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"QURILISHDA YASHIL IQTISODIYOT, SUV VA ATROF-MUHITNI ASRASH TENDENSIYALARI, EKOLOGIK MUAMMOLAR VA INNOVATSION YECHIMLAR" MAVZUSIDAGI RESPUBLIKA MIQYOSIDAGI ILMIY-AMALIY KONFERENSIYA TASHKILIY QO'MITASI

Assessment of the stability of the excavation tunnel and vertical movements of the earth's surface

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Abstract: In the work, a new numerical modeling method for solving the problems of determining the stress-deformation state of the ground massif around the artificial void of the metropolitan walking tunnels under construction is presented. The initial stress and deformation state of the ground array before tunnel excavation, that is, under the influence of volume loading, is determined, and then the values of additional stresses in the array are determined due to the effects of the stresses measured around the artificial space caused by the excavation. In order to increase the potency of the proposed calculation method, development of algorithm and program for digitization of finite elements and their nodes according to order: modern algorithms for graphically outputting data on initial data, displacements in nodes, deformation and stresses in elements were developed
Keywords: tunnel, stress, viscoelastic, seismic impact, vertical stresses, tangential stress, elastic deformation, inelastic deformation

1. Introduction

Checking the stress- deformation condition round tunnels is one of the main issues of the mechanic's of underground structures. Excavation of an artificial space associated with the removal of a certain volumes of ground from the massive leads to a violation of the existing balance in it and a change in the initial field of stresses. In the process of solving the problem of elastic or inelastic parcelling of stresses around artificial spaces located in the ground massif, it is necessary to use a calculation scheme that allows to get rid of rather large errors in determining the stresses and displacements around the artificial space.

The calculation scheme proposed by I.V. Rodin is based on the use of the superposition method [1-9]. At the same time, the stress- deformation state of the undisturbed ground massive under the influence of the initial stresses before tunneling is determined, and then excavation works are performed and the state after "removal" of the stresses on the contour of the artificial cavity is re-measured. The sum of the initials and additional values of stresses and deformations gives the solution of the problem (Figures 1-2).

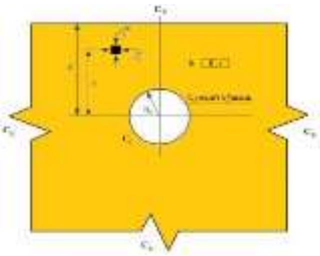


Fig. 1. The scheme for determining the state of stress-deformation round the artificial cavity of the tunnel

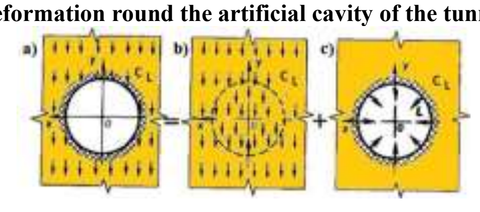


Fig. 2. The scheme for determining the state of tension and deformation round the artificial cavity of the tunnel:

a - artificial cavity with real tension; b – the initial stresses in the specified soil circle; c - "removable" stresses on the contour of the artificial cavity

2. Materials and methods

The sought-after components of the total stresses in the ground field S can be expressed as the summ of two addends, as shown above:

$$\sigma_x = \sigma_x^{(0)} + \sigma_x^{(1)};$$
$$\sigma_y = \sigma_y^{(0)} + \sigma_y^{(1)} \quad (2.1)$$
$$\tau_{xy} = \tau_{xy}^{(0)} + \tau_{xy}^{(1)},$$

The vertical and horizontal components of the pressure of the ground mass at a certain depth equal to the average specific gravity g are calculated according to certain formulas:

$$\sigma_y^{(0)} = \gamma H; \ \sigma_x^{(0)} = \lambda \gamma H \quad (2.2)$$

The loads imposed on the considered part of the array can also be imposed by volumetric gravity forces, divided by boundary normal and shear forces. Appropriate conditions are modeled to prevent perpendicular movement of the considered soil mass zone S at the far boundaries. If the array is multi-layered, the stresses vary considerably from layer to layer and the more the elastic characteristics of the stresses differ, the greater the variation in stresses. Therefore, the parcelling of stresses around the contour of the ground rock at the intersection of the excavation site with layers with different initial stress states is quite different from the homogeneous model. The linear elastic model is based on Hooke's law of isotropic liners elasticity. The model includes two constants: Young's modulus (E) and coefficient Puasson's (υ). We assume that the deformations caused by these forces are small and correspond to the following basic equations [10]:

