POLISH EXPERIENCE IN APPLYING GEOCELL SYSTEMS IN BUILDING AND MODERNIZATION OF RAILWAY INFRASTRUCTURE

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Abstract: Unstable railway embankments and subgrades cause considerable problems and difficulties in railway traffic maintenance. It usually leads to a decrease in traffic speed or in extreme situations to shutting down dangerous track sections. All the above phenomena consequently lead to considerable economic loses. The solution to these problems may be constructions reducing vertical and lateral stresses in the subgrade as well as strengthening and stabilizing soils.

A Cellular Confinement System (CCS) based on geosynthetic material (HDPE) of cellular structure allows a new engineering approach to geotechnical constructions design and is used for soil stabilization and strengthening. Geosynthetic material defined as “geocell” has been successfully introduced to the civil construction industry during recent years. The system may additionally include other geosynthetics, such as geotextiles and geonets.

The technology makes it possible to build on compressible soils, providing full stability and resistance to static, dynamic and hydrodynamic loads as well as having steep faces covered by plants. In comparison to traditional solutions applying CCS allows considerable decreases in time and cost, which is of significant importance in case of emergency. In addition, the solution makes it possible to maintain track strength parameters much longer, which appreciably lowers the exploitation costs. In Poland CCS Geoweb has been successfully used in railways since 1996.

This paper discusses the applications and benefits of geosynthetic CCS and selected case histories of the design and installation of structures for trackbeds, embankments and slopes protection in construction of railways which have been realized in Poland in the period 1996-2006. The first example concerns mainline subgrade strengthening and modernization of the railway embankment in case of weak soils in the Vistula river original basin. The second example refers to rebuilding and protecting embankment slopes and track degraded by landslips on antropogenic soils of low strength.

Keywords: geocell, cellular system, embankment, railway, stabilization, reinforced earth retaining wall.

INTRODUCTION

When designing geotechnical structures aiming at strengthening railway tracks on weak, unstable soils and in the areas of slopes and building embankments or making cuts it is necessary to foresee all possible dangers which may cause changes in the state of soil and the loss of its stability. Optimum technical interference in such cases is the technology combining soil stabilization and its protection together with surface and deep dehydration with concurrent possibility of controlling changes in slopes geometry and structural strengthening. In technical solutions local landscape demands and the natural environment protection should be taken into consideration.

Compressible subsoils of low strength and thinned and degraded embankments cause numerous problems and difficulties in railway traffic maintenance. The solution to these problems may be constructions reducing vertical and lateral stresses in the subgrade as well as strengthening and stabilizing soils, which greatly reduces exploitation costs. Unstable railway embankments and subgrades cause considerable problems and difficulties in railway traffic maintenance. It usually leads to a decrease in traffic speed or, in extreme situations, to shutting down dangerous track sections. Unstable cut slopes and slopes endangered by erosion and landslip in which railways run also cause significant hazard. All the above phenomena lead to considerable economic loses. Independently of the phenomena type that we deal with, all activities should lead to technical interference eliminating causes and results of soil stability disturbance.

The development of geosynthetic material technology allowed a system to form that effectively solves the above problems. The new category of geosynthetic material defined as “geocell” (Cellular Confinement System -CCS) has been successfully introduced to the civil construction industry during recent years. The system is based on modern geosynthetic material (HDPE) of cellular structure that allows a new engineering approach to geotechnical construction design and is used for soil stabilization and strengthening (Martin *et al.*1996).

In this technology, construction materials are confined to a light, elastic cellular geosynthetic (similar to a honeycomb structure) that considerably improves the infilling material properties as well as solves the problems of subgrades and embankments protection in the difficult groundwater conditions. The cellular confinement mechanism reduces the lateral spreading of aggregate materials that occurs under repeated loading in these structures (Bathurst and Karpurapu 1993). Geocell systems, apart from strengthening and stabilizing the subgrades, facilitates building slopes and load supporting structures readjusted to local conditions with no necessity of deep foundations.

CHOSEN APPLICATIONS IN REPAIRING, MODERNIZING AND BUILDING RAILWAY TRACKS IN POLAND (1996 – 2006)

Strengthening of the railway bed of the E-65 trunk line under pre-tensioned pre-stressed concrete switch Sleepers – of weak soils in the Vistula river original basin

The geocell system was first used in Polish railways to strengthen the 200m section of E-65 trunk line in the region of Zabrzeg. Application of this prototype system, in Polish Railway conditions, had been preceded by detailed analyses and comparisons with the traditional methods, taking into consideration, among others, the need to maintain continual traffic on parallel tracks, soil excavation up to two meters in depth and environment protection. The oak trees growing at the foot of the embankment and the need to protect them excluded the method of so called "building chemistry". Poland's lack of experience in using geocell systems to reinforce track embankments caused the modernized section to become an experimental rail proof ground for some time.

