The construction of linear soil structures with the use of geosynthetic materials in the severe hydro geological conditions

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Abstract: The article is devoted to the construction of the linear soil structure in complicated hydro geological conditions with the help of geosynthetic materials. This structure was proposed as an alternative to the applied extensive methods, such as the substitution of the roadbed soft soils for sand or rubble, or the installation of laying, characterized by high energy and material intensity, causing significant harm to the environment. The monitoring of the facility condition makes it possible to predict its high reliability and durability. The proposed structure and construction technology are described in the developed STO 80193846-007-2012 «The recommendations for the use of biopositive structures in complicated hydro geological conditions».

1. Introduction
Linear soil roads are occupied a significant place among the soil structures. In particular, a huge share of the construction of linear soil structures occurs on the territory of the North, Western Siberia, the Far East, which serves as a source of energy supplies to the world markets. These territories are peculiar because they represent a unique ecosystem, where forests and swamps prevail, their territory is characterized by the occurrence of soft water-saturated clay soils and peat, that determines the distinction of these regions and dictates special requirements for the structures and construction technology.

The variety of soil and climatic conditions of the areas where the linear soil structures are to be built, a significant number of the impact factors, combined with a real diversity in the features of the material quality, all of these require a deep analysis when choosing and explaining the appropriate method for improving the physical and mechanical properties of soils. The analysis of the applied methods, that increase the load-bearing capacity of the constructed structures, made it possible to identify long-range ones, among which the earth roads with geosynthetic materials are the most effective ones.

At the same time, when constructing roads, the man-made impact caused on the existing ecosystem in the area, the properties of the roadbed soils are transformed, that leads to a change in the whole ecosystem. The man-made impact often results in a change in the properties of the roadbed soil, which makes significant adjustments to the predicted properties of the constructed facilities.
A significant part of the earth roads is represented by the road embankments. The construction of the road embankments with the use of extensive methods, such as the substitution of soft roadbed soils for sand and rubble, or the track laying, is characterized by high energy and material consumption, and causes a serious harm to the environment. In these cases, the change in a hydrodynamic regime is noticed, territories are occupied with the swamp, and a large number of technogenic soils are formed. This led to the development of the "environment-friendly" technologies, the so-called "biopositive" design solutions with the use of modern building materials.

2. Methods

Recently, various groups of geosynthetic materials have been widely used for the construction of linear road facilities. They include non-woven geotextiles, geomeshes, geogrids, bulk geocells, geotextile fabrics, drainage composites, geomembranes, anti-erosion mats, etc. [1-4]. The research work, conducted to develop and design various soil structures with the use of geosynthetic materials [3, 5, 6], allowed to formulate some certain requirements for biopositive structures, that are aimed at the reduction of the negative impacts.

Biopositive structure and construction technology should provide [4, 6-7]:

- the reduction of the amount of man-made soils, formed during the construction;
- the solution reduction of the material and energy intensity;
- the minimization of the impacts on the geological environment;
- the prevention of the changes in the hydrodynamic regime.

The use of the geotextile does not require any additional use of the non-woven geotextile. The strength of the material and the number of the layers are pre-calculated.

From these points of view, it is more appropriate to use a scheme with a single-layer or multi-layer laying of high-strength geotextile fabrics in the roadbed construction [7,8]. Meanwhile, one or more layers of reinforcing materials should be placed at the bottom of the roadbed to raise the bearing capacity of the roadbed and to provide the overall stability of the structure. To increase the time interval between repairs and to provide the quality of the road surface (for example, to avoid wheel tracking formation), the reinforcing layer (basalt, polyester or polypropylene geogrid) should be located at the top of the roadbed under a layer of rubble. The height of the roadbed is determined by the project and depends on the design vertical profile of the road.

The schema of the construction of the biopositive road is shown in figure 1. According to the analysis of the reinforcing materials, a high-strength geotextile was selected for reinforcement, since it can be laid directly on the soil surface of the roadbed, when it is necessary to apply non-woven geotextiles additionally for geomeshes and geogrids.

Under high strength parameters geotextile fabrics have a solid structure and perform several functions: reinforcement, layer separation and filtration. The geotextile may be sewn into the fabrics in order to provide a greater area of the reinforcement. In addition, the solid structure of the geotextile fabric will allow to install culverts in the body of the embankment. The culverts provide free flow of water and the integrity from the destruction.

