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TECHNOLOGICAL PROCESS AND EQUIPMENT FOR ELECTRIC-DISCHARGE LOCAL SOFTENING OF SOILS HAVING DIFFERENT STRENGTH AND STRUCTURE

An electric-discharge technique for local softening of soils has been developed; a pilot mobile high-energy electric-discharge generator with controlled energy release has been produced. The proposed equipment and technique make it possible to save construction materials and to cut the cost of installation and construction works, in particular, capital investments in alternative energy, industrial and residential construction, as well as in hydraulic engineering in general.

Key words: soil, softening, electric discharge, high-voltage electrochemical explosion.

RELEVANCE OF THE PROJECT

As volumes of earthworks expand, the nature and the quality of works change as a result of toughening requirements for the preservation of environment and landscape and the prevention of imbalance in the shear zones of highlands [1].

The widespread use of solar energy implies the extensive construction works in the areas generally unsuitable for farming, with complex terrain and firm soils, which make it impossible to use the existing mechanical means of excavation. Thus, according to the data of *Belectric* (Germany) to install a solar module with a capacity of 2 MW it is necessary to prepare more than 400 wells having a depth of up to 1 m and a diameter of 0.5 m for driving the module-bearing piles.

At the first phase, the construction of a solar pump station in the Crimea covers an area of more than 80 hectares of hard soil on which the solar modules will be installed. In order to do this it is necessary to excavate more than 50 thousand wells of the above mentioned size. The Crimean solar power station is designed to have a capacity of 80 MW after the completion of works and to consist of 360 thousand ground-based modules located on an area of 160 hectares.

Since the existing rotary drilling machines are not always effective in the areas with complex terrain, are low-productive for large-diameter wells and the explosive techniques are of limited use due to their low controllability and high standards of safety, herein, the authors propose an electric-discharge method which have been tested both for destroying a hard rocky above-ground soil and for deepening a bed [2]. In addition to the abovementioned problems, there are also the problems of local softening the soil for the purposes of civil engineering works (pile driving, foundation bed reconstruction), including construction of roads and bridges in close proximity to the industrial and residential facilities or historic buildings where no seismic load on the ground is allowed.

The development of technique for local softening of soil and the manufacture of mobile compact energy-intensive electric-discharge generator with controlled release of energy are aimed at solving the problem of local softening of soils. This proj-

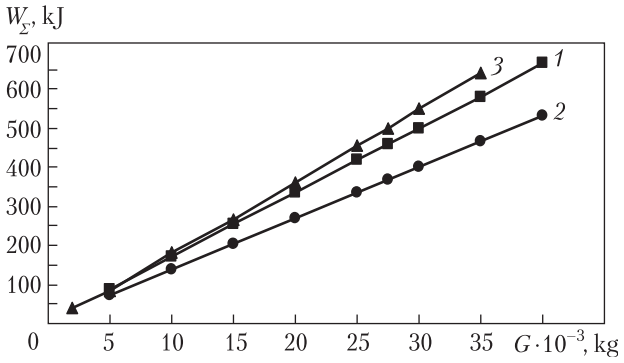

Fig. 1. Dependence of HVEE total energy on HEC mass: *1*) HEC with 60% Al; *2*) HEC with 40% Al; *3*) computed value

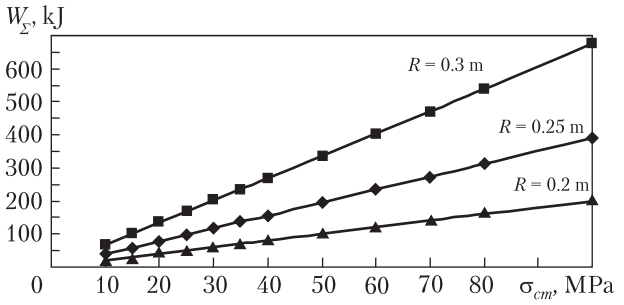

Fig. 2. Determination of required energy W_Σ for the destruction of soil having different strength for the following radiuses of disruptive action: R = 0.2; R = 0.25; R = 0.3 m

ect will contribute to saving on the use of building materials and cutting the cost of installation and construction works, including investments in alternative energy resources, as well as in industrial, residential, and hydraulic engineering, in general.

