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Theoretical Justification of Stresses Generated in the Working Equipment of the Hole Opener Weapon

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Abstract: In the article, resource-saving techniques and technologies for creating high-quality hole drainage in the subsoil layer of saline lands, as well as scientific methods of creating a new generation of modern preparations (liquids) that increase the porosity of the soil and ensure easy absorption of salts into the subsoil layer, and new generation of spraying techniques aimed at the development of the technical basis, the forces acting on the borehole openers, which served to wash the seepage waters under the saline soils, were analyzed.

Keywords: water, soil, saline wash, hole, round, drainage, conical cylinder.

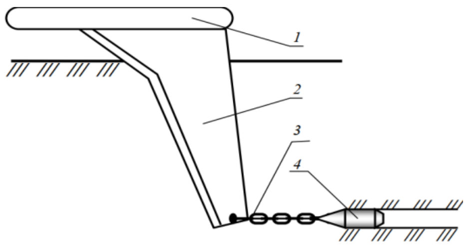
The fact that the current water supply is decreasing requires us to create water- and resource-efficient techniques and technologies. The irrigated land area in the republic is 4.3 million hectares, on average 90-91% of the total water resources are in agriculture, 4.5% are in the communal household sector, 1.4% are in industry, 1, 2 percent was used in fisheries, 0.5 percent in heat energy, and 1 percent in other sectors of the economy. The territory of the republic has its own soil and climatic conditions, and as a result of the lack of natural drainage and the high level of mineralization of underground water, a number of areas are "primarily saline". At the same time, as a result of improper use of water resources and the negative effects of other anthropogenic factors, "secondary salinization" of land is observed in some regions, and 45.7 percent of the irrigated land area is salted to varying degrees. "Sufficient attention is not paid to the preparation of land for salt washing and the systematic organization of salt washing works, their quality and water consumption control. As a result, agroclusters, farmers and peasant farms prepare land for salt washing and wash salt, especially in the northern districts of the Republic of Karakalpakstan, Jizzakh and Syrdarya regions, as well as in Bukhara, Navoi, Fergana and Khorezm regions. In most districts, agrotechnical rules and deadlines are grossly violated, water wastage is allowed, and the effectiveness of salt washing remains low.

85.8% of the 274,612 hectares of irrigated land in Bukhara region have varying degrees of salinity. Therefore, every year, salt washing works are carried out on 180,000 hectares of cultivated land.

In the main irrigated areas of the Central Asian countries, drains are built in order to raise the underground seepage water and effectively organize the salt washing process. Some lands are not saline, but due to the rise of groundwater, the lands become saline, which has a negative effect on the cultivation of agricultural products. In such areas, hole drainage (without filter materials and pipes) is used in drainage construction machines, with the help of which holes are created at a depth of 1-1.2 m and the level of underground seepage water is lowered for a certain period of time.

With the help of tools that create a perforated pipe, holes with a cylindrical cross section are created at a depth of 0.6-0.7 m in the soil layer. Depending on the shape of the working body, perforated pipes can also be made with a round cross-section. Machines that make round holes are called hole punchers or punchers. Perforated pipes serve to reduce and aerate water in the subsoil layer, to maintain moisture in the layer, and to improve the heat and nutrient regimes of the soil. If the surface of the field is uneven, the pipes are laid with a slope of up to 0.002 so that water does not accumulate. The creation of a perforated pipe together with an open network or pipe allows to extend the distance of the channels. As a result, the expenses for the removal of water-soluble salts in the soil and for the drainage network are reduced.

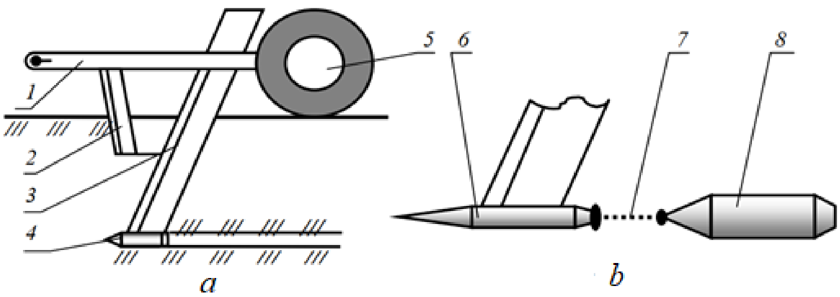
The frame is attached to the tractor base (1) with working equipment. The suspension mechanism ensures the movement of the working equipment along the vertical plane, ensures the working and transport conditions of the equipment, the depth and slope of the hole drainage formation. In the forward movement of the machine (2), the blade cuts the soil vertically, in softened soil, the hole opener (4) connected to the blade (3) by a chain creates an artificial hole drainage.



