide line φ to axis X. Angle ($\varphi + \pi/4$) at one point gives tangent direction to curve slide. Maximum tangent pressure influence at this way.

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Here $K = 0.5(\sigma_1 - \sigma_2)$.

K represents intensive tangent pressure as well;

it can be defined from the formula $K = \frac{\sigma_i}{\sqrt{3}}$ where σ_1 represents intensity of main pressure.

Aside curve slide at specific areas we identify effect of main pressure and angle of its decline at axis X:

$$\sigma_1 = \frac{\sigma_x + \sigma_y}{2} + \sqrt{\left(\frac{\sigma_x - \sigma_y}{2} \right)^2 + \tau_{xy}^2};$$

$$\sigma_2 = \frac{\sigma_x + \sigma_y}{2} - \sqrt{\left(\frac{\sigma_x - \sigma_y}{2} \right)^2 + \tau_{xy}^2};$$

$$\operatorname{tg} 2\varphi = \frac{2\tau_{XY}}{\sigma_X - \sigma_Y}$$

For the main pressure components identified through these formulas there is a fixed schedule where angle of main pressure decline is considered.

Maximum effect of tangent pressure at curve slide is identified through the following

$$\tau_{MAX} = \left(\frac{\sigma_1 + \sigma_2}{2} \right) \cdot \operatorname{tg} \varphi + C$$

and it is concluded that they reach C point at sky line.

Let us discuss the same task when slide surface of asphalt concrete pavement generated from critical pressure represents curvilinear cylinder

(Drawing №3), in addition adjacent strata disposed on parallel planes XOY opposes to the transfer of limit state of this element. In this case task belongs to a plain problem of the theory of elasticity and plasticity – plastic deformation.

At the slide surface of cylinder limit state acts as a shift from elasticity to plasticity (Drawing #3).

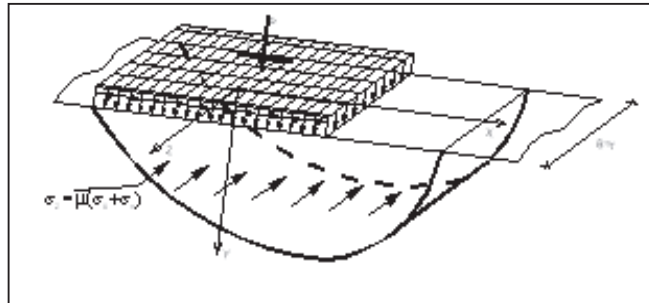
Relative line of plane transverse deformation in the line of axis Z equals to nil.

$$\sum \varepsilon_Z = 0; \quad \varepsilon_Z = 0 = \frac{1}{E} (\sigma_Z - \mu(\sigma_X + \sigma_Y))$$

Concluding that $\sigma_Z = \mu(\sigma_X + \sigma_Y)$.

Reaching limit state in the moment of slide cylindrical element should prevail over not only limited tangent pressure resistance and forces of

inner bond but reactive anti-slide forces, generated into elasticity XOY of strained element and parallel strata.



Drawing №3: Limited state of slide surface of cylinder.

Resultant side pressure equals to additional

$$2\mu \left(\frac{\sigma_1 + \sigma_2}{2} \right) \cdot \operatorname{tg} \varphi + C \text{ pressure.}$$

Conclusion

Therefore maximum horizontal pressure for general thickness elements is calculated with a help of this formula:

$$\tau_{MAX} = \left[\left(\frac{\sigma_1 + \sigma_2}{2} \right) \cdot \operatorname{tg} \varphi + C \right] + \left[2\mu \left(\frac{\sigma_1 + \sigma_2}{2} \right) \cdot \operatorname{tg} \varphi + C \right] = (1 + 2\mu) \cdot \left[\left(\frac{\sigma_1 + \sigma_2}{2} \right) \cdot \operatorname{tg} \varphi + C \right]$$

Calculation scheme of maximum tangent pressure mentioned above depicts actual working conditions of pavement and using it in a commuter program for optimization we will get construction of pavement where intensive influence of horizontal forces will be well considered that eventually gives opportunity to avoid skid deformations of Asphalt concrete pavement.

Experiments revealed the method of calculation of maximum tangent pressure where strong influence of horizontal and vertical pressure depicts actual working conditions of pavement.

The method of calculation of the structure of pavement, taking into consideration other important exploitation requirements as well, gives an opportunity to foresee skid resistance of roadway to avoid destruction of surface plainness.

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ასფალტობეტონის საფარის ოპტიმიზაცია სამთო რელიეფის პირობებში

რეზიუმე

ნაშრომში განხილულია დრეკადობისა და პლასტიურობის თეორიის ბრტყელი ამოცანა, ასფალტბეტონის დამაბულ-დეფორმირებული მდგომარეობის გათვალისწინებით, ავტომობილის მიერ გადაცემული დატვირთვებისგან.

სტატია დაფუძნებულია ზღვრულ მდგომარეობის თეორიისა და სუპერპოზიციის პრინციპებზე, თეორიული და ექსპერიმენტალური კვლევის შედეგების გათვალისწინებით.

დამუშავდა მაქსიმალური მხები დატვირთვის გაანგარიშების მეთოდი, რომელიც საშუალებას გვაძლევს აღვწეროთ საგზაო საფარის მუშაობის პირობები, მოვახდინოთ გასრიალების წინააღმდეგობის პროგნოზირება და თავიდან ავიცილოთ ასფალტბეტონის ზედაპირის დაშლა.

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