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PHENOMENA OF FILTRATION INVERSION AND DEPTH EROSION OF TECHNOGENIC LOADED LOESS SLOPES

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Complement series of loess rocks was carried out to identify a mechanism of the rock restructuring in the process of filtration and to demonstrate qualitative nature of gravel and sludge evacuation as well as its metamorphosis under various conditions. The experiments, concerning filtration movement of water in a device of triaxial compression, make it possible to evaluate structure changes taking place during the process; besides, a method of erosion forming is identified. Series of filtration parameter tests has been carried out under the conditions of triaxial compression in the context of different load values and filtration directions; geostatic pressure has been within 250–300 KPa, and pressure gradient has been controlled by 20 kPa pressure in the sample. Identify prognostic boundaries for transformation of suffusion processes into erosion ones. Average values of particle removal as well as their granulometric composition for the Dnieper region loess soil (2,801 % of the sample weight) have been obtained.

Key words: loess soil, filtration inversion, erosion, triaxial compression.

ЯВИЩА ФІЛЬТРАЦІЙНОЇ ІНВЕРСІЇ І ГЛИБИННОЇ ЕРОЗІЇ ТЕХНОГЕННО НАВАНТАЖЕНИХ ЛЬОСОВИХ СХИЛІВ

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Була проведена серія випробувань льосових порід із метою встановлення механізму перебігу перебудови структури породи при фільтрації, а також для представлення кількісного характеру процесу виносу ґрунтового матеріалу та його зміни в різних умовах. На підставі експериментальних досліджень фільтраційного руху води в приладі тривісного стиску оцінені зміни структури, що відбуваються при цьому, а також встановлений механізм утворення ерозійних вимоїн у зразках. Серія випробувань фільтраційних параметрів порід проведена в умовах тривісного стиснення при різних значеннях навантажень і напрямках фільтрації, геостатичний тиск приймався в діапазоні 250–350 кПа, гідравлічний градієнт контролювався тиском у зразку 20 кПа. Встановлені прогнозні межі переходу суфозійних процесів в ерозійні. Отримані середні значення виносу частинок, а також їх гранулометричний склад для Придніпровського льосового суглинку (2,801 % від ваги зразка).

Ключові слова: льосова порода, фільтраційна інверсія, ерозія, тривісне стиснення.

PROBLEM STATEMENT. In paper [1] we evaluated changes taking place in loess in the process of its saturation and technogenic underflow filtration, which provoke a process of the loess structure transition to the new one characterized by changes in the nature of structural bonds and new geomechanical factors. Experimental results obtained by using a device of triaxial compression TriSCAN (VJTech, Great Britain) helped us to establish the inversion of loess filtration anisotropy in comparison with its natural occurrence. If radial load is σ_3 = 300 kPa, then suffusion, passing into erosion with preceding phase of hydraulically inert cavities formation, is observed. On the assumption of the results, complement series of loess rocks was carried out to identify a mechanism of the rock restructuring in the process of filtration and to demonstrate qualitative nature of gravel and sludge evacuation as well as its metamorphosis under various conditions. Moreover, grain size measurements were performed for the rock and for evacuated material.

Similarly to [1], adown and surface-perpendicular to surface formation effect of filtration flow on soil was analyzed; however, the emphasis is upon the filtration formed in parallel to stratum. Taking into consideration the fact that in terms of adown filtration it is impossible to verify that erosion can not be formed, this very filtration technique has been tested. Samples of loess of quaternary from such Dnipropetrovsk gulches as Tonnelna and Topolyna were tested under the conditions of triaxial compression. To correct load ranges for erosion forming, 250–300–350 kPa geostatic pressure was applied. Pressure gradient in the sample was 20 kPa corresponding to actual conditions of the soil mass. Time was not limited strictly; the experiment was interrupted when dying nature of volumetric changes in the sample was determined, or material evacuation was dying, or when erosion took place.

EXPERIMENTAL PART AND RESULTS OBTAINED. First series of tests met the requirements of adown filtration technique. Fig. 1 demonstrates the results of laboratory tests showing temporal changes in volumetric deformation. Statistical validity is evaluated with the help of R^2=0,98…0,99.

Suffusion with small share of evacuated particles and the greatest activity during first hours after filtration has started (4–5 hours) takes place. As values of volumetric deformation demonstrate, certain impulses of the material evacuation fall at a period of up 2 hours; then the evacuation minimizes, and dying period is 12 hours to be in accordance with the sample gradual restructuring. No deformations, flaws, cavities, and visible dislodgements showed following visual inspection of tested samples.

