Technology for Strengthening Earth Mound’s Foundations, Reinforced with Geosynthetic Materials

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Abstract. Technology of strengthening subgrade foundations, using geosynthetic material at a specific object is described in the article. The use of the proposed geosynthetic material as a reinforcing element is effective, creating load-bearing layers of the earth mound’s foundations, slopes or other types of support structures. Soil base reinforcement of the earth mound with geosynthetic woven material "Stabilenka®" allows increasing the bearing capacity of weak silty clay soils of soft plastic and fluid consistencies to fluid from 1.5 to 5 times, depending on the strength of the material, reduce deformability by 20% and can be considered as the most optimal. We can consider, that the use of a new progressive material allows increasing bearing capacity of the subgrade and reducing the cost and labor intensity of its construction in comparison with traditional methods and the duration of the mound preparation on weak areas is reduced by up to 5 times, using such technology.

1. Introduction
Reinforcement of the soils foundations is performed to increase the strength and stability of the bases [1], which is especially important for the subgrade construction of various types of embankments. The technology for performing reinforcing elements and the technology for their implementation are determined, depending on the physical and mechanical characteristics of soils and the tasks to be solved during reinforcement [2-4]. As a recommendation for increasing the subgrade foundations’ strength and stability of various embankments’ types, it is necessary to take into account their anisotropic properties [5-12]. The calculating results of the stress-strain state for an unevenly distributed external load makes it possible to make the corresponding calculations of the foundations’ settlement of various embankments types [13-16].

One of the ways to improve the subsoils performance, strength and deformation properties of soils is to use as a reinforcing geosynthetic woven material "Stabilenka®", developed by HUESKER [16]. Woven material Stabilenka® is supplied in a standard width of 5.00 m in rolls with a diameter of 450 up to 1000 mm equipped with a paper measuring tape. The weight of rolls varies depending on the Stabilenka® material type from 400 kg to 1000 kg. The possibility of using this material as a reinforcing layer is due to raw material the geotextile is made from. High modulus polyester has low creep when handling high permanent tensile loads.

The lack of subgrade’s bearing capacity is compensated by the tensile strength of the geosynthetic material, using a reinforcing element at the subsoils that resists tensile stresses.

We are able to select and add the missing force to the structure, in order to ensure stability during installation and operation, investigating the material activity in time under the load from the structure.
We select the grade of material for strength with fixed deformation, i.e. relative displacement, depending on the required effort [16].

2. Materials and Methods

The technology of strengthening the earth mound’s foundations, reinforced with woven material is proposed. A diagram of the structure to be arranged is shown in Figure 1.

![Diagram of the structure to be arranged.](image_url)

Figure 1. A diagram of the structure to be arranged.

At the first stage, the soil surface is profiled, where the geosynthetic material will be laid. The subgrade surface must be cleaned of the previous structures, tree roots and stumps, sharp objects and stones. It is necessary to check its marking with the design data, before laying geosynthetics. A roll of geosynthetic material is rolled out over the entire area, intended for reinforcement and cut to the required length with a knife, scissors or thermal cutter.

The cut-off part of the roll is turned perpendicular to the axis of the subgrade. The laying is carried out in successive rows with overlapping strips by 50 sm. Wrinkles should be avoided, laying the material. The fabric should be stretched with stakes or tensioners and slightly pulled, before applying the bulk material. A visual inspection is made of the canvases joining quality, joining evenness, before filling a layer of sand. Sand layer is carried out along the axis of the subgrade to the width of the previously, divided working area.

It is not allowed to move vehicles on the rolled material that is not covered from above. The movement of vehicles is allowed only after creating a bulk layer with a thickness of 0.30 m. The turns of tracked vehicles on a layer up to 0.30 m should be avoided.

The sand is pushed onto geotextiles by the forward method. Compaction of the sand layer should be carried out in layers, using static machines of low and medium weight, in order to avoid the formation of unevenness in the lower soil layer. The compaction ratio of the sand should be 0.95. Sand slope prism is compacted manually in the anchor zone.

Anchoring of the sand layer is performed manually with the addition of soil to each return anchor of geosynthetic material from the end and from the top.

Technological map for the subgrade strengthening device, using geosynthetic material on the road: Omsk-Novosibirsk in the section from the village Prokudskoe to the village Sokur with a bridge over the Ob river near the village Krasny Yar in the Novosibirsk region (PK736 + 50-PK748 + 50) is shown in Table 1.
Table 1. The scheme of operational quality control for the strengthening subgrade device using geosynthetic material is given in tables 2 and 3.

| №/process | process names         | layer parameters          | machines and mechanisms | materials | quality control |
|-----------|-----------------------|---------------------------|-------------------------|-----------|-----------------|
| 1         | soil surface profiling| bottom width of the embankment | Motor grader 98         | 1. Geosynthetic material | Control composition: - elevation marks; - cross slopes Instruments: - level, rail; - roulette |
| 2         |                       | 1. the width of the overlap of the canvases - 0.5m | 1. Dump truck KamAZ - 55111 |            | Control composition: - overlap width - evenness of the geotextile surface Instruments: - roulette - visually |
| 3         |                       |                           | 2. Autogader 98         |            |                 |
|           |                       |                           | 3. Roller for laying -85|            |                 |
|           |                       |                           |                         | 1. sand    |                 |
|           |                       |                           |                         | control composition: - thickness, width of the sand layer - height marks - transverse slope - coefficient of compaction - anchor length Instruments - probe; - level, rail; - roulette; - laboratory. |
|           |                       |                           |                         | 1. Layer thickness ± 5 cm. | 1. Lap width ± 3 cm. |
|           |                       |                           |                         | 2. Height marks ± 5 cm. | 2. No wrinkles |
|           |                       |                           |                         | 3. Cross slope ± 10%. | 3. Cross slope ± 10% |
|           |                       |                           |                         | 4. Purchase no more than 0.04. at 10% | 4. Purchase no more than 0.04. at 10% |
|           |                       |                           |                         | 5. Anchor length ± 5 cm. | 5. Anchor length ± 5 cm. |

