

СТРОИТЕЛЬНЫЕ КОНСТРУКЦИИ. ОСНОВАНИЯ И ФУНДАМЕНТЫ. ТЕХНОЛОГИЯ И ОРГАНИЗАЦИЯ СТРОИТЕЛЬСТВА. ПРОЕКТИРОВАНИЕ ЗДАНИЙ И СООРУЖЕНИЙ. ИНЖЕНЕРНЫЕ ИЗЫСКАНИЯ И ОБСЛЕДОВАНИЕ ЗДАНИЙ

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Construction of enclosing structures of deep excavation pits of buildings constructed in Ulaanbaatar

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ABSTRACT

When constructing multi-story and high-rise buildings in limited spaces of large cities due to lack of area for construction, optimal design of enclosing structures that protect against collapse of the excavation pit wall and against technological and non-technological negative impacts on buildings located in the zone of influence of new construction is one of the urgent geotechnical problems. In connection with intensive construction in large cities of Mongolia, the issue of the optimal solution to this problem becomes relevant. This article discusses the results of the calculation and design solution of the enclosing structure erected taking into account the soil conditions of Ulaanbaatar.

KEYWORDS: regional feature, coarse-grained soil with clay filler, horizontal load, displacement, buildings located in zones of influence

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Строительство ограждающих конструкций глубоких котлованов зданий, возводимых в Улан-Баторе

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АННОТАЦИЯ

При строительстве многоэтажных и высотных зданий в ограниченных пространствах крупных городов из-за нехватки площадей под застройку одной из актуальных геотехнических задач является оптимальное проектирование ограждающих конструкций, защищающих от обрушения стен выемки грунта и от технологических и нетехнологических негативных воздействий на здания, расположенные в зоне влияния нового строительства. В связи с интенсивным строительством в крупных городах Монголии вопрос об оптимальном решении этой проблемы становится актуальным. Рассматриваются результаты расчета и проектного решения ограждающей конструкции, возведенной с учетом грунтовых условий Улан-Батора.

КЛЮЧЕВЫЕ СЛОВА: региональная особенность, крупнозернистый грунт с глинистым наполнителем, горизонтальная нагрузка, смещение, здания, расположенные в зонах воздействия

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INTRODUCTION

The urban development direction of Mongolia, especially the construction of high-rise buildings in the city of Ulaanbaatar, dictates the issue of rational use of the underground space of the built-up area, as a result of which the assessment of the impact of the work carried out on the development of the pit on the wound of built-up buildings and on underground pipelines is relevant.

The analytical solution of the problem of determining the quantitative assessment of the stress-strain state of the enclosing structure and the foundation soil was carried out in a flat formulation. In this solution, it is impossible to take into account and evaluate additional deformations arising in soil massifs and structures of new and existing buildings. Therefore, at present, the problem of determining the joint work of the supporting structures of a newly constructed building and nearby buildings is solved in a spatial formulation by the method of numerical modelling based on the finite element method using various software packages.

In the practice of solving geotechnical problems, including for the design of the enclosing structure of a construction pit, numerical methods are widely used using calculation software packages based on the finite element method, which allow you to estimate the stress-strain state of the soil of the foundations of newly erected and previously built-up buildings located in the zone of influence of construction work. To study the issues of numerical modelling of the stress-strain state of the soil of the foundations of newly erected and previously built-up buildings, the works of G. Dalerci et al. are devoted [1], A.B. Fadeev [2], L. Zdravkovic et al. [3], M.A. Bezgadov et al. [4], J.P. Carter et al. [5], G.T.C. Kung et al. [6], A.I. Golubev et al. [7] and others.

The works of P.G. Hsieh et al. [8], V.A. Ilyichev et al. [9], C. Moormann et al. [10], D.E. Razvodovsky et al. [11], V.I. Telichenko et al. [12], M. Son et al. [13], D.S. Konyukhov et al. [14], V.V. Znamensky et al. [15], S. Nyam-

dorj et al. [16], V.Yu. Leushin et al. [17] and others are devoted to the optimal solution of the problems of calculation, design and construction of deep excavations and their enclosing structures.

