Geosynthetics, J. Kuwano & J. Koseki (eds)
 ISBN 90 5966 044 7

# Experience on using plastic geocells in the construction of roads under conditions of the Arctic of Russia

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Keywords: geocell, road, investigation, test, service life

ABSTRACT: State Road Research Institute "Soyusdornii" in conjunction with Open Joint Stock Company, OJSC "494 UNR" carried out investigation of road sections in Yamalo-Nenetsk and Hanty-Mansiyisk autonomous regions of Russian Federation in order to obtain data on the behavior of plastic geocells in road structures under low temperatures typical for the Arctic. A total of 5 projects in the vicinity of 60° to 66° of latitude north of the equator was investigated. Field investigations revealed quite satisfactory performance of plastic geocells within the structures of slope protection and road pavement.

In the process of investigation some geocell samples were taken from road structures having been in operation for up to 6 years. All taken samples were subsequently subjected to the laboratory tests as per strength and tensile deformation at the temperature of +20°C in order to obtain data on changing geocell properties during their operation under conditions of low temperatures of the Arctic. Laboratory tests showed that the action of natural factors typical for Yamalo-Nenetsk and Hanty-Mansiysk regions did not influence the geocell mechanical characteristics in the case of their operation for up to 6 years.

At the same time similar tests of samples taken from the geocells that previously had not been in operation were performed, which made it possible to investigate a common character of changing strength properties and deformability of the material while decreasing the temperature from +20°C to –60°C. Tests showed that the geocells did not lose their strength properties up to the temperature of –60°C.

## 1 INTRODUCTION

Severe climate conditions of the North place special requirements upon geosynthetic materials used in road structures. However most of these materials are known to have been used in the regions of more temperate climate (Kay D., 2002). Road designers and builders, therefore, have quite understandable doubts a substantiation of using such materials under temperatures of road structure operation to –60°C.

Polyethylene geocells "Prudon 494" were developed from the outset with taking account of their operation under low temperatures. So standard specifications for the product fix the temperature of geocell operation from +55°C to –60°C. In the North of Russia, projects constructed with the use of geocells have been working for 10 years (Bubnovsky V.V., 2002). In order to evaluate the technical state of geocells used in the road structures under conditions of the North, the abovementioned road structures were investigated and the polyethylene geocells were tested in the laboratory.

## 2 FIELD INVESTIGATION OF ROAD STRUCTURES WITH GEOCELLS

Five road projects were investigated in the Yamalo-Nenetsk and Hanty-Mansiyisk autonomous regions of Russian Federation. Table 1 enumerates the road sections investigated.

Table 1. Characteristics of road projects investigated.

| Place of sampling | Service life, year | Section length, m |
|---|---|---|
| 1. Road slope of the Hare Iceland (t. Surgut) | 1 | 800 |
| 2. Slope of Surgut – Nizhnevartovsk road (the Tromyegan river) | 3 | 1500 |
| 3. Slope of Tarco Sale – Pionerny road | 5 | 200 |
| Tarco Sale – Pionerny road pavement | 5 | 3000 |
| 4. Slope of Surgut – Nizhnevartovsk road (the Uryevsky Egan river) | 6 | 1000 |
| 5. Slope of Surgut – Nizhnevartovsk road (the Tromyegan river) | 6 | 1500 |

On the road projects investigated, a polyethylene geocell was used as a structural layer of road pavement and/or in the slope protection structures of subgrades. Figures 1 and 2 show structures of road pavement and slope protection, respectively.

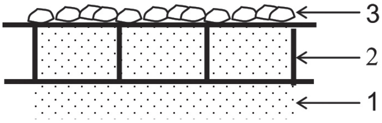


Figure 1. Structure of road pavement with polyethylene geocell. (1) Subgrade soil; (2) Geocell filled with sand; (3) Protective aggregate layer.

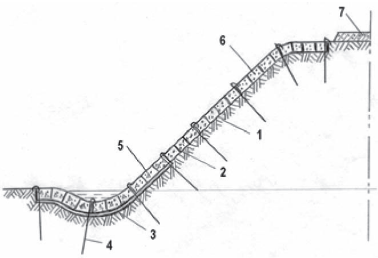


Figure 2. Standard structure of slope protection. (1) Bottom layer of slope; (2) Geocell; (3) Geotextile; (4) Anchor; (5) Gravel fill-in; (6) Turf-sand mixture; (7) Pavement.

In all sections of the slope protection structures investigated, the 20 × 20 × 10 cm geocells were used. The cells were filled with a turf-sand mixture (TSM) followed by subsequent grassing (except project No 3). The geocells were attached to the slope with steel anchors 90 cm long.

Figure 3 shows a typical view of a protected slope.

Figure 3. General view of bridge approach slopes across the Tromyegan river. Slopes are reinforced with geocell (Surgut – Nizhnevartovsk road, Hanty-Mansiyisk autonomous region).

It should be noted that all geocell-reinforced slopes are in a good state. Virtually on all slope surfaces investigated, a well-developed grass cover was formed. In some places in road projects 3 and 4 there was no protective soil layer, nevertheless erosion processes were not observed.

