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Construction of Urban Roads with Concrete Pavers

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Abstract: The materials with high environmental, aesthetic characteristics and maintainability at the required level of transport and performance shall be used in an urban environment as a top coating layer for highways and streets. Concrete blocks, the production of which is mastered in several enterprises of the city may become such a material within the city of Belgorod. At the same time, there is no experience for the design of roads and streets with this type of coatings in Russia. This study describes a city street design technique with the pavement construction which includes a concrete paving coating. The accepted design decisions were analyzed taking into account the long-term operation experience.

Key words: Concrete blocks, city streets, road design, road pavement, rutting, non-rigid pavements, reconstruction of roads

INTRODUCTION

Bitumen mineral materials, particularly dense and porous asphalt concrete are widely used for the road pavement construction. These materials are most preferred because of their good maintainability, high degree of road construction works mechanization and most importantly because of their high corrosion resistance and more favorable conditions for trafficking. At the same time, this type of road pavements has a number of drawbacks: the dependence of the strength and deformation characteristics on the temperature (the main cause of plastic and brittle deformation of pavements which is expressed in the rut formation); the absence of environmental safety at elevated temperatures caused by the evaporation of light bitumen fractions; the significant value which depends mainly on the cost of bitumen, the quality of which is poor and causes to make additional introduction of various polymer additives and (or) surfactants. Depending on the composition of the layed asphalt and concrete mix, the obtained surface asphalt concrete structures, operating conditions and climatic conditions different types of pavement deformations are produced (Sun and Zheng, 2011; Haryanto and Takahashi, 2007; Gorshkova and Shukhov, 2009; Shukhov and Gorshkova, 2010) which require constant monitoring of the pavement conditions. The process of rutting as the most negative deficiency of non-rigid coatings is studied by many researchers and offers a variety of ways to predict the intensity of rutting (Sun and Zheng, 2011). The asphalt and concrete pavements which do not meet the traffic safety requirements due to rutting shall be promptly repaired but in areas with dynamic developing rut the deformations in a cross profile appear not only in the top layer of pavement but in other layers of the road pavement and sometimes the working layer of a road bed. Therefore, the repairs of such road sections may not and should not be limited by the performance of milling operations and leveling layer (made of new mixture) device.

The coatings of cement-based materials do not have these drawbacks but are applied with some restrictions because the issues of repair and ensuring the continuity at sudden temperature change have not been solved yet (Judycki, 2011; Jeong *et al*., 2011). In recent years, the concrete blocks which combine the positive qualities of cement concrete, ease of repair and reconstruction as well as high architectural and aesthetic qualities are widespread for the development of yards, pavements, walkways and plazas. However, the concrete blocks were not widespread in road construction because it is believed that it has a low coefficient of friction, there is no method of road pavement structures calculation with such coatings. It is difficult to provide quality cohesion of such coatings with the coatings made of bitumen mineral materials.

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MAIN PART

The study of literature data showed that at the present time there is no experience in Russia for the design and construction of road pavements coated with concrete tiles, except for several cases of local passages and car parking construction in front of shops within urban conditions. In 2004, during the reconstruction of a city street a road bed was built as an experiment in the city of Belgorod. The road bed was made of concrete pavers produced by "JBK-1" OJSC according to "HENKE" technology. The scientific support of the experiment concerning the calculation of the pavement structure as well as the development and advice for design, building and operation were carried out by BSTU scientists named after V.G. Shukhov.

The need for the reconstruction of Nikolay Chumichov street for the city of Belgorod was caused by the poor state of the existing asphalt concrete pavement as well as by the overhaul of the city main reservoir laid beneath it. During the reconstruction of the street the roadway was widened by reducing the width of the center mall. Under the kept part of this mall an underground storm drainage was built to drain surface waters. More over, due to the reconstruction of the streets the traffic organization and the intersection layout was changed.

