Impact of design decisions on quality of highways

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Abstract. The need for a compulsory record-keeping of the properties of road-building mixtures that determine deformations of highways under the influence of dynamic transport loads, as well as climatic action, is already grounded at the design stage. Special attention should be given to the operational characteristics recommended for the use of road-building materials, including flow (viscosity, fluidity, deformability) and thixotropic (dilution or concentration under the influence of mechanical loads, the ability to restore the destroyed mechanical impacts the original structure) properties of crushed stone sand mixes. The importance of taking into account the mechanisms of interaction of the road base with the surrounding ground is determined, which is connected with the appearance of the defects on the road surface during operation process. Typical effects of pavement deformation Act crack various configuration (mesh, surface, shrink, cross-cutting), potholes and sinks, prosadi and shifts, waves and a comb, track etc. In addition, there are inaccuracies in the recommendations for the construction of individual structural components of highways, presented in regulatory documents, which requires careful consideration as early as at the design stage. Normative documents do not fully take into account the need for selection of macadam-sand mixture, given its deformativnosti influenced by dynamic loads.

1. Introduction
The main postulates of the transport strategy of the Russian Federation for the period up to 2030 (approved by the decree of the Government of the Russian Federation of November 22, 2008, No. 1734-r) are oriented towards the significant development of the road network infrastructure as the aggregate of all public roads in a certain territory. At present, the road economy of the Russian Federation is 1.5 million km of roads of all classes and categories according to data for 2016, and another 18-20 thousand km of roads will be put into operation until 2040.

The basic postulates of the strategy of innovative development of the building materials industry for the period until 2030 in the Russian Federation determine the urgent need to increase the share of alternative products of processing of metallurgical enterprises involved in the construction industry, and, moreover, to reduce the share of mineral raw materials and replace it with industrial waste [1], which emphasizes the relevance of this work. Widespread steel waste is steel-smelting and blast-furnace slags, whose chemical composition is comparable to the Portland cement clinker, which determines the possibility of their use in the construction industry in various directions [2-20].
2. Relevance
Analysis of the metallurgical wastes recycling practice shows the positive results of using them as raw.

The economic development of the country, as is well known, largely depends on the condition and transport systems capacity, as well as on competitiveness in the field of road construction. At the same time, highways remain one of the most important ways of providing communication between regions and countries, since the bulk of transportation is performed by truck transport. The expansion of the road network in the Russian Federation is aimed at ensuring the development of potential points of economic growth within the country, including the integrated development of new territories, primarily in Siberia and the Far East. It is here that the transport and operational performance of highways (continuity, speed, convenience and traffic safety, carrying capacity and loading level, permissible dimensions, axle load and total vehicle mass, environmental, aesthetic and other indicators provided by the road), largely determining the totality of their consumer properties (a combination of transport and operational indicators that directly affect the efficiency and safety of road transport, reflecting the interests of road users and the impact of roads on the environment) are significantly transformed under the influence of climatic factors throughout the service life process. This provision emphasizes the relevance of this work.

3. Formatting the title, authors and affiliations
The structure of highways in the Russian Federation includes 12% of roads with a ground surface and 78% – with a hard surface. In the latter case, 6% are federal roads, 16% of non-public, 21% local and 57% – regional importance. At the same time, only 38% of federal importance highways correspond to regulatory requirements, which is associated with numerous destruction in spring and autumn time, when residents of specific territories remain cut off from transport communications due to flooding of flood waters [21-23].

3.1. Formatting the title
The roads condition in the Russian Federation is determined by a complex of geographic, climatic, and environmental factors, which largely determines the diversity of technologies for their design, construction, maintenance, repair (including overhaul maintenance) and operation. The analysis of the operational practice convinces that from the whole complex of engineering structures of the motor road the most vulnerable structural elements are the roadbed (serves for the placement of the pavement, as well as technical means of traffic organization and road arrangement) and a layered construction of pavement (perceives the load from vehicles and transfers it to the roadbed).

The main reasons for the unsatisfactory state of the structural elements of the highway are miscalculations in the design, insufficient study of the degradation of road building materials, low efficiency of the technologies used. To identify the reasons for the unsatisfactory state of the road, it is advisable to analyze the stages of the highways construction, starting with a complex of works of pre-design investigations and further - design and processes of road construction.