In the structure of a protected slope of road project No 3, fine sand as a fill-in was used without subsequent grassing, whereas in other projects a TSM was used. Nevertheless, a rather developed grass cover formed on the slope surface. Figure 4 shows adjacent sections of protected and unprotected slopes. Figure 5 shows a view of an adjacent unprotected slope where one can see washways up to 8 m deep which spread over part of shoulder.

Figure 4. General view of adjacent sections of protected and unprotected slopes.

Figure 5. General view of unprotected slope section of Tarco Sale-Pionerny road.

On this road section, polyethylene geocells with the 20 × 20 × 20 cm cells were used in the road pavement structure. The length of road section investigated was 3.0 km. The road surface was smooth. There was no rutting on the road. There was one section 100 m long and 2 m wide in which an exposure and crushing of the top parts of geocell ribs (1.5 cm) were observed. This defect occurred due to the additional compaction of the fill-in and flying away of the protective aggregate layer. This imperfection is shown in Figure 6, but it has no influence on the

Figure 6. Damaged pavement section of Tarko-Sale road, Yamalo-Nenetsk autonomous region.

road performance and is remedied by restoring the protection layer thickness over geocells.

Thus, field investigation of road sections in Yamalo-Nenetsk and Hanty-Mansiyisk regions have shown quite adequate work of geocells in the structures of slope protection and road pavement.

## 3 LABORATIRY TESTS OF AGED SAMPLES OF GEOCELLS

During the investigations some samples of polyethylene geocells were taken from the road structures having been in operation for 1.0 to 6.0 years. These samples were subjected to laboratory tests as per tensile strength and deformation at the temperature of +20°C. As a result of these tests the data on developing changes in strength characteristics of geocell strips and joints during geocell operation under conditions of the North were obtained. Table 2 shows the test results.

Table 2. Results of tests as per tensile strength and deformation of samples taken from the geocells that had been previously in operation at the temperature of +20°C.

| Place of sampling | Service life, year | Test results | | | |
|---|---|---|---|---|---|
| | | strip | | joint | |
| | | $\varepsilon_{pm}$, % | $F_{pm}$, kN | $\sigma_{pm}$, MPa | $F^*_{pp}$, kN |
| Standard Specification | – | 25 | 1.85 | 18.5 | 0.925 |
| New geocell "Prudon-494" | – | 21.6 | 2.82 | 22.5 | 1.34 |
| Road slope of the Hare Iceland (t. Surgut) | 1 | 26.5 | 3.40 | 28.3 | 1.62 |
| Slope of Surgut – Nizhnevartovsk road (the Tromyegan river) | 3 | 20.1 | 2.93 | 24.4 | 1.19 |
| Slope of Tarco Sale – Pionerny road | 5 | 23.7 | 2.18 | 17.5 | 1.06 |
| Tarco Sale – Pionerny road pavement | 5 | 15.8 | 2.32 | 22.6 | 0.97 |
| Slope of Surgut – Nizhnevartovsk road (the Uryevsky Egan river) | 6 | 18.5 | 2.26 | 22.6 | 1.02 |
| Slope of Surgut – Nizhnevartovsk road (the Tromyegan river) | 6 | 16.1 | 2.04 | 20.8 | 0.81 |

Notes: $F^*_{pp}$ – load at which breaking of samples takes place, N; $F_{pm}$ – maximum load on the strip, N; $\sigma_{pm} = F_{pm}/A_0$ – maximum tensile strength of the strip, MPa; ($A_0 = \delta \times b$ – area of transverse section of the sample, mm$^2$; where b = 100 mm); $\varepsilon_{pm}$ – relative elongation of the strip at maximum load $F_{pm}$, %.

As the data show, the values of parameters investigated are rather stable (with the exception of some ejections). Spread of experimental points within each series and different series of sample tests at the same operation period is connected to the influence of a lot of factors on the final result: material composition for different lots of geocells, mechanical damages when taking samples, variations in soil and weather-climatic conditions, etc. In this connection experimental data must be accumulated for a subsequent statistical processing. At the same time the data available make it possible to follow the geocell behavior in the process of their operation: for the first three years there occurs some increase with a subsequent decrease of numerical values of $F^*_{pp}$, $F_{pm}$, $\sigma_{pm}$, $\varepsilon_{pm}$. After that a stabilization of numerical values of these parameters is observed.

Comparative laboratory tests of geocell samples taken from road structures investigated and samples taken from the geocells that previously had not been in operation showed that the effect of natural factors typical for Yamalo-Nenetsk and Hanty-Mansiysk regions during operation for 6 years did not worsen mechanical properties of geocell material.

## 4 LABORATORY TESTS OF POLYETHYLENE GEOCELLS IN THE RANGE OF TEMPERATURES FROM +20°C TO–60°C

Laboratory tests of samples taken from geocells, that previously had not been operated, allowed to investigate a common character of changing strength properties and deformability of the material when the temperature drops from +20°C to –60°C. Figure 7 shows a load-deformation diagram for geocell samples at different temperatures.

