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Measuring the soil compaction zone and pressure of deformed soil on underground objects with an asymmetric cylindrical tip

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Annotation. Problem. The main disadvantages of the method are the low accuracy of the trajectory and the significant stress in the soil after its compaction, which can lead to the destruction of adjacent underground objects. The first disadvantage is solved by controlling the trajectory of the soil-piercing working body. To solve the second question, it is necessary to know and take into account the specifics of the formation of communication cavities in the soil with an asymmetric tip, which is used for this purpose. **Goal.** The aim of the work is to establish the regularity of the process of soil puncture by the soil-piercing working body with an asymmetric tip in the form of a cylinder cut at an angle. **Methodology.** The approaches adopted in the work to solve this goal are based on the theories of deep soil cutting, scientific foundations of soil mechanics, their normative physical and mechanical properties and the law of conservation of soil mass before and after compaction. **Results.** The calculated dependences for determining the size of the destructive zone from the elastic-plastic deformation of the soil during its puncture by an asymmetric tip with a frontal surface in the form of a beveled cylinder and the pressure of the deformed soil on underground objects are obtained. It is established that the maximum size of the destruction zone and its pressure on underground objects will occur in solid sand. With a tip diameter of 0.3 m, their values can reach 5 m and 0.245 MPa, respectively. **Originality.** The obtained regularities of soil puncture by a working body with an asymmetric tip in the form of a beveled cylinder made it possible to get an idea of the influence of its deformed state on adjacent communications depending on geometric parameters of the tip and physical and mechanical properties of soils. **Practical value.** The obtained results can be recommended in the design and determination of technological capabilities of installations for static soil puncture.

Key words: trenchless technologies, soil puncture, soil compaction, engineering communications, horizontal well.

Introduction

Among the existing technologies of developing horizontal wells for trenchless laying of utilities, the method of static soil puncture is the most common. Its main disadvantages are the low accuracy of the trajectory and the significant stress in the soil after its radial compaction with a conical tip, which may cause the destruction of adjacent underground communications and other objects. If the first disadvantage can be solved due to the controlled puncture of the soil, the

second disadvantage must be taken into account considering the specifics of the asymmetric tip, which is used. Getting the idea of the level of density and pressure of deformed soil on underground objects with an asymmetric cylindrical tip will improve the quality of work and save from destruction the adjacent communications or other underground structures that occur in the way.

Analysis of publications

Horizontally directed well drilling and controlled drilling of the soil are currently the main directions for development of trenchless technologies of laying communications. The initial stage of development of communication cavities in the soil for both methods is formation of a leading horizontally directed well with a project-defined trajectory of future networks running.

The process of advancing the working body of cylindrical shape and the resulting resistance forces which is determined by the parameters of the working body and the properties of the developed soil is described by the authors in [1, 2].

In works [3] the systematic approach to choosing the method of work is considered with the detailed analysis of advantages and disadvantages of various methods of well development. Trenchless technologies of construction and repair of linear-long pipelines are dealt with in the studies resulted in works [4–6]. The research in [3] is devoted to choosing the method and planning of especially responsible works performed during trenchless laying of underground communications.

Purpose and Tasks

The goal of the work is to determine the density and pressure of deformed soil on underground objects with an asymmetric cylindrical tip.

In accordance with this goal, the dependence should be determined to establish the scale of the change in soil density around the asymmetric cylindrical tip and the pressure of deformed soil on underground objects and adjacent utilities, taking into account physical and mechanical properties of soils and geometric parameters of the soil-piercing tool tip.

Measuring the zone of soil density when it is punctured by an asymmetric cylindrical tip

The object of this study is a soil-piercing working body for static controlled formation of a well in the soil using a soil-piercing working

body with an asymmetric tip.

A schematic representation of an asymmetrical cylindrical tip with a beveled front surface is shown in Fig. 1.

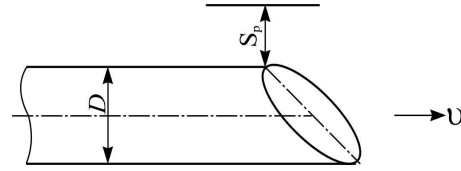


Fig. 1. Scheme of an asymmetric cylindrical tip

Based on the law of conservation of soil mass before and after destruction in accordance with (Fig. 1) we have:

$$\left(\frac{\pi D^2}{4} + DS_p \right) \rho_{ns} = D \int_0^{S_p} \rho_x dx, \quad (1)$$

where S_p is the soil destruction zone; ρ_x is variable soil density along the length of the destruction zone; ρ_{ns} is the soil density in its natural state.

In this expression $\frac{\pi D^2}{4} + DS_p$ is the cross-sectional area of the soil before destruction.

In the first approximation, the regularity of the change in density of the soil mass ρ_x can be assumed to be linear depending on the distance to the side wall [17] (Fig. 2):

$$\rho_x = \rho_{\max} - (\rho_{\max} - \rho_{ns}) \frac{x}{S_p}, \quad (2)$$

where $\rho_{\max}$ is the maximum density of the soil in the side wall of the hole, which acts when $x = 0$ and is in the opposite direction from the bevel of the front surface of the cylinder.

