Design and Construction of Embankment Reinforced with Geotextiles

M. Kulczykowski
Institute of Hydroengineering, Polish Academy of Sciences, Gdansk, Poland

ABSTRACT: In the paper the design method of reinforced earth structures, based on the continuum theory of composites is shortly presented. This method allows to calculate the parameters and to assume the distribution of the reinforcement in reinforced slopes and embankments. Such method can be also adapted to design soil nailing slopes and excavations. Using this method the embankment reinforced with geotextile was design and constructed. For construction the different types of facing have been applied; two vertical faces, one steeply inclined face and one inclined bagwork face. Additionally, the results of tests with grass growth on geotextile are shortly described.

1 INTRODUCTION

The use of reinforced soil in civil engineering works started about 30 years ago. Now, in Poland the industry offers the wide range of good quality geotextile and geosynthetic products. In spite of that, reinforced soil technology is still rather unknown in our country. To popularize such technology in Poland, the geotextile reinforced soil wall with four different types of face was design and constructed in Institute of Hydroengineering Polish Academy of Science in Gdańsk (IBW PAN).

2 DESIGN METHOD

The design of embankment followed the design method based on continuum theory of composites (Sawicki, 1983a,b). The reinforced soil was treated as a homogeneous anisotropy material with the strengthens properties in reinforcement direction. This method was proposed by prof.A.Sawicki, dr.M.Kulczykowski and dr.D.Leśniewska from Soil Mechanics Department IBW PAN (Kulczykowski, 1991). It allows to calculate the required length of reinforcement and determine its distribution in construction for assumed geometry of embankment and soil and reinforcement properties.

2.1 Determination of the density of reinforcement

To determine the required density of reinforcement in construction the plastic limit analysis of reinforced slopes is applied. The solution is obtained by the method of characteristics for the uniform surcharge load. Next, for specified reinforcement layer spacing the bearing capacity of construction can be checked. Additionally, slip line in reinforced zone can be calculated.

2.2 Determination of reinforcement length

The limits of the zone of reinforcement were derived from the external stability analysis. This zone was assumed to behave monolithically. The global stability of construction was evaluated using conventional and modified slope stability analysis taking into account the additional anisotropic cohesion of reinforced soil.

2.3 Tension analysis

The tension analysis allows to check the geotextile for the maximum tension in each layer. This approach, based on elastic theory of reinforced soil can be applied in reinforced structure with irregular layer spacing and whatever surcharge load (including point loads) on the crest of surcharge load (including point loads) on the crest of construction. It is used for checking the correctness of reinforcement distribution and estimating the stress level in soil nearby the face.

3 DESIGN OF CONSTRUCTION

3.1 Soil properties

The soil used as the fill was gravely sand. The properties used for design, obtained in lab tests, were as follows: unit weight γ=19.3 kN/m^3, soil friction angle ϕ=34°, cohesion c=0 kPa, Young modulus E=32MPa, Poisson's ratio ν=0.2. The elastic constants were obtained from oedometric tests with additional measurement of lateral stresses.

3.2 Geotextile properties

The Polish geotextile LENTEX 48124 was selected as a reinforcement. This geotextile is a complex polypropylene structure with the base of the woven fabric. On both sides of such mesh fibre non-woven are mechanically bonded by needle punching. The following properties were obtained or calculated on the base of lab tests: mass per unit area μ=680g/m^2, maximum tension T_{max}=17.5kN/m, maximum tensile stress σ_{max}=4380kN/m^2, elongation at maximum tensile strength ε_{max}=7.24%, tangential modulus at elongation ε=1% E_ε=250 MPa, Poisson's ratio ν=0.37.

3.3 Design and construction details

The embankment was design to be constructed as four, 3.2m high reinforced soil walls with different type of faces. The analysis was performed for the wall with vertical face, for the steeply inclined wall with 60° face angle and for inclined wall with bagwork face. No surcharge loading was assumed at the crest of each slope.

The reinforcement layer spacing of 0.4m was design for vertical wall using plastic limit analysis. Such uniform vertical spacing was applied to whole embankment. The bearing capacity of construction was checked using the RES program (Leśniewska, 1993). The values of the failure load calculated for vertical and inclined walls were q_s=104kPa and q_s=342kPa respectively. The slip lines in reinforced zone obtained for above mentioned cases are presented on Fig.1. and Fig.2.

