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THE RESULTS OF THE DEVELOPMENT OF TYPICAL PAVEMENTS FOR MOSCOW STREETS AND ROADS

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ABSTRACT

The specialists of Moscow Automobile and Road Construction State Technical University (MADI) have updated the portfolio of typical pavements for Moscow. Due to the difficulty of forecasting the situation in the road freight transport sector, the dynamic development of land public transport and the high risks of wrong decisions of design organizations, it is necessary to use typical solutions for designing road surfaces. Moreover, there is a serious problem of making a correct assessment of the design decisions from the state expert body. The modern principles of design and estimation are used for designing typical pavements of Moscow. The best proven road materials extracted and produced in Moscow region are used in the layers of road surfaces. This article describes the fundamental decisions implemented when developing a new version of a portfolio of pavements and provides their examples.

Keywords: typical road surfaces.

INTRODUCTION

For many years, the latest version of the portfolio of typical pavements dated 2010 has been used for designing Moscow streets and roads (SK 6101-2010, 2010). Typical road surfaces ensure standard service life and compliance with the following requirements: allowable elastic deflection, resistance to shear in the underlying soil and lowly cohesive layers, resistance of indistinguishable layers to fatigue fracture caused by bending tension, frost resistance and dewatering.

However, there are several errors and discrepancies in the existing portfolio which can be divided into two groups. The first group includes nonconformities of the document to the current regulations. The second group includes errors and deficiencies of the portfolio of typical pavements.

The existing portfolio of typical pavements is outdated and needs to be revised with consideration of new conditions and parameters of traffic, as well as renovations in the complex improvement of Moscow.

METHODS

The special features of the estimation of new typical pavements are as follows:

The service life of typical pavements of Moscow is 24 years in accordance with Resolution No. 658 dated May 30, 2017 of the Government of the Russian Federation (Decree of the Government of the Russian Federation No. 658, 2017).

Road surfaces are classified at the standard level of responsibility in accordance with the Urban Development Code of the Russian Federation (UDC RF 2015). The safety factor of responsibility for the determination of rated force from traffic loads on a pavement is 1.0 in accordance with requirements No. 384-FZ (2009).

Levels of design reliability and strength factors are established in accordance with the categories of out-of-city motorways and the categories of city streets and roads. The geometrical parameters of the plan and longitude section for the design of city streets and roads are established in accordance with the regulatory document on motorways. Moreover, the design speed of traffic on a city street corresponds to the design speed of traffic on a motorway. It means that the categories of city streets and roads are equated to the categories of out-of-city motorways by the design speed. However, this approach is not acceptable for designing pavements. Pavements are estimated for traffic load. The main criteria for correspondence between the categories of motorways and the categories of city streets and roads must be the number of traffic lanes (impact of trucks' distribution by traffic lanes), the width of a traffic lane, traffic volume and the type of pavement (Table-1).

The required minimum strength factors depend on the level of design reliability (Table-2).

The design parameters of loading for driveways of city streets and roads refer to load class A_2, the design parameters of loading for pedestrian and bicycle paths refer to load class A_{T1} and A_{T2}, depending on the type of municipal cleaning machines which maintain them (Table-3).

The design elastic modules of asphaltic materials are established for the speed of cargo traffic flow in Moscow which is 20 km/h (Table-4). The duration of exposure on the road surface is 0.14 second.

Table-1. Correspondence of the categories of city streets and roads to the categories of motorways.

Category of city streets and roads	Category of roads by design speed	Category of roads by design of pavements
Principal high-speed city roads	IA	I
Principal city streets with constant traffic	IB/II	I
Principal city roads and streets with controlled traffic	IC/III	I
Principal regional streets	IV	II
Local streets and roads, parking and stops, on-site roads	V	IV (major type)
Footwalks, pedestrian streets, park paths, bicycle paths, pedestrian areas, eco-parking	-	V (lightweight type, the calculation is made for load from municipal and/or fire-fighting machinery)

Table-2. Required minimum strength factors for designing typical road surfaces of city streets and roads.

Category of city streets and roads	Level of design reliability	Minimum strength factor on elastic deflection/on shear and tension in bending
Principal high-speed city roads	0.98	1.50/1.10
Principal city streets with constant traffic		
Principal city roads and streets with controlled traffic		
Principal regional streets	0.95	1.20/1.00
Local streets and roads, parking and stops, on-site roads	0.85	1.06/0.90
Footwalks, pedestrian streets, park paths, bicycle paths, pedestrian areas, eco-parking	0.82	1.00/0.88

Table-3. Recommended design parameters of loading.

Group of load	Standard static load on the axis, kN	Design parameters of load	
		P_a, MPa	D, cm
A_{T1}	55	0.60	28/24
A_{T2}	70	0.60	31/27
A_2	115	0.80	34/30
A_P	160	0.80	41/36

Table-4. Design elastic modules of asphalt.

