DESIGNING AND CONSTRUCTION OF ROADS, SUBWAYS, AIRFIELDS, BRIDGES AND TRANSPORT TUNNELS

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Voronezh State University of Architecture and Civil Engineering
D. Sc. in Engineering, Prof., Head of Dept. of Road Construction and Operation
Vl. P. Podolsky
PhD student of Dept. of Road Construction and Operation V. L. Nguyen
Russia, Voronezh, tel.: +7-951-857-42-83; e-mail: long_gtvt@mail.ru
Moscow State Automobile & Road Technical University
PhD in Engineering, Senior Researcher D. I. Chernousov
Russia, Moscow; e-mail: ecodor@bk.ru
Voronezh State University of Architecture and Civil Engineering
D. Sc. in Engineering, Prof. of Dept. of Road Construction and Operation Yu.I. Kalgin
Russia, Voronezh, tel.: +7-951-857-42-83; e-mail: long_gtvt@mail.ru

Vl. P. Podolsky, V. L. Nguyen, D. I. Chernousov, Yu.I. Kalgin

CAUSES OF RUTTING OF ASPHALT CONCRETE PAVEMENTS AND METHODS OF INCREASING THEIR DEFORMATION RESISTANCE IN SOUTH VIETNAM

Statement of the problem. The formation of rutting on asphalt surfaces of roadways reduces the comfort and traffic safety, and also causes a significant damage to national economy. It occurs due to an increase in the cost of automobile transportations because of a low level of consumer characteristics and as well as the need for carrying out repairs of surfacing of the highway more often than it is provided by the normative documents. Therefore the study of the causes of rutting and the development of the methods to increase the deformation resistance of asphalt concrete surfacings are of importance now.

Results and conclusions. Based on monitoring of the state of a road surface, the reasons for the formation of a rutting on asphalt surfaces of automobile roads design are investigated and engineering solutions for the increase of its deformation resistance are proposed; so there is a need for the regulations index R60 to test the asphalt road at 60 ^{o}C. To ensure the resistance of the deformability of the road surface must be used in its construction materials with high strength characteristics and resistance to multiple transport loads.

Keywords: asphalt surface, deformation resistance, rutting, stone mastic asphalt, polymer additive, schungite, index R60, life cycle.

Introduction

A developed network of highways is essential to a country's economic growth. Over the last decade the economy of Vietnam has seen a rapid growth which gives rises to innovation.

However, the development of a road infrastructure is way behind the general development rates. Every year there is an increasing need for solid pavements in order to support the military position of the country. In order to address the problem, a large number of highways have been constructed in Vietnam with over 85% of them being asphalt concrete ones.

One of the major problems dealt with in the construction of roadways is the improvement of deformation resistance of asphalt concrete surfaces. A growing tendency is an increase in the number of heavy vehicles in the transport flow and larger travel speeds which result in a reduction of the life cycle of vehicles and impact their technical condition. Negligence towards the intensity and number of heavy vehicles in choosing road surfaces has recently resulted in a number of deformations in surfaces and their layers which inadvertently ended in the destruction of roadways.

The problem of rutting on asphalt surfaces of highways has been increasingly important over the last decade rather than other defects encountered in surfaces in Vietnam as well as in the Russian Federation. Highway ruts are detrimental to road safety and comfort *as well as cause a massive damage to a country's economy.* This is caused by lower travel speeds and higher transportation costs. Besides, extra procedures should be carried out to maintain, repair and reconstruct highway surfaces. This also causes a significant reduction in the life expectancy of vehicles. In Vietnam rutting is extremely dangerous in the monsoon season when there is water accumulation in the wheel path which affects adhesion and increases the likelihood of hydroplaning and cause a substantial loss of traction. Therefore the road industry now has to face the challenge of studying the causes of asphalt surface rutting and improving deformation resistance of road structures.

The objective of this paper is to identify the causes of rutting based on monitoring the condition of asphalt concrete surfaces and to come up with engineering solutions to enhance the deformation resistance of a road structure.

1. Monitoring the condition of asphalt concrete surfaces and identifying the causes of rutting in a road structure

It is a common assumption that the major cause of rutting on highway surfaces is wear of road surfaces and plastic deformations accumulating in the working area of the subgrade as well as construction layers of surfaces under increasing traffic loads [1, 3—5].

Road use practices of Vietnam indicate a great number of rutted pavements on federal road networks as well as industrial roads. A federal highway I-A experiences rutting in areas crossing Phú Yên, Ha Tin, Kuang Bin and others (Fig. 1). The depth of a rut reaches up to 10cm in some areas which is above the maximum values identified in Table 1 [9].