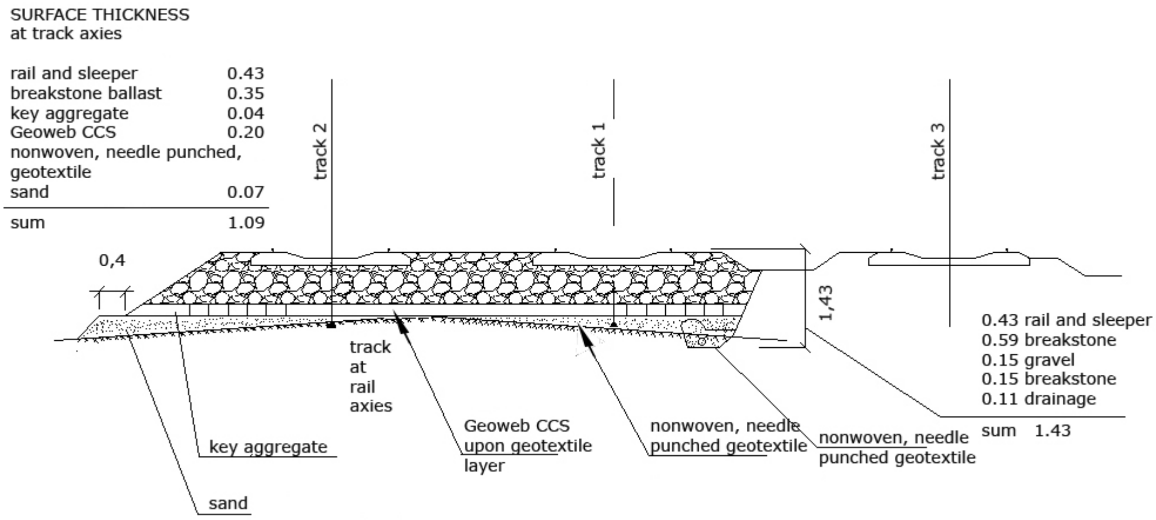

Figure 1. Geocell system track stabilization on Trzebinia – Zebrzydowice line.

The aim of the modernization was to strengthen 5m high embankment lying on the weak soils of the original Vistula river basin. The upper layer of the embankment was formed of the plasticized silts and clays of tixotropic properties. Main assumptions were permanent reinforcement of the subgrade with significant increase in load bearing capacity without the need to replace soil due to direct vicinity of active track, efficient horizontal dewatering of the track zone and full separation of granular material from the subgrade without flooding elimination (Kłosek *at al.* 1997). Modernization was carried out in two stages, first Track 2 then Track 1.

a) Geocell sections were placed perpendicularly to the tracks axis.
- Under Track 2, geocell section of Geoweb type (20 cm in high) was spread in such a way that only half of the nominal dimension was made use of;
- having removed the subballast layer of Track 1 and expanded it to meet the nominal dimension and attaching part of the section to it a reinforcement of a width of 7.2m was created;
- in this way a uniform reinforcement layer for both tracks was obtained. Also it was possible to maintain limited speed traffic on the neighboring tracks.
- Altogether over 2100 m^2 of CCS was installed.

b) Under geocells a layer of geotextiles was placed as well as a sand layer of several centimeters and three horizontal culverts. The total thickness of the subballast and reinforcement layer was 0.66 m.

c) After breakstone supplementing and turnouts and rails tamping both tracks could be used again at the initial maximum speed of 30km/hour, gradually achieving the time table speed of 120km/hour in May 1997.

Modernization was carried out between 13 November and 10 December 1996. Now, ten years after it, railway traffic is run with no limits at its normal speed of 120km/hour. Apart from lower costs, applying geocell system allowed to modernize the track without disruption to traffic on the neighboring tracks, the time of works carried out was shorter, settling of the soil very much limited while exploitation period became more durable (Kłosek 1998; Kessler 2006*)*.

Figure 2. Track stabilization on Trzebinia – Zebrzydowice line.