Frame 1; 2nd blade; 3-connecting chain; 4-hole opener

Figure 1. Scheme of the working equipment of the machine that creates a suspended artificial hole drainage

Below we present the work equipment integrated in this type of machine. The machine consists of (1) frame, (2) disk or knife root cutter, (3) main blade, (4) hole opener, (5) support wheel. The hole opener (4) is fixed to the main blade and is fixed. The resulting hole drainage depth is made by changing the depth of the main blade into the soil relative to the frame.



Frame 1; 2nd root is sharp; 3rd main blade; 4-hole opener; 5th base wheel;

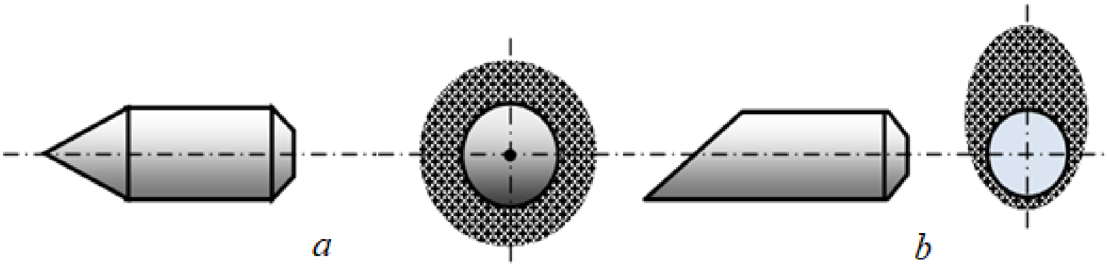
6-front hole opener; 7th chain; 8-back hole opener

a) with one hole opener; b) with two hole openers

Figure 2. Schematic diagram of semi-suspended hole drain forming machine

Double hole opening equipment is used to create large diameter hole drains. The front hole opener is fixed to the main knife mounted on the frame of machines with this type of work equipment (6) and the rear hole opener (8) is connected by means of a chain (7).

Hole openers with a conical tip and cut horizontally at an acute angle are used to create hole drains.



a) conical tip; b) hole opener cut lying at an acute angle

Figure 3. Hole opener types and the scheme of formed holes

The considered hole is distinguished by artificial hole drainage created by openers. The reinforced walls of the perforated drain make it difficult for seepage of storm water. Leaving the walls empty will shorten the service life of the perforated drain, that is, cause it to collapse. For this reason, the hole opener is constructed in several ways.

Another type of artificial hole punching equipment is a machine with a hole opening knife. The working device is fixed to the frame and creates an artificial hole drainage from the advancing movement of the pulling machine. The difference of the formed drainage from the previous ones is the strength of its wall and the lower part. The flow of seepage water seeps through the upper part of the drain and becomes easier to take the direction of the flow for the strength of the lower part. The disadvantage is that a high power is required from the traction machine, because the resistance of the soil to the working equipment is high. In the process of work, the device that creates a hole drainage is average in soils with an average mechanical composition of the soil $\sum F_{tq} = 27 \div 33$ kN resistance force is studied.

The power required during the operation of the device is determined using the following formula.

$$N_{ish} = \frac{\Sigma F_{tq} \cdot V_{ish}}{\eta_{ish}} \text{kVt} \; ; \; N_{ish} = 52 \div 79 \text{kVt} \quad (1)$$

In this: N_{ish} - power required for a hole drain generator, kVt;

V_{ish} - operating speed of the device, m/s;

η_{ish} = 0,80-0,85- useful operating factor of the machine.

$$R_{kes} = \Sigma R_y \cos\beta + \Sigma R_x \sin\beta , \quad (2)$$

ΣR_y , ΣR_x – effort and normal constituents of resistance force, N.

$$\Sigma R_y = \frac{N_{ish}}{\vartheta} , \quad (3)$$

in this N_{ish} – power consumption of the work equipment, Vt.

ϑ – the speed of the car, m/s.

