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EXPERIMENTAL RESEARCH TECHNIQUE OF RETAINING WALLS OF A SPECIAL TYPE

The article reviewed the issue of wide use of the retaining walls in construction. It is established the existing retaining walls are not designed for additional forces from horizontal soil displacement that consequently leads to the destruction of the structure. In this regard, there is a need for the development of new structural solutions for retaining walls. The purpose of the research is to develop the technique for conducting experimental studies of the contact interaction of retaining walls and a deformable base. The experiments were carried out on small-scale models in a specially designed tray. At modeling was applied the method of the expanded similarity in which geometrical, mechanical and power analogues with a real object are maintained. As base soil, the models used loamy structure. Models of retaining walls were made on a digital 3D model. A technique for conducting experimental studies of the contact interaction of retaining walls and a deformable base has been developed. The technique is universal and will allow carrying out model experiments under equal conditions, which will ensure reliable results.

Keywords: *technique, experiment, model, foundation, retaining wall.*

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МЕТОДИКА ЕКСПЕРИМЕНТАЛЬНОГО ДОСЛІДЖЕННЯ ПІДПІРНИХ СТІН СПЕЦІАЛЬНОГО ТИПУ

Висвітлено питання широкого застосування підпірних стін у будівництві. Встановлено, що існуючі конструкції підпірних стін не розраховано на додаткові зусилля від горизонтального зрушення ґрунту, що призводить до руйнування конструкції. Доведено необхідність розробки нових конструктивних рішень підпірних стін. Розроблено методику проведення експериментальних досліджень контактної взаємодії підпірних стін і деформованої основи. Проведено експерименти на маломасштабних моделях у спеціально сконструйованому лотку. При моделюванні застосовано метод розширеної подібності, в якому витримуються геометричні, механічні та силові аналоги з реальним об'єктом. Як ґрунт основи в моделях використано суглинок порушеної структури. Моделі підпірних стін виготовлено за цифровою 3D-моделлю. Доведено, що ця методика дозволяє проводити модельні експерименти в рівних умовах, що забезпечить отримання достовірних результатів.

Ключові слова: *методика, експеримент, модель, основа, підпірна стінка*

Introduction. The retaining walls are now widely used not only in civil and industrial construction, but also in town planning for complex landscapes.

There are situations of objects construction in cramped conditions, in unfavorable areas with active deformation effects, which complicates the use of existing types of retaining wall structures.

According to expert estimates, 90% of the territory of Ukraine is characterized by complex engineering and geological conditions, deteriorating due to the impact of natural and man-made factors [1].

Analysis of recent studies and publications sources. Currently, this problem is relevant for work areas and subsidence grounds, because with complex deformations of the base, it is not always possible to realize the available technical solutions in view of their inability to work conditions. Existing constructions of retaining walls are not designed for additional forces from horizontal soil displacement, which causes stress concentration in the lower part of the faceplate, which consequently leads to the destruction of the structure [2, 3].

Numerous studies of the behavior of various soils (loess subsidence, gypsum, hacked, karst, etc.) with soaking showed that their bearing capacity and compliance (rigidity) are closely related to the degree of their moisture content. At the same time, an increase in humidity is accompanied by a decrease in the rigidity characteristics of the base, which can cause uneven subsidence [4, 5].

Allocation of previously unresolved parts of a common problem. Designing optimal design solutions, taking into account specific operating conditions, is one of the main engineering tasks. For retaining walls used in work areas with horizontal and vertical soil movements, this task is particularly important. Experimental studies have shown that the stress-strain state of the substrate is largely determined by the design characteristics of the operating and loading conditions [2]. In this regard, there is a need to develop new design solutions for retaining walls capable of perceiving additional impact from an unevenly deformable base.

Formulation of the problem. The aim of the research is to develop a methodology for conducting experimental studies of the contact interaction of retaining walls and a deformable base.

Main part and results. Classification of the experiment:

– by structure – a model experiment (a retaining wall model, a base model);

– at the stage of scientific research – bench tests (obtaining information about the SSS of the retaining wall);

– organization of the experiment – conducting an experiment in the laboratory;

– by the method of conducting – an active experiment (with the possibility of active influence on the object).

