Improving the Quality of Agricultural Roads

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Abstract. The article considers the issues of improving the quality of construction and operation of agricultural roads. The main reasons for the need for the construction control of the quality of work are considered. The stages of the control of quality of pavement made of stone materials have been sequentially analyzed. The actual consequences of violation of the quality of construction and assembly works are given. The modeling of the work of the system «roadbed – pavement» in conditions of increased traffic load and watering of agricultural roads has been carried out. Recommendations for increasing the service life of agricultural roads using new building materials are presented and substantiated.

1. Introduction

Agricultural roads, as a rule, are arranged from local natural stone materials or dispersed soils. Most often, the highway route is laid at zero marks, low embankments, trying to avoid exceeding more than 1 m above the earth's surface. They also try to avoid sections with recesses deeper than 0.5 m. The road surface is made of durable stone materials up to 25-30 cm, while the use of organic and inorganic binders is prohibited (bitumen, cement, ash and slag binders) to avoid soil contamination [1-3].

In the design and construction of agricultural roads, much attention is paid to the aspects of the environmental impact of the transport infrastructure facility on the environment. First of all, high-strength natural stone materials should be used. This is necessary both to reduce the formation of dust and for the passage of heavy agricultural equipment.

The construction of roads at zero marks and the ban on the use of binders and stabilizing additives leads to the need to carry out work to systematically maintain the quality of roads in a standard condition. The frequency of repairs and works on the restoration of the geometric outline of roads is increasing in comparison with public highways. All this leads to a significant reduction in the overhaul life of agricultural roads. Also, the service life of the road surface is influenced by the high level of groundwater, the top water and sources of artificial moisture and soil amelioration [3].

It is also known that waterlogging of the layers of the base of the pavement structure made of loosely bound dispersed soils during the spring thaw period leads to a sharp loss of strength and stability of the system "roadbed - pavement" [4]. The main indicators for assessing the strength and stability of the pavement are the modulus of elasticity (deformability) of the material, the homogeneity...
and integrity of the layers of the structure. The results of earlier studies [5] showed that the modulus of elasticity of materials and soils nonlinearly depends on moisture (the dependence is close to exponential) and when the moisture changes 10-15% above the calculated moisture, the strength of soils decreases by about 1.5-2.0 times ... A change in the moisture content of the materials of the base of the road structure and the soil of the subgrade, in the direction of its increase, leads to catastrophic consequences, loss of stability, sliding and destruction of the slopes of the subgrade. These conclusions correlate with the results of studies to determine the thresholds for fluctuations in the moisture content of the subgrade soils and the strength of the road pavement in the spring and summer seasons for the European and central regions of the Russian Federation [6].

2. The main factors affecting the quality of primer coatings

Dirt roads are situated on natural soil and are characterized by the absence of a hard surface. Prolonged rainfall or snowmelt cause washing out of dirt roads and they become unserviceable. It is safe to drive on such roads in dry weather or with the onset of frost, when the ground is thoroughly frozen.

As a rule, the width of a dirt road should be 4–5 meters, which is quite enough for two cars to pass each other. Dirt roads are divided into several types:

- Stabilized dirt road – used between the district settlements. These roads are strengthened with sand and gravel mix or crushed stone;
- Dirt country road – does not have a permanent surface, it is built from local soil.

The main reason for the destruction of dirt roads is the deterioration of the strength of the roadway influenced by water, destruction of the surface by natural and technological factors, wrong or excessive grading. In addition, dirt roads are not able to sustain the load from heavy vehicles for a long time. That is why the main problems that significantly reduce the quality of agricultural roads are the following:

- Potholes and excess rutting;
- Abrasion and dustiness of the pavement;
- A sharp decrease in the strength of the pavement in the rain and with excessive moisture;
- Stagnation of water in roadside ditches;
- Development of erosion processes and embankment slumping.