Rebuilding and protecting the damaged embankment of Track 3 of cargo rail line Katowice-Warszawa on anthropogenic soils of low strength

After a period of intensive precipitation in July 1997 there were observed deflections of the embankment crown of Warszawa – Katowice line track in Chruszczobród. The deflections consisted of track deformations, soil cracks and fissures, due to which the embankment lost its stability over 110 m long section. The most dangerous deformations occurred in the highest section (from 9 to 11 m) of the embankment. In spite of undertaking stabilizing works (supplementing and compacting breakstone bed) further deformations of the embankment were visible.

Geological and geotechnical characteristics

The embankment subsoil is formed from Trias rocky formations, diagnosed to the depth of 8.0m below area surface and weathering slates, silts and clays, whose floor area allows a convenient sliding plane for an uneven layer of coherent sedimentary formations above and for the compact and coherent embankment soils of the lower part of the subbase. The structure of the embankment causes small but systematic slides and deliquescence of the embankment basis. On such not very stable subsoil and embankment basis there are loose soils comprising the middle and upper part of the embankment. They are in the form of grate furnace slag of about 3.5 m in thickness, density index I_S=0.85–0.88 (values inadmissible for railway embankments).

In the embankment body, at the depth of 5 – 6 m, occasional filterings of ground waters occur. Water-bearing level I of stabilized character is in the floor of rocky formations.

Repair of the subballast and railway embankment

The aim of the planned repair was to build an even, strong and safe subballast, as well as rebuilding and protection of the damaged embankment. The works were to comprise;

- exchange of soil in the upper part of the embankment,
- embankment grading and protection against erosion,
- protecting the embankment against soil sliding by means of a retaining wall,
- building dewatering ditches on both sides of the embankment.

A design with geocell system was chosen. It was of decisive importance in this choice that railway traffic could be restored in a short time, there was no necessity of deep soil exchange, the costs were much lower. At the same time, basing on the hitherto gained experience, it was expected that using CCS would strengthen subballast under soft and compressible soils, periodically containing much moisture. It would also be possible to achieve the same bearing conditions over the endangered segment, to distribute the loads evenly and thus to minimize settlement – all this makes it possible to obtain an even, strong and safe railway. Complex protection of the subballast and embankment comprises the following works:

1. Demolishing the track structure over 110m long segment.
2. Excavating a layer of low carrying ground of about 1.0m in thickness.
3. Grading of the embankment crown and the right slope to the ruling grade, with uncovering the slope bottom for building a retaining wall.
4. Building of the strengthened subballast, including: making improved subsoil from good quality and compacted aggregate; laying geonet on permeable geotextile; making compacted sand and breakstone ballast

of about 80 cm in thickness; laying geotextile of filtrating properties; laying 5 cm thick compacted sand layer; laying geocell Geoweb type of 2x10 cm in height, filled with breakstone; building track structure.

5. Building a 20 cm high retaining wall, including: soil compaction under the wall; building a 9-layer geocell type wall (each layer 20 cm high) on previously spread geotextile, covering the lower part of the slope and the base of the wall; filling each layer with granular material (wall face filled with concrete); making a drain leading to a ditch behind the back wall.
6. Protecting of the graded slope, including: laying geotextile; laying 10 cm high Geoweb CCS, using polymeric tendons; filling geocells with humus and sand and sowing with grass.
7. Building drainage ditches on both sides of the embankment.