The design like this allows to avoid the substitution of the roadbed soils, to avoid the construction of the enclosure structures and track laying, and other special events. A positive feature of the design is the absence of restrictions on the work execution in dependence to the seasons.

It should be noted that the design of the biopositive structure is based on the principle that is aimed to provide structure strength and stability on soft soils of the roadbed, the so-called "floating structure".

In this case, the roadbed settlements of the biopositive structure can reach great values, they can be equal to several meters, and last for a long time. They are considered to be a major difference between the biopositive structure and the existing structures of the earth roads.
The forecast of the soil structure settlements on soft soils (peat and/or silt), where geosynthetic materials are used, is not currently fully developed. Therefore, the article includes geotechnical monitoring, the results of which will give a comprehensive assessment of the biopositive structure efficiency during its operation, as well as will expand the range of scientific knowledge in order to forecast soft roadbed settlement of the soil structures.

3. Research results
During the research the complicated sections of the earth roads were studied in the complicated hydrogeological conditions on the territory of Western Siberia near Salym. Figure 2 shows the grade profile of one of the studied sections. The capacity of soft soils, consisted of peat, reached up to 6 m. Therefore, the use of the traditional methods to construct the soil structures, which involve peat reclamation (figure 3) or track laying, can result in a significant economic and environmental losses.

Besides the biopositive structure which does not involve peat reclamation or track laying, it was introduced the method of the embankment construction that allows to build quickly and cheaply (figure 4).

On having finished site erection work of the road construction, the monitoring was carried with the help of visual and instrumental observations methods. The changes in the structure shape of the embankment were visually monitored, the formation of local sinkholes, craters, and structure deformations were recorded. A transit theodolite NET1 was applied to measure the vertical movements of the roadbed.

The monitoring period was set due to the calculation which takes into account the complete stabilization time of the roadbed settlements on the basis of the theory of soil filtration consolidation.

When it was time to complete the observations, the real settlements reached 90% of the designed values. The settlement values of the roadbed were calculated with the help of two methods: the ICS 26-90 and the limited power layer method, both of which showed similar results.
Figure 3. The grade profile of the embankment SD 31-SD 58+40.

Figure 4. The schema of the biopositive structure erection on the earth road in the complicated hydrogeological conditions.
Embankment settlements monitoring included several cycles. The first cycle of surveys - sequential, as the road was being constructed, that lasted 20 days. The following 8 cycles were carried out immediately on all culverts alongside the section. It is vital to say that the first 10 months are characterized by the intensive development of the settlements. Then the increments of settlement decrease and after 20 months, since the commencement of the road construction, they are equal to no more than 2 cm/month, that indicates the consolidation process completes. It should be noted, that when the construction was finished, the soil structure (road embankment) was immediately put into operation.

The values of the designed and the real settlement in 10 and 20 months are shown in figure 5.

![Figure 5](image)

**Figure 5.** The values of the designed and the real settlement (in vertical direction) in 10 and 20 months (in horizontal direction there are numbers of station distance (in 200m.), in vertical direction – the values of settlement, m).

The analysis of the field studies allows to state:

- No local damages of the roadbed or the road surface were detected in the biopositive structure along the entire length of the section;
- The values of the real settlements turned out to be slightly less than it had been designed. At the same time, there was no direct dependence of settlement on the power of the soft layer.
- The earth road is in a stable condition alongside the monitored section, and there is no need for repair work.

These results were broadly applied and implemented in the construction practice of the earth roads in Western Siberia, they were also used to develop the STO 80193846-007-2012 «The recommendations for the use of biopositive structures in complicated hydro geological conditions» [9].

### 4. Conclusions

The proposed biopositive structure with the use geosynthetic materials has been developed and implemented in order to minimize the impact on the environment during the construction of road embankments. Moreover, the geosynthetic material has been selected in such a way to provide the greatest efficiency and processability of construction. The monitoring data confirm the reliability and durability of the biopositive structure.

The obtained results allow to conclude that the application of the biopositive structure and technology is the most environmentally safe method of construction of earth roads in the complicated hydro geological conditions.
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