During construction in a limited urban development site, during mandatory geotechnical monitoring to determine the technical condition of nearby buildings, and also monitoring of additional technological settlement of buildings and movement of the pit fence, while the horizontal deviation of the pit fence is standardized from the point of view of the strength and rigidity of the supporting structure. It is important to note that the permissible bending of the pit fence can lead to significant deformations of the foundation of new and existing buildings and the development of limit state zones in the soil massif of the foundation.

MATERIALS AND METHODS

The enclosing structures of pits are erected in Ulaanbaatar by various methods, including the use of metal sheet piles, I-beams and tubular structures with a wooden filler, bored piles. And the classic method of erecting a “wall in the ground” of the trench type has not yet been implemented, due to the lack of design experience and special techniques for this work.

Currently, the construction of urban underground structures of civil buildings and pipelines in our country is carried out by an open method of excavation of pit soils. The depth of their pit can most often reach 5.0–9.0 m in practice for 1–3 underground floors in soil conditions of coarse-grained and clayey soils, mainly in the presence of groundwater. As an example, below is considered the calculation of the enclosing structure of a deep pit of an 8-story hospital building.

Engineering and geological conditions. The 8-story hospital building (56 × 6 m) was planned with two-story basements on a reinforced concrete slab foundation (Fig. 1, 2), monolithic frame structure, gravelly loam soil foundation (Table).

Physical and mechanical properties of soil

Soil name	IGE	Parameters of soil's					
		$\rho_s, \text{g/sm}^3$	e	E, MPa	C, kPa	φ, grade	R_0, kPa
Gravel with sandy loam fillers, semi-solid consistency	IGE-1	2.22	0.35	48	9.3	39	450
Gravel with loamy fillers, semi-solid consistency	IGE-2	2.21	0.36	41	7.3	36	450
Gravelly loams, fluid consistency	IGE-3	2.22	0.20	19	19	17	250