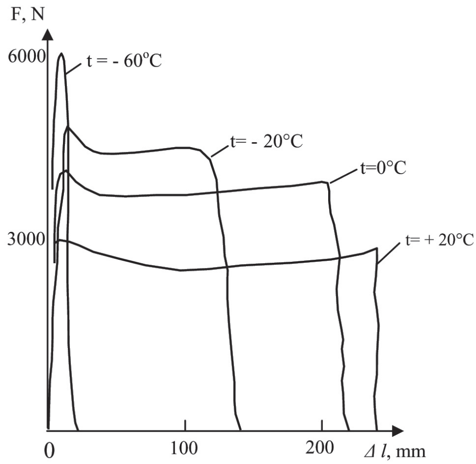


Figure 7. Load-deformation diagram of geocell samples at different temperatures.

The diagram shows that at the temperature from +20°C to –20°C a common character of diagrams does not change, the material does not change its plastic properties, at the same time the maximum tensile strength increases and the fluidity area of the strip reduces. At –60°C essentially there is no fluidity area and a sample failure takes place practically immediately after achieving the $F_{pm}$ value. Table 3 shows numerical values of parameters investigated.

As it is seen from Table 3, geocells do not lose their strength properties up to the temperature of –60°C. When the temperature drops from +20°C to –60°C, the strength of strips increases 1.5–2 times and that of joints – 1.1–1.4 times, and at the same time the maximum tensile deformation of strips decreases approximately 20–30 times, which testifies to the fact that plastic properties of geocell material decrease considerably.

Table 3. Test results of samples as per tensile strength and deformation at the temperature from +20°C to –60°C.

| Temperature, °C | Test results | | | | |
|---|---|---|---|---|---|
| | strip | | | | joint |
| | $F_{pm}$, N | $\sigma_{pm}$, MPa | $\varepsilon_{pm}$, % | $\varepsilon_{pp}$, % | $F^*_{pp}$, N |
| +20 | 2793 | 22.5 | 21.6 | 492 | 1335 |
| 0 | 3613 | 28.9 | 20.0 | 302 | 1247 |
| –20 | 4214 | 33.7 | 26.8 | 306 | 1942 |
| –60 | 5976 | 47.8 | 15.5 | 15.5 | 1554 |

## 5 LABORATORY TESTS AS PER FORECASTING AN OPERATION PERIOD OF POLYETHYLENE GEOCELLS

In order to specify a warranty period of geocell operation under North conditions, tests of geocells were performed in accordance with Russian standards "Methods of accelerated tests as per climatic ageing". According to the procedure the duration of one conventional year of climatic ageing is 33 days. Samples of strips and joints are subjected to the effect of low temperature of –60°C; high temperature of +70°C; temperature of transition through the dew and frost points from –60°C to +55°C; ultra-violet radiation, and the action of the medium with pH = 4–11 and sea water. After that deformation-strength properties of geocell samples are tested. The duration of accelerated tests was 22 months, which corresponds to 20 conventional years. Table 4 shows the results.

The procedure makes it possible to extrapolate these results for the operation period of geocells for not less than 50 years under more severe conditions than actual conditions of their work.

Table 4. Test results as per strength and deformation of artificially aged samples at the temperature of +20°C.

| Duration of tests, years | $F_{pm}$, N | $\sigma_{pm}$, MPa | $\varepsilon_{pm}$, % | $F^*_{pp}$, N |
|---|---|---|---|---|
| | 1602 | 23.4 | 16 | 755 |
| 10 | 1662 | 24.0 | 18 | 603 |
| 12 | 1982 | 28.7 | 12 | 691 |
| 14 | 2263 | 30.4 | 12 | 705 |
| 16 | 2420 | 35.0 | 10 | 734 |
| 18 | 2206 | 32.0 | 10 | 651 |
| 20 | 2227 | 32.2 | 8 | 721 |

Note: The sample size is 50 × 100 mm

## 6 CONCLUSIONS

Investigation of road projects in the North and subsequent tests of polyethylene geocells showed that these geocells proved themselves well in the structures operated.

Comparison laboratory test of geocells samples extracted from the road structures operated for up to 6 years and the new samples showed that the mechanical properties of aged samples had not become worse.

Investigations on the prediction of the service life of geocells using the accelerated test methods showed than the warranty period of geocells operation was not less that 50 years even under conditions which are more severe than the real conditions of the North of Russia.

## ACKNOWLEDGEMENT

The authors of the paper express their special gratitude to Prof. V. Kazarnovsky for his valuable notes and suggestions as well as to the Road Department of Hanty-Mansiyisk autonomous region for assisting with the fulfillment of field investigation.

## REFERENCES

Kay, D., Senf, D.F., Blond, E. and Vermeersch (2002). "Durability of cellular confinement systems in Quebec. Geosynthetics – 7th ICG. – Volume 4, pp. 1435-1438.

Bubnovsky, V.V. (2002). "Improvement of safety and strength of road structures with the use of plastic geocells under West Siberia conditions". Report propositions, Workshop of Scientists and Engineers of Road Scientific and Design Organizations, c. Tyumen, pp. 25-27.