The project objective is to develop a technique for local softening of soils having different strength and structure, as well as a mobile compact equipment for its implementation.

The Institute of Pulse Processes and Technology (IPPT), NASU, has developed a method of soil destruction based on the use of high-voltage electrochemical explosion (HVEE) technique applying for destroying soils and rocks of natural and artificial origin. The tests have showed good prospects for the application of this method due to a significant energy release and a compact size of electrical equipment.

DESCRIPTION OF THE PROJECT RESULTS

As part of this project a complex research, engineering, and design works aimed at solving the problems of local destruction of soils have been carried out. Using a pulsed high-voltage discharge as a source of high-density energy the optimum parameters of HVEE in a closed environment have been studied; established dependence of total energy release on the mass of high-energy compound (HEC) [2]:

$$W_\Sigma = G \cdot w_\tau \left(1 + \frac{\mu}{w_\tau}\right), \qquad (1)$$

where W_Σ is HVEE total energy, J; G is HEC mass kg; w_τ is relative efficiency of chemical energy conversion, J/kg; and μ is HEC specific electrical combustion efficiency, J/kg.

The dependences of HVEE total energy on HEC mass measured and computed for the HEC with 60% Al and 40% Al are showed in Fig. 1.

An electrode system has been designed; the dependence of radius of disruptive action on HVEE parameters and soil strength has been established:

$$R_p = \sqrt{B_e \cdot \frac{G \cdot w_\tau (1 + \frac{\mu}{w_\tau})}{\sigma_{st} \cdot h_w}}, \qquad (2)$$

where R_p is radius of soil destruction, m; V_e is coefficient of energy balance depending on the completeness of HEC combustion and the number of the longest cracks; for the closed volume V_e = 8; σ_{st} is compressive strength limit, Pa; h is depth of the hole, m.

The energy required for the destruction of soils having different strength to a depth of h = 0.5 m with a given radius of disruptive action has been computed. The results are showed in Fig. 2. A technique and technical documentation for a prototype mobile equipment have been elaborated. An *EDG*1 prototype has been manufactured and tested (Fig. 3).

The industrial tests have confirmed the effectiveness of the prototype for the destruction of soils of