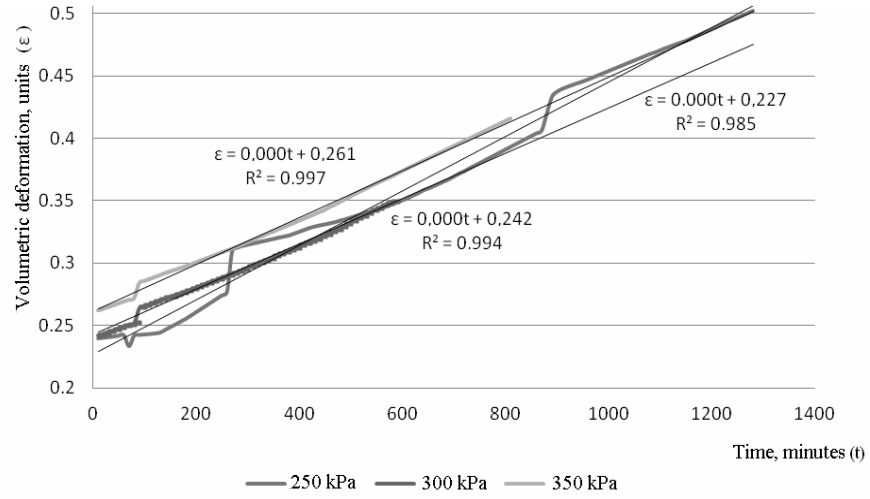

Figure 1 – The results of quaternary loess adown filtration tests: 250, 300, and 350 kPa are radial loads

The results obtained while using the tests, carried out in parallel to stratum, are much different. Fig. 2 demonstrates temporal changes in volumetric deformation for 250 and 300 kPa loads accordingly. R^2=0,92–0,96 is applied to evaluate statistical validity.

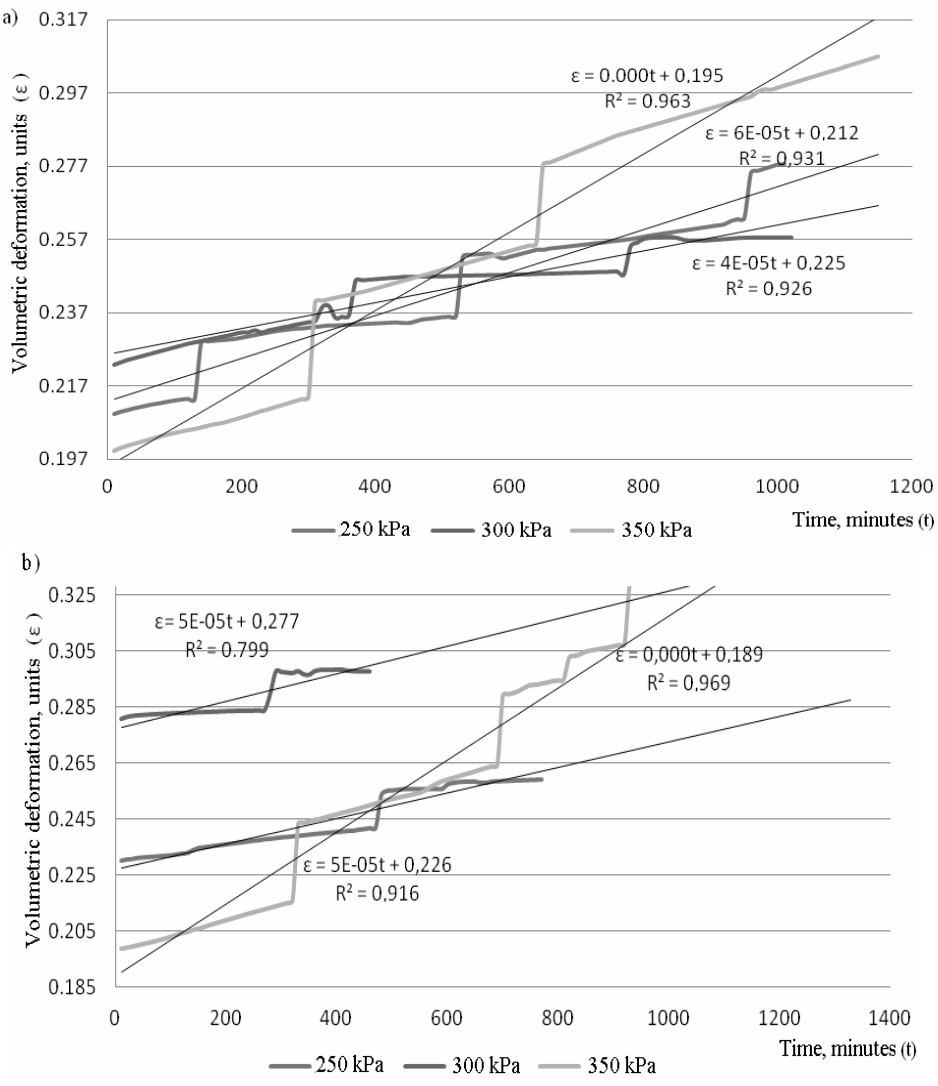

Figure 2 – The results of quaternary loess tests while filtrating in parallel to stratum with such values of geostatic pressure as 250 kPa (a) and 300 kPa (b)