In most cases rutting of highways takes place in the right lanes where heavy and multi-axial vehicles travel since the overall strength of a road structure is not consistent with current axial loads. This is caused by axial loads being significantly higher than design loads as set out in the process of designing highways. Large axial loads result in such deformations that being multiply repeated they cause irreversible deformations in the subgrade and construction layers of non-rigid surfaces which is a cause of rutting [4].

a

b

Fig. 1. Rutting of asphalt concrete surfaces in Vietnam:

a) in a highway of Chuong Tin in Danang; b) in a highway I-A in Quang Binh Province

Table 1

Assessment scale of the condition of asphalt concrete surfaces according to the depth of rutting

Design travel speed, km/h	Total depth of rutting h_k, mm	
	acceptable	maximum acceptable
>120	4	20
120	7	20
100	12	20
80	25	30
60 and fewer	30	35

Rutting also takes place in speed left lanes of multi-lane highways where only motor vehicles and motorbikes travel despite the fact that the axial load they cause is so small that it is neglected in modern road surface design guidelines.

Road surfaces are designed to sustain current large loads and surfaces are made of asphalt concrete which is prone to shear deformation.

One of the best examples of that is Vostok-Zapad highway constructed in 2009: a deep rutting took place after it started being operated (Fig. 2).

Rutting is caused by a number of factors [1]:

– external factors are loads, climate factors, air temperature and radiation as well as moistening of the subgrade;

– internal factors are physical and mechanical characteristics of a road structure: shear deformation resistance, structural state, strength and compaction of surface layers and the subgrade, subgrade type and its properties.

Fig. 2. Rutting in the highway “Vostok-Zapad” constructed in 2009

There is presently a guideline document in Vietnam [10] which makes provisions for asphalt concrete being used in the design and construction of non-rigid pavements and they are to be designed and tested at the maximum temperature of 50 ^{o}C; therefore, road pavements are tested using the methods [11] at the temperature of 0, 20 and 50 ^{o}C.

However, in practice, the temperature in fact reaches the highs of 70 ^{o}C and more in hot summer weather (Fig. 3) [5].

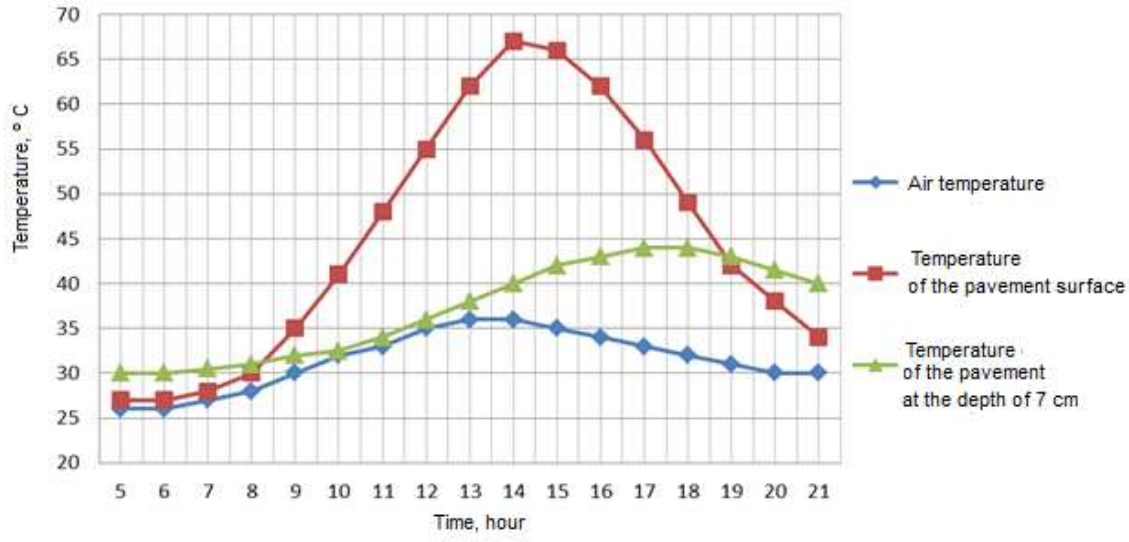

Fig. 3. Average daily temperature oscillations of asphalt concrete surfaces in different times of July in 621 km of the

I-A highway in Vietnam

At high summer temperatures asphalt concrete loses some of its strength and deformation resistance and cannot therefore respond to and distribute loads experienced by lower layers. This is why multiple traffic loads on asphalt concrete surfaces give rise to plastic deformations such as rutting and longitudinal cracking (Fig. 4).

Fig. 4. Rutting on the surface of the federal I-A highway in Buang Bin Province

2. Ways to improve the rutting resistance of asphalt concrete surfaces

Knowing the factors that influence rutting, we can put them to use to decrease chances of rutting taking place. In order to ensure deformation resistance of asphalt concrete surfaces, it is necessary to control the quality of all the processes taking place as the layers of pavement surfaces are laid in particular prevent the thermal segregation of the mix which results in under-compacted areas of surfaces. It is necessary to control the compaction coefficient of each layer of pavement surfaces without the separation of the aggregates of stone material.

The rutting resistance of asphalt concrete surfaces can be improved by a variety of procedures in order to enhance plastic deformation resistance in subgrades and construction layers of pavement surfaces.

