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Solution for road construction on soft ground

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ABSTRACT

At present, sufficient experience has been gained in the design and construction of roads with the use of geocells, in particular, on weak soils. One of the main building properties of geocells is their ability to maintain strength and carrying capacity. When under loads an uneven subsidence occurs, geocells bend and take the base surface shape, redistribute load over a large area and reduce subsidence unevenness.

However, normally geocells are made of HDPE with no additional reinforcement, and the material strength is usually determined by presence of secondary polyethylene and strip thickness. The main drawback of this is high elasticity of the material that can be up to 250%, thus geometry stability of the cells under loads cannot be maintained. As a result, we see filler material over-consumption and structure deformations.

To overcome this drawback, we performed the reinforcement of polyethylene strips which are used in geocells production. This was made in order to obtain an additional safety margin and stability of the geometric characteristics, since polyethylene stretches under pressure, temperatures and over time.

Now we would like to present a geocell for road construction – namely in structures that require high and uniform indicators of strength and durability.

Key words: geocells, road construction, soft ground, embankment reinforcement, unstable ground, elongation.

1.INTRODUCTION

The problem of roads construction on soft soils is very important for Russia, since more than 50% of the territory of the country is located in areas with difficult soil and geological conditions (Figure 1).

Figure 1. Temporary roads on soft soils.

In accordance with the Manual on the design of the subgrade of roads on soft soils, soft soils are cohesive mineral, organic, and organomineral soils with shear strength when tested by a rotational shear scheme of less than 0,075 MPa or by settlement modulus of more than 50 mm/m with a load of 0,25 MPa (deformation modulus below 5,0 MPa). And in the absence of test data, weak soils should include: peat and peaty soils, silts, sapropels and clay soils with a consistency coefficient of more than 0,5.

There are two approaches for roads construction on the soft soils: the first method assumes the complete replacement of soft soils with sand. This method has one significant drawback - it requires a large amount of imported material, which significantly increases the cost of construction. Therefore, the second method of construction was developed - the use of soft soil as the base of the embankment with appliance of measures that ensure the stability of the foundation and accelerate its sediment, as well as the strength of the road dressing being built on such a subgrade.

There are many technologies for the roads construction on weak subbases: construction on a lay flooring from logs, the use of piles, the technology of slow filling of the embankment, the use of drainage belts and so on. Recently, geosynthetics such as non-woven and woven geotextiles, geomatrixes and soil containers, geogrids, three-dimensional geocells are increasingly being used for these purposes. The appliance of three-dimensional geocells will be discussed in this article.

A three-dimensional geocell is a geosynthetic material of a three-dimensional "honeycomb" or similar cellular structure according to (Figure 2), formed from the stripes interconnected with each other and produced in the form of a folding module.

Figure 2. Three-dimensional geocell.

Three-dimensional geocells were invented by the American company PRESTO together with the engineering corps of the US Army in the late 1970s for the rapid construction of roads in inaccessible regions to ensure the passage of heavy military equipment.

At the end of the 1990s, our company brought this technology to Russia and in 1998, our first project with appliance of three-dimensional geocell was built. It was the highway Khanty-Mansiysk - Nyagan in Siberia (Figure 3), with a total length of 292 km.

Figure 3. Highway Khanty-Mansiysk- Nyagan.

The appliance of three-dimensional geocells creates a composite layer in the road body, in which the aggregate is rigidly fixed in the cells. Due to this, when transport loads are applied, they are redistributed in the plane of the composite layer.

Traditionally, in the design of the road, the problem of load perception is solved by increasing the thickness of the structural layers. An alternative way to increase the bearing capacity of the structural layers of roads is to use the three-dimensional geocells. It is proved that geocells contribute to an increase in the bearing capacity of bases and road dressing. In addition, they can reduce the thickness of the structural layers and use cheaper local materials instead of expensive imported ones. This saves up to 20% of the project cost. The appliance of geocells, until recently, was difficult due to their prone to deformation. The polyethylene from which three-dimensional geocells are made stretches up to 100% under load, which causes deformation of the base (Figure 4).

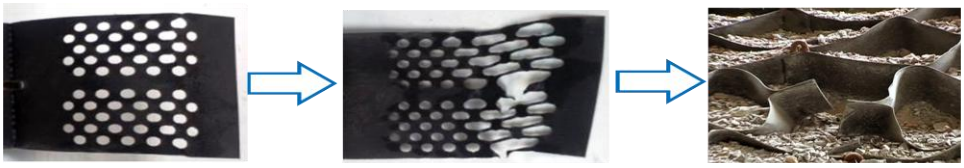


Figure 4. The deformation of the cell under the load.

This drawback has been eliminated by reinforcing polyethylene stripes from which geocells are made with extra-strength fibers.
The main advantage of the reinforced geocell is its increased resistance to plastic deformations. Designs with reinforced geocell keep the specified indicators of bearing capacity for many years, which increases the service life of the road. In addition, reinforced geocell is more resistant to high temperatures, which also has a positive effect on its appliance in road construction.
Important features of the reinforced geocell are texturing and perforation (Figure 5). Perforation improves the removal of water from the composite layer, and texturing serves to increase adhesion between the cell walls and the filler material, which improves the strength characteristics of the structure. All our geocells are produced with a textured surface.
The main geometric parameters of geocells for road construction are shown in (Table 1).