The evaluation of the length of reinforcement was based on the global stablility of construction. First, the calculation for the structure without reinforcement was performed. Then the stability of reinforced slope was checked. The required reinforcement length was calculated for the factor of safety FS≥1.3. For vertical wall the uniform reinforcement length L=2.0m was specified. For inclined walls the linear reduction in reinforcement length for successive layers above the bottom layer was designed. The length of reinforcement was decreased from L=2.0m at the base to L=1.2m at the crest of embankment. On Fig.3 the extension of factor of safety for structure without reinforcement (FSS) and for reinforced slope (FSR) is presented.

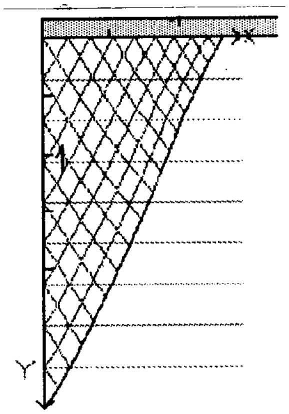

Figure 1 Stress characteristics and slip line for vertical wall.

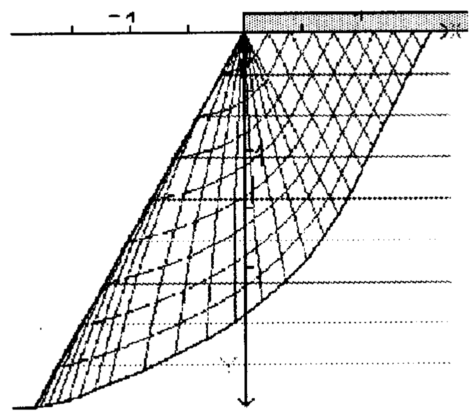

Figure 2 Stress characteristics and slip line for inclined wall.

The tension analysis in reinforcement was performed using finite element method for the most critical section with vertical face. The maximum value of tensile force in reinforcement T=6.04kN/m<T_{max}=17.5kN/m was obtained in the bottom layer.

4 PERFORMANCE

The embankment was constructed as a wall with geotextile wraparound face detail, in four, 2.1m width sections. As the side walls of each section the side timber panels were applied. To obtain the better alignment of vertical faces, two 3.2m high temporary formworks were used. For Section 1 (vertical face) the geotextile was simply wrapped around the fill in layers (Fig.4). For Section 2 (vertical face) and Section 3 (steeply inclined face) the internal rigid-forming elements, made of net of steel rods, were used to minimize the bulging at the face (Figs 5-6). For Section 4 (bagwork face) the geotextile was wrapped around two courses of hessian sandbag previously filled with the granular soil (Fig.7).

