Development engineering of light embankments on water saturated soft soils

K.Sh. Shadunts
Department of Civil Engineering, Kuban State Agrarian University, Russia

O.Y. Eschenko
Department of Civil Engineering, Kuban State Agrarian University, Russia

ABSTRACT: In the article new development engineering of light embankments made of reinforced earth is discussed when the construction is carried out on water saturated soft soils. New engineering is confirmed with a patent. In order to describe engineering a cargo sea port design in the city of Temruyk (Sea of Azov) is taken as an example. Taking into consideration low bearing capacity of the basement and relatively high seismic load a design of the reinforced embankment is suggested made of the material with unit weight of nearly 1300 kg/m^3. In the article an influence of various factors is analysed when suggested engineering is used, and the data of the laboratory experiments as well as the calculation results of the stress - strain state of the light embankments with the help of the finite element method are given.

1. INTRODUCTION

The combined use of the technology of the reinforced soil and the principles of construction bionics allows to erect the effective designs of the constructions, especially when the construction is performed under the complicated engineering and geological conditions. For example, there appears a possibility to form almost any predetermined stress - strain State (SSS) of the earth construction. The use of various reinforcement distribution diagrams in the embankment's body for various purposes has been discussed earlier (Eschenko 1989, Shadunts & Eschenko 1990). The application of light fillers (waste of metallurgic and chemical production, foam - like plastics and slag granules) is another way of the construction SSS control. Such combination of the materials allows to reduce the embankment's weight considerably (without a sufficient increase of the cost) which can be a determining factor for the construction stability on a weak basement, landslide slope or under high seismisity of the construction site.

2. PRACTICAL EXAMPLE

A cargo sea port in the city of Temryuk (the Sea of Azov) can be taken as an example of this situation. A main wharf will be constructed here under the complicated engineering and geological conditions: a layer of weak sea mud with thickness of more than 12 m is in the basement, and the calculated seismic acceleration is equal to 0.26 g.

When the traditional technologies are used, the construction of the sea port becomes low profitable, because one should use an alternative site for the arrangement of the main wharf and perform a large ground deepening work in the area of water of the sea port and in an approach (supply) canal.

In order to solve this problem a construction and a technology of the erection of a lightly - built reinforced embankment made of the complex material with volume weight of nearly 1300 kg/m^3 have been worked out.

3. DESCRIPTION OF TECHNOLOGY

In general the discussed construction technology of the lightly - built reinforced soil construction is carried out in the following way (Figure 1).

Proceeding from the concrete conditions of the development the whole construction is divided into the units. Along the external boundaries of the units the embankments 1 are arranged inside of which a layer of the light granulated filler 2 is filled. Then the reinforcing nets 3 are placed above the layer of the filler which are fastened to the basement after tightening with the help of the fixing elements 4 (Figure 1). Then an aggradation of soil above the reinforcing nets is carried out with the help of any known method (for example, a method without trestle). In the next layer the operations are repeated.

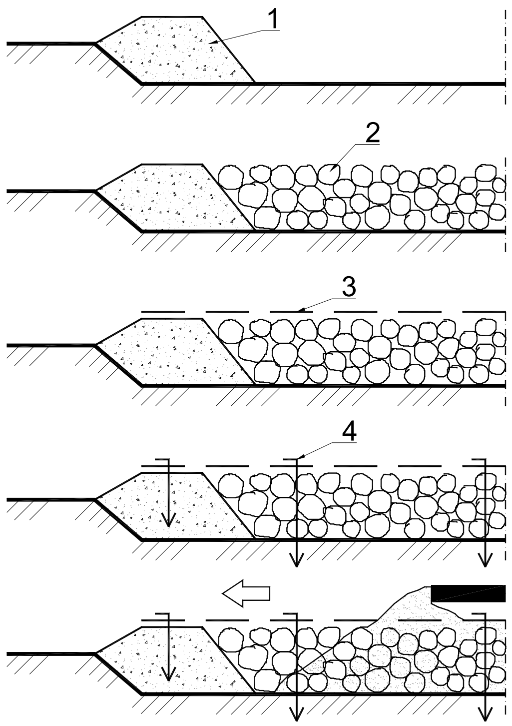

Figure. 1. Main technological operations

This technology suggests the nets fixing the light filler should perform two functions:

