The use of polyester geotextiles in civil engineering

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ABSTRACT

In the article, the author presents the implementation of construction with the application of polyester woven geotextiles. By using woven geotextiles, it's possible to reduce significantly the time and cost of construction. The author presents selected projects to inspire other engineers to use polyester woven geotextiles in their everyday design work or construction work. The application of PES woven geotextiles solves many technical problems while being easy to build.

1. INTRODUCTION

The technological development of the production of polyester woven geotextiles has made them extremely competitive compared to other geosynthetics. The weaving technology and the production of yarns allow products with very high tensile strengths at a low cost of production. Commonly used are PES woven geotextiles with tensile strength: 100, 200, 300, 600 or 1000 kN/m. A few years ago materials with such parameters were very expensive and produced only by special order. Currently, polyester geotextiles have practically replaced polypropylene or polyethylene geosynthetics on the Polish market due to better mechanical properties and lower production cost.

It should also be noted that polyester woven geotextiles are characterised by a lower elongation at break than polypropylene products. The average elongation at break of polyester woven geotextiles is 10% and polypropylene products 18%. For this reason designers became more likely to use polyester woven geotextiles. Another reason why polyester products are designed is the development of knowledge about them. Today, polyester geotextiles are the so-called qualified geosynthetics. A full range of tests are available that enable the determination of long-term design strength, as well as durability and resistance in acid or alkaline environments.

Moreover, these materials are resistant to damage during backfilling (e.g. high static puncture resistance). Therefore it is very common to use geotextiles together with a crushed backfill aggregate. As a result, geotextiles are widely used in Poland not only in applications with natural aggregate, but also using crushed aggregate backfill. Of course, due to the geological structure of Poland, the backfill is more often made of natural aggregates, which is more widely available compared to crushed aggregate transported from the mountains - the south of Poland. The above-described features of polyester woven geotextiles caused the use of them in the solutions presented below. Examples of realised projects confirm that technology with use of polyester woven textiles was the best choice from a technical and economical point of view.

2. TEMPORARY CONSTRUCTION ON RAILWAY 286

2.1 Description of the technical problem

The extension of the Ścinawka Średnia station along the 286 Railway Line assumed the overhaul of the railway viaduct at km 13.665. Due to the lack of consent for the closure of train traffic, the overhaul of the viaduct assumed staging of works - the works were to be completed in stages.

The first stage *(Figure 1)* assumed the construction of steel sheet piles GU 16N, 15.0 m and 16.0 m long, with 10 m long anchors 116 kN/pcs load capacity each. Then, rebar works were performed in the excavation as a part of the overhaul of the railway viaduct together with the construction of a retaining structure reinforced with polyester woven geotextiles. Retaining structure made of geosynthetics in these case was to provide the stability of the trackway during the second stage of works.

The second stage ***(Figure 2)*** included the dismantling of the track and transferring the traffic over the retaining structure made of geosynthetics. Then, the excavation works were performed in front of the reinforced soil together with the disassembly of the anchors and further work on the railway viaduct. The sheet piling was not removed.

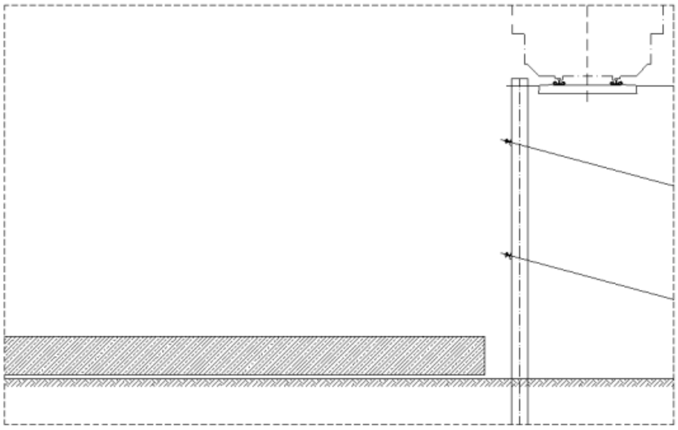

Figure 1. Stage I.