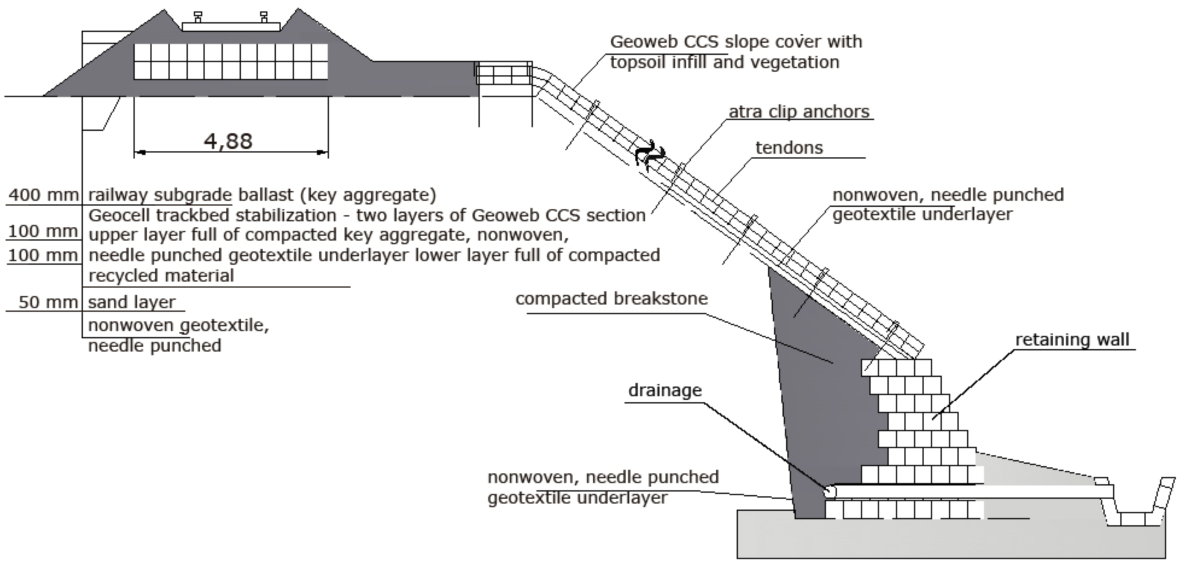

Figure 3. Track stabilization on Warszawa – Katowice line and protection of the railway unstable slope embankment.

Figure 4. Geoweb CCS protection of the railway unstable slope embankment.

Investigations on bulk modulus, density index and track vertical displacements survey

In the final stage of building, before laying track structure, investigations of bulk modulus were carried out by means of VSS plate, as well as investigations of density degree and index by means of a light percussive probe. The following results were obtained:

a) E_2 secondary modulus in the railway subgrade crown without geotextile and protective layer 26.5 - 50 MPa.
E_2 secondary modulus on protective layer on geotextile 81.8 - 86.5 MPa.
E_2 secondary modulus on geoweb layer 112.5 - 115.4 MPa.

b) Subballast density degree and index before rebuilding, I_D = 0.15 - 0.25 which gives an I_S =0.85 – 0.88 (required I_S = 1.00). Density degree and index in the protective layer of about 1 m thickness laid on geotextile, and before geoweb laying:
I_D = 0.80 – 0.98, which gives an I_S = 0.96 – 1.00.

Surveys of track grade line were carried out from 16 July 1998 till 3 September 1998. The biggest settlements, 4 mm on average, occurred in the first stage after restarting railway traffic, which was between 16 and 19 July 1998. Practically, there were no further settlements – on average they amounted to 1 – 2 mm in a week cycle, which means they were within the survey limit of error (surveys were carried out by means of Ni020 leveling instrument – 1 mm leveling accuracy). The last survey carried out on 3 September 1998 showed stability of the whole modernized railway line section (Hadrian, Kondek 2000).

CONCLUSIONS

1. Hitherto experiences in solving geotechnical problems connected with repairing, modernizing and building railway track proved the possibility and technical and economic usefulness of using cellular confinement systems in typical applications. In Poland geocell system has been successfully used in railways since 1996.
2. The technology makes it possible to build on compressible soils, providing full stability and resistance to static, dynamic and hydrodynamic loads as well as having steep faces covered by plants. In comparison to traditional solutions applying geocell system allows to decrease time and cost considerably, which is of significant importance in case of emergency. Besides, the solution makes it possible to maintain track strength parameters much longer, what appreciably lowers the exploitation costs
3. Built-in geocell system causes significant increase in subsoil load capacity. The results of the site investigations of the railway low bearing capacity subballast strengthened with the geocell system, together with the railway embankment slope also protected with geocell as well as geocell type retaining wall showed:
    - unusually quick stabilization of the accumulation processes of plastic strains in track grade line until almost eliminating them, ensuring full elasticity conditions of the subballast operation,
    - effectiveness of the applied solution, guaranteeing durable increase in subballast load capacity as well as stability of the protected slope,
    - possibility of radically limiting the scope of indispensable earth works and other protective works when modernizing railway subballast while the traffic is in operation. As a result it is possible to minimize the time of track closing and to restore traffic very quickly,
    - possibility of durable anti-erosion slope protection, simultaneously improving dewatering of the subballast and embankment, what is especially important in case of periodical over irrigation subsoil .
4. After ten years of applying geocell systems in many investments in Poland, including numerous railway projects and after installing several hundred thousand square meters of geocells it can be stated that cellular confinement systems have proved to be a justified technical solution and they are an important and useful technology.

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