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FINITE-ELEMENT MODELING OF STEADY BOREHOLE STABILIZATION OF SOIL NEAR TUNNEL

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Abstract *Questions of Mechanics and Mathematical Modeling soil with boulder and hardening zone near production by pumping cement through boreholes. Here are the results of the finite-element simulation and calculation of stability of tunnel cross-section of the circuit output when driving through a weakly stable ground. Analyzes the impact of soil stabilization in the picture set of stresses and strains on the perimeter of the circuit. It is shown that an intermediate stage of drilling formations before hardening weakens resistance workings.*

1 INTRODUCTION

In many countries around the world extensively mastered underground space in the national economic and special duty in the big cities, many public facilities are underground, there is an extensive network of public utilities and transport tunnels, subway tunnels on several floors.

As for Kazakhstan, a large part of it, namely, fertile southern areas and industrial development of the East Kazakhstan region are areas of high seismic activity, defined geodynamic regime of the Northern Tien Shan. In the largest city of Kazakhstan Almaty subway construction in earthquake with a magnitude of $M = (7 \div 8)$.

Real environment surrounding the underground structure, often composed of various heterogeneous layers, sometimes very different from each other in physical and mechanical properties. An example of this is the sloping ground stratum layered structure with alternating clusters of boulders in the foothill areas. In the process of making a tunnel drilled in the ground on the way there are a variety of cuts. Deposited clay with gravel, pebbles, sand, etc. depending on the degree of connectivity and related categories techno-plastic and soft-plastic. In these sections there is the problem of preventing the collapse of the dome. In practice, the construction of the underground are weakly stable soils are not uncommon. For example, the area of production of the access shaft art. "Dostyk" in Almaty complex pebbly soil with sandy and sandy loam filler incorporating boulders and sandy layers, water-saturated and a density of up to 2.22 g / cc, with a coefficient of porosity of 0.71, the deformation modulus of 30 MPa, Poisson's ratio 0 , 27, on a scale factor of a stability MM Protodjakonova 1.2 - 1.7 [1-3].

According to Deck company "Almatymetrokurylys" analysis of the conditions of construction showed the need to develop and apply methods of artificial hardening of unstable soils for successful and safe facilities in which developments. Here, for the construction of tunnels with a diameter of 5.5 m accepted way to solid bottom, and for the station tunnels and workings of a similar section tunnel way with preliminary chemical fixing roofs station tunnels. Area trails throughout metro complex less humid incoherent pebble, boulder-clay and boulder bottoms.

All of this suggests that there is a problem of seismic stability of underground structures.

2 STATEMENT OF THE PROBLEM

The paper must be written in English U.K. within a printing box of 16 cm x 24 cm, centred in the A4 page, meaning that margins of 2.85cm should be assigned to the top and bottom and 2.5cm to the right and left. The paper including figures, tables and references must have a minimum length of 6 pages and must not exceed 10 pages, except for Invited lectures that are not subjected to page limits. The style implemented in the Times New Roman or similar, designated further for simplicity just Roman Figure 1a, b, c show the stages of the passage of the extended tunnel axis in the array weak-connection collapsing soil. Tunnel development lies at the depth of the earth's surface. The height and length of the computational domain, and, half-height, width and radius of the arch, respectively: () and (1). The array consists of gravelly-sandy soil with lower elastic properties. Consideration of the stress-strain state (SSS) of the array around loose tunnel using the criteria defined limit equilibrium instability region near the contour. Analyzes the effect of strengthening the stability of the soil around the perimeter of the tunnel.

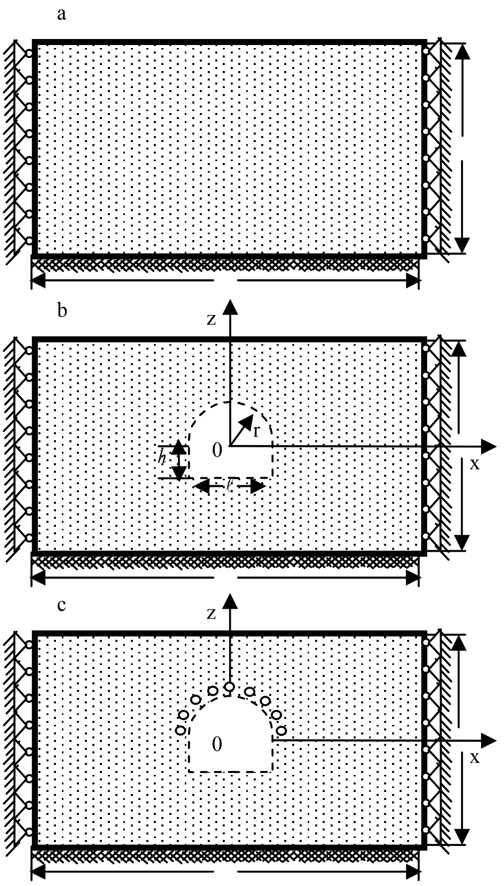

Fig. 1. The computational domain weakly stable array of tunnel excavation. A - plane section of loosely coupled ground array; b - projected contour tunnel with characteristic dimensions; c - space holes in the ground for the construction of the fortifications of the future path..