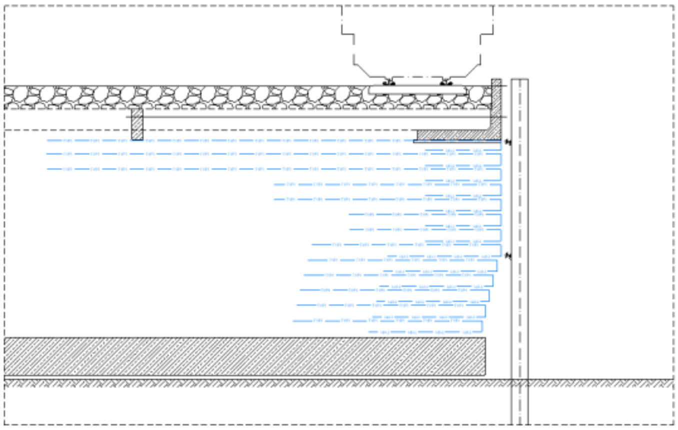

Figure 2. Stage II.

2.2 Design assumptions

It was assumed that the reinforced soil structure would be temporary and that is why the long-term tensile strength has been reduced to only five years (through appropriate reduction factors due to creep). Polyester woven geotextile with high tensile strength in MD direction was used. Live load - model LM71 ***(Figure 3)***. The height of analysed structure is 6.40 m and geometry is according to ***Figure 2***. The backfill was made of non-cohesive soils with a minimum internal friction angle of φ = 35°. The soil laying below is silty clay soil with internal friction angle φ=14.2° and cohesion 15 kPa.

Figure 3. Live load esample - LM71.

Reinforced soil structure design assumed that the geotextile cannot press the sheet piling. It was based on the assumption that the allowed elongation of the reinforcement could not exceed 2%. After determining the strength in individual reinforcement layers, it was possible to choose the appropriate strength of the geotextiles and finally determine the technological empty space between the sheet piling and the face of the reinforced soil structure. Empty space size was designed to allow elongation of geotextile (SLS).

The design was carried out in a static condition according Eurocode 7 (EN 1997-1) using a partial safety factor concept. Using this concept, it is assumed that the structure is stable when overdesign factor is ≥1. For the stability check it was required to verify the structure using design approach A2+M2+R3. The characteristics of PES woven: long-term design tensile strength based for five years rheological coefficient (temporary structure). Of the attention to difficult structure long-term strength has been calculated with safety factor value 1.3. Serviceability Limit State (SLS) was calculated to tensile strength by 2% elongation and reduced to five years long-term strength.

During calculations, local and global stability of a reinforced soil structure was checked. The following factors were taken into account: overturning, sliding, reinforcement pull-off, ultimate load-bearing capacity of the reinforcement. At the end global stability calculations was checked separately – where critical slip failure was beyond the structure.

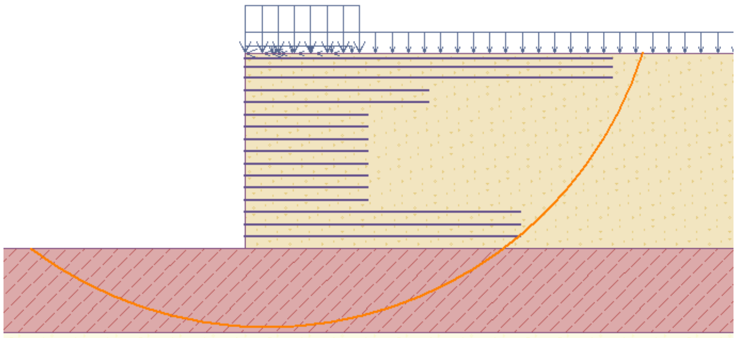

Figure 4. Critical slip failure.