1. Equilibrium equations (Static equations)

$$\frac{\partial \sigma_x}{\partial x} + \frac{\partial \tau_{xy}}{\partial y} + \bar{X} = 0, \quad \frac{\partial \tau_{yx}}{\partial x} + \frac{\partial \sigma_y}{\partial y} + \bar{Y} = 0 \quad (2.3)$$
$$\tau_{xy} = \tau_{yx} = \tau,$$

where X and Y are volumetric forces in the form of initial stresses or in matrix form $A\vec{\sigma}+\vec{P}=0$,

$$\text{here, } A=\begin{bmatrix}\frac{\partial}{\partial x} & 0 & \frac{\partial}{\partial y}\\ 0 & \frac{\partial}{\partial y} & \frac{\partial}{\partial x}\end{bmatrix},\ \vec{\sigma}=[\sigma_x\sigma_y\tau],\ \vec{P}=[\bar{X}\ \bar{Y}].$$

2. Connections between deformation and displacements (geometric equations)

$$\varepsilon_x=\frac{\partial u}{\partial x},\quad \varepsilon_y=\frac{\partial v}{\partial y},\quad \gamma_{xy}=\frac{\partial v}{\partial x}+\frac{\partial u}{\partial y},\qquad (2.4)$$

$$\text{or}\qquad \vec{\varepsilon}=A^T\vec{U},$$

$$\text{here, } A^T=\begin{bmatrix}\frac{\partial}{\partial x} & 0\\ 0 & \frac{\partial}{\partial y}\\ \frac{\partial}{\partial y} & \frac{\partial}{\partial x}\end{bmatrix}\vec{\varepsilon}=[\varepsilon_x\ \varepsilon_y]^T,\ \vec{U}=[u\ v]^T.$$

3. Physical equations (Hooke's law)

$$\varepsilon_x=\frac{1}{E}(\sigma_x-\nu\sigma_y),$$

$$\varepsilon_y=\frac{1}{E}(\sigma_y-\nu\sigma_x),\qquad (2.5)$$

$$\gamma_{xy}=\frac{\tau_{xy}}{G}$$

or $\vec{\varepsilon}=B\vec{\sigma}$ here

$$B=\frac{1}{E}\begin{bmatrix}1 & -\nu & 0\\ -\nu & 1 & 0\\ 0 & 0 & 2(1+\nu)\end{bmatrix}.$$

Analysis of the stress-deformation state with the finite element method allows to evaluate the deformation and stress changes that occur in the system as a result of the non-uniformity of elastic properties and changes in geometric shapes, fulfilling the conditions of the static equilibrium stateFace stability during tunneling is one of the most important static problem's in the field of tunneling. Nowadays, the tunnel usually collapses due to troubles in the excavation of the face. This phenomenon is observed both in tunnels made in the ground and those made in rock. In addition, collapses in the tunnel were recorded in both shallow and deep tunnels [11-14].

3.Numerical results and discussion

In this regard, we will consider the problem of determining the stability of a tunnel excavation, which was carried out-using a Herrenknecht TBM. In the course of solving the problem, the initials stress field, zones of limit states in the vicinity of the excavation and vertical displacements of the surface of the soil mass were calculated. In this case, the main linear dimensions of the model are as follows: model width (dimension in the direction of the X axis) – 100 meter; model height (dimension in the Y-axis direction) – 70 meter.

For this purpose, the physical and mechanical properties of the rock mass along the tunnel route between the station were used Turkistan to st. Yunusabad, which are presented in table 1. The depth of the tunnel varies from 8 to 22 meters.

The diameter of the TBM shield for tunneling is 5860 mm; therefore, the diameter of the excavation in front of the shield is taken in these equal values. Figure 3 show numerical finite element model's of a rock mass with tunnels at various depths [15].