For all samples tested at σ_3 =300 kPa, and one sample tested at σ_3 =250 kPa, erosion formation was visually documented; the erosion exposes after 6-8 hours after filtration process has started. The quantity of particles exposing in the period of the test has been documented; granulometric analysis (according to Sabanin) of both original and evacuated rock material has been carried out (Fig. 3). Fig. 4 demonstrates visible changes in the samples.

The most intensive process of the particles evacuation (72 % of total mass) took place from 2,5 to 6,0 hours in terms of the filtration start. Fig. 2 demonstrates that in the majority of cases the period takes noticeable changes in the sample volumetric deformation values.

The nature of evacuated particles in loess can be explained as follows. In loam soil, suffusion depends on pore sizes in the soil, and in loess (in accordance with direct microexamination of S.V. Astapov) separate pores have been identified; diameter of the pores exceeds 0,01 mm (in this case it is also important that the filtration is formed in parallel with stratum).

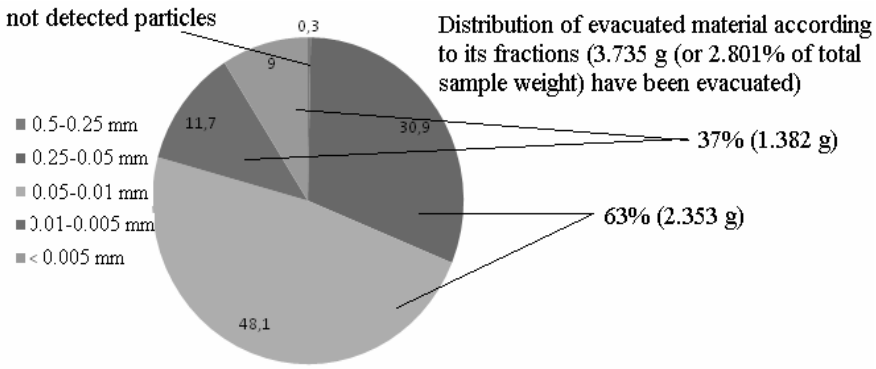

Figure 3 – Averaged results of granulometric analysis of covered loess in the process of suffusion

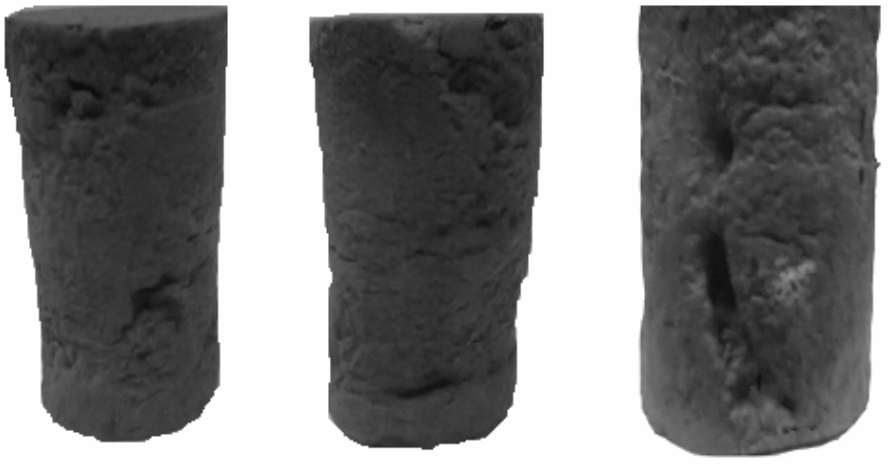

Figure 4 – Erosion in loess samples for filtration technique taking place in parallel with stratum

Thus, due to pore undersize, congeries exceeding them can not be pushed out of soil column, and it takes much intensity for smaller particles removal. Removal of soil particle congeries (when molecular adhesion between congeries is strong) may take place even if gradients are much less to compare with those for separate particle removal [2].