The calculations were made using the GEO5 - Reinforced Embankments computer program based on the assumptions of the standard: Eurocode 7 and calculation sheets integrating forces depending on the zone in which the reinforcement is located (zones: active and passive).

A major design problem was the location of the live load next to the face of the retaining structure - the load is shown in *Figure 2*. To prevent displacements of the rail truck the design included a retaining wall at a 1.6 m height.

The design solution is presented in *Figure 5*.

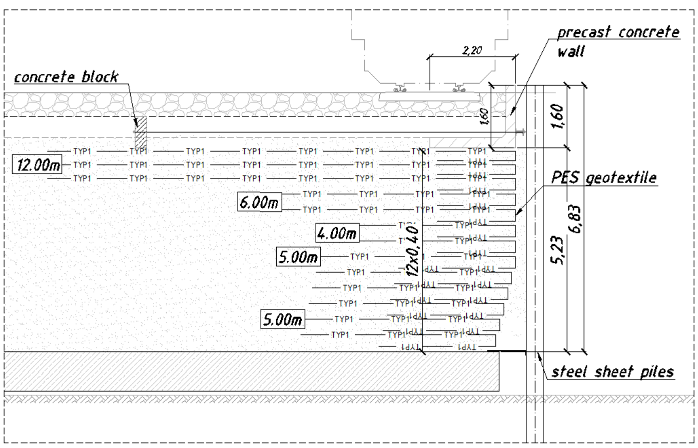

Figure 5. Temporary retaining.

Figure 6. Construction works.

2.3 Summary

Live load test at the end of construction works confirmed the correctness of the assumptions and design calculations. During the test geodetic measurements of the wall and tracks were done. Displacement and track deformation observed were within prescribed limits. The use of soil reinforced with polyester geotextiles made it possible to replace the classic anchoring of the sheet piling in the second stage of works. In this case, it accelerated significantly the construction works and allowed for significant financial savings.

3. TECHNOLOGICAL ROAD - BYPASS

3.1 Description of the technical problem

As part of the construction of a new road viaduct over the Railway Line no. 009 Warszawa Wschodnia - Gdańsk Główny along the road in Tczew, it was necessary to build a bypass road for the construction period. Embankment was designed as a soil reinforced with polyester geotextiles. It was an alternative solution to MSEW structure (concrete panels as facing).

3.2 Design assumptions – methods of calculation

It has been assumed that the reinforced embankment will be a temporary structure as a bypass around the road for the time of the of the railway viaduct construction. The construction time was planned for two years (determining the long-term design strength of geotextiles).

In order to optimise the solution, the retaining walls were replaced with a reinforced embankment with a slope angle of 80°. This solution was cheaper and faster to implement. The normal section through the embankment is shown in *Figure 7*.

Determining the stability of the embankment, the load with the A-class load was assumed (according to PN-85/ S-10030). The geological condition is good. Subsoil is built of loose sand. For backfill the same soil is used but with proper density. Before project calculations existing soil was tested and internal friction angle was determined. The soil properties are shown in *Table 1*.

3.3 Stability calculations

MSE stability checks were performed using the proprietary software GEO5 - Reinforced Embankments. The most unfavourable cross section was chosen to evaluate the system. During calculation, local and global stability of a reinforced soil structure was checked. The following factors were taken into account: overturning, sliding, reinforcement pull-off, ultimate load-bearing capacity of the reinforcement and displacement. For reinforcement PES geotextile with strength 150/ 50 kN/m has been used. MSE wall sliding safety factor is 2.6, overturning safety factor is 3.0 and bearing capacity safety factor 2.1. These calculations do not cover the global stability calculations as the global stability – it was checked separately in GGU Stability program. Stability analysis with circular surfaces according to Bishop's Method showed Factor of Safety of 1.2.

