УДК 69.001.5; 624

A. Petrovskiy

A. Borisov

I. Babiy

A. Petrovskiy, Ph.D, Professor of the department of Technology of building production, Odessa State Academy of Civil Engineering and Architecture, 4, Didrihsona str, Odessa, 65029,
tel: 0487236151, e-mail: paf2012@ukr.net
A. Borisov, Ph.D, assistant professor, the department of Technology of building production, Odessa State Academy of Civil Engineering and Architecture, 4, Didrihsona str, Odessa, 65029,
tel: 0487989083, e-mail: etinvest@gmail.com
I. Babiy, Ph.D, assistant professor, the department of Technology of building production, Odessa State Academy of Civil Engineering and Architecture, 4, Didrihsona str, Odessa, 65029,
tel: 0487716969, e-mail: igor_babiy76@mail.ru

Петровський А. Ф., к.т.н., проф., професор кафедри Технології будівельного виробництва, Одеська державна академія будівництва і архітектури, 65029 м. Одеса, вул. Дидрихсона, 4,
тел: 0487236151, e-mail: paf2012@ukr.net
Борисов О. О., к.т.н., доц., доцент кафедри Технології будівельного виробництва, Одеська державна академія будівництва і архітектури, 65029 м. Одеса, вул. Дидрихсона, 4,
тел: 0487989083, e-mail: etinvest@gmail.com
Бабій І. М., к.т.н., доц., доцент кафедри Технології будівельного виробництва, Одеська державна академія будівництва і архітектури, 65029 м. Одеса, вул. Дидрихсона, 4,
тел: 0487716969, e-mail: igor_babiy76@mail.ru

SIMULATION OF SOIL PERMEABILITY IN LAMINAR AND TURBULENT FLUID FILTRATION

МОДЕЛЮВАННЯ ПРОНИКНОСТІ ГРУНТУ ПРИ ЛАМІНАРНІЙ І ТУРБУЛЕНТНІЙ ФІЛЬТРАЦІЇ РІДИНИ

МОДЕЛИРОВАНИЕ ПРОНИЦАЕМОСТИ ГРУНТА ПРИ ЛАМИНАРНОЙ И ТУРБУЛЕНТНОЙ ФИЛЬТРАЦИИ ЖИДКОСТИ

Annotation. The article represents results of researches of injection solution in the sand from the point of view of the physical phenomena. During theoretical studies of the propagation of the fluid phase in a porous medium, actual is the definition of the parameters of the jet, necessary for layer material discontinuity in the contact zone of the jet to the surface. It can be achieved through the injection process modeling in a dispersion medium by constructing geometrical similarity of injection jet. It is found that the propagation of the fluid phase in the solid body pores suggests that as they reach the point at the distance from the injector to the «end» of the jet in pores pre-saturated by water occurs a gradual change in injection rate depending on the initial rate of efflux and viscosity.
Keywords: soil injection, dispersion medium, physical modeling, solution jet, dispersion medium.
Анотація. Розглянуто процеси ін'єкції розчину в пісок з позиції фізичних явищ. При теоретичних дослідженнях процесу поширення рідкої фази в пористої середовищі актуальним є визначення параметрів струменя, необхідних для порушення цілісності шару матеріалу в зоні контакту струменя з поверхнею. Цього можна досягти за допомогою моделювання процесу ін'єкції в дисперсне середовище шляхом побудови геометричної подоби струменя ін'єкції. Встановлено, що розподіл рідкої фази в порах твердого тіла передбачає, що в міру досягнення крайньої точки відстані від ін'єктора до «кінця» струменя в попередньо насичених водою порах відбувається поетапне зміна швидкості ін'єкційного розчину в залежності від його початкової швидкості витікання і в'язкості.
Ключові слова: ін'єкція ґрунтів, дисперсне середовище, фізичне моделювання, струмінь розчину.
Анотация. В статье рассмотрены процессы инъекции раствора в песок с позиции физических явлений. При теоретических исследованиях процесса распространения жидкой фазы в пористой среде актуальным является определение параметров струи, необходимых для нарушения сплошности слоя материала в зоне контакта струи с поверхностью. Этого можно достигнуть с помощью моделирования процесса инъекции в дисперсную среду путем построения геометрического подобия струи инъекции. Установлено, что распределение жидкой фазы в порах твердого тела предполагает, что по мере достижения крайней точки расстояния от инъектора до «конца» струи в предварительно насыщенных водой порах происходит поэтапное изменение скорости инъекционного раствора в зависимости от его начальной скорости истечения и вязкости.
Ключевые слова: инъекция грунтов, дисперсная среда, физическое моделирование, струя раствора.