The resistance strength of clay soil, i.e. soils with high humidity, is determined as follows

$$F_p = 2 \cdot 10^3 P_k \cdot A_{yu} \quad (4)$$

$A_{yu} = \frac{\pi d^2}{4}$ – surface of the cross-section of the formed perforated drainage, m^2.

in this d_m – the diameter of the perforated drain, m.

We determine the tensile strength of the steel rope connecting the work column and the conical cylinder using the following expression.

$$F_{tro} = \frac{K_a \ell_a + K_a^{/}}{1000}, \qquad (5)$$

in this K_a - specific resistance of the steel rope, its value of the perforated drain $h_ч$ =0,60; 0,70; 0,80; 0,90; 1,0 m according to their depth K_a=58; 53; 49,1; 47,6; 46,5 MPa is equal to the location depth of underground seepage waters, varies depending on the relative resistance of the steel rope. The length of the steel rope used to connect the working column to the tapered cylinder (ℓ_a),the following condition $\ell_a \geq (0{,}1 - 0{,}15)$, m based on.

$K_a^{/}$ – the initial specific resistance force in traction, Pa.

The resistance force of the working column of the device that creates a perforated drain.

$$F_{us} = 10^3 K_k A_d f_m, \qquad (6)$$

in this K_k – specific resistance of soil in compression K_k = 0,01-0,12 Pa;

A_d – surface softened by the working body, m^2;

f_m – coefficient of friction between metal and soil $f_m = 0{,}4 - 0{,}7$.

In order to organize the normal operation of the hole drainage device before autumn salt washing, the physical and mechanical properties of the soil depend on its mechanical composition and salinity level, the depth of processing depends on the correct choice of salt washing method. it is necessary to determine the boundaries and study the dynamics of changes in the amount of harmful salts in the soil before and after salt washing.

In the process of creating a hole drain, we find the surface of the cone part and the cylindrical parts of the hole opener, and the sum of both parts is calculated as the cone-cylinder hole opener working device. Based on the above, the forces acting on the surface of the perforator during the formation of the perforated drainage are calculated.

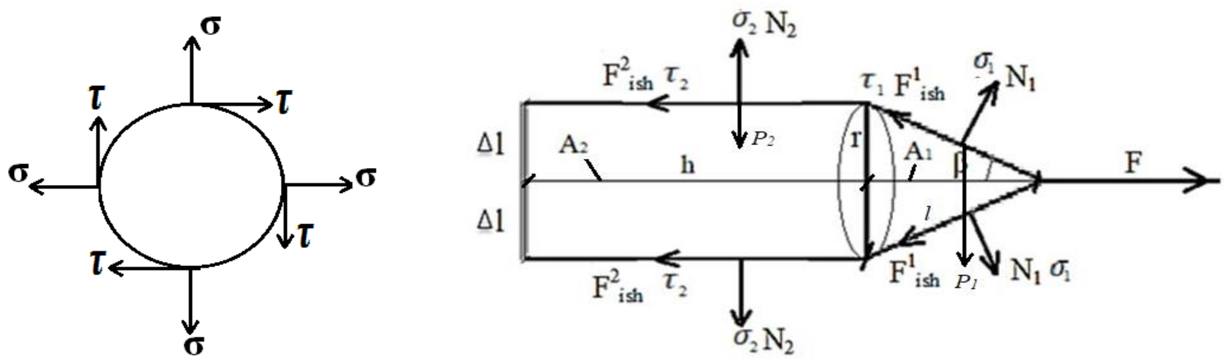


Figure 4. Stresses generated in the tool of the hole opener.

σ – Normal voltage, kN/m^2

τ - Test voltage, kN/m^2

F^1_{ish}, F^2_{ish} – frictional force acting on the hole opener, N

F - The pulling power of the technique, N

d - the height of the cylindrical part of the hole opener (diameter of the opened hole) ,m

$S_k=\pi rl=A_1$, $S_s=2\pi rh=A_2$ (7)

$$\Delta l = r \quad r = l\sin\beta \quad \Delta l = l\sin\beta \qquad (8)$$

S_k- the face of the cone section , m^2

S_s- the surface of the cylinder part, m^2

A_1 – the surface of the cone part of the hole opener, m^2

A_2 – the surface of the cylindrical part of the hole opener, m^2

l- side length of the cone section, m

These indicators can be used to determine numerical values in formulas.