The adoption of design decisions was complicated by the fact that the road bed construction shall be done in 1 year with the heating main repair and the street crossing should stay with an asphalt concrete pavement. Moreover, the coefficient of friction for concrete blocks was not high enough which also required a decision of building an underground stormwater drainage system under the dividing strip of the street. The stormwater sewage operation is provided in gravity flow as the longitudinal profile has a sufficient slope for this throughout the reconstructed street.

The analysis of the existing international experience allowed us to formulate the following basic conditions that were the basis of studies:

- This type of pavement is applied for the constant movement of passenger transport and periodic motion of small-capacity vehicles, mainly for the transportation of goods to retail outlets with the speed limited by Traffic Regulations for the settlement territories
- The design of road pavement must necessarily include the base made of the drainage material
- The strength of concrete tiles should not be taken into account during the calculations and the road pavement structure should be calculated according to the desired elasticity module on the top layer surface of the base
- The pavers (preferably without chamfer) should be laid diagonally for better pressure distribution of loads while providing its more stable operation and also the moving vehicle noise is reduced
- If a tiled pavement is framed by a border, the gaps should be well filled and sealed to ensure a tight coupling of tiles

The road pavement design calculations were carried out according to ODN (2001) "Designing of non-rigid road beds" according to the following criteria: the allowable elastic deflection, the shear-resistance condition in the road bed subgrade and the resistance of monolithic layers to flexural strength. In this case, in order to save draining materials, the calculations were initially performed for the drainage and the resistance to frost heaving.

Two versions of pavement structures were designed where the following materials are taken as the fortified bases:

- Gravel, reinforced with cement in accordance with GOST (1995b) (Fig. 1)
- Black crushed stone (crushed stone processed with bitumen in the device) (Fig. 2)

The first version was adopted as economically and technologically justified within these circumstances with a more rigid base of crushed stone, reinforced with cement (in the device).

Invalid shear strain in the structure will not be accumulated if the following condition is provided:

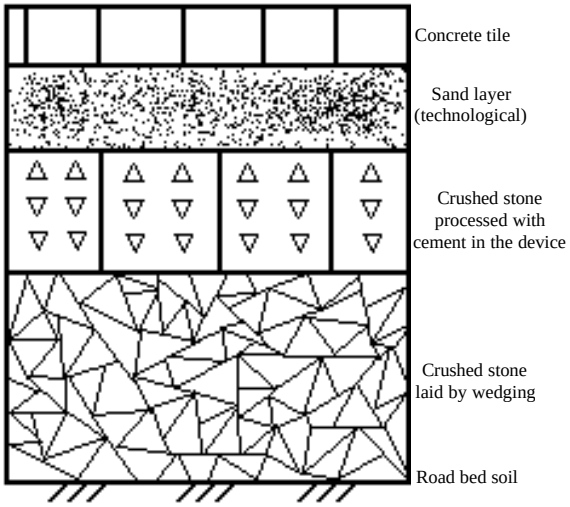

Fig. 1: Road bed design construction #1

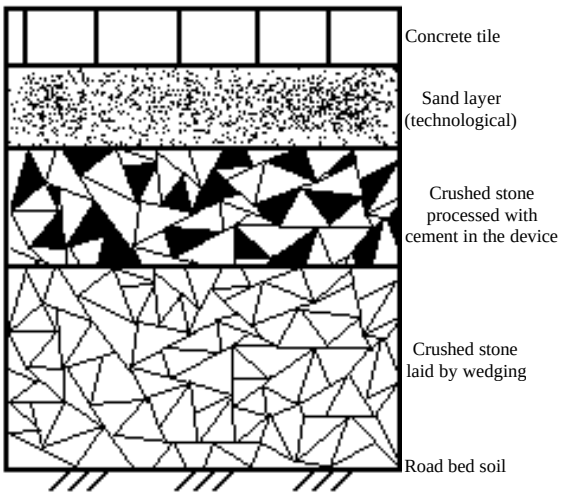

Fig. 2: Road bed design construction #2

$$T \le \frac{T_{np}}{K_{np}^{mp}} \quad (1)$$

Where:

K_{np}^{mp} = The required minimum value of the strength coefficient, determined according to a specified level of reliability

T = Designed active shear stress (the shear stress part, not put out by internal friction) in the calculation (the most dangerous) point from the current temporal load

T_{np} = Extreme value of the active shear stress (in the same point), the excess of which makes a shear strength violation

Preliminary specified road construction was presented in a Two-Layer Calculation Model. The soil with its design characteristics was adopted as the lower layer of the model and the elasticity modulus of the top layer model was calculated as the weighted average one. The calculations showed that the road bed construction shear resistance condition for underlying subsoils is not performed.