Table 1

Average value's of the main physico-mechanical parameters of the soil of the metro tunnel route

Layer	h, (m)	γ, (kH/m³)	E_0, (MPa)	C, (kPa)	φ, (gr)	υ_0
I	2	18,2	4,2	5,4	7	0,32
II	4	17,1	10,7	9,0	12	0,30
III	7	18,7	13,8	11,6	15	0,28
IV	20	19,4	16,5	-	17	0,30

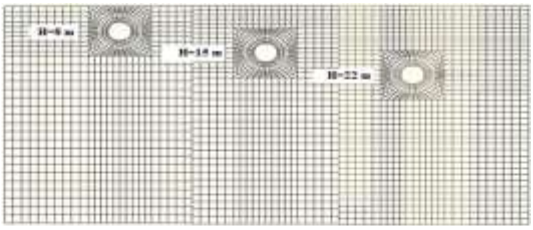


Fig. 3. Numerical models of a massive with workings of a tunnel section of various depths

Figure 4 shows the fields of vertical displacements of a given area for an elastic problem in which the deformation parameters of the soil have not yet changed. Further, as a result of calculations, local zones of local destruction or zones of loss of stability around the tunnel opening were found.

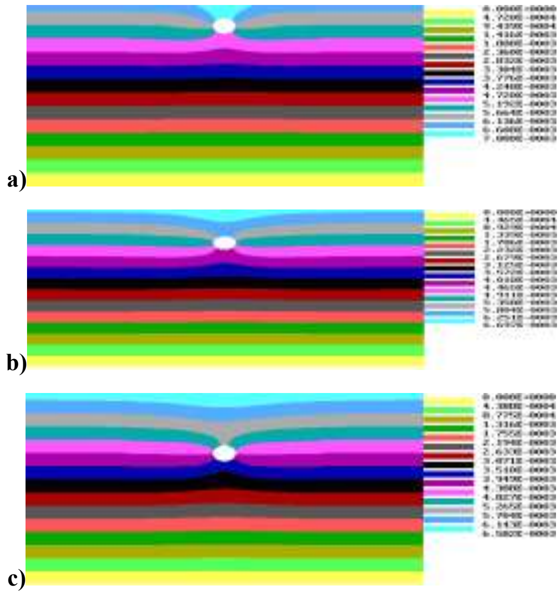


Fig. 4. Isochromes of vertical displacement's of a given are for an elastic problem, at depths:
a) H=8 meter, b) H=15 meter, c) H=22 meter.

The zones are expressed through certain values of ground safety factors η, which are formed as a result of plastic destruction according to the Mohr-Coulomb strength (limit state) condition (Figure 5) [13].

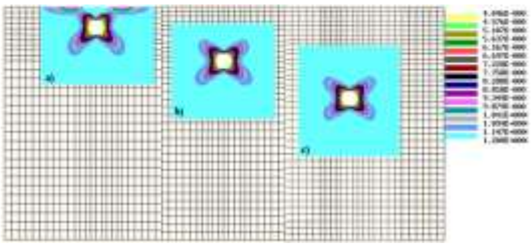
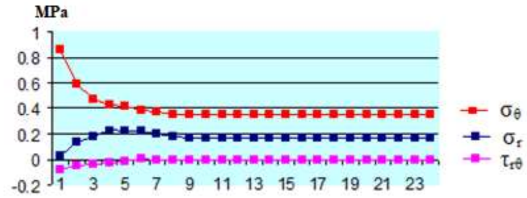


Fig. 5. Isochromes of safety factors η for a given area at tunnel sections: a) H=8 meter, b) H=15 meter, c) H=22 meter

Taking into account plastic destruction with changes in the deformation parameters of the ground for each case (H = 8 meter, H = 15 meter, H = 22 meter) shows that they significantly changed the picture of the stress- deformation state of the ground around the tunnel. The zones of instability round the tunnel opening becomes limited as the excavation depth increases. In figure 6-11 show in the form of graphs the distributions of values of radial, tangential and tangential stresses when problems were solved without and taking into account local destruction in the ground area around the tunnel. Analysis of the graphs shows that the formation of an area of plastic deformation leads to a decrease in the level of stress at the excavation contour in comparison with the solution of the elastic problem. The maximum stress moves deep into the massive to the interface between the elastic and inelastic regions.