3. Field survey of roads

In the summer of 2016, work was performed to inspect the A-370 Ussuri highway Khabarovsk - Vladivostok at the site near the settlements of Dalnerechensk and Airport, which are within 355 to 366 km. The purpose of the instrumental survey was to establish the reasons for the unsatisfactory quality of the road surface on the main road, as well as to determine the quality and volume of work performed on the construction of adjacent agricultural roads with a coating of stone material (crushed stone-gravel-sand mixture S-1).

The purpose of the work was visual and instrumental inspection and quality control of construction and installation works on the arrangement of the pavement of an agricultural road with a coating of stone material. According to the project, the coating was made of crushed stone-gavi-sand mixture S-1 [3].

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Visual and instrumental examination was carried out in a warm period of time, at an air temperature ranging from 15 to 20°C, without rain and fog. The surface was clean and dry with no visible signs of recent renovations. The diagnostic examination of the road was carried out in accordance with the requirements of ODN 218.0.006 (Road industrial methodical document) [7]. The main requirements and recommendations for quality control of works on the construction of highways are presented in SP 78.13330 (Code of Practice) [1] and SP 37.13330 [2].
To determine the volume of excavation, it is necessary to determine the height of the subgrade and its geometric outline. The control of the volume of earthworks is carried out by determining the difference between the actual and design marks, taking into account the rate of natural settlement and the development of the processes of additional compaction and soil stabilization. According to the requirements of the norms for the construction of highways given above, the magnitude of the natural fluctuation in the height of the subgrade should not exceed 5 cm per year, in absolute value. The results of determining the deviation between the design and actual marks are shown in table 1.

| Measurements performed | Measurements performed up to 10 mm | Number of absolute deviations from 10 to 20 mm | More than 20 mm |
|------------------------|-----------------------------------|-----------------------------------------------|-----------------|
| 127                    | 74                                | 41                                            | 12              |
| Percentage             | 58.3 %                            | 32.3 %                                        | 9.4 %           |

The width of the top of the pavement made of crushed stone sand gravel mix С-1 was determined by a road tape measure from the right edge of the pavement to the left perpendicular to the center line of the road every 50 m. The tape measure was applied perpendicular to the axis of the road. The accuracy of measurement is up to 1 cm. The results of determining the deviation between the design and actual width of the road surface are shown in table 2.

| Measurements performed | Number of absolute deviations from plus 5 cm to up to 10 mm | More than 10 mm |
|------------------------|-------------------------------------------------------------|-----------------|
| 87                     | 37                                                          | 17              | 33              |
| Percentage             | 42.6 %                                                      | 19.5 %          | 37.9 %          |

To determine the magnitude of deviations in the longitudinal evenness of the top of the roadbed, a three-meter road rail of the RDU "Condor" was used. The longitudinal evenness of the coating was determined in the forward and reverse directions, on a control section 300 m long. The clearance under the rail was determined with a wedge or tape measure (in cases where it was impossible to determine the gap with a wedge). In addition, using a horizontal level located in the middle of a three-meter rail, the slope and direction of water flow from the roadway were determined. The results of determining the deviation of the deviation of the longitudinal evenness of the coating are shown in table 3.

| Measurements performed | Number of absolute deviations up to 7 mm | More than 7 mm |
|------------------------|------------------------------------------|----------------|
| 174                    | 63                                       | 62             |
| Percentage             | 36.2 %                                    | 35.6 %         |

Transverse slopes were not measured, since it can be seen from the photographs that the longitudinal roughness was not maintained over a considerable length of the research object (figure 1).
In addition to measuring the geometric parameters, it was necessary to determine the thickness of the pavement and check the compliance of the stone material with the requirements of GOST 25607-2009 (National State Standard) [8].

Six samples of the pavement material were taken for laboratory tests. It was necessary to determine the type and type of materials, to determine the granulometric composition of the samples, the strength and abrasion of the stone part of the material, as well as its frost resistance. The samples were studied in a specialized laboratory of building materials in accordance with GOST 25607-2009, GOST 5180-2015 [9] and GOST 12536-2014 [10].