Type of asphalt	Design elastic modules, MPa, under temperature, ^{O}C		
	0	10	20
Stone mastic asphalt	9,000	4,850	4,850
Dense and sandy asphalt from bitumen BND 60/90 or BND 70/100	4,100	2,900	1,550

Local streets and roads, parking and eco-parking comply with the requirements for the location of fire-fighting machinery and conducting fire-fighting works (it has been checked that they can be exposed to A_p class static load).

Additional layers of sand are designed to absorb water due to the absence of slopes for water release and shallow drainage. In urban areas, shallow drainage should be connected to the drainage system. Such a connection is not always possible due to the height differences of shallow drainage and storm drain. Moreover, restoration of

performance of longitudinal tubular drains results in the problem of traffic management due to the blocking of edge lanes of the driveway on the streets and roads of cities.

Typical pavements of Moscow are designed to ensure standard service life. Their design is based on the advanced Russian and world experience in designation and combination of road materials in the road surface layers, taking into account climate, soil and hydrological conditions (Catalogue des structures types de chausses neuves, 1998; Guide for Mechanistic-Empirical Design of New and Rehabilitated Pavement Structures ARA, 1999; Modello di catalogo delle pavimentazioni stradali, 1993; Neuerungen im Vorschriftenwerk, 2012; RStO 11, 2011; Ushakov, *et al.* 2016; STO AVTODOR 2.25-2016, 2016; Lopashuk, *et al.* 2014), as well as the construction technology and operation conditions.

Main principles of designing road surfaces are as follows:

a) Silt soils, such as sandy silts, silt sandy loams, light and heavy silt clay loams; light silt clay and heavy clays are excluded from the list of soils used for a working zone of a subgrade. They are excluded because the use of silt soils requires very thick frost protection layers. In some cases, a frost protection layer can be 100 cm thick. This result in irrational road surface designs and contributes to the development of inelastic deformations in frost protection layers and, as a result, the need to increase their shear resistance by building-up roadbeds. Typical pavements are designed with the use of such soils as sands, sandy loams, heavy and light sandy clay loams, sandy clays.
b) It is prohibited to use man-made soils with a prohibitive amount of inclusions (waste) for designing pavements:

- If soils contain 20% and more of concrete and reinforced-concrete junk (with some elements no larger than 120 mm) and land waste;
- If soils contain 10% and more of municipal and industrial waste;
- If soils contain 5% and more of organic impurities, crushed bricks.

If there are different inclusions in the man-made soil, their total amount should not be 20% and more subject to the abovementioned limitations. Otherwise, the working zone of the subgrade will contain a prohibitive concentration of substances; and it is impossible to forecast their behavior during long-term service life under temperature and moisture effects and transport load. When the soil contains fewer inclusions, it is more intimate and sustainable and can be characterized in the composition of the main soils by its values.

c) When designing pavements on clay soils, a geotextile layer is required between the road surface and the sand subbase. During long-term service life, the thickness of pure sand decreases because of silting-up; the drainage capacity of the subbase reduces; the risk of developing unallowable frost heave increases. During full repairs, not only base layers but also subbases need to be changed. The installation of a geotextile silt protection layer ensures the service life of drainage and frost protection layers.
d) A geotextile protection layer is required between a subbase and a roadbed of unfixed aggregates. It prevents from the embedding of crushed stone into the underlying sand layer during compaction and allows avoiding excess use of crushed stone (crushed stone and gravel and sand mixture - CSGSM). Moreover, gradual grinding of aggregates results in slow-paced pollution of sand, because of diffusion of the silty material under transport load and gravitational water.
e) The asphalt road surface should be reinforced with cracks stopping layer installed between the bottom layer of the surface and the top asphalt roadbed in order to slow down the formation of fatigue and reflective cracks. This measure is used for road surfaces with rigid roller compacted concrete bases.
f) A technological layer from CSGSM (dry bound crushed stone) is required between the rigid roller compacted concrete base and the subbase. This measure complies with the recommendations of managers of construction organizations who criticize the absence of the technological layer in the existing portfolio.
g) The maximum thickness of an asphalt layer is 12 cm in accordance with the technological requirements. This measure is explained by industrial capacities. Not all construction organizations, even in big cities, have equipment for compaction of asphalt layers which are thicker. The minimum thickness of the rigid roller compacted concrete base is 15 cm in accordance with the construction requirements. Less thick layers have weak resistance to crack formation.

When designing city streets and roads, priority is still given to flexible pavements. Rigid pavements are quite rarely constructed on the city streets and roads. In spite of their obvious benefits, cement concrete pavements also have their significant disadvantages for urban areas; they increase the level of noise, they are not enough resistant to ice-melting chemicals; it is more difficult to repair them. However, heavy cement concrete surfaces are used as foundations in two-stage construction.