The increase of road bed construction shear resistance may be achieved by increasing the pavement structural layer thickness or the strength characteristics of a road bed underlying soil. The most appropriate and cost-effective is the increase of the road bed upper soil layer strength characteristics due to the implementation of the layer with the thickness of 25 cm made of soil and crushed stone mixture according to the GOST (1995a) by the method of mixing on the road with the ratio of 1:1.

The following designs of road pavement structure were of equal strength and satisfying all the calculation criteria for specific traffic conditions and regional climatic conditions: graded crushed stone, packed in the manner of wedges 31 cm; black crushed stone or the crushed stone of the chosen granulometric composition, reinforced with cement 16 cm; fine sand (technological layer) 10 cm; concrete crushed stone with the thickness of 8 cm made of class B 30 concrete.

After the completion of construction in 2004, the traffic observations, the monitoring of roadway pavement as well as the analysis of Road Traffic Accidents (RTA) statistics for the corresponding periods of the year were held annually before and after the reconstruction.

The survey of the built area, carried out by the experts from the department of roads and railways of the Belgorod State Technological University Named after V.G. Shukhov in 9 years of operation showed the following results:

- The values of the longitudinal pavement evenness in all areas of the street is much higher than the requirements for highway and street pavements
- The transverse profile demonstrate the strain as a rut along a track strip within the zones of inhibition before traffic lights. The absolute values of the rut on the ninth year of operation shall not exceed 27 mm and the mean calculated value of the rut at the locations detected by the visual inspection of sites made 21 mm which meets the regulation requirements
- The rolling strip in the areas of acceleration and braking demonstrates a slight wear of pavers by depth, resulting in crushed stone frame baring and the coating roughness increase. At the same time the coefficient of adhesion increased (from 0.27 in 2004 to 0.35 in 2013) but it still does not meet the requirements of GOST (1994). The colored paving stones are more prone to wear
- The conjugation of paving with asphalt concrete pavement of crossed streets made in the form of a curb concrete basis, manifested itself positively there is no strain in coating
- The continuity of crushed stone pavement in the locations of manholes is not broken, there are slight subsidences and damages of the plate edges

The use of conventional content methods, including the struggle with icy roads through the distribution of sand-salt mixture does not lead to the number of road accidents increase caused by poor road conditions. The available statistics indicates the absence of traffic accidents, the indirect or direct cause of which is a coating material.

SUMMARY

Thus, one may talk about the validity of requirements put forward in the process of design and construction and the experience in the city street pavement construction with the concrete paving shall be recognized as successful and worthy of attention. Taking into account the need for the periodic disassembly of city street pavement to perform routine and emergency repairs of communications, located as a rule, under the cover of city streets as well as the better maintainability of concrete paving, you may make a reasonable conclusion about the possibility of using such coatings in compliance with the restrictions (conditions) listed earlier in this study.

CONCLUSION

To ensure the mass introduction of such highway and street coatings the further observations are required to adjust the methodology of design, construction and operation for such road pavements. The future research should be focused on:

- Determination of strength characteristics of the road bed structure taking into account the concrete tiles that will allow to design road beds on city streets with these types of pavements reasonably and economically feasible, taking into account the traffic intensity and composition
- The increase of traffic safety by improving the cohesion quality of concrete pavers (increasing its roughness without compromising the strength of the upper layer) by changing the production regulations of concrete paving stones
- The development of specific recommendations to provide the required coefficient of a car wheel friction with the coating made of concrete paving stones in winter time with the differentiation depending on the traffic design speed

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