The methodology of the pre-design survey includes geological, geodetic, hydrogeological studies for the purpose of detailed study of the conditions of specific territories, as the most important factor that determines the choice of relevant work technologies.

Road design is carried out taking into account the results of previous studies, the climatic features and prospects for the development of transport infrastructure in the regions, including the emergence of the new modes of transport (unmanned vehicles). In addition, the design takes into account the features of the geological structure (the presence of hard rocks) of the proposed routes for laying road networks and transport highways, as well as a variety of soils (clayey, heaving, marshy, cryogenic, etc.), which determines an individual approach to the design of future routes [24].

3.2. Formatting author names
However, when designing roads, insufficient attention is paid to the composition, structure and properties of road-building materials recommended for use, including rheological and thixotropic
properties of crushed stone and sand mixtures [24-26]. These circumstances further lead to significant
deherations of the road foundation, including the elevation of the roadsides and the dividing strip
over the carriageway in the absence of a curb; underestimation of roadsides and dividing strip with
respect to the adjacent edge of the roadway in the absence of a curb; presence of separate damages,
subsidence and stagnation of water on the roadsides and the dividing strip; destruction of the drainage
system [26]. The most common defects on the road surface are cracks, potholes, rutting, longitudinal
and transverse comb [27].

In addition, the design and road construction [21,25] does not take into account the facts of
continuous dynamic impact on the roadway, which is comparable to the frequency vibration, as well
as the interaction of the groundwork base with the surrounding ground, which leads to deformation of
the groundwork base and defects of the road surface [28-30]. The existing technologies for the
construction of the groundwork base provide for the installation of a double-layer crushed stone base
by the method of jam-hold; single-layer crushed stone (gravel) bases and coatings from dense
mixtures; crushed stone, processed in the upper part of the sand-cement mixture by impregnation
(pressing), etc. At the same time, a greater amount of work is done to select the composition of
crushed stone and sand mixtures and to establish the base of the road. For the rapid selection of
the composition of the densest mixtures, it is expedient to use a method for selecting the composition of
heavy concrete, which is universal in nature, allows us to expand the range of used sand and gravel
fractions, and allows the manufacturer to perform an independent selection of crushed stone and sand
mixtures.

In the SRT NOSTROY 2.25.31-2011 “Highways. Bedding of Road Pavement. Part 3. Bedding
Construction of Mineral Materials That Have Not Been Treated with Astringent” established
requirements for the subgrade, arranged without the use of binding materials, including the modulus of
elasticity of the base, and ODN 218.046-01 “Design of Flexible Pavement”, where calculation of
pavement with layers of mineral materials not treated with astringents is presented. But, unfortunately,
these regulatory documents do not fully take into account the need to select the composition of the
rock-sand mixture, taking into account the densest packing of grains of various sizes, and also the
deformability of such a mixture under the influence of loads (static and / or dynamic). We [28]
proposed a technique that allows obtaining the densest compositions of mixtures already at the design
stage, and therefore choose the densest composition of the crushed stone and sand mixture, taking into
account possible deformations of the road foundation, which increases the responsibility of the
contractor for the quality of the work performed. The used mixtures must have not only the maximum
density with the least deformability under load, but it is also necessary to take into account the
rheological properties of loose bases, which are determined by various interactions with the enclosing
soils (soils surrounding the compaction base of the road on all sides) during operation. Practice shows
that by now a system for monitoring the condition and stability of this kind of soils has not been
sufficiently developed.

3.3. Formatting author affiliations
Moreover, we have presented a method [29] for determining the movements of enclosing soils in the
process of designing and operating pavements, which controls the appearance of defects on the road
surface and improves the safety of traffic on roads. The proposed method makes it possible to
determine the deformations of the enclosing soils and, if necessary, to prescribe measures to
strengthen them.

To increase the stability of the groundwork base, it is most expedient to use dense rocks that do not
contain clay, muddy organic impurities. This means that the requirements for materials for the
groundwork base must meet the requirements for heavy concrete fillers (GOST 8267-93 “Crushed
Stone and Gravel from Dense Rocks for Construction Work. Technical Conditions.” GOST 25607-
2009 “Mixtures of Crushed Stone and Gravel-Sand for Coatings and Bases of Highways, and
Aerodromes. Technical conditions.”) With the appropriate compaction of such materials, sufficiently
stable road bases can be obtained, during the process of which it is necessary to take into account possible motions of the bases of the enclosing soils.