Soil type	Properties		
	Internal friction angle, φ (°)	Cohesion, c (kPa)	Unit weight, γ (kN/m³)
Subsoil	29	0	18
Backfill	34	0	19.5

Table 1. Geotechnical characteristics of the soils.

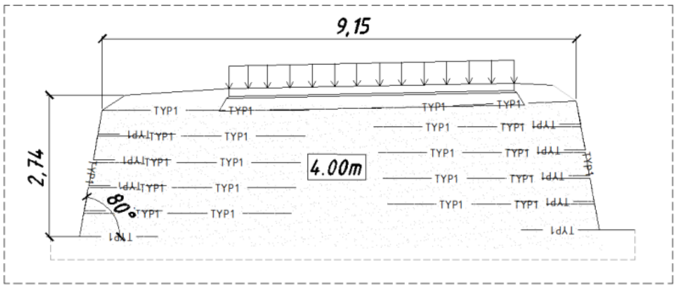

Figure 7. Geometry of reinforced soil.

The geometry of the structure with vertical specimen of reinforcement is shown in *Figure 7*.

After determining the global and local stability, it was analysed, how to secure the 80° slope. A well-known disadvantage of geosynthetics is the lack of resistance to UV. Polyester woven geotextiles need to be covered within two weeks of installation due to UV resistance. UV resistance is tested according to EN 12224 standard and declared by the producer. Leaving the half-mattresses rolled up to direct sunlight would damage the reinforcement and damage the structure's stability, either locally or globally.

Several solutions were considered to protect the geotextile against UV, e.g. anti-erosion geomats or, precast concrete. Finally, due to the temporary construction, it was decided to protect against UV rays by covering the face with polypropylene geotextile (*Figure 8)*. The solution was not aesthetic, but was extremely cheap and easy to install.

Figure 8. Bypass temporary construction - facing.

3.4 Summary

The presented example shows how to speed up works and reduce the costs of implementation. The construction of reinforced soil was done faster and without the need of additional elements: for example the foundation which is required for the construction of retaining walls. Also, the disadvantage of geotextiles, which is the lack of resistance to UV, has been solved. The author hopes that this simple example will point out that these are materials sensitive to UV, which is often forgotten by designers and contractors - without securing geotextiles.

4. SOIL REINFORCEMENT

4.1 Description of the technical problem

As a result of optimisation - reducing the costs of the bridge's construction, direct foundation was decided to support the bridge structure. It was possible only after reducing lateral earth pressure to the abutment. Soil reinforced with polyester geotextiles was designed, to take over the earth pressure and not transfer it to the abutment. The project was part of the S-3 Express Road Nowa Sól – Legnica Project.

4.2 Design assumptions. Methods of calculation

In the construction of reinforced soil the following design assumptions were made: high-strength polyester woven geotextiles as reinforcement. Calculations were conducted for each heights of abutment. A class A load was assumed in accordance with PN 85/ S-10030. Cross section with loads as presented in *Figure 9*. Loads from cars, pedestrians, soil weight, concrete plate weight, and earth pressure from dead and live loads were calculated. Also calculations considered the horizontal force from brake load.

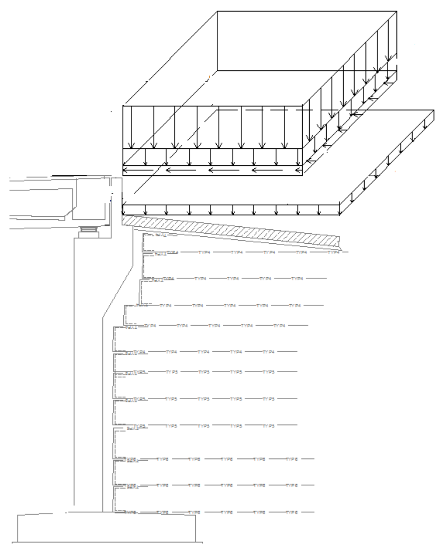

Figure 9. Calculation cross section.