As a result of a laboratory study of the seized soil samples, it was found that the material used for paving agricultural roads is classified as coarse, low-cohesive crushed stone soil with an admixture of heavy sandy loam. The use of this material in the road surface is a violation of the existing standards for the construction of agricultural roads and public roads with transitional and lower types of coverage.

In general, according to the results of the studies performed, it can be said that the agricultural road at 355 - 366 km of the Khabarovsk - Vladivostok highway does not meet the regulatory requirements and is subject to reconstruction.

4. Mathematical modeling of the stability of the system «base – roadbed»

In order to develop a technique for assessing the stability of embankment slopes, a study was carried out by numerical modeling of the stress-strain state process by the finite element method using Geo5 software (educational license) which uses the finite element method and the results of experimental studies.

An embankment with slope angle $\alpha = 36^\circ$, load $P = 5$ kN/m$^2$ and soils with the characteristics given in Table 4 was used as a design model. All calculations were carried out by a numerical method in the Geo5 software package. The variation range of the specific gravity of the embankment soil (fine sand) is $\gamma = 16.5-18.5$ kN/m$^3$ with a step of 1 kN/m$^3$.

Three series of calculations were carried out to create slide lines and calculate on them the value of the safety factor for the embankment (h = 5.0 m, b = 10 m, slope 1:m = 1:1.5, R = 14.16 m).

The radius of the sliding surface is determined by the GeoStab program as critical and equals to R = 14.16 m. Based on the current design standards, the acceptable coefficient of stability of the embankment slopes $K_s$ is 1.50. The calculation of the stability of the embankment slope (according to Bishop) is shown in figure 2.

Calculation of safety factor by the Morgenstern-Price method, moments:

$$K_s = \frac{\Sigma M_{reacti}}{\Sigma M_{acti}}$$  \hspace{1cm} (1)

$$K_s = \frac{5729.2}{5844.5} = 0.980$$  \hspace{1cm} (2)
Calculation of safety factor by the Morgenstern-Price method, forces:

\[ K_s = \frac{\Sigma F_{act}}{\Sigma F_{act}} \]

\[ K_s = \frac{358.0}{365.2} = 0.980 \]

\[ (3) \]

\[ (4) \]

**Table 4.** Physical and mechanical characteristics of soils.

| №   | Soil type          | Specific gravity of soil at natural moisture, \( \gamma \), kN/m³ | Specific cohesion of soil at natural moisture, \( s \), kPa | Angle of internal friction at natural moisture, \( \phi \), deg | Specific gravity of soil at full water saturation, \( \gamma_{sat} \), kN/m³ |
|-----|--------------------|---------------------------------------------------------------|--------------------------------------------------------|--------------------------------------------------------|--------------------------------------------------------|
| 1   | Fine sand          | 15.0                                                          | 3.0                                                    | 28.0                                                   | 31.0                                                   |
| 2   | Soft sandy loam    | 18.0                                                          | 10.0                                                   | 15.0                                                   | 20.3                                                   |

Since the coefficient of slope stability does not meet the requirements of ODM 218.2.078-2016 (Road industrial methodical document) «Guidelines for the selection of the structure for strengthening the slopes of the road bed of public roads», the program includes methods for strengthening slopes, for example, using anchors to increase the coefficient of slope stability.

**Figure 2.** The results of assessing the stability of the system «base – roadbed» \((h = 5.0 \text{ m}, b = 10 \text{ m}, 1:m = 1:1.5)\) by sequential modeling of its construction.

5. **Recommendations for strengthening the system «base – roadbed»**

Nowadays the following schemes of slope reinforcement are most effectively used: permanent anchors and geosynthetic materials. Characteristics of materials are presented in tables 5 and 6.