1. During the aggradation of the next layer covered by the nets they function as the membranes with an oriented selected penetrability (i.e. to let different materials - soil and filler - pass or not in a definite direction). For this purpose a size of the nets' meshes is selected in such a way that letting the soil particles moving from above pass they stop the filler material granules coming to the surface,

$$D^{f}_{\min} > L^{n}_{\max} \quad (1)$$

$$d^{s}_{\max} < L^{n}_{\min} \quad (2)$$

where $D^{f}_{\min}$ = minimal size of the filler granules, m; $d^{s}_{\max}$ = maximal size of the soil particles, m; $L^{n}_{\max}$ and $L^{n}_{\min}$ = maximal and minimal sizes of the net meshes, m, respectively.

2. 2. After the aggradation they function as reinforcement. For this purpose the mechanical characteristics are selected taking into account the known criteria for the reinforced soil constructions.

The application of this technology allows to obtain a homogeneous composite medium. But in general there is an opportunity for the construction SSS control by means of an alternation of the light layers with the layers made of the aggradated or made ground without light filler, the change of thickness of the layers, the sizes of the units or mechanical characteristics of the filler. The novelty of the technology being suggested is conformed by the author's certificate for the invention (Shadunts & Eschenko 1990).

In order to find out the character of the influence of different factors on SSS of the construction the experimental investigations and a series of the calculations have been carried out with the help of the boundary elements method.

4. CALCULATION METHOD

SSS calculation of the light - built reinforced wharf construction was performed with the help of the limiting elements in accordance with the program «ARMDAM» for the conditions of the static loading and seismic influence with maximal acceleration 0.26 g. As there was no real accelerogram of the calculated earthquake, SSS forecast was performed for the synthesized accelerogram, obtained by means of static processing of four earthquakes with the force of nearly 8 numbers in accordance with MSK-64 scale.

The construction was 7.6 m high, it was reinforced by the nets of TENSAR SR-2 type. Coarse sand with an angle of internal friction 31°, with unit adhesion of 1 kPa and volume weight of 18.2 kN per m^3. Soil was modelled by the ideal elasto-plastic medium with Poisson's ration of 0.3.

During the calculations three distribution schemes of light filler (volume weight of 7.4 kN per m^3) according to the height of the construction were discussed:

1. constant concentration;

2. the content of the filler is minimal at the bottom and is increased to the top of the embankment in accordance with different dependencies determined with the help of the equation:

$$C^{f}_{i} = aH^{b}_{i} + C^{f}_{0} \quad (3)$$

where C^{f}_{0} and C^{f}_{i} = the initial and the current concentration of the filler, respectively; H_i = current height of the construction, m; a and b = the factors.

3. the content of the filler is maximal at the bottom and becomes less to the top of the embankment in accordance with the equation (3).

For each scheme such horizontal distribution of the filler was selected which provided maximal stability of the construction when the calculation combinations of the loads are specified.

Physical and mechanical characteristics of the composite mixture depended on the content of the components in the following way (Ziangirov et al, 1984).

As the soil aggradation should be carried out in a slot between the granules of the filler, volume weight of the composite material being obtained has been determined according to the formula:

$$\gamma^k = (1-n)\,\gamma^f + n\gamma^s \qquad (4)$$

where n = filler porosity; γ^f = unit weight of the filler material, kN/m^3; γ^s = unit weight of soil, kN/m^3.

