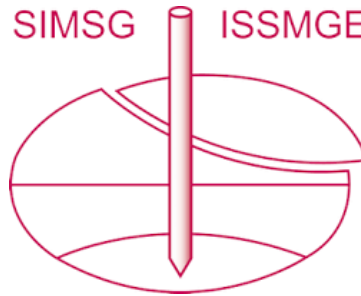


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## PNEUMATIC PUNCHERS USAGE FOR REINFORCEMENT WITH MICROPILES

### REINFORCEMENT DES BASES PAR MICROPIEUX FAITS AVEC POINSONS

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#### SYNOPSIS:

Invented in Russia the pneumatic puncher of the "mole" type is intended for making holes 100-200 mm in diameter, with forcing out of soil and compaction of surrounding massive. There is considered the usage of the reinforced-concrete piles (called "micropiles") of different length, produced in such holes. The calculation method of zone compaction around piles with account of shearing resistance and deformational characteristics of soil is given. There is expounded the experience of buildings bases reinforcement with horizontal, vertical and sloping micropiles and making new foundations with them in the straitened conditions of construction.

In Russia for more than a quarter of a century investigations are being carried out in perfecting pneumatic punchers for punching holes in soil. This invention, made under the leadership of Dr. Sci. (Tech.) A.Kostylev, was patented in 25 countries, 14 licences for "underground Russian rockets" are sold.

Punching of a hole is accompanied by forcing out of soil and compaction of surrounding massive. Usually the holes are used for the tube and cable laying under the roads and other constructions. Scientific Design Production Enterprise "Geotechnic" (Saratov) widely implements pneumatic punchers for making pile in holes, which, due to their small cross-section, are called "micropiles".

These micropiles (cross-section diameter 100-200 mm) are manufactured of concrete or reinforced concrete, both vertical and sloping, and can be up to 10-15 m in length.

The technology of micropiles making in the punched holes consists of the following operations. With the help of compressed air the puncher is immersed in the fixed point through the guiding device to the project depth, and is then extracted out of the formed hole, which is afterwards filled with the corresponding portion of concrete mixture. The repeated immersion presses the mixture to the bottom and the walls of the hole. This results in the compacted zone dimension increase down the hole. If necessary, the armature is put down in the newly built hole and the concrete mixture is laid with bed-after-bed compaction by a depth vibrator.

The main elements of the equipment for the micropile making is pneumatic instrument and an extracting device with a hydraulic station. In the upper cylindrical part of the pneumatic instrument there is a reverse switch and

a link joining the instrument with the extracting device, composed of a support plate and a guiding strut with an alternating angle of gradient. The hydrocylinder with a pulley is mounted on the guiding strut, and the winch placed on the support plate.

The hydrocylinder drive is fulfilled from a pumping station. The construction of the device enables it to extract the working instrument from different depth in case pressure is insufficient for creating the reverse motion.

The depth compaction of the whole pressed base massive may be carried out by layer-after-layer filling of tamped holes with concrete, broken stone as well as local soil or sand. For the formation of the solid compacted area the distance between the axis of the vertical holes in the plan must equal  $0,866D$ , where  $D$  is the diameter of the compacted zone around the hole, determined by the formula (F.Lapshin, 1979)

$$D = d \left[ \frac{6 + c \cdot \operatorname{ctg} \varphi}{6_p + c \cdot \operatorname{ctg} \varphi} \right] \cdot \frac{1 + \sin \varphi}{2 \sin \varphi} \quad (1)$$

Here  $d$  - the hole diameter;

$c, \varphi$  - respectively the cohesion of soil and its angle of internal friction.

The compacting pressure is calculated by the formula

$$\sigma = \sigma_1 + \sigma_2 - 2c \cdot \cos \varphi / (1 - \sin \varphi), \quad (2)$$

where  $\sigma_1$  - the maximum value of the radial tensions, emerging in the "h" depth while passing a hole;

$$\sigma_1 = \left[ \frac{E}{46\rho \cdot (1-\gamma^2) - 2\sigma_0(2-\gamma)} \right]^{\frac{\sin \varphi}{1+\sin \varphi}} \cdot$$

$$\cdot (\sigma_p + c \cdot \operatorname{ctg} \varphi) - c \cdot \operatorname{ctg} \varphi; \quad (3)$$

$\gamma$  - unit weigh of soil;  
 $E, \gamma$  - respectively the deformation modulus of soil and the Poisson's ratio;

$$\sigma_0 = \frac{\gamma \cdot \gamma \cdot h}{1-\gamma}; \quad (4)$$

$$\sigma_p = \sigma_0(1 + \sin \varphi) + c \cdot \cos \varphi. \quad (5)$$

The additional soil deformation in the "h" depth takes place due to the hole widening in the "u" radius value while laying soil, broken stone or concrete with compaction under the action of horizontal stress (F. Lapshin, 1986).

$$\sigma_2 = \left[ \frac{2 \cdot E \cdot u(d-u) / d^2}{26\rho(1-\gamma^2) - \sigma_0(2-\gamma)} \right]^{\frac{\sin \varphi}{1+\sin \varphi}} \cdot$$

$$\cdot (\sigma_p + c \cdot \operatorname{ctg} \varphi) - c \cdot \operatorname{ctg} \varphi. \quad (6)$$

The pitch of the reinforced concrete piles along the length of a building is determined out of the necessity of soil compaction. Fig. 1 shows the different schemes of foundation reinforcement with micropiles which were used by "Geotechnic" in its construction

plots.

