Test of ground embankment model with the use of geosynthetic elements of reinforcement to static external load

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ABSTRACT: The article presents the results of trough (model) tests of a soil embankment subject to static loading. Within the framework of the work program, two models of a soil embankment were subjected to static tests: without reinforcement elements and using reinforcement elements from geosynthetic material. The test results are presented in graphical and tabular form. A qualitative and quantitative analysis of the load-fall curve was carried out.

Keywords: model tests, soil embankment, geosynthetic reinforcement elements

1 INTRODUCTION

The use of geosynthetic materials as reinforcement elements to strengthen the earth embankments has a great world practice and wide application, and in recent years, its intensive implementation in Kazakhstan in the field of road construction has been observed.

Reinforcement of the soil embankment implies the use of reinforcement elements to increase the overall stability of the structure and the mechanical properties of the soil embankment. Nevertheless, the issue of qualitative design primarily depends on the correct calculation, the choice of the design scheme, the evaluation of the effect of reinforcement elements on the overall stability of the embankment (Shin & Young 2006).

The pilot tests were carried out in the laboratory of the Karaganda Industrial State University in June 2014.

The tests were conducted with the aim of:

- evaluation of the stress-strain state of the embankment at different loading values;
- evaluation of the effect of reinforcement elements on the general stability of the soil embankment model.

Experimental studies on models are performed by the method of equivalent materials and have as their goal the study of the work of a soil embankment model loaded with static pressure of different sizes, as well as the effect of reinforcement elements on the external and internal stability of the structure.

2 SELECTION OF MODEL MATERIALS

The materials from which the model is to be manufactured are selected on the basis of the general law of dynamic similarity, taking into account the simultaneous action of gravity and internal stresses [Zhussupbekov & Lukpanov 2007].

The law of dynamic similarity of Newton:

$$EA = T \cdot t \cdot t_g \cdot \frac{w_g}{s} \cdot, \kappa H \qquad (1)$$

where K is the "determining criterion for similarity" of processes of deformations and fractures of soil under conditions of gravity and stresses arising in the soil;

γ_M ; γ_H - specific gravity of model and full ground;

i; I - linear dimensions of the dam and full-scale dam model;

N_M;N_H - the value corresponding to different power characteristics of the state of the model and nature, the dimension of which is the force / area.

Equation (1.) is reduced to the form (2), according to which the mechanical characteristics of equivalent materials are selected

$$N_M = \frac{i}{J} \cdot \frac{\gamma_M}{\gamma_H} \cdot N_H \quad (2)$$

Knowing the parameters E_o;φ ;C; ν_o modeled objects, having chosen the scale of modeling γ_M / γ_H, at selection of equivalent materials, it is necessary to be guided by following parities:

$$E_M = \frac{i}{J} \cdot \frac{\gamma_M}{\gamma_H} \cdot E_H ; \quad (3)$$

$$C_M = \frac{i}{J} \cdot \frac{\gamma_M}{\gamma_H} \cdot C_H ; \quad (4)$$

$$\vartheta_M = \vartheta_H ; \quad (5)$$

$$\varphi_M = \varphi_H ; \quad (6)$$

The scale of the model is 1/20÷1/2. The material of the ground base model is represented by a mixture consisting of 97% fine quartz sand and 3% spindle oil by weight. Oil, which has a grip, allows you to model cohesive soils. Parameters of soils and equivalent material are presented in Table 1.

Table 1. Parameters of soil and equivalent material

Type of soil	**Specific gravity, *γ* (кН/м^3)**	**Cohesion C, (кПа)**	**Angle of internal friction, (град)**	**Modulus of deformation, *E* (Мпа)**	**Poisson's ratio *ν***
Loam	2,05	40	22	20	0,3
Equ. material	1,7	0,90	39	0,27	0,25

To model the reinforcement element, only one parameter of the material is required: axial elastic rigidity:

$$EA = T \cdot t \cdot t_g \cdot \frac{w_g}{s} \cdot, \kappa H \quad (7)$$

where EA is the axial elastic rigidity, kN / m; t is the thickness of the reinforcement, m; T is the tensile force, kN / m; tg - thickness of geogrid rods (figure 2), mm; wg - width of geogrid rods (figure 1), mm; s is the step between the geogrid rods (Figure 1), mm.

