The Use of Cold Recycling Technology to Increase the Resistance of Pavements to Rutting

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Abstract. The purpose of the article is to develop the construction of pavement with increased resistance to rutting, arranged during the repair of existing asphalt concrete pavements by cold recycling. It was established that the location of the ruts on the roadway is due to the distribution of the driveways of wheels of transport along the width of the lanes. Constructions of pavement with unequal strength along the width of the lane are proposed. Such constructions are arranged during the repair of pavement by milling asphalt concrete at the locations of the ruts by their width (90–100) cm and mixing the asphalt granulate with cement using cold recycling technology. The resulting mixture is placed in pits obtained by milling ruts, and compacted. As a result, two parallel strips of new monolithic material are obtained on the surface of the repaired coating within each lane. A new leveling or structural layer of asphalt mix is arranged on the existing coating with repaired ruts. During the exploitation of such pavement, hidden elements are hidden from the driver. Therefore, the nature of the distribution of passages along the width of the carriageway remains the same, but sections of the base located under the places of formation the rut under the new coating are made of durable, slightly deformable material.

1. Introduction

Rutting is a problem of the road sector in many countries. During the exploitation of the road, the rut depth increases, and, having reached certain values, it becomes the cause of road traffic accidents. The negative impact of the rut on traffic safety is explained by the fact that the track is the place where rainwater is concentrated. Until the thickness of the water layer reaches values equal to the depth of the rut, water in the rut can drain only along the longitudinal slope. Therefore, the thickness of the water film in the rut is determined by the depth of the rut and the intensity of the rain. The thickness of the water film effect to the adhesion coefficient value of the coating with the tire. It is known that at the same conditions (speed, roughness parameters, etc.), the adhesion coefficient is the smaller, the greater the thickness of the aqueous film. Therefore, to ensure traffic safety, it is necessary to limit the rut depth by the limit values [1–4].

The works aimed at determining the limit rut depth [1, 2] from the conditions of placing rainwater in it, rely on the results of studies of the aquaplaning effect [5–11]. Therefore, the limiting depths of the ruts obtained in [1, 2] can be considered critical values for traffic safety.

Currently, much attention is devoted to the development of methods for predicting changes in rut depth during the operation of the road. Such methods can be divided into two groups:
– mechanical-empirical methods [12–15], connecting the rut depth with deformations accumulated by asphalt concrete or granular material of the pavement foundation, or subgrade soil;
– mechanical, at which the rut depth is determined by the sum of the plastic displacements of the surface of the layers of the pavement and the subgrade. Such plastic displacements are caused by the accumulation of residual deformation in materials and soils. Residual deformations are calculated as a function of the stress value, the number of loads, or the total time of repeated loads, as well as the parameters of materials and soils [16–20]. The displacement of the layer surface is determined by integrating the plastic deformation function along the depth of the layer under consideration.

Depth rut forecasting methods can be used to design pavements. In this case, it is possible to select for the various structural layers the materials that are resistant to the accumulation of residual deformations. It is also possible to calculate the thickness of the structural layers at which is provided a safe value of pressure that transmitted to the underlying layer.

Special designs of road pavements are known in which hidden elements are arranged along the lanes of the most probable passage of cars. Such elements are hidden from the driver by the road pavement. Examples of road pavement are shown in figure 1.

![Figure 1](image)

**Figure 1.** Road pavements for road of II technical category with hidden rut element: a – with creation a hidden rut element in the base of granular materials; b – with creation a hidden rut element in the subgrade; 1 – coating layers and bases from materials treated with an organic binder; 2 – layers of granular materials; 3 – hidden rut element from material or soil treated with a binder; 4 – subgrade.

2. Materials and methods
Both structures, shown in figure 1, can be built under new construction conditions, as well as during overhaul of pavement. In conditions of overhaul, the design shown in figure 1a, can be arranged when reinforcing road pavements of crushed stone coating by a new asphalt concrete layer. The design shown in figure 1b, in the conditions of overhaul can be built only after dismantling the existing pavement. Thus, the area of application the pavement shown in Fig. 1, in the conditions of overhaul is limited.