While designing the base reinforcement of bearing walls of a four-storeyed building, there were made vertical piles of reinforced concrete, 150 mm in diameter and 4,4 m in length. Clayey soil had the following characteristics:

$$\gamma = 16,8 \text{ kH/m}^3; \quad \varphi = 22^\circ; \quad c = 30 \text{ kPa};$$

$$\gamma = 0,35; \quad E = 5,2 \text{ Mpa}.$$

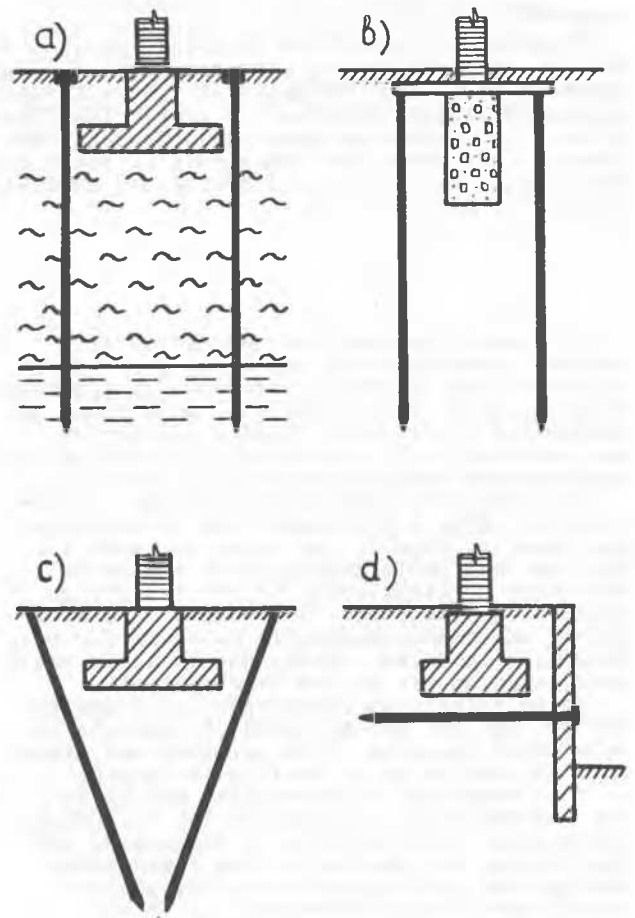


Fig. 1. The schemes of foundation reinforcement with micropiles.

In keeping with formula (1), the diameter of the compacted zone equals 0,994 m  $\approx 1,0$  m. Hence the pile pitch along the building

length is taken for 1 m. The piles bearing capacity was determined according to (Lapshin, 1986):

$$Q = Q_s + Q_p. \quad (7)$$

Side surface resistance of a pile

$$Q_s = \pi d \sum \ell_i (\delta_{p_i} \cdot \tan \varphi_i + c_i), \quad (8)$$

where  $\ell_i$  - the length of a pile section no longer than 1 m, within limits of "i" soil layer.

Resistance under the lower tip of a pile

$$Q_p = \frac{d^2}{n_1} (\delta' + n_2 \cdot c_0), \quad (9)$$

where  $\delta'$  - pressure is calculated by formula (2) for "h" corresponding to the set of a piles lower end by soil characteristics under it;

$c_0$  - cohesion of soil under the piles edge;

$n_1, n_2$  - coefficients defined after (Lapshin, 1986).

$$n_1 = \frac{2 \cdot [1 + \tan(\frac{\lambda}{2} + \varphi_0)]}{\pi [1 + \tan(\frac{\lambda}{2} + \varphi_0)]}; \quad (10)$$

$$n_2 = \frac{2 + \tan(\frac{\lambda}{2} + \varphi_0) + \tan(\frac{\lambda}{2} + \varphi_0)}{2 [1 + \tan(\frac{\lambda}{2} + \varphi_0)]}; \quad (11)$$

$\varphi_0$  - the angle of internal friction of soil under piles edge;

$\lambda$  - angle of edge cone of a pile.