The purpose of the tray studies is to determine the optimal design parameters of the proposed design of the retaining wall of a special type, as well as to identify the qualitative patterns of its joint work with the base.

The experiments were carried out on small-scale models in a specially designed tray. At modeling the method of the expanded similarity in which geometrical, mechanical and power analogues with a real object [6, 7].

As a base soil in the models, a loam of broken structure was used. To create a uniform foundation, the soil was dried to a full loss of moisture and crushed by grinding in a mortar to a powdery state. Then the resulting powder was sieved through a sieve with a hole diameter of 0.5 mm. Taking into account the necessary moisture content of the soil, its density and volume determined the necessary amount of powder and water for its moistening. Humidification was carried out by a nebulizer with a constant stirring of the mixture. The base of the paste was laid in layers of 15 mm, the compaction was carried out by a rammer made in the form of a rod with a welded base of a square cross section of 200 g. The purpose of preparing the model base was to obtain physicomechanical characteristics similar to natural soil.

We simulated loams with the following characteristics (E = 13,5 MPa, c = 19,5 кPa, γ = 1,82 t/m3, φ =22°).

The physical and mechanical properties of the base model were determined using a field laboratory FLL-9 (ПЛЛ-9) (fig. 1 a, b) in accordance with the methodology [8]. The strain modulus was determined with the help of a compression device of the Litvinov system. The cohesion coefficient of the soil and the angle of internal friction were determined by means of a shearing device P10-S (П10-С). Sampling was carried out from a tray with a pitch of 150 mm in height, the results of certain characteristics are presented in (tab. 1), the comparative characteristics of soils are presented in (tab. 2).

a

b

Figure 1 – Preparation of the device:
a – FLL-9 (ПЛЛ-9); b – characterization of model soil

Table 1 – Sample test results

№ point	The depth of sampling from the top of the array, m	Volume weight, γ, т/m^3	Modulus of deformation, E, MPa	Shift parameters		
				tgφ	φ°	c, MPa
1	0,15	1,826	9,3	0,38	21	0,014
2	0,15	1,812	9,5	0,32	18	0,019
3	0,3	1,831	8,9	0,36	20	0,016
4	0,3	1,822	9,1	0,46	25	0,012
5	0,45	1,816	8,5	0,48	26	0,009

Table 2 – Comparative characteristics of soils

Name of soil	Physicomechanical characteristics of the base			
	E, MPa	c, кPa	γ, т/m^3	φ, deg.
Full-face soil	13,5	19,5	1,82	22
Model base	5,62	6,8	1,71	22
Coefficient of transition	1/1,5	1/1,5	1	1

Design features of a retaining wall of a special type: a monolithic retaining wall of an angular type that has voids on the contact surface of the vertical and foundation elements, in the form of truncated pyramids of the same size and directed in a smaller base in depth [9, 10]. With the development of the deforming load in time, that is, with vertical and horizontal movements of the soil with respect to the monolithic wall of the angular type, after its installation, gradual penetration of the soil into voids occurs. Premature filling of voids is prevented by sheets of elastic material. As a resiliently compliant material, a polyethylene film was used with the following characteristics: a thickness of 200 μm, a density of 916 kg / m^3, a tensile strength of 165 kgf / cm^2.

Models of retaining walls were made using the method of layer-by-layer creation of a physical object using a digital 3D model (fig. 2 a, b). For this, a 3D printer was used Graber i3.