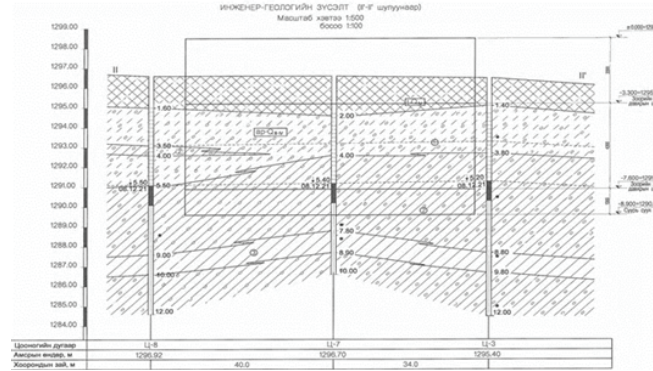


Fig. 1. Engineering-geological section

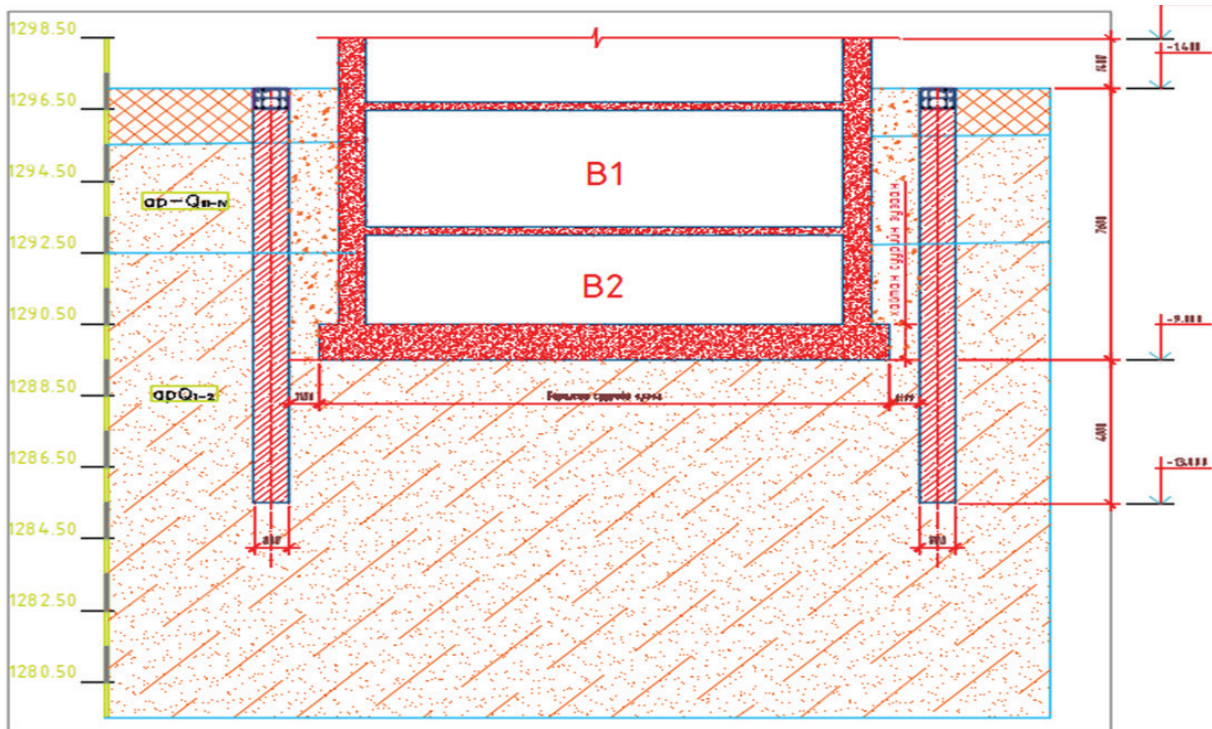


Fig. 2. Calculation scheme of the enclosing structure

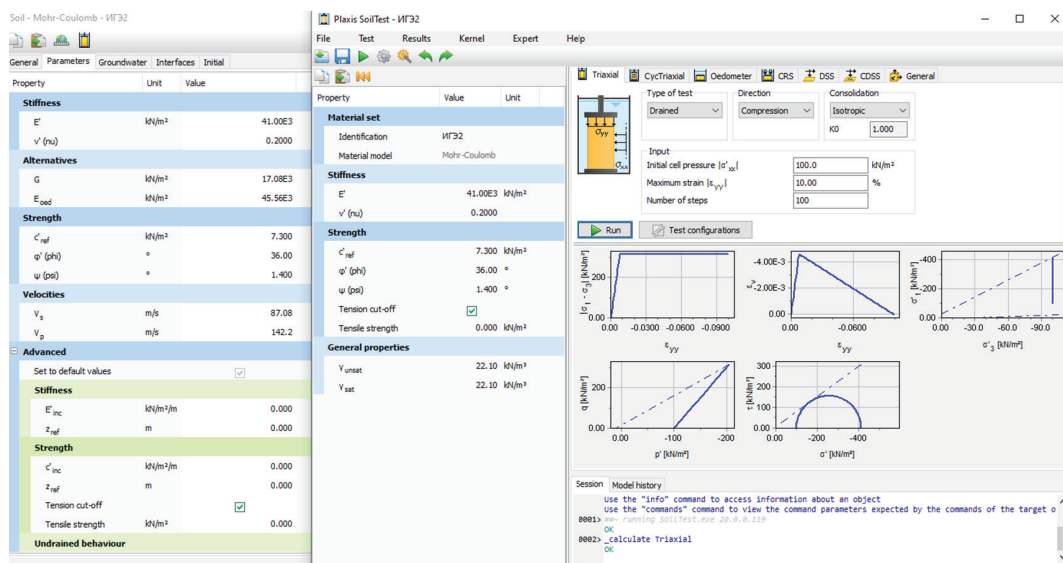


Fig. 3. Calculated data of soils

This numerical calculation was carried out using the software package Palaxis 3D, the calculated indicators of the building foundation soils were modeled in accordance with the methods described in the works of R.A. Mangushev et al. [18], PLAXIS Finite Element Code¹. Calculation scheme of the enclosing structure (Fig. 3).

RESULTS

Determination of the bending rigidity of piles of the enclosing structure (Fig. 4):

EA — compressive rigidity of piles;

EJ — bending rigidity of piles;

¹ PLAXIS — Finite Element Code for Soil and Rock Analyses. User's Guide. Version 7. Saint Petersburg, NIP-Informatika, 2004; 274.