**Table 5.** Characteristics of anchors.

| №   | Depth, m | Diameter, mm | Angle of inclination, deg | Unsupported length, m | Anchor length, m | Force, kN |
|-----|-----------|--------------|---------------------------|----------------------|------------------|-----------|
| 1   | 1.50      | 300          | 25                        | 2.50                 | 2.00             | 120       |
| 2   | 2.50      | 300          | 25                        | 2.50                 | 2.00             | 120       |
Table 6. Characteristics of geosynthetic materials.

| №  | Depth, m | Width of layer, m | Angle of inclination, deg | Shear strength, kN | Tensile strength, kN |
|----|----------|-------------------|--------------------------|-------------------|-------------------|
| 1  | 0.50     | 6.50              | 0                        | 0.80              | up to 35          |

The most promising way to restore and strengthen roads with transitional and lower types of pavement, which include agricultural roads, is the use of geosynthetic materials [11], such as geocell consolidated materials trademark «NEOWEB» [12].

Geosynthetic material with three-dimensional honeycomb structure is formed of corrugated perforated or non-perforated strips of geosynthetic material connected by ultrasonic welding, made of polymer nanocomposite alloy «NEOLOY», produced in the form of a folding structure and supplied in the bags in a folded state. They are a three-dimensional honeycomb structure obtained by staggered ultrasonic welding of polymer strips.

The results of modeling in the *Geo5* program are shown in figure 3 for permanent anchors, and in figure 4 for a structure reinforced with geosynthetic materials.

![Figure 3](image)

Figure 3. Results of assessing the stability of the system «base – roadbed» reinforced with permanent anchors.

Calculations have shown that the use of permanent anchors as reinforcement increases the safety factor by 28% in fine sand and by 35% in soft sandy loam, which meets the requirements of ODM 218.2.078-2016 (Road industrial methodical document) «Guidelines for the selection of the structure for strengthening the slopes of the road bed of public roads».

A decrease in the specific gravity leads to an increase in the total coefficient of stability by about 1-2%, which does not have a large effect on the overall stability of the embankment soil (table 7).
Figure 4. The results of assessing the stability of the system «base – roadbed» reinforced with geosynthetic materials.

Table 7. Calculated values of the safety factor.

| №  | Specific gravity, $\gamma_i$, kN/m$^3$ | Safety factor, $K_s$ | Safety factor using geosynthetic material, $K_s$ |
|----|--------------------------------------|----------------------|-----------------------------------------------|
| Silt sandy loam | 20 | 1.54 | 1.52 |
| | 17 | 1.58 | 1.55 |

It should be noted that strengthening the road structure with geocells will not only increase its strength and reliability, but also reduce the consumption of expensive stone material (table 8).

Table 8. Pavement design.

| Material Layer thickness, cm | Total modulus of elasticity, MPa |
|------------------------------|---------------------------------|
| Original solution | | |
| Crushed stone sand gravel mix C-1 | 40 | 155 |
| Medium sand | 40 | |
| Roadbed – silt sandy loam | - | |
| Solution with geocells | | |
| Crushed stone sand gravel mix C-1 | 25 | |
| Protective layer of medium sand | 5 | |
| «NEOWEB» geocells filled with sand | 15 | 167 |
| Medium sand | 10 | |
| Roadbed – light sandy loam | - | |
6. Conclusion

The issues of assessing the stability of embankments on weak base are always relevant for road construction. The use of methods of mathematical modeling allows to consider a variety of factors at the design stage and to exclude the most common situations that affect the stability of the system «base – roadbed – pavement».

The assessment of the stability of the slopes of the systems «base – roadbed» and «base – roadbed – pavement» showed that it is necessary to provide measures for the comprehensive strengthening of slopes using anchor systems or geosynthetics for high embankments (5 m and more), located on weak thawed soils.

Reinforcement is the most effective way to strengthen slopes and increase the stability of embankments on weak base. Reinforced materials and soils have better physical and mechanical characteristics than unreinforced ones. The use of reinforcing structures and materials in the construction of the roadbed increases the service life and significantly increases the reliability of the embankment both under standard operating conditions and medium level of seismic activity.

The use of geocell systems allows to reduce the consumption of building materials, increase the strength and stability of pavements and extend the inter-maintenance period of the road. In addition, the use of geocell systems does not harm the environment and does not lead to environmental pollution, which is very important for agricultural roads.

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