Calculations assumed backfill made of non-cohesive soils with an internal friction angle of minimum $\varphi = 34\,°$, cohesion $c = 0$ kPa and maximum weight $\gamma = 19.0$ kN/ m^3. An empty space is made between the reinforced soil and the abutment. The calculations were made using the GEO5 - Reinforced embankments computer program based on the assumptions of the standard Eurocode 7 and original calculation sheets integrating forces depending on the zone in which the reinforcement is located (zones: active and passive). After determining the forces in each reinforcement layer, the appropriate strength of the geotextiles was chosen, and then the stress of each reinforcement layer in the active zone was determined. On this basis, the width of the technological space was determined, that will prevent the transmission of the strength to the abutment. During the performed calculations local and global stability of a reinforced soil structure, sliding, reinforcement pull-off, ultimate load-bearing capacity of the reinforcement and displacements was checked. As reinforcement has been used PES geotextile with strength from 200-400 kN/m. MSE wall for that assumptions has factors: sliding safety factor is 1.8, overturning safety factor is 2.0 and bearing capacity safety factor 1.6.

According to the requirements for the reinforced soil, the space behind the abutment and the reinforced soil should be made in such a way that during the service life of the structure, after all displacements (construction period, load, rheological effect), the reinforced soil does not come into contact with the abutment and transfer any load. The width of empty space should take into account the following stages: construction stage, and the service life of the structure. Calculation of space between abutment and face of MSE has been considered difference elongation at construction stage and end of predicted service life of the structure (100 years). Force by 2% elongation was used and considered in long-term material behaviours. Each layer has been calculated and checked displacements. At the end a width of a dilatation gap has been determined. Elongation length has been considered in active zone L_a.

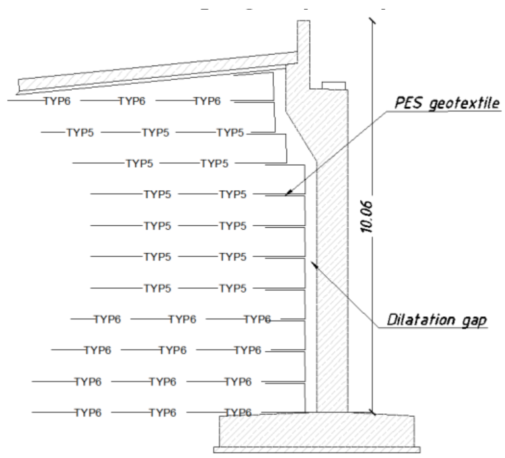

Figure 10. Section of reinforced soil - solution.

5. CONCLUSIONS

The presented projects have shown that the use of polyester woven geotextiles can significantly accelerate and reduce construction costs. The number of designed and implemented soil structures reinforced with polyester woven geotextiles shows that both designers and as well contractors have gained confidence in this type of solution.

Finally, it should be underlined that the complicated implementation of reinforced soil is in fact trivial compared with the performance of works that could be avoided thanks to its use. Reinforced soil does not require the use of specialised machines or the work of specialists. Reinforced soil can be made by unskilled workers using basic machines used in earthworks.

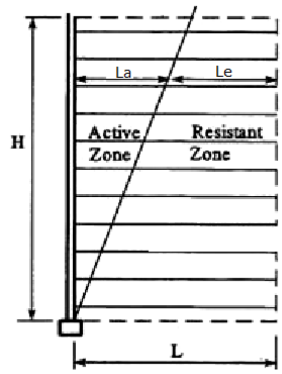

Figure 11. Active zone graph.

Nowadays, when construction sites struggle with the lack of workers, it may become very important to choose the right technology to compensate.

The author, as a proponent of technical solutions with the use of polyester geotextiles, hopes that the popularity of solutions based on these geosynthetics will increase, and that the construction projects themselves will be the best advertisement for them among designers and new contractors.

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