a b

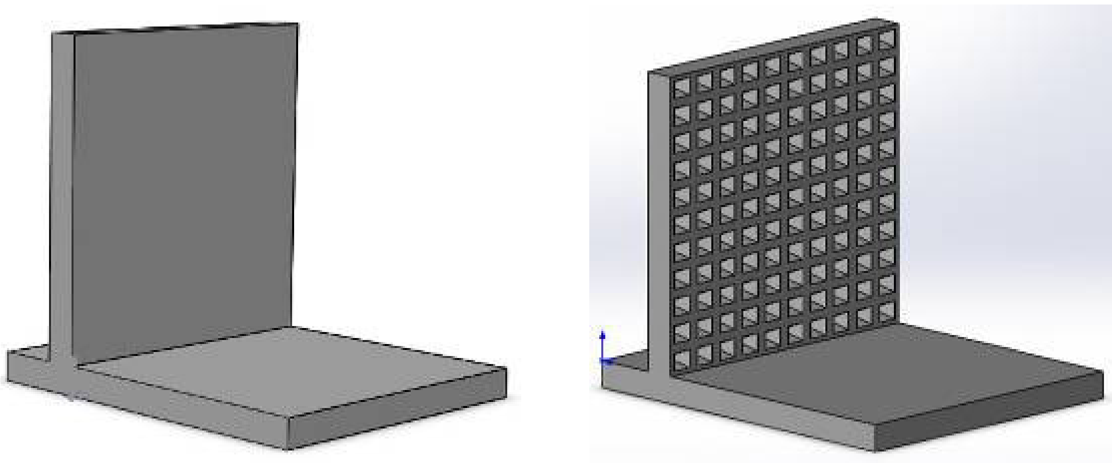

Figure 2 – Experimental models:
a – angled retaining wall; b – retaining wall of a special type

The tray tests were carried out in a metal tray with a transparent front wall made of plexiglas. The tray dimensions are 600×650×680 mm. Its edges are made of corners 80 × 80 mm, the upper belt of steel strip width of 50 mm. All facets except for the front are made of chipboard 16 mm and rigidly fixed by two corners 60 × 60 mm. The working space for installing the retaining wall is fenced off by a partition of 16 mm chipboard. To prevent friction of the soil against the wall of the tray, the inner part of the walls was covered with an easily deformable polyethylene film in two layers with a layer of technical petroleum jelly.

The purpose of the first series of tests was to identify the degree of structural factors influence on the bearing capacity of the model of the proposed retaining wall of a special type.

The second series of tests were conducted to compare the stability of the anti-shear position of the retaining wall of the corner type and a retaining wall of a special type.

Preparation of the tray for testing was carried out by installing it on the supports, after which the inner surface was covered with a polyethylene film. The second layer of polyethylene film was laid after applying a layer of technical petroleum jelly.

Preparation of the base model was carried out by layer-by-layer laying of pre-prepared ground paste. Each layer of paste was compacted by a rammer. When reaching a pre-marked height, the surface of the ground was planned, after which a retaining wall was installed. Further, the layered laying of the soil paste from the front side of the vertical retaining wall element continued until the mark indicated on the retaining wall. Backfilling was also performed using paste, the paste was laid layer by layer with a seal of 0.95 from the base under the foundation element to the top face of the retaining wall. A metal plate with dimensions of 150×200 mm was laid on the planned backfill surface.

To obtain information on the displacements and sediments of model structures and grounds, we used hour-type indicators ICh-10 (ИЧ-10), 6-PAO (6-ПАО) programmers, which were verified in the center of metrology, standardization and certification. Before the free surface of the retaining wall, a bar with two clock-type indicators was rigidly mounted to measure horizontal deformations (displacements) of the wall in two levels. Over the retaining wall, on a specially prepared console, there were installed deflectors to measure vertical deformations (displacements). All instrument readings were set to the initial values and recorded in the log.

Load on the platform was created in steps of 1.5 kPa. The load was maintained until the conditioned stabilization of the soil. The sedimentation rate of the model that does not exceed 0.1 mm in 30 min was taken as a criterion for the conditional stabilization of deformation. Each subsequent stage of pressures was also maintained during the time of conditional stabilization (fig. 3 a, b).

Loading models were carried out until the full loss of stability of the retaining wall. The values of the devices were recorded and recorded in the log, after which the graphs were constructed.

At the end of each experiment, the soil from the tray was removed, dried in a drying cabinet and ground. In order to carry out the next experiment, again, according to the foregoing technology, the ground paste was prepared and re-stacked in a tray.

The conducted studies showed that with the same ground base (the geometry of the layers and the physical and mechanical characteristics), the load and the boundary conditions evident for the retaining wall of a special type is the inclusion in the work of the entire soil massif and the uniform redistribution of stresses at the contact along the face and base slabs; uniformity of general deformations of structures and soil base, which, in turn, provide greater stability of the retaining wall of a special type.

a b

Figure 3 – Testing:
a – pad loading; b – readings from instruments

Conclusions. A technique for carrying out experimental studies of the contact interaction of retaining walls and a deformable base has been developed. This technique is universal and will allow carrying out model experiments under equal conditions, which will ensure reliable results.

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