Standard structures of road pavements for highways of the Baikal region

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Abstract. A network of regional highways in the Russian Federation urgently needs good and cost-efficient road constructing materials. Obtaining such materials is possible by strengthening local soils with inorganic binders. For the purpose of efficient application of such materials in the process of structures roads and highways in the Baikal region it is necessary to develop standard structures, which take account of regional characteristics. The regulatory documents in force on the territory of the Russian Federation do not contain standard structures in which materials reinforced with inorganic binders are used. The paper discusses some results of investigation bound up with development of standard structures of road pavement using local soils of the Baikal region, which are reinforced with inorganic binders.

1. Introduction
Currently, the length of public roads and highways of regional or inter-municipal significance is 11,901.264 km [1]. These roads are owned by the Irkutsk region. The length of public roads of local significance in the Irkutsk Region is 17,525.5 km (according to the data of Federal Statistics Department (Rosstat) in the end of 2019) [2].

A substantial part of the regional and local highways does not satisfy regulatory transport and exploitation requirements. The unsatisfactory condition of highways leads to a substantial increase in the cost of transported goods (up to 15–20%), to the growth of the average fuel consumption (by 1.5 times), to the growth of the costs of car maintenance (by 2.5-3.4 times) and, as a result, to some decrease in the average velocity of transporting goods (3 to 5 times) [3].

In order to bring the roads and highways to the normative state, and also to improve their transportation-exploitation characteristics, it is necessary to develop perspective technical decisions. According to the author’s opinion, one of such decisions presumes the application of local soils in the construction of roads and highways, which may be reinforced with inorganic binders.

The usage of local soils, which are reinforced with inorganic binders, makes it possible to obtain the layers with high construction and exploitation characteristics, which have a number of advantages to compare the pavements made of stone granular materials:

1. These materials do not require long-distance transportation by roads or by railroads.
2. Preparation of hardened soils may be carried out in a mixing plant and by the method of mixing on the road.
3. The ingress of moisture to the subgrade soil from top to bottom through the pavements is practically excluded, when the road foundations are made of hardened soils. As a result, the
moisture content in the upper part of the subgrade is smaller than in case of constructing the road foundation of stone materials.

4. Owing to the good distribution capacity of the layers of hardened soils, the evenness of pavements built on the road foundations of hardened soils is better than on the road foundations made of stone materials.

5. Substantial improvement of the water-thermal regime for the subgrade due to the low residual porosity.

6. Reduction of the total thickness of the pavement by 20–50% due to higher strength properties of hardened soils in comparison to the situation with granular materials.

7. The presence of reinforced layers, especially the soil of the ballast road bed and the frost protection layer, which completely prevents from mixing the material of the road foundation with the materials of the underlying layer, improves the compaction conditions for the overlying layers and hence ensures the achievement of high evenness of their laying.

The reinforced layer may be temporarily used for transporting the vehicles. Taking into account the peculiarities of the Baikal region (soil distribution, the presence of man-made waste, etc.), the following methods of soil strengthening seem to be the most interesting:

1. strengthening the soils with Portland cement;
2. strengthening of the soils with complex binders based on ash and slag waste.

Efficient application of these materials necessitates the availability of standard decisions bound up with constructing pavements, which take account of specific conditions of the region.

The normative documents, which are in force in the territory of the Russian Federation, do not take account of the standard structures, which imply the usage of the materials reinforced with inorganic binders.

So, the Idea of the present investigation is to develop Standard structures of the road pavements presuming the application of local soils, binding materials and technogenic waste.

2. Materials and methods

The process of constructing pavements in Russian Federation is conducted in accordance with the requirements of the following regulatory documents:

- SP 34.13330.2012 «Highways. Updated edition of SNiP 2.05.02-85* (with Amendment No. 1, Amendment No. 2»).
- PNST 265-2018 Automobile roads of general use. Flexible pavement design.
- PNST 390-2020 Automobile roads for general use. Non-rigid road clothes. Typical designs.
- ODM 218.2.104-2019 Album of standard structures of non-rigid pavements in various road and climatic zones.

In Irkutsk region, as well as in the Baikal region on the whole, the major part is represented by highways of the 4-th technical category "figure 1". In this connection, standard structures of road pavement have been developed corresponding to the capital, lightweight and transitional type public highways of category IV located in the road-climatic zone I.

Figure 1. The share of the Irkutsk region highways of various technical categories with respect to the length.
Structures of road pavement have been developed, while proceeding from the computations for the following three strength criteria [4]:

- admissible elastic deflection;
- the condition of shear stability of the underlying soil and the weakly connected structural layers;
- resistance of monolithic layers of the pavements to fatigue fracture as a result of stretching in case of bending.

The estimated service life of the pavement has been accepted to be 24 years according to the requirements of PNST 265-2018 Table 8 [5].

In order to reduce the probability of appearance of "reflected" cracks on the pavement, the minimum thickness of the layers made of materials, which are reinforced with mineral binders and laid on the top layer of the road foundation made of materials reinforced with cement, it is necessary to plan the layers reinforced with cement. The thickness of the layers of the materials reinforced with organic binders shall be not less than 12 cm. The computation of the pavements was carried out with the use of the software package Topomatic Robur “figure 2”.

3. Principal results of this investigation

Standard structures have been designed for different types of the subgrade soil: light sandy loam, heavy loam, light coarse sandy loam, fine sand.

The computation of drainage of the pavement has been conducted for schemes 1 and 3 of moistening the soil of the ballast road bed on the subgrade soil made of clay and sandy silty soils. The exploitation of the drainage layers of the pavement structures is organized according to the lag principle, when an additional road foundation is installed over the entire width of the subgrade. The layouts of pavement structural elements with a pavement top layer of asphalt concrete are shown in figure 3. Examples of standard structures of road pavements are given in Table 1.