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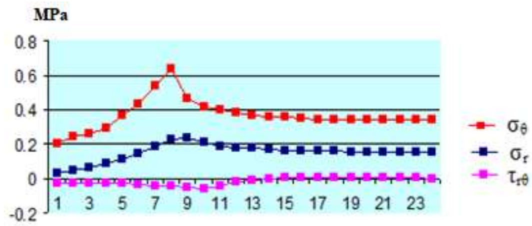
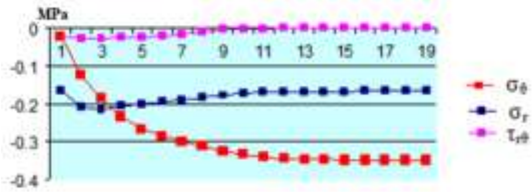


b)

Fig 6. Parcelling of tangential, radial and tangential stresses around the excavation at θ=0º and H=8 meter: a) elastic deformation, b) inelastic deformation



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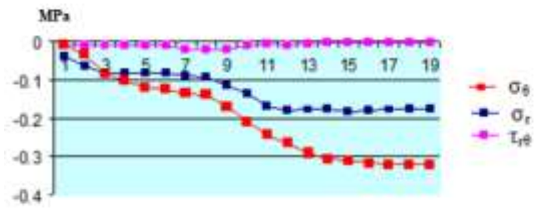
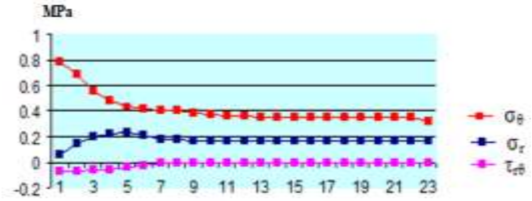


b)

Fig. 7. Parcelling of tangential, radial and tangential stresses around the excavation at θ=180º and H=8 meter: a) elastic deformation, b) inelastic deformation



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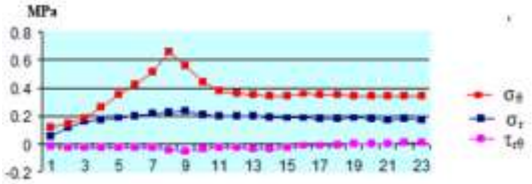
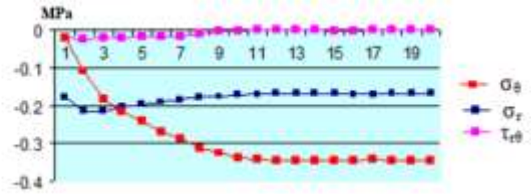


b)

Fig. 8. Parcelling of tangential, radial and tangential stresses around the excavation at θ=0º and H=15 m: a) elastic deformation, b) inelastic deformation



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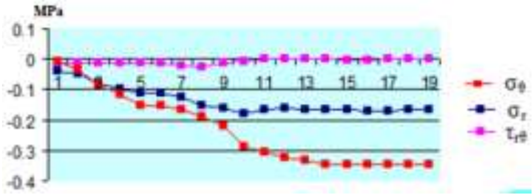
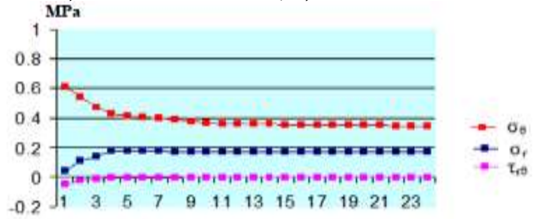


b)

Fig. 9. Parcelling of tangential, radial and tangential stresses around the excavation at θ=180º and H=15 meter: a) elastic deformation, b) inelastic deformation



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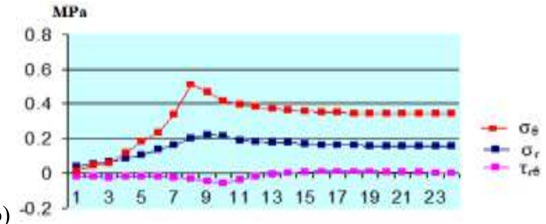
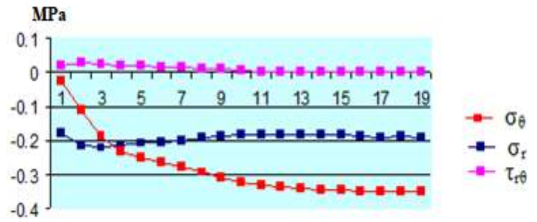


b)