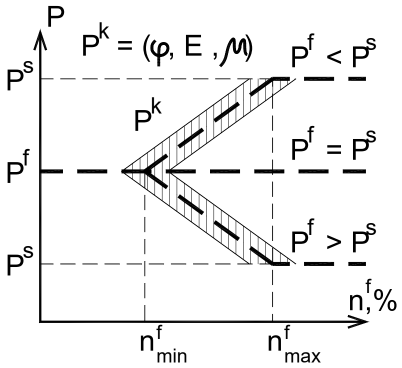

Figure 2. Dependence of the properties of the composite on the properties of the components

Angle of internal friction φ^k, modulus of deformation E^k and Poisson's ratio μ^k of the composite were determined in accordance with the simplified method both for gravel clay mixture by means of linear approximation of the graph in Figure 2 in the range of current values of the filler porosity:

$$P^k = \frac{(P^s - P^f)(n_i^f - n_{\min}^f)}{n_{\max}^f - n_{\min}^f} + P^f \qquad (5)$$

where P = design variable.

Taking into consideration that the light filler is an ideal granular material the adhesion of the composite has been accepted equal to adhesion of the soil.

The condition of strength of the composite has been accepted in the complex form: it has been considered that the material is in the limit state if one of the components has reached the limit of its strength. A usual condition of strength Coulomb – Moor has been used for the soil, and the condition for normal (crushing) stress has been used for the filler.

During the calculation the displacements and the efforts have been noted in all elements of the composite material and the reinforcement. For the convenience of the analysis of the results being obtained a simplified deformed diagram of the construction has been displayed in the distorted scale of the displacements as well as the facing settlement diagram (point "A") and the diagram of the factors of safety (FS) averaged according to the horizontal layers in the soil elements (Eschenko, 1991). The typical picture of the stress - strain state of the wharf construction is shown in Figure 3.

During the experimental investigation the technological peculiarities of the construction have been studied according to the suggested technology.

5. MAIN RESULTS

During the experimental and theoretical investigations the following main results have been obtained:

1. The laboratory experiments have shown that the traditional technologies of the soil aggradation can be used for the development of the suggested structure made of light - built reinforced soil. An additional equipment or a change of the technological scheme is not required.
2. The relation of the strength characteristics and the deformation ones of the soil and the filler has a determining influence on SSS of the construction. The general regularities of the change of the field of the factors of safety of the composite F_s in the cross section of the construction have proved to be similar to the dependencies for usual reinforcement soil embankments.
3. The wharf construction on a weak foundation had maximal stability when the seismic influences were calculated in case of the distribution of the light filler according to the second variant. The character of the density change of the composite according to the height of the construction has little influence on its SSS. When the index of power «*b*» in the formula (3) increases from 0.2 to 8, maximal change of F_s under the static loads has comprised not more than 8% and under the seismic loads not more than 14%. Even in the limit case when the composite material became a two layer medium (heavy soil at the bottom and light filler at the top), this increase does not exceed 20%. An absolute value of the volume weight of the composite and its characteristic plays a decisive role (it has been mentioned above).
4. Provided that Poisson's ratios of the soil and the filler are almost similar in accordance with the absolute value it is impossible to increase an internal stability of the construction as a whole due to the redistribution of the weight of the composite in the vertical or horizontal direction, it is possible to improve SSS in the upper layers.