Introduction.

During the study of the interaction of the dispersion medium with the dispersed phase it is rational to create a model on the level of structural inhomogeneities. For a long time it was thought that in a moving jet of dispersion medium, which is a multi-phase non-Newtonian fluid, soil particles can not accumulate or transfer mechanical energy from the rotor flux [1].

Analysis of recent research and publications of sources.

In hydro or aeromechanical interaction the kinetic energy of the selected soil particles can be transformed into potential, although the effectiveness of such an accumulation of potential energy is much smaller than in the case of motion of Newtonian fluids in disperse systems [2, 3, 4]. For a qualitative description of such processes one of the effective ways at an early stage of their research is their modeling [5.6]. Physical modeling of injection into the soil it is the fundamental definition of their parameters under the model characteristics found in its study [7,8]. A feature of the physical modeling is that the characterization does not require a mathematical description of the processes, but an idea about the mechanism (physical nature) of the phenomena, in order to properly calculate the parameters of the main subject according to tests of its model. Since the physical modeling of the physical nature of the phenomena that occur in natural product and the model is the same, according to the results of experiments on the models we can evaluate the nature and effects of the quantitative relationship between the values for field conditions [9].

Isolation of previously unsolved aspects of the problem.

The task of theoretical studies of the propagation of the fluid phase in the porous medium includes determining of a minimum dynamic pressure of the jet necessary to discontinuities in the material layer of the jet in the contact zone with the surface.

Formulation of the problem.

To determine the fluid jet parameters required for dynamic fracture of the layer of porous material, it is necessary to study the interaction of the jet with the surface of the solid phase particles.

In order to assess this interaction it is necessary to know the characteristics of spreading of free axially symmetric jets.

Main material and results.

The model of the propagation of the jet injection in the soil was taken as an analysis object. Under the injection jet it is considered the jet that goes from the injector into the thickness of the material, with a shape that is characterized by a length L and propagation diameter D0. The model of conical jet allows to analyze the mechanisms of its propagation depending on the pressure. The form of propagating jet in the form of a cone assumes that, depending on the width of its propagation, in its volume, the fluid phase is in the free state, in the form of polyabsorption layers and a monoabsorption layer in close proximity to the apex of the cone. At the fluid discharge from the injector in heterogeneous environment, by virtue of obstacles, there is a pressure on certain areas. Based on this assumption, we conditionally allocated four zones that characterize the gradual spread of the fluid phase to a solid medium at ρ = const, fig.1.

Visual observation of the spread of model liquid in the sand at a different time of injection showed the following:

1) for injection into the ground, after some time the solution was showed at a distance from the injector nozzle.

2) a further injection led to the fact that the injectable solution, sealing the sand at a distance gradually began to fill the space near the injector nozzle.

3) observed that the distance from the injector nozzle is observed by filtering the water of the pigment particles.

Depending on the accepted model of fluid phase injection into the solid, one or another mechanism of interaction is proposed. When presentation of soil as a capillary-porous systems the main focuse is made on processes and phenomena that occur in the pores and cavities of various sizes in the propagation of fluid in them. The main factors influencing the spread of fluid in the system include: – discharge pressure effect on the modeling material particles; – a hydraulic pressure of the fluid and its migration to the weak places; – capillary effects associated with changes in pressure, depending on the concentration of the fluid; – osmotic phenomena associated with the occurrence of concentration gradients of pore fluid; – crystallization pressure that occurs during chemical reactions of hydration.