The main concerns can be caused by the shifting of the surrounding ground in the direction of the slopes of the road. Such movements should be identified using the above method. In this case, compaction of the road foundation should be carried out until the pressure change in the ground is minimal. The method proposed by us makes it possible to determine the deformation of the enclosing soils and, if necessary, to prescribe measures to strengthen them.

Particular attention should be paid to the degree of validity of the recommendations presented in the regulatory documents, where materials that are not sufficiently resistant to water and temperature are offered as components of the road foundation. For example, in JV 34.13330.2012 “Highways” when loading the working layer of the roadbed (paragraph 7.11), it is recommended to use fine sand, sandy silt, loam, heavy loam and clay for II-IV road-climatic zones. It should be emphasized that the use of such materials increases the deformability of soils, but reduces their stability, and under conditions of direct and even hygroscopic moistening it turns them into plastic and therefore movable mixture.

In addition, the use of sand or sand materials for the construction of structures that undergo significant dynamic loads is unadvisable, due to the insufficient knowledge of their rheological properties. It is advisable, when constructing the groundwork base, to envisage and implement the support of the road foundation solely on continental soils. Otherwise, it is necessary to build pile foundations with the subsequent construction of a rigid foundation of the road (road slabs, monolithic concrete).

A great doubt in connection with the instability of soils is caused by the ways of producing works for the construction of road pavement (p.8 SP 34.13330.2012). Road pavement must meet the general requirements imposed on the carriageway as a transport facility. These requirements are ensured by the choice of the design for pavement, the corresponding roadway coverings, the construction of the carriageway roadway with the roadside and the dividing strip, as well as the types of fortifications of the roadsides, the formation of an even and rough surface of the carriageway. The design of the pavement and the type of coverage are designed based on the transport-operational requirements and the category of the road being designed, taking into account the traffic intensity, the vehicles mix, climatic and soil-hydrological conditions, sanitary and hygienic requirements, and also the material security of road construction area with local building materials.

As mentioned, road pavement can consist of one or more layers. If there are several layers, they consist of a coating, a base and additional base layers. The layered backfilling of the road foundation includes layers of sand, crushed stone mixtures of various fractions and composition. We have justified [30] the need to take into account the transformation of asphalt-concrete cover layers and their transformations under the influence of time and climatic factors. Methods for improving the stability of asphalt-concrete coating reliability under the impact of operational loads in order to achieve a defect-free operation of a road are suggested. To achieve defect-free operation of asphalt concrete pavement layers, it is necessary to take into account the ability of transformations of their state, starting from the system described by the elastically viscoplastic model to the state described by the elastic model. The quality of pavement layers will be optimal in conditions of tracing the properties of each of the model types under given conditions of impact of transport loads and climatic factors.

It is inadvisable to use recommended in the normative documents way for pressing a cement-sand mixture with subsequent moistening and rolling them with rollers, as well as using crushed-mastic mixtures for the bottom course that tend to soften under the influence of high temperatures during the summer period (8.33, 8.44 JV 34.13330.2012). When constructing layers of road pavement from dense mixtures, the used materials of grain-size composition take into account such quality indicators as breakability of crushed stone, abrasion, frost resistance, grain content of lamellar and needle-shaped granules, water resistance, ductility, and structural stability. In this case, the stability of the structure is determined only for crushed stone from the incidentally extracted overburden and enclosing rocks and
substandard waste of mining enterprises for processing ores, crushed stone from slags of ferrous and non-ferrous metallurgy. At the same time, the requirements for strength, abrasion and frost resistance to crushed stone from active and highly active slags, like wastes from metallurgical enterprises that are part of ready mixtures, are not imposed.

Deficiencies in normative documentation are also manifested in the recommendations on the use of measures to ensure the strength and stability of the working layer or to enhance pavement in conditions of impossibility or inadvisability to meet the established requirements (paragraphs 7 and 8 of SP 34.13330.2012): a list of possible activities without the basis for their implementation in specific conditions is provided.

In general, the construction of highways at all stages of production should be accompanied by strict implementation of quality control procedures, starting with the procedure for construction and technical expertise of design documentation, development of technological maps and ending with the development of documents for the acceptance of the road to operation. The processes of production and use of road building materials and technologies, taking into account specific situations deserve special attention and control.

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