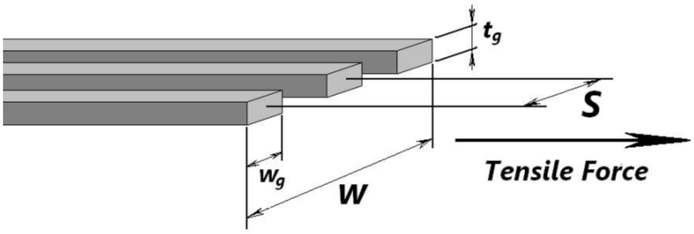


Figure 1. Geometric geogrid parameters

From equation (7), the axial rigidity of one rod of the reinforcement element is EA = 51 kN / m. To determine the axial rigidity of the reinforcement elements of the model, we use the dynamic similarity law for 1 m of a full-scale dam or 1/40 m of a simulated dam:
The axial rigidity of the reinforcing element of 1 m of the natural dam is 51·5=255 kN / m (where 5 is the number of rods per 1 m of the full-scale dam).
The deformation modulus (2%) is 200,000 MPa.
The diameter of the cross section is 0.8 mm, the cross-sectional area is $0{,}524 \cdot 10^{-6}$ m.
Thus, the axial rigidity of one rod of the model reinforcement element is: EA = 100.48 kPa

3 TEST RESULTS

The tests were carried out in accordance with the test program. The load increment was carried out in steps of 3.02; 5.055; 4.04; 2.03 kg. (table 2). Each stage of loading of a soil embankment was conditioned to a conditional stabilization of 0.1 mm of displacement in 15 minutes of observation. The observation (test) was conducted until the collapse of the embankment completely collapsed (Figure 2).

Table 2. Load on the soil embankment

Step No.	**1-11**	**12-13**	**14-15**	**16-17**	**18**	**19-21**	**22-n**
Increment of load, kg	3,02	5,055	3,20	5,055	3,02	4,04	2.03
Full load, kg	33.22	43.33	49.73	59.84	62.86	74.98	77.01-n

To allow lateral movement of the subsoil base, pits with a depth of up to 20 cm were first made from each edge of the tray (Figure 2). To fix the deformation of the soil embankment, grades and deflectors (for fixing vertical movement) were used. The distances between the brands were 50 mm horizontally, 100 mm vertically. Elements of reinforcement (three layers) are located in the lower part of the embankment at a distance of 100 mm (vertically). Dimensions of the mound 50x50 cm on the base, 20x20 cm above, height 40 cm. The scheme of the soil embankment is shown in Figure 2.

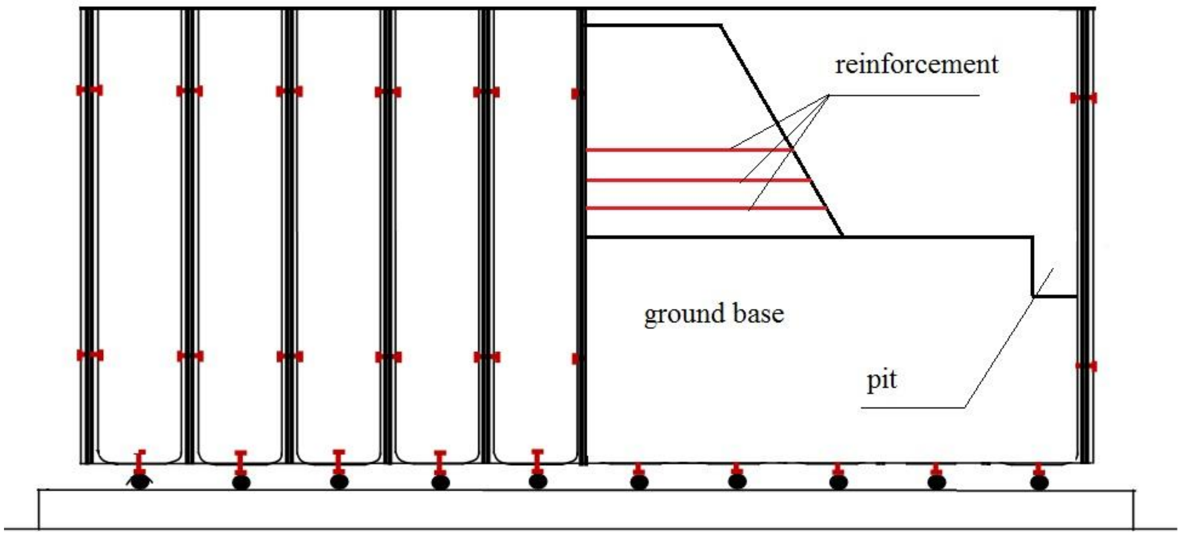
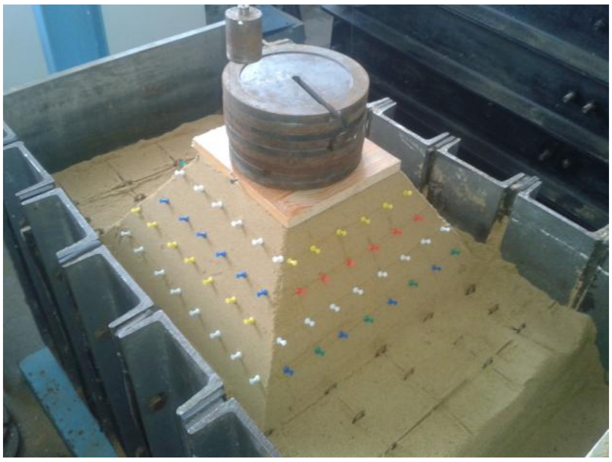


Figure 2 - Scheme of a tray and a soil embankment


Formation of a mound


Control marks


Formation of the pit


Prodrugomers

Without reduction

With reinforcement

Figure 3 - Tests in the tray

Figure 4 shows loading-draft charts for a reinforced mound and a mound without reinforcement. According to the schedule, the maximum load at which the earth embankment collapsed was: for a mound without reinforcement elements 24.8 kg (10.8 kPa); For embankment using reinforcement elements 89.9 kg (39.2 kPa). The maximum deformation (vertical movement) without disrupting the structural integrity (the penultimate stage of loading) was: for a mound without reinforcement elements 1.68 mm; For embankment using reinforcement elements 2,68mm.