Therefore, the goal of our work is to develop a construction of pavement resistant to rutting for the conditions of repair and overhaul of pavement with asphalt concrete coating.

According to conventional opinion, the depth of the rut is determined by the sum of the two components. The first component is the residual displacement of the surface of the coating as a result
of the accumulation of residual deformations by the structural layers of the road pavement and the subgrade. The second component is the wear of the coating due to the separation of particles of material from its surface caused by the action of tires. Under various traffic conditions, one of these components prevails over the other. Considering the displacement of the surface of the coating as a result of the accumulation of residual deformations, it can be argued that in different designs of pavements, the greatest deformation accumulates in one of the structural layers or in the subgrade.

Experimental research allows us to determine the conditions under which the greatest deformation accumulates either in the soil of the subgrade, or in one of the layers of pavement (asphalt concrete pavement or granular base). Such experiments are performed on the basis of measurements of the displacements of the surface of the layers and the subgrade in trenches excavated perpendicular to the axis of the roadway.

In figure 2 shows illustrations of an experimental study that we performed to determine the contribution of pavement layers and subgrade to the depth of the rut on the surface of the 24th Severnaya road in Omsk.

![Figure 2. An experimental study of the contribution of pavement layers to the rut: a – trench in pavement with stretched twine (rope) which fixing the initial location of the surface of layers; b – thickness measurement of asphalt concrete pavement; c – subgrade surface displacement measurement](image)

The trench shown in figure 1a, located at a distance of 10 m from the intersection with the road on the street Gercena. Traffic at the intersection is regulated by a traffic light. Therefore, within the trench there are two sections of the road with different traffic conditions. The right traffic lane refers to the acceleration section where cars pick up speed after the traffic light allow signal. In the left traffic lane, vehicles stop when the traffic light is forbidden signal, the brake section is located here. When performing the experiment in the trench, the initial location of each layer was determined and fixed it with stretched twine. With this fixation, the displacement of the layer relative to the twine is clearly visible. In figure 1c, the displacement of the subgrade surface is clearly visible, and it can be measured.

As a result, it was found that in the acceleration section, the subgrade contributed the most to the depth of the rut, the displacement of its surface was 83% in the outer rut and 77% in the inner rut. The total thickness of the asphalt concrete layers measured at 10 points of the lane was the same and amounted to 27 cm, which allowed us to conclude that there was no wear. Measurements of the thickness of the asphalt concrete layers within the area of braking showed that in the ruts the total thickness of the asphalt concrete is 3 mm less than between the ruts. The depth of the outer rut is 33 mm and the inner one is 29 mm. Therefore, the contribution of wear to the depth of the ruts was 9 and 10% for the outer and inner ruts, respectively. The displacement of the subgrade surface by the outer and inner rut was 24 and 21 mm. Thus, the contribution of the subgrade to the depth of the rut was 73 and 72%.

By analyzing the results of tests performed by US experts, we can expand the list of causes of rutting. In figure 3 shows the trenches arranged on the roads of the USA with different road pavements and traffic conditions.
Figure 3. Experimental studies of US specialists: a – deformation of the base of the pavement; b – shear deformation of granular base material; c – asphalt concrete shear deformation in a two-layer coating.

From the analysis of experimental data and figure 3 it follows that the main cause of the ruts is the residual deformation of the compaction and shear in the materials of the structural layers. The rut shown in figure 3a, has no lateral bulging, and the thickness of the base in the rut is less than the thickness of this layer between the ruts. It follows that the main reason is the deformation of the compaction of the base material. The rut shown in figure 3b has lateral bulging, and the thickness of the base of granular material in the rut is less than the thickness of this layer between the ruts and in the lateral protrusion. Moreover, the thickness of the base in the lateral bulge is greater than the thickness of this layer between the ruts. Hence the conclusion that the main cause of the rut is the displacement of the granular material from the central part of the rut to the area of lateral bulge. Consequently, this plastic deformation of shear of granulated material causes the formation of ruts. The rut shown in figure 3c is a consequence of shear deformations of asphalt concrete in a two-layer asphalt concrete pavement. Evidence of this is the different thickness of the asphalt layers at the bottom of the rut and in the side bulge.