Viscous bitumen BND 60/90 is used for production asphalt mixes for Moscow streets and roads. Only dense asphalt is used for designing pavements of Moscow streets and roads.

Depending on the type of a pavement, the following types of asphalt mixes are used in the top layer:

- stone mastic asphalt SMA-20 (SMA-22), SMA-15 (SMA-16);
- asphalt Type B Brand One (asphalt Type B Brand Two should be used on driveways and parking of cars).

Coarse asphalt Type B or Type V Brand Two should be recommended for the bottom layer of the surface and the top layer of the base (asphalt Type B Brand Three should be used on driveways and parking of cars).

The following types of asphalt should be used for the construction of footwalks, pedestrian streets, park paths, bicycle paths, pedestrian areas:

- If the width of the area is less than 3.0 m, asphalt Type D Brand Three should be used.
- If the width of the area is more than 3.0 m, asphalt Type D Brand Two should be used.

The best material for the bottom layer of the base under the top asphalt layer of the base is rigid roller compacted concrete. The typical pavements are designed with the bottom layer of the base from rigid roller compacted concrete with compression strength B7.5.

Unfixed aggregates are used in roadbeds of streets and roads of Moscow. They are used as:

- a technological layer under fixed base layers;
- a construction layer on the areas of city streets and roads with little traffic flow.

CSGSM ensure the best technological and operational performances. The minimum crushability of CSGSM should be no less than of crushability of Brand 600.

Subbases have drainage and frost protection functions. The following materials can be used in subbases:

- small-sized sands, middle-sized sands, large-sized sands, extra-large-sized sands;
- sand and gravel mixtures.

Geogrids with breaking strength no less than 100 kN/m must be used for reinforcement of the asphalt surface. The breaking strength of the geotextile installed between crushed stone and sand must be no less than 12.5 kN/m; the static loading (CBR) must be no less than 1.5 kN. The breaking strength of the geotextile installed between sand and the surface of subgrade must be no less than 7.5 kN/m; the static loading (CBR) must be no less than 1.0 kN.

RESULTS

Taking into consideration that city streets and roads are different with various traffic conditions, public transport, as well as that the construction of city streets and roads in large-scale residential areas is staged, the typical pavements are classified as follows (without regard to soils and hydrological conditions of operation):

- principal high-speed city roads, principal city streets;
- principal regional streets;
- local streets and roads with public transport;
- local streets and roads without public transport; parking for trucks;
- local streets and roads in large-scale residential areas with two-stage construction;
- driveways, parking for cars;
- footwalks, pedestrian streets, park paths, bicycle paths and pedestrian areas with asphalt pavement;
- footwalks, pedestrian streets, park paths, bicycle paths and tiled pedestrian areas;
- eco-parking of yard areas.

Therefore, the typical pavements are divided into nine groups. The typical pavements of driveways vary based upon the soils and hydrological conditions:

- the type of the working zone of subgrade;
- the distance from the road surface to the expected level of groundwater.

The typical pavements on pedestrian and bicycle paths, and on eco-parking vary not only based upon soil and hydrological conditions but also based upon the width of the area which determines the size and load of municipal cleaning machines and ability to locate fire-fighting machinery and to conduct fire-fighting works in the nearby buildings.

The designation of the typical pavement is defined based on the initial data.

The initial data is established by the design task; new data is added during the designing process. The initial data includes the category of a city street, the composition of traffic flow, the planning concept, soil and hydrological conditions, the decision on organization of construction.

The procedure for the designation of the typical pavements:

- the category of a city street or road is established;
- the planned component from the planning concept is selected (a driveway, footwalk, parking, etc.); the width should be determined for some components of the planning concept;
- the type of soils of the working zone of the subgrade is determined or designated;
- the expected level of groundwater in relation to the road surface is determined;
- the table with typical pavements is selected in accordance with the abovementioned initial data;
- the materials and width of layers of the road surface are determined in accordance with the table with typical pavements;
- the materials are specified with due regard for the requirements of relevant regulations and the existing portfolio of typical pavements; a technical and economic assessment can be carried out, if necessary.

The examples of typical pavements in Moscow are presented in Figures 1-3. The following abbreviations are used on the layers of road surfaces in Figures 1-3: SMA - stone mastic asphalt, A dense - dense asphalt, RRCC - rigid roller compacted concrete, CSGSM -

crushed stone and gravel and sand mixture, CSM - cement and sand mixture, R - reinforcing net, G - geotextile. The thickness of typical pavements is specified in centimeters.

CONCLUSIONS

The results obtained helped to develop a new portfolio of typical pavements for city streets and roads of Moscow. Typical pavements ensure the required operating condition of roads; thus, road surfaces become reliable and safe. The security of transport and participants of road networks is guaranteed as well.