$$F^1_{ish} = \mu P_1\cos\beta \quad F^2_{ish} = \mu P_2 \quad \beta = \frac{\alpha}{2} \qquad (9)$$

P_1 - gravity of the cone part, N

P_2 - the weight of the cylinder part, N

ρ - soil density, kg/m^2

μ - coefficient of friction, %

$$N_1 = P_1 = \rho V_1 g\sin\beta \quad N_2 = P_2 = mg \qquad (10)$$

$$V_1 = \frac{1}{3}\pi r^2 h = \frac{1}{3}\pi r^2 l\cos\beta \quad V_2 = \pi r^2 h$$

N_1 - normal force on the cone section, N

N_2 - normal force on the cylinder part, N

V_1 - volume of cone section, m^3

V_2 - the volume of the cylinder part, m^3

h - the length of the cylindrical part of the hole opener, m

In this process, s normal and t tensile stresses occur under the influence of forces. The normal stress always occurs perpendicular to the surface and serves to compress the soil around 360^0 in the formation of hole drainage, and it has the following form. According to Pascal's law, under the pressure of external forces, it is transmitted equally in all directions, that is, it spreads to every point under the influence of external forces without change. Based on this, the density of the hole created by the cone-cylinder-shaped working device is as follows.

$$F = P S_{um} = \rho g h_{ch} S_{um} \quad S_{um}=A_1+A_2 \quad \rho = \frac{F}{g h_{ch} S_{um}} \qquad (11)$$

F – drag force, kN

P – pressure, Pa

S_{um} – the total surface of the conical cylinder, m^2

h_{ch} – processing depth of the working column, m

The normal and experimental stresses generated in the cone tip part of the working body will look like this,

$$\sigma_1 = \frac{N_1}{A_1} = \frac{N_1}{\pi \mathrm{rl}} \quad (12)$$

$$\tau_1 = \frac{F^1{}_{ish}}{A_1} = \frac{\mu\rho V_1 g\cos\beta}{\pi r l} \quad (13)$$

The normal and experimental stresses generated in the cylindrical part of the working body will look like this

$$\sigma_2 = \frac{N_2}{A_2} = \frac{N_2}{2\pi \mathrm{rh}} \quad (14)$$

$$\tau_2 = \frac{F^2{}_{ish}}{A_2} = \frac{\mu\rho V_2 g\cos\beta}{2\pi r h} \quad (15)$$

The total normal and tensile stresses generated in the impact of the entire tapered cylinder working body will have the following form:

$$\sigma_{\mathrm{um}} = \sigma_1 + \sigma_2 = \frac{N_1}{\pi \mathrm{rl}} + \frac{N_2}{2\pi \mathrm{rh}} = \frac{2N_1 h + N_2 l}{2\pi \mathrm{rlh}} = \frac{\rho g(2hV_1\sin\beta + V_2 l)}{2\pi \mathrm{rlh}}$$

$$\sigma_{\mathrm{um}} = \frac{K}{\omega}\left(\frac{l+2h}{V_1+V_2}\right)\left(\frac{(2hV_1\sin\beta + V_2 l)}{2\mathrm{lh}}\right) \quad (16)$$

$$\tau_{um} = \tau_1 + \tau_2 = \frac{\mu\rho V_1 g\cos\beta}{\pi r l} + \frac{\mu\rho V_2 g\cos\beta}{2\pi r h} = \frac{\mu\rho g(2hV_1\cos\beta + V_2 l)}{2\pi r l h}$$

$$\tau_{um} = \frac{\mu K(2hV_1\cos\beta + V_2 l)(l+2h)}{2lh\omega(V_1+V_2)} \quad (17)$$

$$K = \frac{\omega F}{A_1 + A_2} = \frac{\omega\rho(V_1+V_2)g}{\pi r l + 2\pi r h} \quad (18)$$

$$\frac{\rho g}{\pi r} = \frac{K}{\omega}\left(\frac{l+2h}{V_1+V_2}\right)$$

K- soil hardness, MPa

ω - soil moisture, %

In this process, normal and experimental stresses were studied depending on the density, hardness and moisture of the soil. Taking into account that all working columns of the drilling machine are subjected to the same normal and test stresses in the working device of the hole opener, these calculated formulas were considered relevant for all hole openers.

The research shows that it is recommended to place the hole drainage device at the specified depths perpendicular to the direction of the ditches in the areas where the underground seepage water is located close to the surface and the salinity level is high.

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