In the project norms for pile foundations, USSR, 1986, for  $\lambda = 90^\circ$ , the coefficient values of  $n_1$  and  $n_2$  are accepted according to Table 1.

| $\varphi_0^\circ$ | $n_1$ | $n_2$ | $\varphi_0^\circ$ | $n_1$ | $n_2$ |
|-------------------|-------|-------|-------------------|-------|-------|
| 4                 | 0,53  | 0,94  | 24                | 0,24  | 0,69  |
| 8                 | 0,48  | 0,88  | 28                | 0,20  | 0,65  |
| 12                | 0,41  | 0,83  | 32                | 0,15  | 0,62  |
| 16                | 0,35  | 0,78  | 36                | 0,10  | 0,58  |
| 20                | 0,30  | 0,73  | 40                | 0,06  | 0,54  |

In the described soil condition the piles bearing capacity equalled  $Q_L = 144,4$  kH. According to these calculations, the vertical load allowable per a described micropile is taken for  $114/1,4 = 81,71$  kH. The testing of tow piles by the static load showed their bearing capacity to be  $Q_L = 137,5$  kH.

The compacted zones dimentions and the effect of base reinforcement with piles was thoroughly investigated when reconstructing the two hostel buildings of medical and polytechnical institutes in Saratov. The five-storeyed brick hostel building of the medical institute has  $77,3$  m x  $15,5$  m plan dimentions. According to its constructing scheme it is frameless with four longitudinal bearing walls and two staircases. There is a lot of vertical and sloping cracks with the aperture width up to 8 mm. The aperture width of temperature joint in the cause of the marked deformation is the presence of soft clayey soil of plastic and yield consistence in the base of strip foundations of the strongly compacted loam of plastic and flowing consistence. Besides, in separate places there was stated the soil porosity increase as a result of mechanical piping.

The underpinning was accomplished after the schemes "Q" and "C" of Fig. 1.

The hole making was carried out with pneumatic punchers, their working organ 150 mm in diameter. The micropiles were made by multi-tudal filling of the punchholes with concrete mixture. The formation around the piles of the compacted zones 6-7 hole diameters, was stated. The physical and mechanical soil characteristics in the compacted zone have considerably grown - unit weight in 1,2 times, cohesion in 1,7 times.

The performed testing of base soil, both natural and reinforced with micropiles by stamps with base square  $A = 3136$  cm<sup>2</sup>, has shown that the deformation modulus has grown in the second case in 2,8 times, and the soil has become medium compacted. Both in this and all other cases the deformation development has ceased after carrying out the works in foundation reinforcement with micropiles.

During restoration of a four-storeyed wrecked building in Voronezh, there was carried out the base reinforcement of highly compressible clayey soil with micropiles 150 mm in diameter. 1065 piles were produced, their pitch from 500 up 1000 mm. The scheme of their arrangement depended on the width of the foundation foot, its deepening in regard to the soil surface and the marks of the basement floor, as well as to the value of base deformation in the described plot. The results of the experimental determination of the soil characteristics changes at different distances from a pile are shown in Fig. 2, where

$\gamma$  - unit weight of soil, kH/m<sup>3</sup>;

$\gamma_d$  - unit weight of dry soil, kH/m<sup>3</sup>;

$e$  - void ratio of soil;

$E$  - modulus of deformation, MPa.

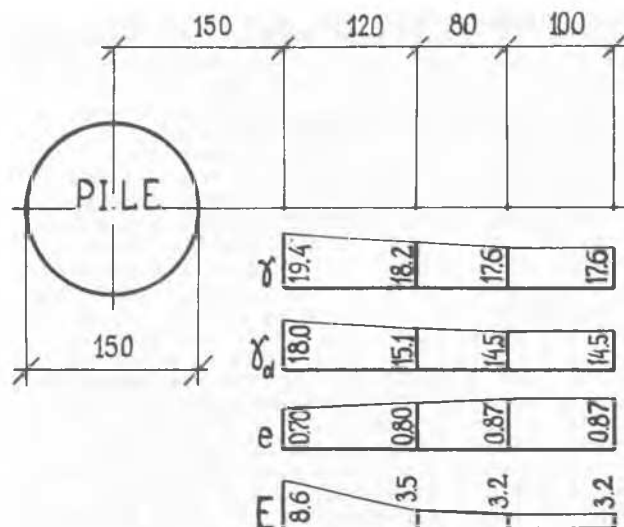


Fig. 2. The points of soil selection and its characteristics

It should be noted that the usage of pneumatic punchers is especially efficient in the straitened conditions of buildings' reconstruction.

#### REFERENCES

- LAPSHIN F.K. (1979). Calculation of Pile Foundation of Ultimate State. Publishing House of Saratov University, Russia. - 152 p. (In Russian).
- LAPSHIN F.K. (1986). Base and Foundation at the diploms design. Publishing House of Saratov University, Russia. - 224 p. (In Russian).