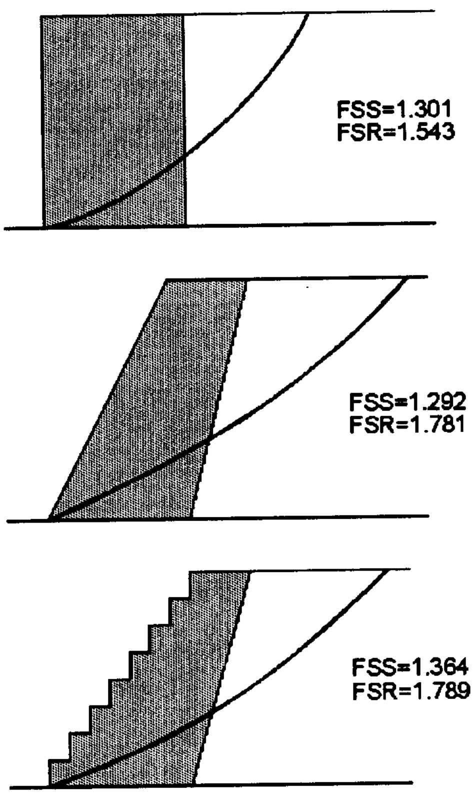

Figure 3 External stability analysis

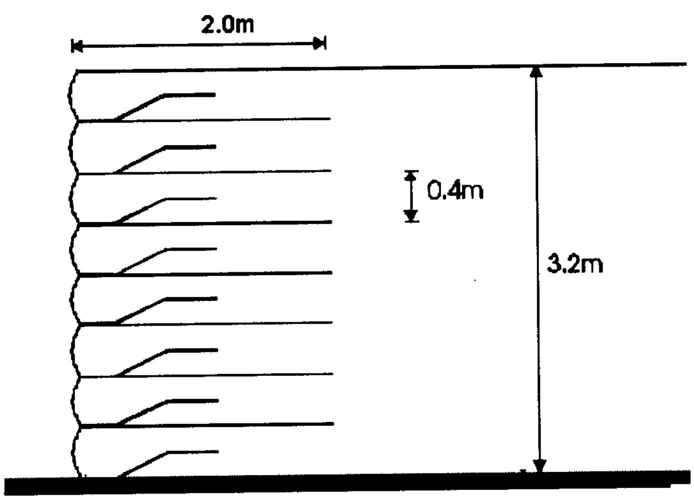

Figure 4 Configuration of Section 1

For each section the fill was placed onto geotextile using the excavator bucket. The soil was hand compacted in 0.2m lifts using the vibratory plate compactor. The quantity of turf was placed against the face during construction. In order to promote the growth of vegetation on the surface of embankment, the crest of each slope and the faces at Sections 3 and 4 were covered with flax textile with seeds of grass.

Figure 8 shows completed project in Section 1 and Section 2. In Figure 9 the front view of Section 3 and Section 4 is presented.