In the event of adoption of a fictitious soil model as a two-component system, consisting of a matrix in which the distributed switching (sand), the main attention is devoted to the differences in the absolute values of grain parting coefficients of matrix and impurities of the material.

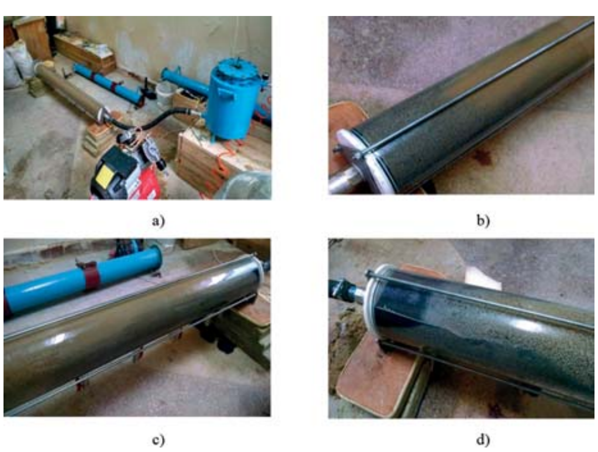

Figure 1. Visual monitoring of the spread of model liquid in the sand at different injection time:
a) general view of the installation; b) distribution of the liquid in the initial period of injection;
c) distribution of filtered water along the length of the tube;
d) soil compaction and sedimentation near the injector nozzle

Analysis of the structure of moistened (system moisture is about 5-6% by weight) quartz sand (as a false model) sandy soil showed capillary interaction of small particles of sand large. «Adherent» particles form aggregates-globules, which are in turn building the «arched» structure. This penetration of the fluid under pressure in its pore spaces may lead to a parting of the grains and the violation of their capillary interaction.

Due to the fact that the adhesion strength between particles varies due to the difference in their size, it is logical to assume that the first fluid jet will increasingly lead to a breakdown in communication and greater parting directly at the head of the injector, i.e. where the speed of the outflow is maximum. It may be due to the fact that the adhesion strength of the particles is much lower than jet response force.

For structures composed of discrete units, interacting through the internal interface, the diffusion mass transfer coefficients may vary by orders of magnitude. Therefore, in such cases, it is appropriate to speak not about the local («crevice») mechanism of mass transfer, but the front as wide enough area formed under the effect of gradients jet velocity. Such assumptions allow to extend the idea of distributing a fluid phase jet at different pressures in the discharge of its bulk of the solid. Due to the fact that first of all at samples injecting into thickness the solid particles come into operation, producing surface effects, when selecting the model we will assume that the jet extends deep into the compressed material in the form of a cone. Model of false soil with a single jet in the form of a cone, the base of which is ellipse, shown in Fig. 2a.

In general terms cone surface of the second order is based on ellipse; in a suitable Cartesian system of reference (x-axis and y-axes is parallel to ellipse axis, the top of the cone coincides with the origin, center of the ellipse lies on the axis Oz) its volume equation has the form:

$$V_{cm} = \tfrac{1}{3}\pi\, Rr\cdot H = \tfrac{1}{3}\pi\, Ox\cdot Oy\cdot Oz = \tfrac{1}{3}\pi\, O_1A_1\cdot O_1C\cdot OO_1$$

In the most general case, when the cone is supported by an arbitrary flat surface, it can be shown that the equation of the lateral surface of a cone (with the vertex at the origin) is given by the equation, where the function is homogeneous, i.e. satisfying the conditionfor any real number α.