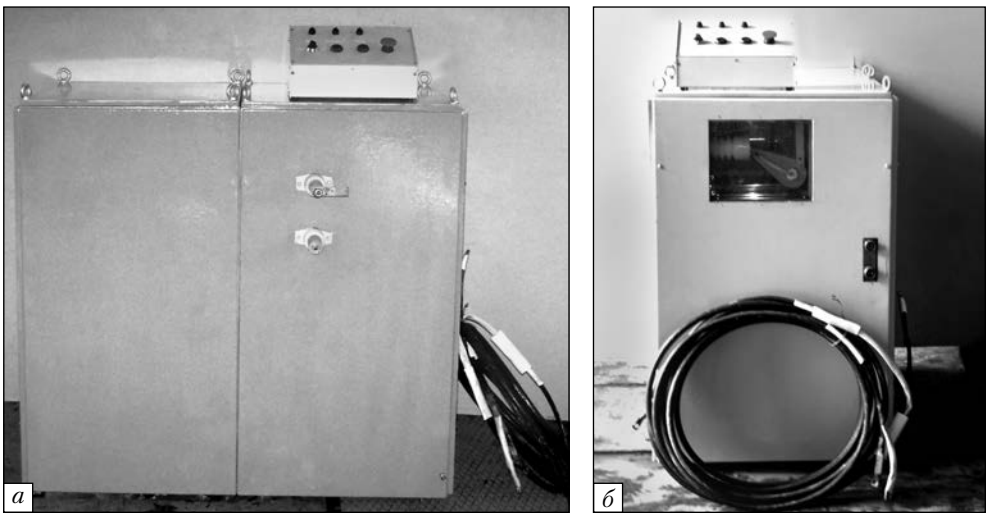

Fig. 3. Appearance of EDG1

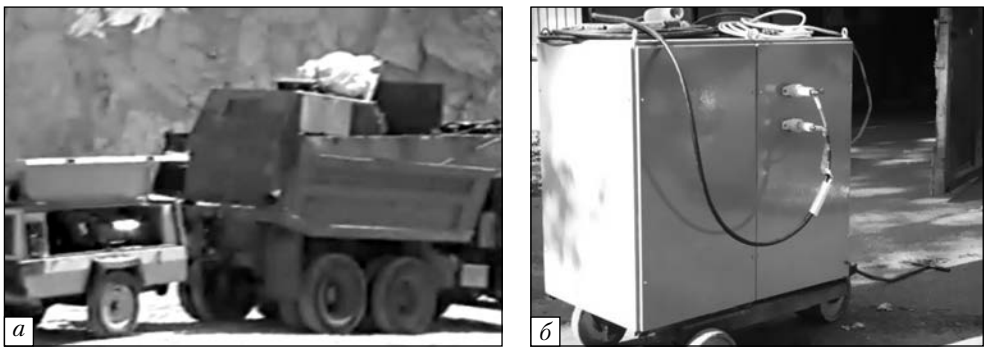

Fig. 4. Difference in transportation of *Basalt* ED Unit (*a*) and EDG1 (*b*)

the 4th group of strength; the equipment has proved itself to be reliable and easy to maintain.

EXISTING DOMESTIC AND FOREIGN ELECTRIC-DISCHARGE GENERATORS (EDG)

Analysis of patent documents show that the problem of local softening of soils is very relevant. The widespread use of solar energy implies a significant volume of construction works in the areas unsuitable for farming and having difficult terrain and firm soils. The effective earthworks in these soils require the development of innovative methods of soil destruction based on the results of the latest scientific research, cutting-edge techniques, and special machinery driven by physical effects.

The patent search has showed that the inventive activities related to electric-discharge softening of soils having different structure and strength are carried out in Ukraine, UK, Germany, Russian Federation, and Japan. However, the known technical proposals do not deal with local softening of soils. The developed technique makes it possible to ensure with a high-voltage pulse energy up to 7 kJ a complete combustion of exothermic mixture and a release of up to 500 kJ energy that is sufficient for softening of soils of different strength and structure, to locate the discharge channel in the hole according to the scope and configuration of soil destruction. These technique

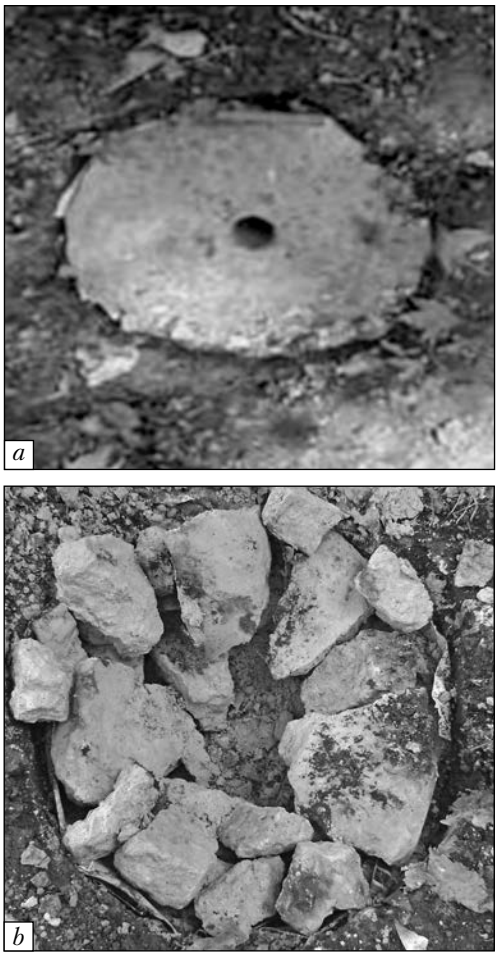

Fig. 5. Soil before and after the destruction by one electric discharge: (*a*) a rock before treatment, (*b*) the same rock after treatment

***EDG1* Main Technical Characteristics**

Parameter	Value
Nominal stored energy, kJ, at least	6.0
Total power, kW, at least	5
GIS dimensions, m, max	1.2 × 0.7 ×1.25
Length of electrode system cable, m	25
Mass, kg, max	300
Mass of electrode system, kg	21
Rated operational voltage, V	25000
Average current in network, A	40
Power supply, V	220

is based on the use of compact mobile equipment with controlled release of energy. This technical solution is much more effective than the existing analogues of domestic and foreign production. Its novelty has been patented in Ukraine [3].