Fig. 10. Parcelling of tangential, radial and tangential stresses around the excavation at θ=0º and H=22 meter: a) elastic deformation, b) inelastic deformation



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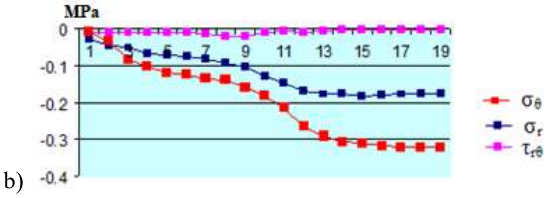

Fig. 11. Parcelling of tangential, radial and tangential stresses around the excavation at θ=180º and H=22 meter: a) elastic deformation, b) inelastic deformation

4. Conclusion

As a result of the numerical calculations performed, the settlement of the earth's surface during tunneling using the shield method was determined. It was found that the maximum precipitation of the ground surface decreases with increasing tunnel section (Fig. 12 - 13). This is due to the fact that when tunnels are laid deep, settlements are largely determined by a decrease in the vertical ground pressure on the tunnel due to the formation of a limited disturbed zone around the workings.

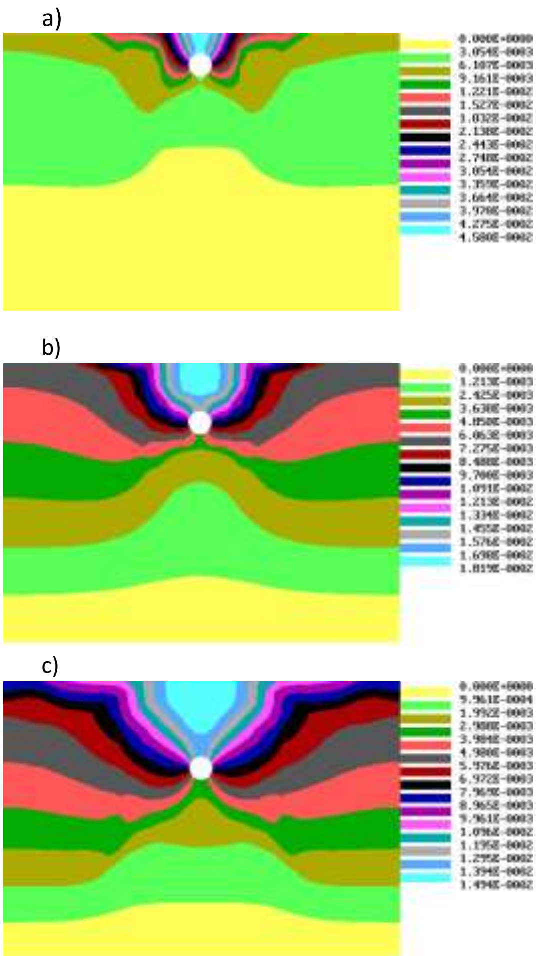

Fig. 12. Isochromes of vertical displacements of a given area of formation of a zone of inelastic deformations at depths: a) H=8 meter, b) H=15 meter, c) H=22 meter

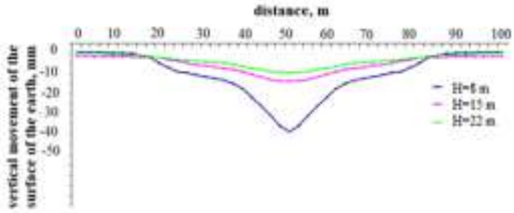

Fig. 13. Settlement of the earth's surface during excavation of a distillation tunnel at depths: a) H=8 meter, b) H=15 meter, c) H=22 meter

Through the created methods, the vertical subsidence of the soil massif around the artificial spaces of the tunnel between the Turkestan and Yunusabad stations located at a depth of 8, 15 and 22 meters, and unstable zones of failure were determined. Real physical and mechanical properties of the surrounding soil array were used in the calculation process. The obtained results made it possible to reveal and determine the specific laws of the changes in ground stresses, the formation of inelastic and non-resilient deformation zones around (near) the contour of the artificial cavity when the metropoliten pedestrian tunnels increase their depth

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