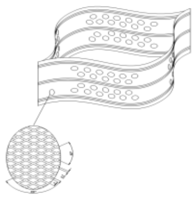


Figure 5. Texturing and perforation.

Indicator	Value			
Cell size by side (2a), mm, ± 10%	330	344	356	445
Cell size by diagonal (a1), mm ±10%	244	254	263	325
Cell size by diagonal (b1), mm ±10%	205	214	221	275
Density of cells, pieces/m2	40	39	35	22
Cell height (h), mm, ±10%	150/200/30			

Table 1. Reinforced three-dimensional geocell size requirements recommended to use in road construction construction in accordance with STO 17996082-001-2013.

A typical passage design with appliance of the reinforced geocell (Figure 6) is as follows: a three-dimensional geocell is laid on top of a separation layer of non-woven geotextile, with a density of at least 300 g/m2 and filled with local material. A protective layer is formed above the geocell, the recommended thickness not less than 5 cm.

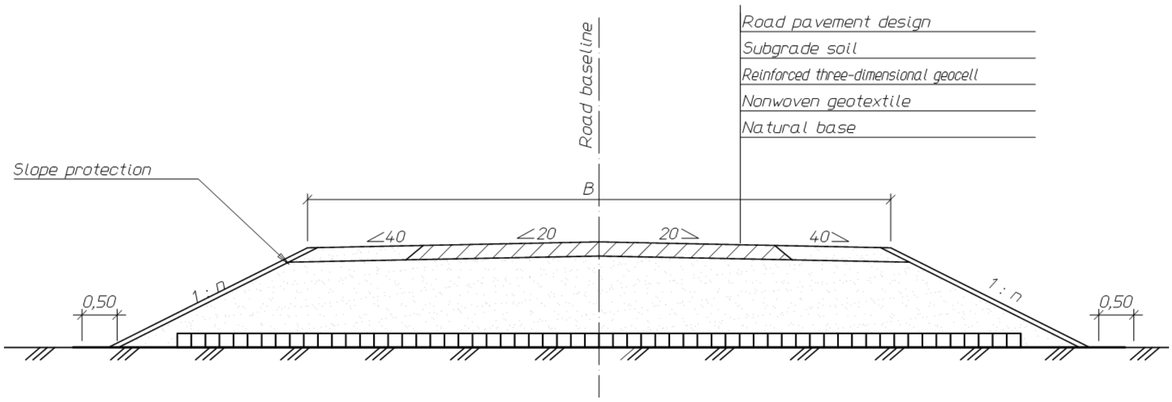


Figure 6. Typical road design on a weak subbase.

Calculation:

1. Determinate the maximum allowable load on the base [Eq.1]:

$$q_a = N_c \cdot c_u \qquad [1]$$

2. Determine the required thickness of the mound without geocell [Eq.2]: :

$$z_u = \frac{R}{\sqrt{\frac{1}{\left(1 - \frac{q_a}{p}\right)^{\frac{2}{3}}} - 1}} \qquad R = \sqrt{\frac{P}{p \cdot \pi}} \qquad [2]$$

Where:

C_u - Subgrade shear strength;

N_c – Bearing capacity coefficient - based on design traffic;

P – Design wheel load;

p – Contact pressure;

φ - Angle of internal friction of the reinforced geocell infill material;

δ - Angle of shear resistance between the granular infill and reinforced geocell wall;

z_t – Depth from surface to top of geocell cell walls;

z_b – Depth from surface to bottom of geocell cell walls;

R – Radius of loaded area (i.e. effective radius of single or dual tires).

3. Calculate vertical stress at the top of the reinforced geocell section [Eq.3] :

$$\sigma_{vt} = p\left[1 - \left(\frac{1}{1 + \left(\frac{R}{z_t}\right)^2}\right)^{3/2}\right]$$ [3]

4. Calculate vertical stress at the bottom of the reinforced geocell section [Eq.4]:

$$\sigma_{vb} = p\left[1 - \left(\frac{1}{1 + \left(\frac{R}{z_b}\right)^2}\right)^{3/2}\right]$$ [4]

5. Calculate the horizontal stress at the top and bottom of the reinforced geocell section [Eq.5]:

$$\sigma_h = K_a \sigma_v$$

$$K_a = \tan^2\left(45 - \phi/2\right)$$

$$\sigma_{ht} = K_a\, \sigma_{vt}$$

$$\sigma_{hb} = K_a\, \sigma_{vb}$$

$$\sigma_{avge} = \frac{\left(\sigma_{ht} + \sigma_{hb}\right)}{2}$$

$$\sigma_r = 2\left(\frac{H}{D}\right)\sigma_{avge}\tan\delta$$ [5]

H – reinforced geocell cell depth in mm;

D – Effective reinforced geocell diameter.