Note: The soil surface, where the geosynthetic material is laid, should not have ruts, pits and other irregularities more than 3 sm. The surface of the soil must be profiled with a motor grader, before laying the synthetic material and the material itself must be checked for marking with the project. The geosynthetic material laying is done manually by rolling a pre-cut canvas across the axis of the roadbed.

The laying is carried out in successive rows, with overlapping strips by 50 sm. Visual inspection of the canvases joining quality, before pouring a layer of sand, the joining evenness is performed. Laying sand is carried out along the axis of the mound to the width of the previously divided working area.

The movement of vehicles on the canvas is allowed only after creating a layer of sand with a thickness of 30 sm. Compaction of the sand layer should be carried out with static machines of low and medium weight in order to avoid the formation of unevenness in the lower soil layer.

The compaction factor of the sand should be 0.95. Anchoring of the sand layer is performed.
manually with the addition of each return soil anchor of geosynthetic material from the end and from the top.

**Table 2. Scheme of operational quality control.**

| p/p | Controlled parameters | Deviations allowed |
|-----|-----------------------|--------------------|
| 1   | Elevations along the axis of the subgrade base | ±5.0sm |
| 2   | Subgrade base width | ±10sm |
| 3   | Cross slopes | ±10% |
| 4   | Evenness of the subgrade surface (clearance under a three-meter rail) | 10mm |
| 5   | Geotextile panel length | ±10sm |
| 6   | The amount of geotextile canvases overlap | ±3sm |
| 7   | Sand backfill thickness | ±5sm |
| 8   | Uncompacted sand layer thickness | -3sm |
| 9   | Sand layer elevations along the axis | ±5sm |
| 10  | Compaction coefficient deviation of the bulk layer in 10% of samples | Not more -0.04 |
| 11  | Length of geotextile anchoring part | ±5.0sm |

**Table 3. The process description.**

| Technological processes and operations subject to control the process organization | Grading the soil surface | Laying of geosynthetic material and filling a layer of sand |
|---------------------------------|--------------------------|---------------------------------|
| Control composition (what is checked) | 3. Bottom width of the mound | 1. Amount of overlap 2. Thickness and width of the layer |
| Control method (how and what is verified) | 3 Level, staff, measuring tape | 1. Measuring tape 2. Measuring tape, measuring ruler |
| Type, mode, scope of control | 3. Selective after 50sm | 1. Selective, every 10m 2. Selective, at least every 100m |
| Control time (when to control) | During the production of works | |
| Who controls | Master | |
| Who controls | Site manager | |
| Who is involved in the audit | Surveyor | - |
| Where results are recorded | Work production log | |

Safety instructions, performing work are as follows: before starting work, it is required to establish a parking space for road construction equipment; outline the ways of its movement to the work place; determine the availability of utilities at the construction site and coordinate the production of work in their security zone with the owners.
In addition to meeting safety requirements during operation, the following requirements must be observed, operating road machines of all types: it is forbidden to work with clay soils in rainy weather on slopes that do not provide a stable movement of machines.

The distance from its edge to the motor grader wheel, a dump truck, excavator, bulldozer caterpillar must be at least 1 m., filling mound from cohesive soils.

Following each other, it is necessary to keep a distance between them of at least 5 m. developing, transporting, unloading, planning and compaction of the soil by two or more self-propelled or trailed machines (graders, rollers, bulldozers, etc.).

Reverse movement of dump trucks to the place of loading and unloading of soil is allowed at a distance of no more than 50 m and must be accompanied by a sound signal.

The edges of a high mound must be compacted from a prepared compacted area (at a distance of 2 m from sideways), and then shift the roller passes by 1 / 3 of its width towards the edge up to a distance of 0.5 m (from the edge of the embankment).

Warning sound signal must be given, changing the direction of rollers movement of all types. Workers servicing the equipment must have installed overalls, shoes and gloves.

3. Results
The usual technical standards for earthworks and construction of bases and foundations apply in principle, creating load-bearing base layers of earth mound, slopes or support structures with reinforcement from woven material "Stabilenka®". Soil base reinforcement of the earth mound with geosynthetic woven material "Stabilenka®" allows increasing the bearing capacity of weak silty clay soils of soft plastic and fluid consistencies to fluid from 1.5 to 5 times, depending on the strength of the material, reduce deformability by 20% and can be considered as the most optimal. The absence of specialized machines use, as well as trained specialists in the technological process, allows the reinforcement with the existing forces of local contractors without additional costs. The duration of the mound preparation on weak areas with the use of this technology is reduced by up to 5 times.

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