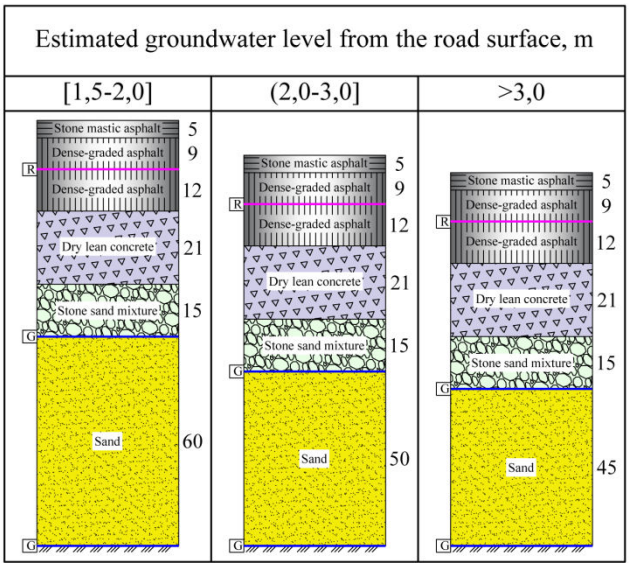

Figure-1. Typical pavements of Moscow on driveways of principal high-speed roads, principal city streets and roads; the soil of the subgrade - clay loams and sandy clays.

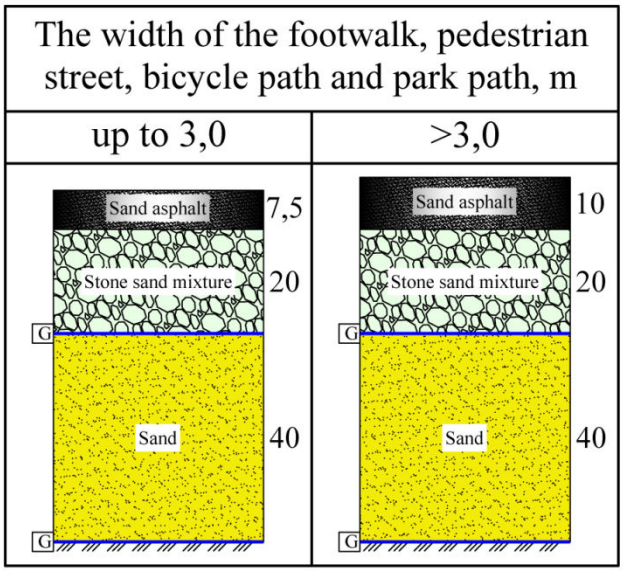

Figure-2. Typical pavements with asphalt covering of pedestrian and bicycle paths of Moscow; the soil of the subgrade - clay loams and sandy clays.

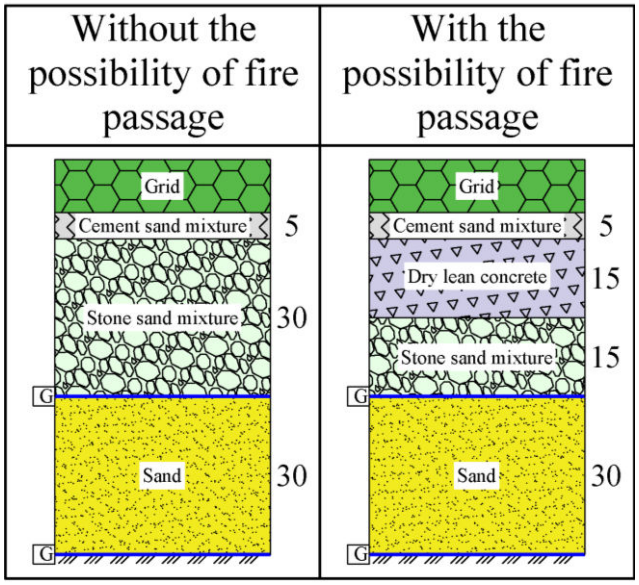

Figure-3. Typical pavements of eco-parking of Moscow; the soil of the subgrade - sandy loam.

The analysis of regulations and results of monitoring of pavement condition in Russia and abroad allowed to identify the latest achievements of pavements design. These achievements have been considered for the development of a portfolio of typical pavements.

The practice of designing, construction and operation of city streets and roads allowed to define the shortcomings of the existing portfolio of typical pavements of Moscow and to propose ways of their elimination.

The principles of estimation and design of pavements have been developed. These principles ensure the design of pavements at the level of international practice and their compliance with the requirements of modern regulations and state expert bodies, and recommendations of construction organizations.

A new portfolio of typical pavements has been developed; it conforms to the world standards of design of pavements and ensures reliability, endurance and safety of their operation.

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