3 ALGORITHMS FOR SOLVING PROBLEMS AND CRITERIA STABILITY

The area of the weakly bound of the array, as shown in Figures 1a, b, c is modeled by finite element method. The load supports its own weight of overlying layers of the array. The problem is solved in a plane elastic formulation. The equations of static equilibrium are [4, 5]

$$[K]\cdot\{U\}=\{P\} \tag{1}$$

Where is$[K]$ – the stiffness matrix of the system; $\{U\}$ – the displacement vector; $\{P\}$ – vector load of its own weight.

Vector strain and stress are calculated using the expressions:

$$\{\varepsilon\}=[B]\{U\} \tag{2}$$

$$\{\sigma\}=[D]\{\varepsilon\} \tag{3}$$

where is $\{\varepsilon\}=\{\varepsilon_x.\ \varepsilon_z.\ \lambda_{xz}\}$, $\{\sigma\}=\{\sigma_x.\ \sigma_z.\ \tau_{xz}\}$ – the strain and stress; $[B],[D]$ – matrix of base functions and the elastic properties of the elements and $\{U\}$ – the vector displacement nodes split.

Depending on whether you are connected or disconnected ground, select different sustainability criteria [6].

Limit equilibrium conditions for cohesion less soils are of the form

$$\frac{(\sigma_z-\sigma_x)^2+4\tau_{xz}^2}{(\sigma_z+\sigma_x)^2}=\sin^2\varphi \tag{4}$$

For cohesive soil

$$\frac{(\sigma_z-\sigma_x)^2+4\tau_{xz}^2}{(\sigma_z+\sigma_x+2Cctg\varphi)^2}=\sin^2\varphi \tag{5}$$

where is φ – the angle of internal friction, C – friction coefficient.

Another convenient form of criteria expressed in terms of maximum and minimum principal stresses in the form

$$\frac{\sigma_{\max}-\sigma_{\min}}{\sigma_{\max}+\sigma_{\min}+2Cctg\varphi}=\sin\varphi \tag{6}$$

The principal stresses computed by expressions

$$\sigma_{\max,\min}=\frac{1}{2}(\sigma_x+\sigma_y)\pm\sqrt{\frac{(\sigma_x-\sigma_y)^2}{4}+\tau_{xy}^2}$$

$$\tau_{\max,\min}=\pm\frac{\sigma_{\max}-\sigma_{\min}}{2} \tag{7}$$

The angle between the ordinate and the area of the principal stress is calculated using the

$$tg2\alpha=\frac{2\tau_{xy}}{\sigma_x-\sigma_y} \tag{8}$$

Conditions limiting equilibrium finally be formulated as

$$tg\theta_{\max}\le tg\varphi \tag{9}$$

$$\theta_{\max}=arctg\left(\frac{\tau_{\max}}{\sigma_{\max}+2Cctg\varphi}\right) \tag{10}$$

For non-cohesive soils in the criteria (5), (6) and (10) will not appear on the term $2Cctg\varphi$.

4 BACKGROUND AND BOUNDARY CONDITION OF THE PROBLEM

The Shown in Figure 1b size of the computational domain: The height and width of the computational domain are $H=80м$, $L=200м$. Width, height and radius of a set of production respectively $h=r=2.5м$, $\ell=2.5м$.

Physical - mechanical strength properties and weakly stable ground: Young's modulus – $E=78Mna$, Poisson's ratio – $\nu=0.27$, volume weight $-\gamma\cdot10^2=2.25\,Мн/м^3$, angle of internal friction – $\varphi=38^0$, coefficient of coupling – $C=0.036Mna$.

Similarly, the value of physical - mechanical properties of cementation restorative material are, respectively $E=3200Mna$, $\nu=0.25$, $\gamma\cdot10^2=2.5\ Мн/м^3$, $\varphi=35^0$, $C=4.5Mna$.

The boundary conditions of the problem. Ground surface, shown in Figure 1, free of stresses: $\sigma_x=\sigma_z=\tau_{xz}=0$. The base is rigidly fixed $u=\vartheta=0$. At the sides are no horizontal movement: $u=0,\vartheta\ne0$.

The computational domain is divided into 5832 eight unit iso-parametric elements with a total of 17,892 units. Number of fixed nodes on the left and right boundaries of the computational domain of 104 ($U = 0,\ V \neq 0$),and on the basis 204 ($U = 0,\ V \neq 0$).

Therefore, these degrees of freedom minus the number of equations is 2x (17892-408) = 34,968. To solve a system of linear algebraic equations (SLAE) of this order is reasonable to apply the iterative scheme voltage is calculated at 9 points within each iso-parametric element.