It is known that under the effect of transport loads asphalt concrete surfaces is a complex strained state. The amplitudes of vertical compressive stresses in asphalt concrete layers are great. Besides heavy vehicles in asphalt concrete surfaces cause significant horizontal stresses these days which can reach the level of vertical stresses. Therefore in the process of designing non-rigid road structures in highways with intensive traffic flows the upper layers of surfaces it is necessary to make provisions for multi-aggregate asphalt concrete with high strength characteristics and sustainability to multiple traffic loads.

However, the world's experience of designing and constructing non-rigid road structures suggests that enhanced operational properties of pavement surfaces is provided not only by rigid requirements to the upper asphalt concrete layer but also by the selection of asphalt concrete of the lower layers. It is necessary to consider a variety of lower asphalt concrete with high strength characteristics (strong polymer modified asphalt concrete, strong resin bitumen polymer, aggregate resin asphalt concrete, etc.). High physical and mechanical and rheological properties show shungite-based asphalt concrete as suggested by research conducted in the Voronezh State University of Architecture and Civil Engineering [6, 7, 8].

Over the last years in world practices aggregate resin asphalt concrete is used as a special asphalt concrete material which is intended to be used in the upper layers of the surface. Aggregate resin asphalt concrete is a composite material with a set of properties and qualities to provide a high aggregate and bitumen content.

The structure of aggregate resin asphalt concrete enhances shear resistance which is part of rutting resistance. A great amount of large aggregate resin asphalt concrete enhances wear resistance and smoothness of the surface which is crucial to the adhesion coefficient. Table 2 shows the ratio between the size of a plastic aggregate resin rut, strong asphalt concrete of type A, B and porous asphalt concrete using American tests.

As Table 2 suggests, aggregate resin asphalt concrete has less great rut depths and limit deformation which is indicative of a high rutting resistance. Therefore in order to improve the rutting resistance of asphalt concrete surfaces, it should be recommended that aggregate resin asphalt concrete should be used for the upper layers of the surface.

However, high bitumen content in the aggregate resin asphalt concrete mix requires stabilizing supplements to prevent the excess binder from flowing during the production, transportation and compaction of aggregate resin asphalt concrete. The use of stabilizing additives that promote adhesive bonds and is preventive of rutting which results from the “migration” of asphalt concrete particles.

Table 2

Correlation between the plastic rutting predictions according to the laboratory analyzer o f asphalt surfaces, Georgia, and in the highway at 60°C (USA) [2]

Type of an asphalt concrete mix	formation according to the laboratory tests, mm	Predicted irreversible deformation, mm	Irreversible deformation in the highway, mm	Range (class) along the wheel-path, %
Aggregate resin asphalt concrete	1.1	1.7	2.5	1 (100 %)
Strong asphalt concrete of type A	4.0	6.3	5.6	2 (224 %)
Strong asphalt concrete of type B	4.0	6.3	6.4	2 (256 %)
Porous asphalt concrete	6.4	10.2	10.7	3 (428 %)

At high summer temperatures particularly in the South of Vietnam the rutting resistance of asphalt concrete surfaces is achieved by creating a carcass mineral frame, increasing the viscosity of bitumen, introducing modifying strengthening supplements (polymer and reinforcement supplements).

One of those is Forta-FI® which is a patent mix of two synthetical fibres that work in conjunction thus improving the characteristics of asphalt concrete. Therefore the use of fibres Forta-FI® in the construction of asphalt concrete surfaces significantly contributes to a lower cracking and rutting as well as less thick layers affected by the loss of resistance (Table 3) [12].

Table 3

Comparison of the major characteristics of asphalt concrete of type B and type B +Forta-FI®

Name of the characteristics	Magnitudes of the characteristics	
	Type B	Type B + 0.05 % Forta-FI®
Average density, g/cm^3	2.41	2.41
Compression strength, MPa, at 50 ^{o}C	1.4	1.8
Split crack resistance at 0 ^{o}C	5.2	5.7
Characteristics of the shear resistance		
Internal friction coefficient	0.87	0.88
Adhesion, MPa	0.38	0.49
Rutting resistance tests on the “wheel” device		
Average rut depth, mm	20	10
Rutting rate of the wheelpath, mm/1000 load cycles	1.11	0.51

The data of Table 3 shows that the rutting rate and depth of the rut is twice as small. This suggests that the use of the supplement Forta-FI® contributes to a higher shear resistance.

Conclusions

1. Rutting of highways affects the traffic safety and convenience and also causes a significant damage to the country's economy. Therefore there is no question of the importance of identifying them and thus improving the deformation resistance of asphalt concrete surfaces.
2. The major causes of rutting in a road structure are heavy traffic loads, larger axial loads and poor shear resistance of asphalt concrete surfaces at high summer temperatures.
3. The experimental study showed that in the summer season the temperature can get as high as 70 ^{o}C and more on the surface of asphalt concrete surfaces and therefore it is necessary to introduce the characteristics R_{60} into the guideline documents to put asphalt concrete to test at 60 ^{0}C.
4. In order to provide deformation resistance, the structure of surfaces should be in accordance with the transport and operational loads which are predicted for a particular road category along with its content and traffic flow. It is necessary to use materials with high strength characteristics and resistance to multiple transport loads.

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