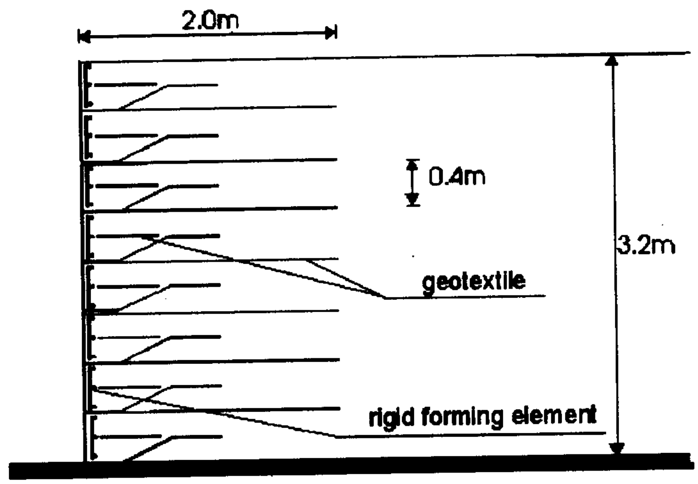

Figure 5 Configuration of Section 2

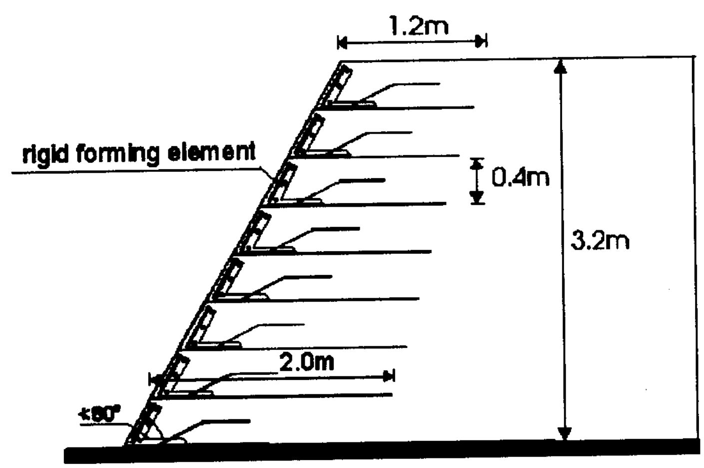

Figure 6 Configuration of Section 3

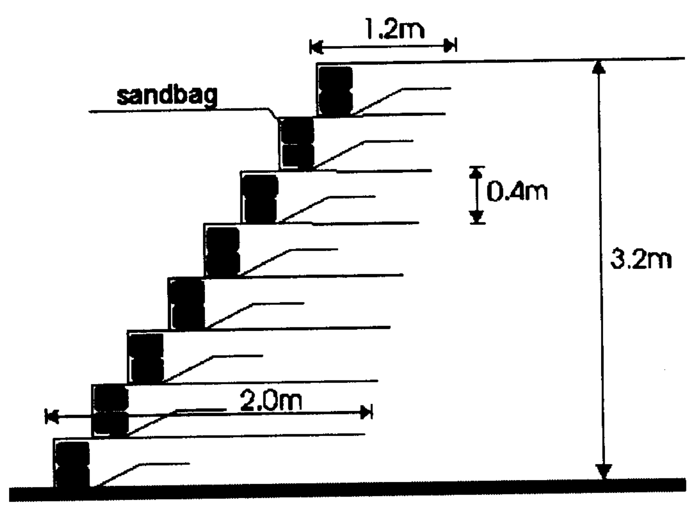

Figure 7 Configuration of Section 4

Figure 8 General view of Section 1 and Section 2

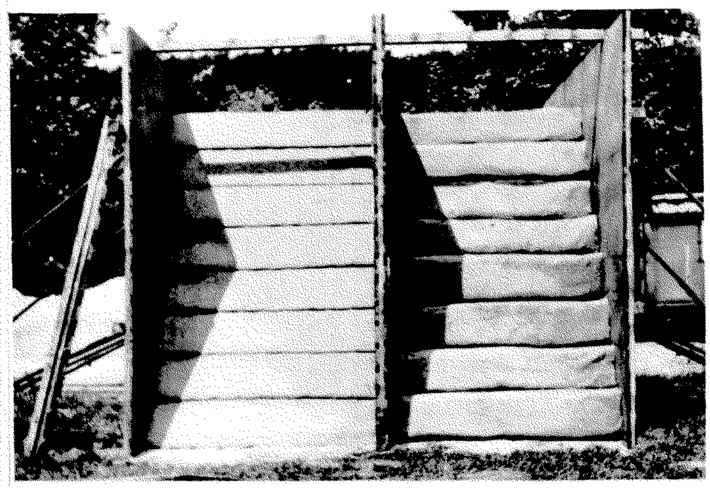

Figure 9 General view of Section 3 and Section 4

6. GRASS GROWTH TESTS

The surface of the embankment was to be covered with the grass. For this purpose three grass genera were selected: *Arrhenatherum*, *Festuca*, and *Poa*. In order to choose the best way of covering the faces, a few sowing methods were tested:

a. the seeds were placed on the surface of geotextile;
b. the seeds were placed under geotextile;
c. the mixture of seeds, humus and water was sprayed on geotextile;
d. the geotextile was covered with so-called "biotextile";
e. the "biotextile" was placed under geotextile.

The "biotextile" was flax needle-punched textile with seeds of grass. In all tests geotextile was placed in the test stands on the thin layer of humus. It appeared that the a., b., c. and d. methods were the most efficient.

The method d. was applied for covering the faces of embankment. In Figure 10 the inclined faces growing-up with the grass were presented. This photo was taken one month and a half after finishing the construction.

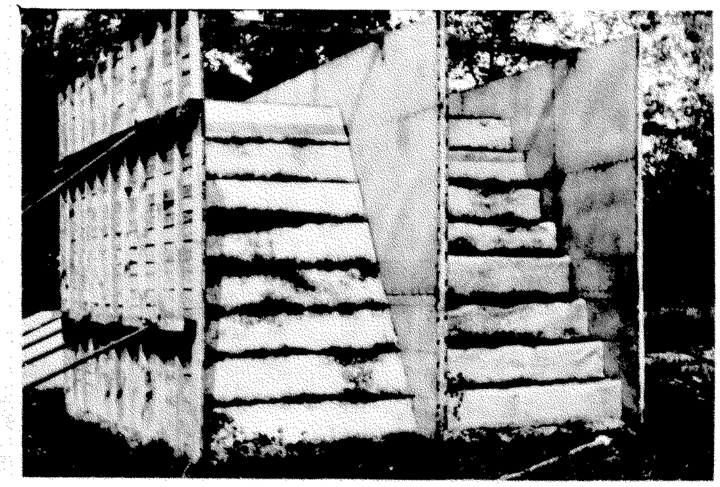

Figure 10 The growth of vegetation on the surface of embankment

ACKNOWLEDGEMENT

The author wish to acknowledge that this work was undertaken with the support of Polish Research Committee (KBN) Grant "Design method for reinforced soil structures based on theory of composites" No. 7 S103 020 04.

REFERENCES

Kulczykowski, M. (1991) Design method of the soil nailing retaining structures, *Arch. Hydrot.*, 3-4:141-150.

Leśniewska, D. (1993) RES - a numerical program for reinforced-soil slopes based on the rigid -plastic theoretical model, *Geotextiles and Geomembranes Int. Jnl.*, 12:435-439.

Sawicki, A. (1983a) Engineering mechanics of elasto - plastic composites. *Mechanics of Materials*, Elsevier, 2: 217-231.

Sawicki, A. (1983b) Plastic limit behaviour of reinforced earth, *J. of Geot. Engrg.*, ASCE, 109: 1000-1005.