Evaluation of the accuracy of calculations. Calculated values σ_z are compared with the value of the voltage γH: the deviation is not more than 1-2%. Error of calculation of stress σ_r in the sides and on the vault of 1-2%, and in the corner areas reached up to 8-10%.

5 BACKGROUND AND BOUNDARY CONDITION OF THE PROBLEM

As a result, the task of the above expressions of the algorithm (1) - (3) Find the components of displacements, strains and stresses at the nodes of a breakdown inside cells. Expressions (6) and (7) are computed principal stresses and directions of the principal sites. Finally, the expression (10) for all nodes within the calculated elements to calculate the critical value of the maximum deflection angle $\theta_{\max}$. The values found were compared with the value $tg\varphi$.

Figure 2 shows the diagram of the tangential compressive normal stresses σ_θ. I should say that here the index θ is related to the coordinate system. In strengthening the soil concentration of compressive stress significantly shifted to the corners on the bottom of the circuit. The lowest compressive stresses occur in the set, and on the bottom there are small tensile stress.

Relevant to these cases diagrams radial displacements are shown in Figure 3. Side areas barely moved. Move set after soil stabilization decreased by 11 cm.

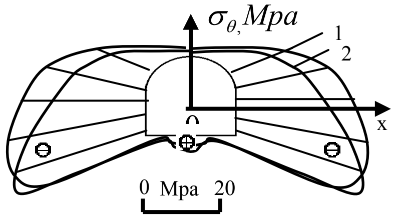

Fig.2. Diagram of the tangential normal stresses on the contour tunnel. The curved lines correspond to soils: 1 - unfortified 2 - strengthening.

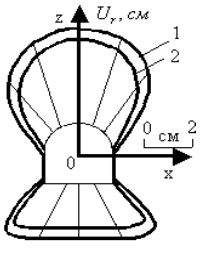

Fig.3. Curves of radial displacements in unfortified (curve 1) and fortified (curve 2) soils.

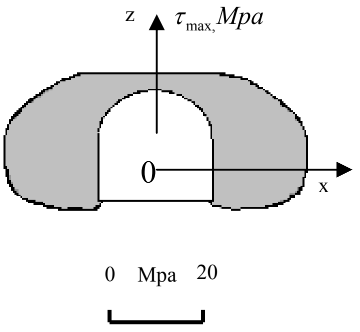

Fig.4. Zone of instability unfortified loosely ground around the tunnel.

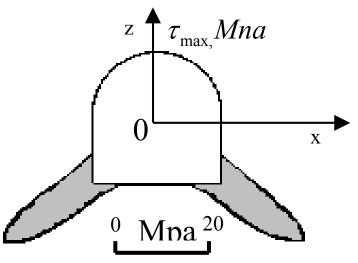

Fig.5. Soil instability region after the consolidation of the crest part.

As shown in Figure 5, the soil loses its stability of loosely ground immediately around the circuit. Area of the initial collapse shows staining. After strengthening the stability of the ground becomes almost everywhere except in the corner areas. The corresponding region of instability for the case of soil stabilization is shown in Figure 6. Smoothing the sharp corners of the contour tunnel leads to a full sustainable capacity of the soil.

6 CONCLUSIONS

Thus it is shown that the calculation methods satisfactorily describes the loss of stability of the soil near loosely ground subway tunnel. Here, the case for cohesive soil. For non-cohesive soils calculations can be carried out similarly. This opens up the opportunity to determine the optimal parameters calculated soil stabilization.

REFERENCES

[1] Aytaliev MCCORMACK, Baimakhan R.B., Eskaliev M. E., Ukshebaev M. T. etc. Metropolitan Almaty: the problem of residual seismic passed tunnels and prospects for the resumption of construction, In. "Transport Eurasia: A Look into the XXI century". Proceedings of the First International Scientific and Practical Conference. , Almaty, 2000, p 123-128.

[2] Aytaliev MCCORMACK, Baimakhan R. B., Ukshebaev M. T. To the calculation of seismic Almaty subway on the updated seismicity areas, In. "Actual problems of Transport - communications complex on the threshold of the third millennium," Proceedings of the International Scientific Conference. , Almaty, 2001, p. 174-178.

[3] Aitaliev Sh. M., Baimakhan R. B., Ukshebaev M. T. On Seismic Conditions of Territory and Seismic Stability of Almaty Underground, Kazakhstan-Japan joint geotechnical seminar. - Astana, Kazakhstan. 2-3 august, 2001, p. 98-108.

[4] Zienkiewicz O., Finite Element Method in Engineering. - Academic Press, 1975. 541 p.

[5] Baimakhan R. B. Calculation intense seismic state of underground structures in heterogeneous column finite element method. (Edited by Academician of NAS RK Aytalieva S. M.) - Almaty, 2002, - 232 p.

[6] Tsytovich N. A. Soil Mechanics-M.: 1979. - 272 p.