KEY ADVANTAGES OF EQUIPMENT

Unlike the existing domestic- and foreign-made electric-discharge equipment for destroying nonmetal materials of natural and artificial origin (rocky soils, concrete and reinforced concrete structures, etc.), which cannot be modified at the customer request without significant extra cost. The proposed technique and equipment are flexible and adaptable to the majority of soils. The *EDG*1 designed at the IPPT NASU ensures up to 500 kJ energy release by HVEE method.

The compact mobile equipment for local softening of soils developed within the framework of the project constitutes a practical value of the project.

As compared with known *Basalt* equipment (Fig. 4) the energy consumption of electrochemical process decreased 12 times: from 0.019 kW · h to 0.0016 kW · h (power consumption per a discharge is 90 kJ and 6 kJ, respectively).

The implementation of technique for local softening of hard soils by high-voltage electrochemical explosion involves the use of compact mobile equipment, the number of capacitors in which is 5-time less (25 in *Basalt* versus 5 in *EDG*1). Given the cost of capacitors IK 25–3.9 (UAH 20 000 per unit) the proposed technique allows the customer to save UAH 400 000. The equipment mass decreases 10 times: from 3,000 to 300 kg, which can significantly reduce the cost of transportation and maintenance. The main technical characteristics of equipment are given in Table.

THE PARTNERS

The project partner of IPPT NASU was *VKP REMBUD*, LLC, which contributed to the project results through performing the following activities:

- Provision of information on the experience related to long-term operation of electric-discharge equipment for destroying the blocks of natural and artificial origin;
- Supply of materials for research;
- Training, support, and participation in testing the technique and equipment.

OPPORTUNITIES FOR EDG1 APPLICATION

Figure 5 shows an example of local destruction of soil having a strength of 40 MPa for the installation of solar module supporting pillar. One can see the formation of radial cracks that reach a critical size. This helps to create conditions for further development of hole without the use of heavy machinery.

Among the users of equipment might be local and foreign firms dealing with installation of solar modules, construction companies and various civil engineering, industrial, and hydraulic engineering companies.

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ТЕХНОЛОГИЧЕСКИЙ ПРОЦЕСС И ОБОРУДОВАНИЕ ДЛЯ ЭЛЕКТРОРАЗРЯДНОГО ЛОКАЛЬНОГО РАЗУПРОЧНЕНИЯ ГРУНТОВ РАЗЛИЧНОЙ ПРОЧНОСТИ И СТРУКТУРЫ

Разработан технологический процесс электроразрядного локального разупрочнения грунтов и изготовлен опытный образец специального мобильного малогабаритного высокоэнергоемкого электроразрядного генератора с управляемым выделением энергии, предназначенного для его реализации. Применение предлагаемого оборудования и технологии позволит значительно снизить объем строительных материалов и уменьшить стоимость монтажно-строительных работ в частности и капитальных вложений в альтернативную энергетику, промышленное, жилищное и гидротехническое строительство вообще.

Ключевые слова: грунт, разупрочнение, электроразряд, высоковольтный электрохимический взрыв.

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ТЕХНОЛОГІЧНИЙ ПРОЦЕС ТА ОБЛАДНАННЯ ДЛЯ ЕЛЕКТРОРОЗРЯДНОГО ЛОКАЛЬНОГО ЗНЕМІЦНЕННЯ ҐРУНТІВ РІЗНОЇ МІЦНОСТІ І СТРУКТУРИ

Розроблено технологічний процес електророзрядного локального знеміцнення ґрунтів та виготовлено дослідний зразок мобільного енергоємного електророзрядного генератора з керованим виділенням енергії. Застосування пропонованого обладнання і технології дозволить значно знизити об'єм будівельних матеріалів та зменшити вартість монтажно-будівельних робіт зокрема і капітальних інвестицій в альтернативну енергетику, промислове, житлове та гідротехнічне будівництво взагалі.

Ключові слова: ґрунт, знеміцнення, електророзряд, високовольтний електрохімічний вибух.

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