6. Determine the design allowable stress on the subgrade with the reinforced geocell cellular confinement system [Eq.6]:

$$q_G = q_a + \sigma_r$$ [6]

7. Determine the total required thickness of granular pavement with reinforced geocell [Eq.7]:

$$z_G = \frac{R}{\sqrt{\frac{1}{\left(1 - \frac{q_G}{p}\right)^{2/3}} - 1}}$$ [7]

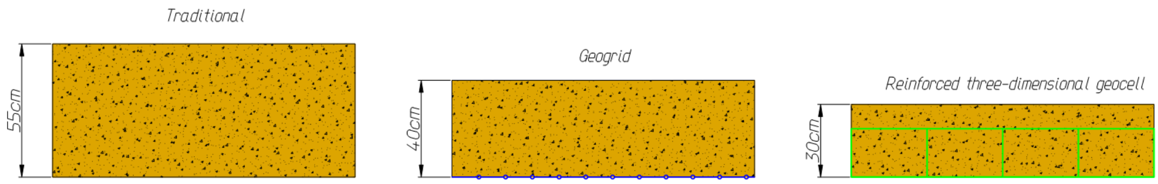


Figure 7. Comparison of the required thickness of a composite layer without geocell / with geogrid / with reinforced geocell.

Reinforced geocell has been successfully applied when constructing roads on weak grounds. The highway along the Bovanenkovo – Ukhta main gas pipeline system on the Yamal Peninsula. According to the calculation results, due to the appliance of reinforced geocell, it was possible to reduce the thickness of the crushed stone layer from 80 to 30 cm (Figure 7).

Several roads built for the mining industry in a weak ground conditions at the base with the appliance of the reinforced geocell.

The main advantages when using three-dimensional geocells:

- use of local road building materials, instead of expensive imported
- reduced rutting
- increase in the average speed of movement in the area
- possibility of laying directly on a weak base
- driving along the road is possible immediately after laying the geogrid and filling it
- high speed of construction
- it is not necessary to arrange multilayer structures, as when using geogrids and geotextiles

In addition, three-dimensional geocells are widely used in the construction of bulk site structures on weak foundations (Figure 8). The main difference of such objects is that their construction is carried out in the winter by frozen soil. Because of this, in summertime during the defrosting of the embankment, uneven subsidence occurs.

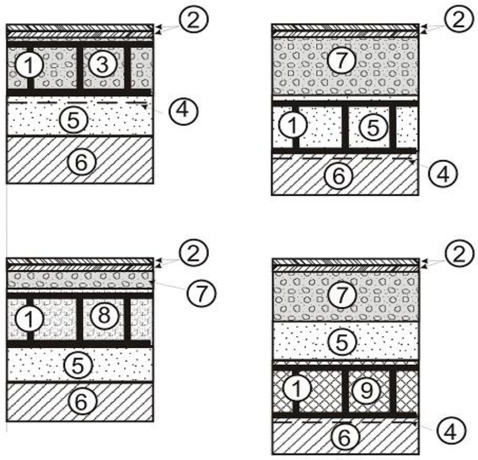
Figure 8. Well cluster in a gas field.

One of the main building properties of three-dimensional geocells is their ability to maintain strength and bearing capacity under conditions of accumulation of uneven settlements in their base. When an uneven settlement occurs under the action of a load, the three-dimensional geocell bends and takes the form of the base surface, while the geocell redistributes the load over a large area and reduces the unevenness of the settlement.

By calculation it was found that when applying reinforced geocell, the settlement of the embankment is reduced by 35% - 40%, and the consolidation time is reduced by 2 times.

In addition, reinforced geocell has been widely used in the construction of road pavement. The main intended purpose of the road pavement is to take the load from the transport and transfer it to the underlying foundation, wherein road pavement is the most expensive part of the road.

As known, road pavement, especially those built on an unstable base, are subject to destruction due to uneven settlement. Over time, pits, cracks and ruts may occur in the coating layer. The elimination of such destruction requires significant costs. That is why we recommend to apply reinforced geocell to reinforce these structures. Typical pavement designs are shown in Figure 9. General rules for the design and calculation of pavement are given in PNST 265-2018



1. Reinforced geocell
2. Asphalt
3. Crushed stone, gravel etc.
4. Protective layer of non-woven geotextile
5. Sand
6. Natural base
7. Pillar base
8. Sand treated with cementing
9. Local soil

Figure 9. Road pavement with appliance of reinforced geocell in accordance with ODM 218.3.032-2013.

Reinforced geocell is appropriate for all types of road surfaces. Its application allows to increase the strength characteristics of the road, to reduce shear stresses and increase the overhaul time. In addition, when using reinforced geocell it is possible to reduce the thickness of the layers of road pavement without loss of operational characteristics, which gives significant savings during construction.

REFERENCES

1. ODM 218.3.032-2013 “Methodical recommendations on strengthening of the design elements of highways with appliance of three-dimensional geocells”.

2. PNST General technical conditions “Automobile roads of general use. Flexible pavement design”.

3. STO 17996082-001-2013 Technical conditions “Three-dimensional polymer reinforced geocell GEOCORD”.

4. Manual on the design of the subgrade of roads on soft soils.