In accordance with granulometric ratio of coming out particles, periodicity and changes in volumetric deformations one may conclude that in considered loess, soil congeries removal takes place rather than separate particle removal. That can be realized owing to formation of microfissures (starting from 0,2–5 μ fissure opening or even less), which filtration follows the rules of pressure flow of water [3], and erosion process starts. Just at initial stages of filtration the evacuation of relatively identical soil fraction took place; subsequently, fractional evacuating composition coincides with total one. Hence, if only separate particles release was involved, then the structure experienced its transformation forming dislodgement zone rather than erosion cavity.

Analysis of the results concerning changes in volumetric deformations, the qualitative ranges of removed particles as well as visual observations makes it possible to identify prognostic zone of suffusion transformation into the first erosion stage and formation of closed channel with inert drain surface (Fig. 5).

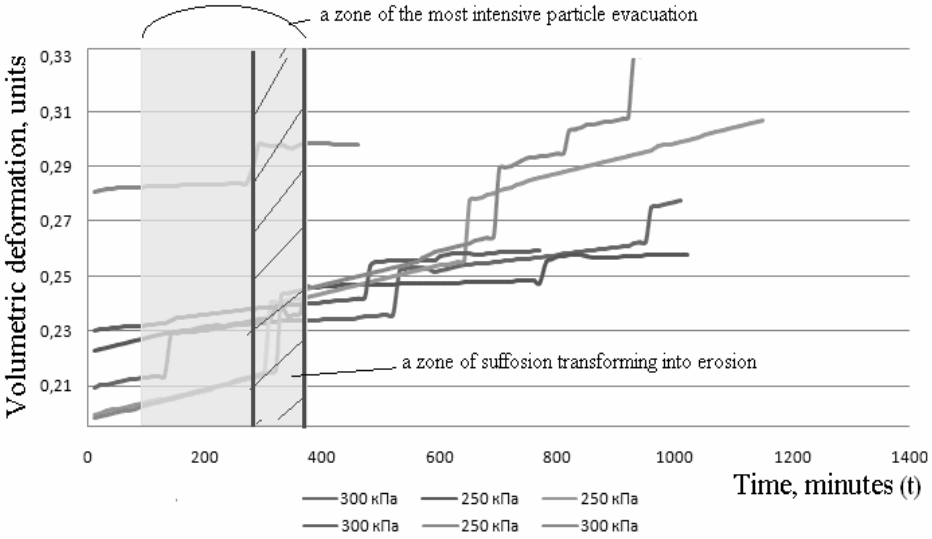

Figure 5 – Generalized results of loess tests in parallel to stratum: 250 and 300 kPa are load ranges

CONCLUSIONS. The experiments, concerning filtration movement of water in a device of triaxial compression, make it possible to evaluate structure changes taking place during the process; besides, a method of erosion forming is identified. Series of filtration parameter tests has been carried out under the conditions of triaxial compression in the context of different load values and filtration directions; geostatic pressure has been within 250–300 KPa, and pressure gradient has been controlled by 20 kPa pressure in the sample. Erosion can not be formed in the process of vertical filtration; if filtration in parallel to stratum takes place, then changes in volumetric deformation, quantities and periodicity of particle removal are applied to identify prognostic boundaries for transformation of suffusion processes into erosion ones. Average values of particle removal as well as their granulometric composition for the Dnieper region loess soil (2.801% of the sample weight) have been obtained. The research is the basis to prognosticate so-called liquefaction slides being a result of technogenic filtration load of slopes.

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ЯВЛЕНИЯ ФИЛЬТРАЦИОННОЙ ИНВЕРСИИ И ГЛУБИННОЙ ЭРОЗИИ ТЕХНОГЕННО НАГРУЖЕННЫХ ЛЕССОВЫХ СКЛОНОВ

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Была проведена серия испытаний лессовых пород с целью установления механизма протекания перестройки структуры породы при фильтрации, а также для представления количественного характера процесса выноса грунтового материала и его изменениях в различных условиях. На основании экспериментальных исследований фильтрационного движения воды в приборе трехосного сжатия оценены изменения структуры, происходящие при этом, а также установлен механизм образования эрозионных промоин в образцах. Серия испытаний фильтрационных параметров пород проведена в условиях трехосного сжатия при различных значениях нагрузок и направлениях фильтрации, геостатическое давление принималось в диапазоне 250–350 кПа, гидравлический градиент контролировался давлением в образце 20 кПа. Установлены прогнозные границы перехода суффозионных процессов в эрозионные. Получены средние значения выноса частиц, а также их гранулометрический состав для Приднепровского лессового суглинка (2,801 % от веса образца).

Ключевые слова: лессовая порода, фильтрационная инверсия, эрозия, трехосное сжатие.

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