Analyzing the constructions of road pavements, presented in figure 1, it can be argued that the application of hidden elements from a durable and less deformable material will reduce the pressure transmitted to the underlying layer and all layers located below, including the subgrade. Therefore, road pavements with hidden elements are designed to reduce the residual deformations accumulated by the subgrade figure 1b and the deformations accumulated in the "base of granular material - subgrade" system figure 1a. Such structures cannot provide a reduction in rut depths at wear of asphalt concrete or at shear of asphalt concrete. Nevertheless, we note that according to the generally accepted opinion in qualitatively constructed asphalt concrete pavements, plastic shear deformation occurs as a result of heating the pavement to high temperatures. Heating of asphalt concrete to critical temperatures is a rare occurrence, and in the event of an extreme increase in air temperature, the movement of heavy vehicles can be limited. In all other cases, the cause of the occurrence of shear deformations of the asphalt concrete is considered either a violation of the technology of construction, or errors made when selecting the composition of the mixture. An example of such errors is the high bitumen content for the weather - climate conditions in which the road is operated.

Significant wear of the asphalt concrete pavement occurs in areas of braking of transport of not long length. Wear of coatings is 60–80% of the rut depth, is observed in braking sections of 10–20 m long, located at intersections unregulated by traffic lights with a rotation angle of about 90 degrees.

Therefore, over the vast majority of the road network, the main reason for the appearance of ruts is deformation of the compaction and shear of the base layers from granular materials and soils of subgrade. To reduce the ruts caused by this reason, it is possible to offer a applying of hidden elements.

3. Results
The above analysis and the presented results of experimental studies of the causes of rutting allow us to offer pavement clothes with hidden elements, shown in figure 4.
Figure 4. Road pavement with hidden element designed for repair and overhaul conditions on a III category road: 1 – constructive asphalt layer or wear layer of the new coating; 2 – leveling asphalt concrete layer of a new coating; 3 – existing pavement with asphalt concrete; 4 and 5 – hidden elements arranged in the places of the outer and inner ruts; 6 – subgrade.

The construction shown in figure 4 is intended for installation in the conditions of repair and overhaul of pavement with asphalt concrete pavement by cold recycling. Hidden elements are arranged at the locations of the outer and inner ruts on the surface of the existing coating. If necessary, before applying such elements to increase the evenness and correction the transverse slope, the surface of the existing coating can be milled over the entire area. With this milling, the lateral bulge of the rut are removed. Further, using road milling cutters with a milling width corresponding to the width of the hidden element, the existing coating is milled to the required depth, capturing, if necessary, the material of the underlying layers. Cement and water are added to the obtained asphalt granulate, and then mixed by a mill at its repeated passage. With the applying of hidden elements up to 10 cm thick, the operations of milling and mixing can be performed in one pass with the preliminary distribution of cement in front of the mill. After mixing, the mixture is leveled and compacted. For the compacted material of the hidden element is arranged care, which consists in pouring film-forming substances on the surface, and provide a technological break of the required duration. During a technological break on the surface of hidden elements, traffic is not allowed. After a technological break, making leveling and structural layers of asphalt concrete pavement or any other layers provided for by the project is produced.

4. Discussion
The proposed design has two advantages. The first advantage is associated with a decrease in the material consumption of the pavement, compared with the traditional construction with equal strength in width. This is due to the fact that the thickness of the reinforcement layers of traditional pavement is calculated for the entire number of calculated cars traveling in the lane, that is, for 100% of the calculated loads. The thickness of reinforcement between the ruts is calculated at 20% of the design loads. This calculated reinforcement thickness is assumed to be the same at all points of the structural layer. Then, the thickness of the hidden element is calculated, for which the number of design loads is taken in the amount of 80% of the design loads.

The second advantage is due to the fact that the deformations of the layers of the pavement and the roadbed under the hidden elements are less than the deformations of the same layers between the elements. As a result, the inhomogeneity of the deformation of the pavement along the width of the lanes is reduced, thereby contributing to a decrease in the rut depth.

5. References
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