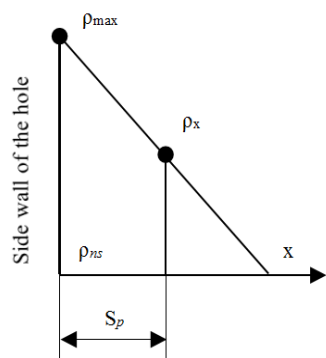


Fig. 2. Regularity of changes in soil density in the zone of destruction

Determining the deformed soil pressure on underground objects during its puncture with an asymmetric cylindrical tip

If $x = 0$, then $q_{\max} = (0.126 \dots 0.23) E_s$, MPa – for solid sand; $q_{\max} = (0.081 \dots 0.148) E_s$, MPa – for semi-solid loam; for tough clay it is $q_{\max} = (0.057 \dots 0.104) E_s$ MPa.

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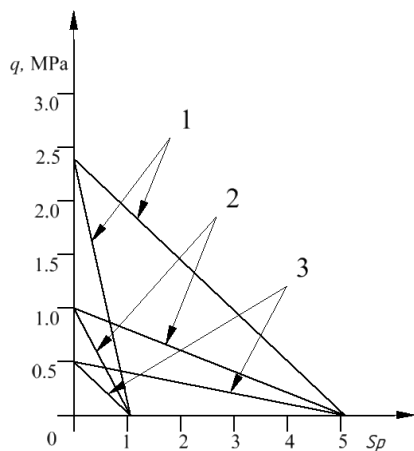


Fig. 3. Dependence of the change in soil density in the zone of destruction for diameters of the tip $D = 0.13$ m and $D = 0.325$ m in its different types: 1 – in solid sand; 2 – in semi-hard loam; 3 – in tough clay

The average maximum pressure in this case will be in close proximity to the tip and is 0.245 MPa in the formation of a well in hard sand, 0.103 MPa – in semi-hard loam and 0.050 MPa – in tough clay, Table 1.

Table 1. Indicators of statistical significance of regression coefficients

Type of transport	Coefficient of determination	Standard error (million pass.)	The average error of approximation
Railway	0.9697	1.97	0.68 %
Road transport	0.941	4.41	0.52 %

The obtained pressure values allow to calculate the strength of the communications adjacent to the route or other underground objects and to establish the distance to them. This is especially important when developing soil cavities in dense urban conditions.

Conclusion

From a comprehensive analysis of the technical literature, it was determined that the expansion of the most effective and most common static method of soil puncture in trenchless utilities is possible by increasing the puncture distance through controlling the trajectory of the working body. Its tip should have an asymmetrical shape, one of them is a cylinder with a beveled front surface.

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The obtained ideas of the regularities of formation of soil consolidation zone and the zone of pressure from its deformation on underground objects from the action of an asymmetric cylindrical tip on it can be recommended for consideration at designing and executing works at trenchless laying of underground communication networks.

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Conflict of interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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Визначення величини зони ущільнення ґрунту та тиску деформованого ґрунту на підземні об'єкти асиметричним циліндричним наконечником

Анотація. Проблема. Головними недоліками методу є низька точність траєкторії та значне напруження в ґрунті після його ущільнення, яке може привести до руйнування прилеглих підземних об'єктів. Перший недолік вирішується керуванням траєкторії руху ґрунтопроколюючого робочого органу. Для вирішення другого питання треба знати та враховувати специфіку формування комунікаційних порожнин в ґрунті асиметричним наконечником, який для цього використовується. **Мета.** Метою роботи є встановлення закономірності процесу проколу ґрунту ґрунтопроколюючим робочим органом з асиметричним наконечником у вигляді зрізаної під кутом циліндру. **Методологія.** Прийняті в роботі підходи до вирішення поставленої мети базуються на уявленнях теорій глибокого різання ґрунту, наукових основ механіки ґрунтів, їх нормативних фізико-механічних властивостей та закону збереження маси ґрунту до його ущільнення та після. **Результати.** Отримані розрахункові залежності для визначення розміру руйнуючої зони від пружно-пластичної деформації ґрунту при його проколі асиметричним наконечником з лобовою поверхнею у вигляді скошеного циліндру та тиску деформованого ґрунту на підземні об'єкти.

Встановлено, що максимальний розмір зони руйнування та його тиску на підземні об'єкти будуть виникати в твердому супіску. При діаметрі наконечника 0,3 м їх величини можуть досягати 5 м та 0,245 МПа, відповідно.

Оригінальність. Отримані закономірності проколу ґрунту робочим органом з асиметричним наконечником у вигляді скошеного циліндру надали можливість отримати уявлення про вплив його деформованого стану на прилеглі комунікації залежно від геометричних параметрів наконечника та фізико-механічних властивостей ґрунтів у яких він відбувається.

Практичне значення. Отримані результати можуть бути рекомендовані при проектуванні та визначенні технологічних можливостей установок для статичного проколу ґрунту.

Ключові слова: безтраншейні технології, прокол ґрунту, ущільнення ґрунту, інженерні комунікації, горизонтальна свердловина.

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