Application of materials reinforced with inorganic binders for the capital types of pavement leads to some increase in the cost of the pavement in comparison to the standard structures according to PNST 390-2020.
Table 1. Standard structures of road pavements
(I3 Road climatic zone, IV category, 1st scheme of moistening the ballast road bed,
The subgrade soil is represented by light sandy loam).

| Structures of road pavement | Elastic modulus, MPa | Layer thickness, cm | Structures of road pavement | Elastic modulus, MPa | Layer thickness, cm | Structures of road pavement | Elastic modulus, MPa | Layer thickness, cm |
|-----------------------------|----------------------|--------------------|-----------------------------|----------------------|--------------------|-----------------------------|----------------------|--------------------|
| 1 Pavement                  | AB A11VL based on BND 100/130 | 3600 | 5 | The dry bound macadam treated by organic binder | 900 | 12 | Protective layer: AB A11VL based on BND 100/130 | - | 4 |
| 2 Pavement                  | Light sandy loam treated with 6% cement (GOST 23558), corresponding to the grade M20 | 300 | 10 |
| 3 Road foundation           | AB A22OL based on BND 100/130 | 2150 | 7 | Light sandy loamy sand treated with 6% cement (GOST 23558), corresponding to the grade M20 | 300 | 12 | Crushed stone-gravel-sand mixtures for the road foundation according to PNST 327 | 200-230 | 15 |
| 4 Road foundation           | Gravel-sand mixtures treated with 6% cement (GOST 23558), corresponding to the grade M20 | 500 | 20 | Crushed stone-gravel-sand mixtures for the road foundation according to PNST 327 | 200-230 | 22 | - | - | - |
| 5 Additional road foundation| Medium sand according to GOST 32824 | 120 | 30 | Medium sand according to GOST 32824 | 120 | 22 | Sand and gravel mixtures according to GOST 23735 | 130 | 27 |
| 6 Subgrade soil             | Light sandy loam |
Figure 3. Layering of pavement structures on the roads without a median lane.
1 – top layer of the pavement with a wearing course or with a blanket course;
2 – bottom layer of the pavement;
3 – the road base;
4 – the middle layer of the road foundation; 5 – the subbase;
6 – additional layer of the road foundation;
CW – carriageway; RS – roadside; V – verge;
S – strengthened part of the roadside; U – unpaved part of the roadside;

4. Principal results of this investigation
Under the conditions of insufficient density of the Russian Federation road network and urgent need for the repairs and reconstructions of existing highways and for constructing new ones, there appears the need of finding cost-efficient technical decisions in the field of road construction. This is important, in particular, for the roads of low technical categories, and the length of such roads in the Baikal region is about 90% of the total road length.

The use of hardened soils, new processed materials as well as ash and slag waste in the construction of highways instead of high-strength stone materials shall reduce the costs of construction, reconstruction and capital repairs.

The standard structures of road pavements elaborated take account of the regional characteristics, and this may improve the efficiency of application of these materials.

References
[1] The list of public roads of regional or inter-municipal significance of the Irkutsk region Available at: http://dor38.ru/wp-content/uploads/2020/05/Perechen-avtomobilnyh-dorog-obshhego-polzovaniya-regionalnogo-ili-mezhmunitsipalnogo-znacheniya.pdf
[2] The length of public roads of local significance in the Irkutsk Region at the end of 2019 Available at: https://irkutskstat.gks.ru/storage/mediabank/prot2019.html
[3] Alekseeva V V 2012 Regional transport infrastructure and directions of its modernization Dissertation, HAC of RF 08.00.05
[4] SP 34.13330.2012 Highways. Updated edition of SNiP 2.05.02-85* (with Amendment No. 1, Amendment No. 2)
[5] PNST 265-2018 Automobile roads of general use. Flexible pavement design.
[6] Road Construction Lime for Soil Stabilization and Soil Modification A Proven Solution Quicklime and Hydrated Lime Available at: http://www.carmeusena.com/
[7] Hummel H U 2001 Untersuchungen zur hygromehanischen Stabilitat von kristallinem Calciumsulfat-Halbhzdrat
[8] Volkova E V, Ivanov E I and Nechaev D N 2015 Consideration of nonstabilized condition of ground during the assessment of spatial slope stability of banked ground of automobile roads Proceedings of Universities. Investments. Construction. Real estate 2(13) pp 45-50
[9] Smirnov A V, Shestakov V N, Sirotyuk V V, Nikitin V P, Bobrova T V and Mironov A A 2005 Constructions and technologies of road construction in difficult natural conditions Omsk: Publishing house SibADI
[10] Guryachkov I L 1965 Strengthening loamy soil with cement and addition of fly ash Materials for the V Meeting on consolidation and consolidation of soils Novosibirsk NIIZhT pp 563–567
[11] Design Procedures for Soil Modification or Stabilization 2008 Production Division Office of Geotechnical Engineering 120 South Shortridge Road Indianapolis
[12] Kestler M A 2009 Stabilization Selection Guide for Aggregate and Native-Surfaced Low Volume Roads Department of transportation U.S. Department of Agriculture, Forest Service, San Dimas Technology and Development Center
[13] Solodky A I 2009 Organizational and economic foundations of the road network formation in the context of regional development Dissertation HAC of RF 08.00.05
[14] Available at: http://www.fundamental-research.ru/ru/article/view?id=31278
[15] Available at: http://www.tonar-ukp.ru/phosfogips/