If the relation takes place

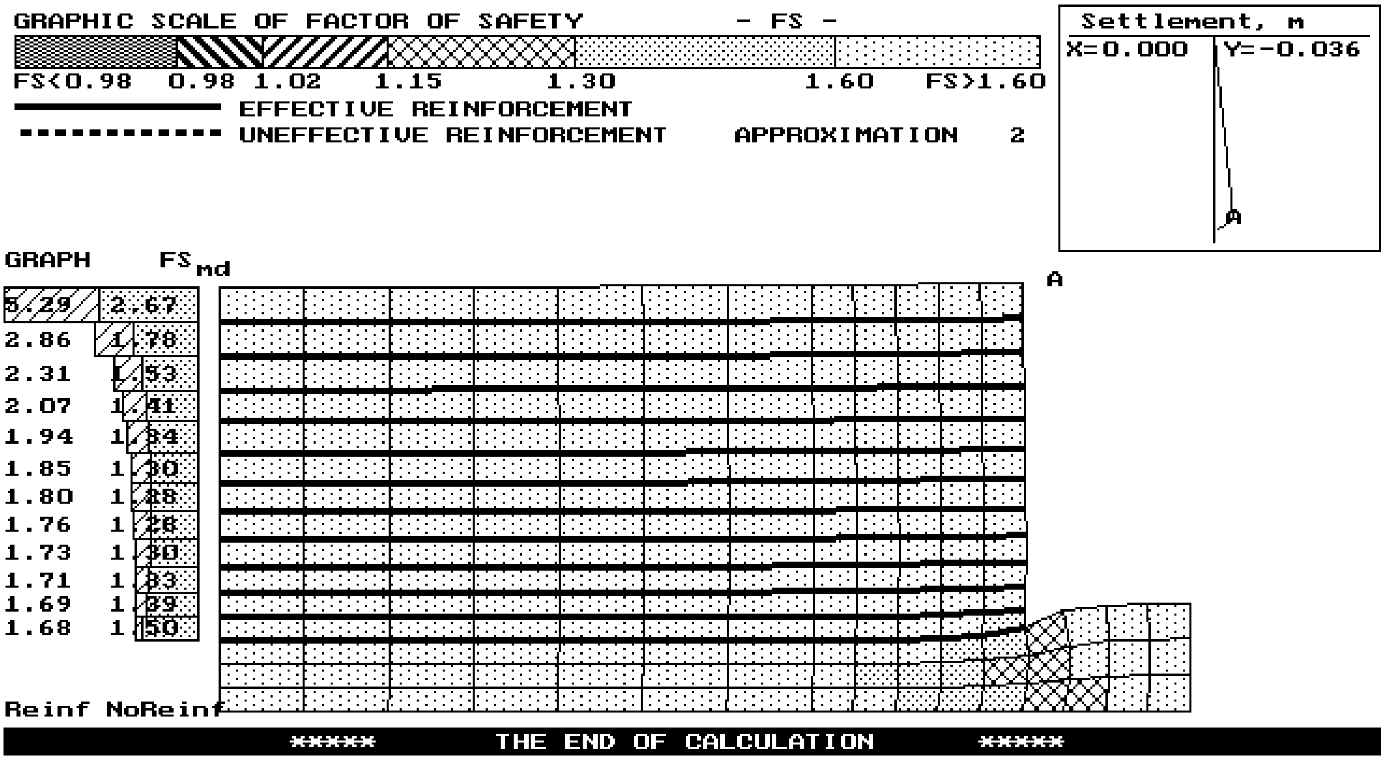

Figure 3. Stress – strain state of the light - built reinforcement soil wharf construction on a weak basement

$$\mu^s < \mu^f \qquad (6)$$

where μ^s = Poisson's ratio of the soil; μ^f = Poisson's ratio of the filler, the internal stability either is not increased at all or even a certain worsening of SSS takes place, especially under the significant surface loads.

5. Practically, stress – strain state of a weak basement does not depend on the character of the distribution of the filler according to the height of the construction and is determined only by rigidity of the composite material and the total weight of the embankment.

6. For the example being considered the reduction of weight of the wharf construction has allowed to reduce the cost of the project significantly and to increase freight turnover (due to the arrangement in more favourable place).

6. CONCLUSIONS

The investigations being carried out have helped to find out the main factors determining the stress - strain state of the reinforced soil embankments made of composite materials and can be used to optimize the structures being constructed on a weak basement.

REFERENCES

Ziangirov R.S. et al. 1984. *Practical work in mechanics of soils*. Moscow: MSU

Eschenko O.Y. 1991. *Reinforced soils and basements.* Thesis for the candidate degree, Krasnodar: KSAU.

Shadunts K.Sh., Eschenko O.Y. 1990. *Construction method of an earth structure*. Author's certificate of the USSR No. 1608299 E 02 D 17/20.