As adopted in the terminology and characteristics of the jet in the hydrodynamics it includes present exterior free jet boundaries, which are characterized by their surface area; jet front, defined by its length or length; jet pole, estimated by radius of the pole. At the first stage we will analyze planar (two-dimensional) model of a jet, which is a sectional view of a bulk jet passing through its axis of symmetry (ADB, fig. 2.b). Thus, as the jet model dimensional wedge jet is adopted, which is characterized by the spread diameter (D), a length (L1), exterior boundaries (AB, CD) and the radius of the pole, fig. 2. b.

Let us assume that the diameter of the jet propagation (D) is influenced by the initial velocity of its outflow. The wedge shape of the jet suggests that along its length the speed of propagation varies. Propagation of the fluid in a solid body over time may not match the rate of movement depending on the structure of the matrix material. It is due to the fact that with increasing of particle size of the solid material as the distance from the injector in the volume of the material the propagation velocity decreases. Moreover, it is interesting to note that such jet propagation is observed in the air as well [1]. The adopted jet model and the jet propagation speed change scheme depending on the distance from the pole.

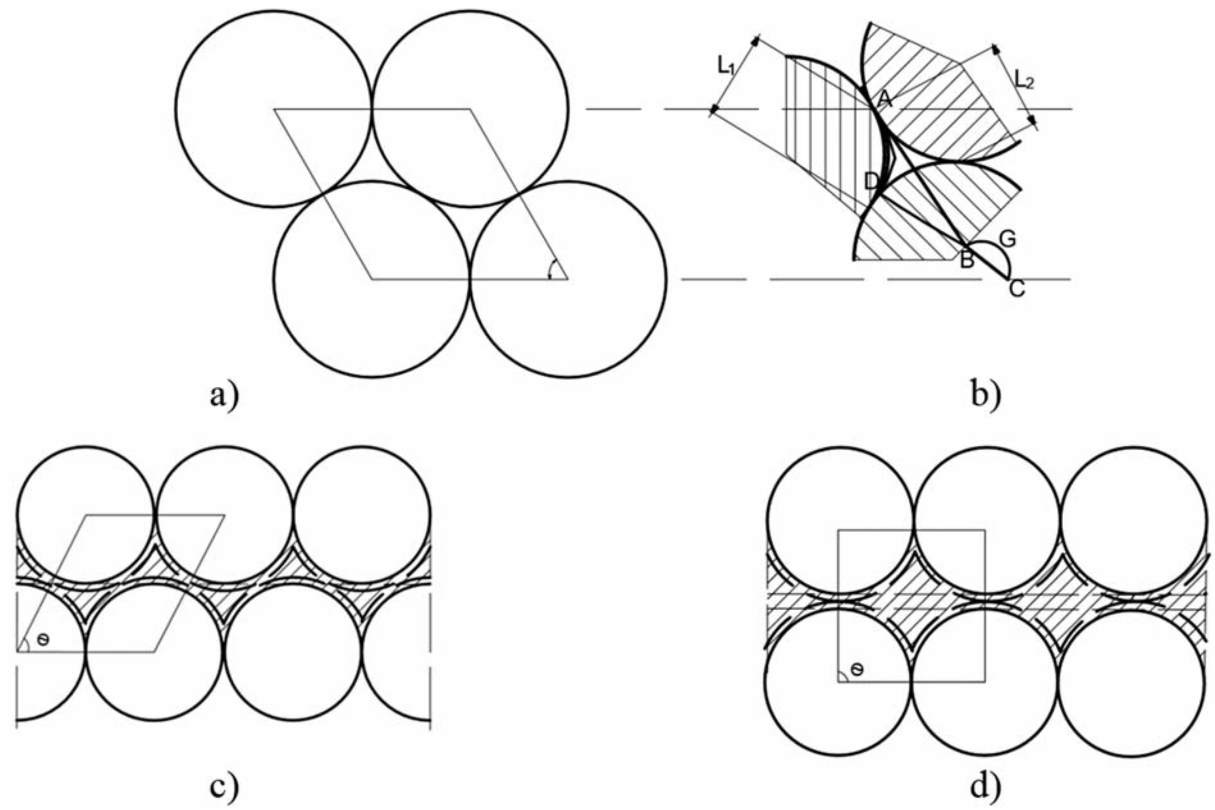

Figure 2. Location of the mineral particles in the fictitious ground:
a) – the displacement of particles at row packaging; b) – the trajectory of the fluid in the pore space;
c) – pores in a fictitious chess packaging; d) – the pores in the dummy row package