According to the nature of the distribution of the load-sediment curve, it can be seen that at the initial stage of loading (up to a precipitation of 0.78 mm), both curves are comparable. This is due to the fact that the reinforcement element was not fully incorporated into the work, as a result of loading, and as a result of the migration of the particles, a densification takes place. Further, a sharp change in the nature of the curve of the reinforced mound indicates the inclusion of reinforcement elements in the work.

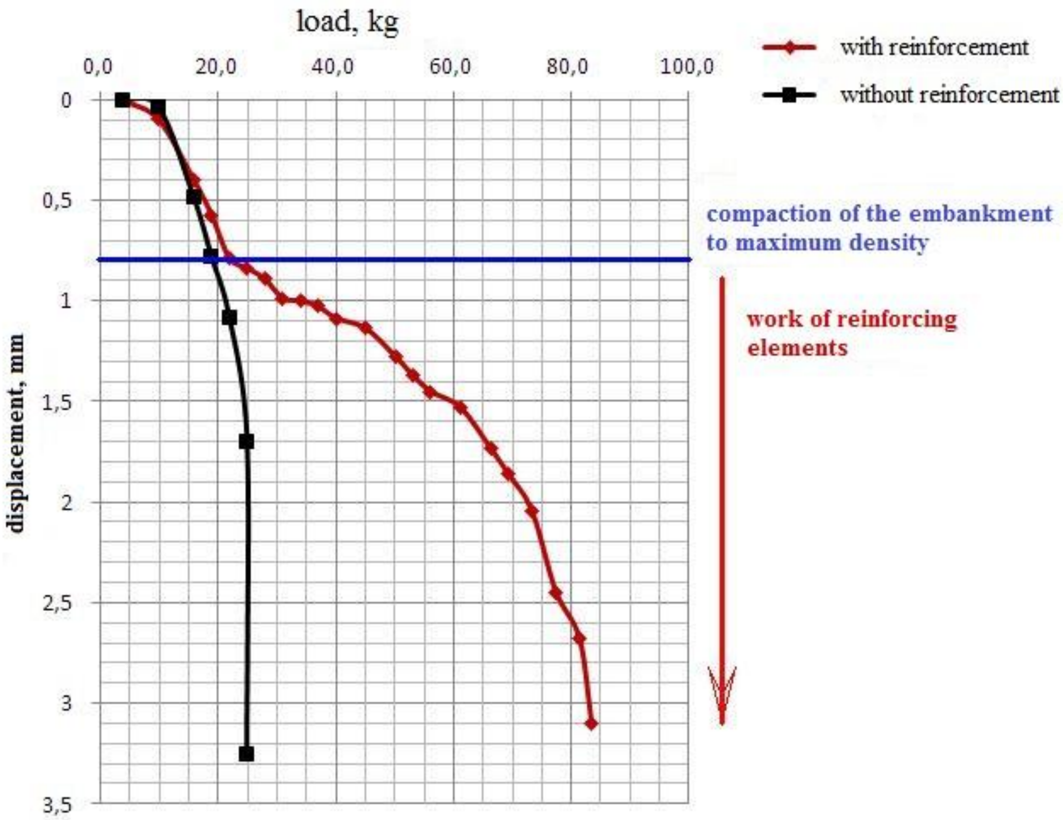


Figure 4 - The load-sludge diagram

According to the test results, a soil embankment using reinforcing elements is able to withstand (without loss of general stability) a load 3.5 times (89.9 / 24.8) higher than a bulk without reinforcement. At the same time, due to reinforcement, the soil embankment is capable of deforming without loss of stability 1.5 times more than with a load of 4 times (87.9 / 21.8) exceeding in comparison with a bulk without reinforcement.

4 CONCLUSION

The results presented in the article are actual for road construction, they require further analysis and thorough research. Nevertheless, according to the test results, the use of reinforcing elements of reinforcement will significantly reduce costs for the construction of unpaved road or railroad embankments. Working in close contact with the ground, the reinforcement elements redistribute the load between the sections of the embankment structure, ensuring the transfer of voltage from the overloaded zones to adjacent underloaded zones. The constructed model of a shallow embankment confirms the practicality of using reinforcement material as an element of reinforcement, and its wide use in world practice is a successful basis for its application.

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