Model of junctioning rigid and non-rigid road pavement

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Abstract. The junction of sections on rigid and non-rigid road pavement is a source of severe load. In course of time residual strain causes the formation of subsidence in road surface. This is not significant defect of road pavement but it has a negative impact on driving comfort. This effect reveals itself not only for road pavement damaged by overloading. The unavailability of verification and quality control during work is not considered to be a reason of the problem. It is based on the internal physical processes that occur in the junction of sections on rigid and non-rigid road pavement under wheel loading. The issue under discussion in this article is related to the problem of the formation of non-rigid road pavement subsidence in the junction of sections of rigid and non-rigid road pavement. Subsidence at the junction of the pavement most often occurs in the area of bridge approach. The subsidence of the non-rigid road pavement can later lead to the formation of pits on the road. The reason for the formation at non-rigid road pavement subsidence is irregularities in the procedure, suffusion. It is necessary to consider the degree of impact not only of the amount of load from the wheel, but also its direction.

Key words: bump at bridge, transition plate, rigid road pavement, non-rigid road pavement, subsidence at non-rigid road pavement, settlement.

1 Introduction

The research subject is in the sphere of road construction and maintenance. The article analyzes the causes of the subsidence formation at approach section from non-rigid to hard road pavement. The reasons for the phenomenon of this drawdown have not been studied. There is no clear idea of the nature of appearance of mould and its structure at the boundary between the rigid and non-rigid pavement.

In the reviewed articles, a large amount of attention is paid to the comprehensive study of the transition from fracture to tension to fracture associated with soil stability problems [1, 2], the creation of composite materials based on them [3,4]. When calculating pavement, the formation of subsidence is determined based on the application of loads on the surface of the coating [5, 6]. The subjects of preventing the occurrence of subsidence are given a lot of attention when strengthening both base soils and coating materials so as to increase the bearing capacity [7]. Different types of impact on structures under the influence of external environmental factors, such as water-thermal [8], aggressive media [9] are also widely studied. The work of the material under various hydraulic regimes of free water in soils has been the subject of many articles [10-13], and the calculation is carried out using half-space methods [14, 15, 16], without taking into account the indispensable component as a load motion vector. The loads used in the calculations are static. The study of this issue is increasingly moving away from the consideration of the root causes of formation. It delves into the process of improving existing materials [17-20]. This circumstance prompted an in-depth study of the question on the causes of the appearance of mould at the pavement of rigid and non-rigid pavement.

2 Materials and methods

2.1 Analysis scheme the sections of junction of rigid and non-rigid road pavement

The design is intended to support forces from asymmetric loads. This load is caused when driving a car on the section from non-rigid to rigid road pavement. It distributes the force into two components: the tangent, which is extinguished in the concrete kernel, and the vertical load – normal wheel loading. The main property of this section is the absence of a constant equivalent modulus of elasticity, and the availability of its component in a variable value. The analysis scheme has such items that the entire
section does not have a constant equivalent modulus of elasticity, but corresponds to its divisible unit, increasing from a non-rigid road pavement to a rigid one. This distinguishes the load distribution of dynamic objects in a closed system. The forces create the equilibrium of stability. The external forces that occur disappear when the area is momentarily displaced or the shape of material is changed [1].

The part of the basis for joining rigid and non-rigid pavement has shear requirements. This ensures flatness, strength and stability, and to achieve damping forces can arise due to the high difference of units of equivalent modulus of elasticity [2].

Figure 1 shows the section of pavement where a non-rigid (1) and rigid (2) road pavement is junction, with movement of a car wheel (3). The load of the car wheel is the force of the coupling weight - normal wheel loading \( P(4) \), and the torque \( M(5) \), transmitted in the contact slick of the wheel (6), generated by the traction force \( F(6) \). On the contact surface (bond) of two materials in the road pavement, reactive forces appear from the applied wheel load – the bending moment in the non-rigid pavement \( M(7) \) and the reaction force of the foot \( P(8) \).

Figure 1. The junction of sections of rigid and non-rigid road pavement, along which the car wheel moves.