In general, the following areas for the propagation velocity of the jet can be identified

- OE area, wherein the jet has a velocity substantially equal to the nozzle outlet;
- EG area, wherein the jet slows down the speed of propagation due to the frictional forces on the surface of the particles;
- GO1 portion1 wherein the jet practically lost initial kinetic energy, water is in monoabsorption state.

Propagation of the fluid phase in the pores of a solid body suggests that as they reach the point at the distance from the injector to the «end» of the jet in pores pre- saturated by water a gradual change in injection rate occurs depending on the expiration of the initial rate and viscosity.

Conclusions.

The research which were carried out allows us to take for analysis the following jet propagation models in the model soil:

1. Model jet propagation in sand, arranged on a principle «fluid in the solid body» includes jet injections at different levels of structural inhomogeneities due to its propagation. The analysis allowed simulate jet which, depending on the distance from the injector changes the propagation form and speed. Such jets includes jet, the propagation of which took place at a pressure = const.

2. As a jet model a two-dimensional wedge-shaped jet with fixed parameters is adopted. The wedge shape of the jet is taken on the assumption that along its length, due to changes in the distance from the injector, its speed reduces due to increasing friction with the soil particles. At that, changes of communication between the soil particles occur between the opposite shores. It involves changing of the radius of the propagation by length of the jet.

References:

1. Kostryukov V. A. Osnovy gidravliki i aerodinamiki / V.A.Kostryukov. – M.:Vysshaya shkola, 1975. – 220 s.
2. Proizvodstvo gidrotexnicheskix rabot: Chast 2. Proizvodstvo podzemnyx rabot i specialnye sposoby stroitelstva / Pod red. M. G. Zercalova. – M. : Izdatelstvo associacii stroitelnyx vuzov, 2012. – 328 s.
3. Пухов П. П. Некоторые пути повышения производительности при добыче песчано-гравийной смеси / П. П. Пухов, В. В. Королев // Сб. науч. тр. ГИИВТа. – Горький: ГИИВТ, 1973. – № 135. – С. 81 – 86.
4. Камбефор А. Инъекция грунтов / А. Камбефор. – М. : Энергия, 1971. – 333 с.
5. Дьячков Ю.А. Моделирование технических систем / Ю.А. Дьячков, И.П. Торопцев, М.А. Черемшанов. – Пенза, 2011. – 239 с.
6. Fernando V. Use of cavity expansion theory to predict ground displacement during pipe burstening / V. Fernando, Ian D. Moore // Pipelines 2002: Beneath Our Feet: Challenges and Solutions. – 2002. – P. 1 – 11. – Режим доступа: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.610.9587&rep=rep1&type=pdf
7. Головко С. И. Основы физического моделирования процесса цементации грунта / С. И. Головко, Н. Е. Шехоркина // Современные проблемы строительства. – Донецк, 2013. – Вып. 16. – С. 53 – 56.
8. Bearing capacity improvement of loose sandy foundation soils through grouting / T. G. S. Kumar, B. M. Abraham, A. Sridharan, B. T. Jose. // International Journal of Engineering Research and Applications. – 2011. – Vol. 1, Issue 3. – P. 1026 – 1033. – Режим доступа: http://www.ijera.com/papers/vol%201%20issue%203/XO01310261033.pdf
9. Collins I. F. Cavity expansion in sands under drained loading conditions / I. F. Collins, M. J. Pender, Y. Wang // International journal for numerical and analytical methods in geomechanics. – 1992. – Vol. 16(1). – P. 3 – 23. – Режим доступа: http://onlinelibrary.wiley.com/doi/10.1002/nag.1610160103/full