To compute the wheel loading acting at the moment when the wheel passes over the pavement in the direction from non-rigid to rigid road surface, a designing load spreading scheme is made. The surface of the non-rigid road pavement is a console with a pinching at the junction with the rigid road surface, at point O (Figure 1). Computational forces transmitted to the non-rigid road surface and reckoning up moment diagrams are determined by the total torque relative to the O point. It displays 3 control points of the console at a distance of 0.94 m, 0.45 m, and 0 m, respectively.

The force of weight of the wheel \( P \) is shown in Figure 2 numbered \( 1_1, 1_2, 1_3 \) is equal to the value of 2 642 N. The \( M(1) \) (torque) from the car wheel displayed by the numbers \( 2_1, 2_2, 2_3 \). The value of the torque \( M(1) \) is 996 N*m.

Figure 2. Scheme of spreading load at junction of sections of rigid and non-rigid road pavement.
Figure 3 shows a diagram of the moments when the wheel passes directly and the direction of the torque when approaching a hard road pavement. The forces are distributed by applying them to the beam, according to the laws of theoretical mechanics.

![Figure 3. Outline of bending moment](image)

Only the forces acting on the load are indicated on the moment to distribution. The calculation of the junction of sections of rigid and non-rigid road pavement is based on the conditions of the design scheme with a hard pinching at the interface with a hard road surface. The calculation performed at three control points, based on the condition of an absolutely rigid surface, the impact of moments taken into account by the following signs: clockwise- negative, counter-positive.

The bending moment, turning of non-rigid pavement hard without the interface area of rigid and non-rigid pavement slab affects the hard pavement causing it to perceive the relief load. A negative counterclockwise torque causes reinforce concrete plate to bend.

2.2 **Design of load diagram**

The wheel loads acting on rigid and non-rigid sections of road pavement are linked to adjacent sections. The forces arising from all sides are dampened by distributing the tangent tensile stresses, compressing the filler concrete. The scheme of distribution of forces from the impact of the wheel load in this section shows elements OAS in Figs. 2a, 2b. The OAS area is reference surface, and wheel load distribution occurs along it. Find a formula describing this line, and then calculate it. (Figures 4a, 4b).

![Fig 4a. Scheme of wheel load distribution of the resultant force directed at an angle of 55°.](image)
**Figure 4b.** Scheme of wheel load distribution of the resultant force directed at an angle of 87°.

Figures 5a and 5b display the total stress distribution results calculated using Plaxis software.

**Figure 5a.** Model of stress movement of the road pavement substructure under wheel load.
3 Results

The premise for the development of road construction at the junction of rigid and non-rigid road clothing is based on the effect that a moveable wheel generates forces in the substructure that act normally on the rigid road pavement.

Theoretical calculation and field experiments confirm the accepted theory about the influence of the wheel traction force on the vertical shift of the hard pavement plate. It is one of the reasons for subsidence at the junction of the pavement, which is confirmed in the proceeding experiments (Figs. 6a and 6b).

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**Figure 5b.** Model of stress movement of the road pavement substructure under wheel load.

**Figure 6a.** Experiment. Construction.
4 Discussions

The formations of subsidence at the junction of sections of rigid and non-rigid road pavement were studied. The torque acting on the road pavement from the wheel changes from positive to negative. The moment of approaching the junction of rigid and non-rigid pavement sections has been studied. Rigid road pavement needs to be unloaded. The shear loads force the soil to take the form of a wheel imprint, stretching out in a cloth-like fashion. The loads from the car wheel were found using theoretical and practical methods. It was calculated that the traction force of the wheel changed the vector of the applied force depending on the gear selected in the gearbox and the acceleration start speed.

A full-scale experiment was carried out to determine the coating trough and at the junction of the rigid and non-rigid road pavements the loads from the loads transmitted through the car wheel. The experiment showed the fidelity of methods and calculations for the determination of subsidence at junction of sections of rigid and non-rigid road pavement. The proposed construction of pavement for pairing rigid and non-rigid pavements should minimize the formation of troughs at the junction with rigid pavement. This system in the form of an element of the base design of the interface between rigid and non-rigid road pavement reduces stresses arising during the movement of a car wheel. Also system decreases deformation of the material.

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