$E = 3 \cdot 10^7 \text{ kN/m}^2$ — modulus of deformation of reinforced concrete;

$$EA = 3 \cdot 10^7 \cdot d \cdot 1 \text{ pm}/0.85 = 3 \cdot 10^7 \cdot 0.8 \cdot 1/0.85 = 28.235 \cdot 10^6 \text{ kN/m};$$

$J = (\pi D^4)/64$; m^4 — pile rigidity, where D — pile diameter;

$$EJ = 3 \cdot 10^7 \cdot \frac{d^3 \cdot 1 \text{ pm}}{12 \cdot 0.85} = 3 \cdot 10^7 \cdot \frac{0.8^3}{12 \cdot 0.85} = 150.588 \cdot 10^4 \text{ kN/m}.$$

Loads and impacts. The loads acting on the pile wall of the enclosing structure were calculated based on design solutions and material consumption, including loads from the adjacent four-story brick building located 8.0 m from the designed building, and loads from the road located 9.0 m from the edge of the pit cliff. The loads from the road were calculated in accordance with GOST R 52748–2007 (Fig. 5).

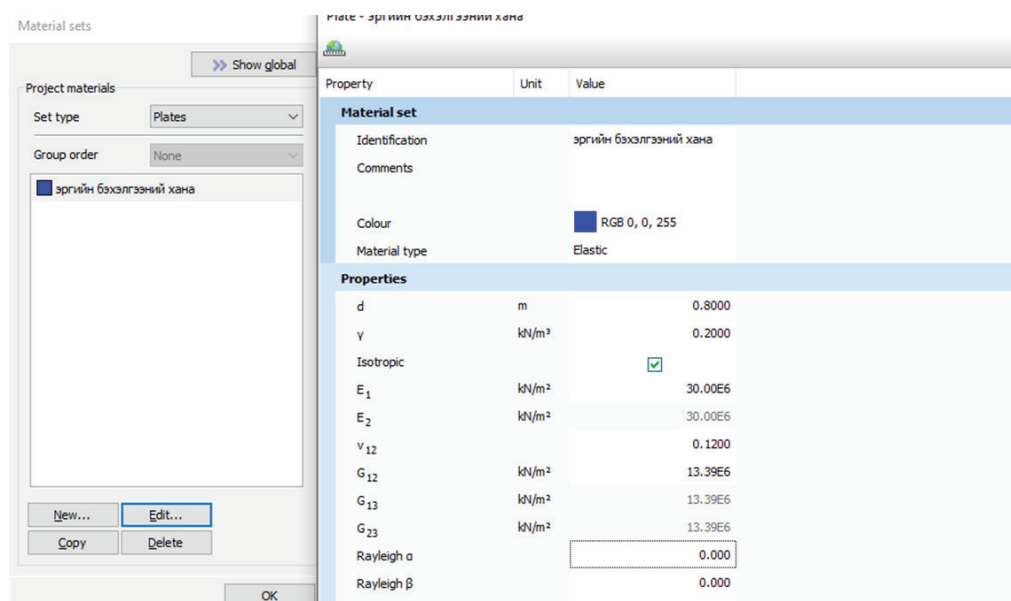


Fig. 4. Calculated pile data

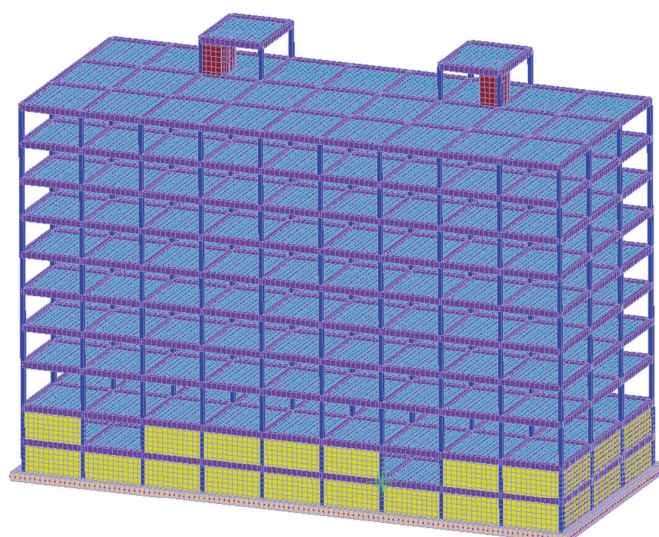


Fig. 5. Calculation model of the designed building

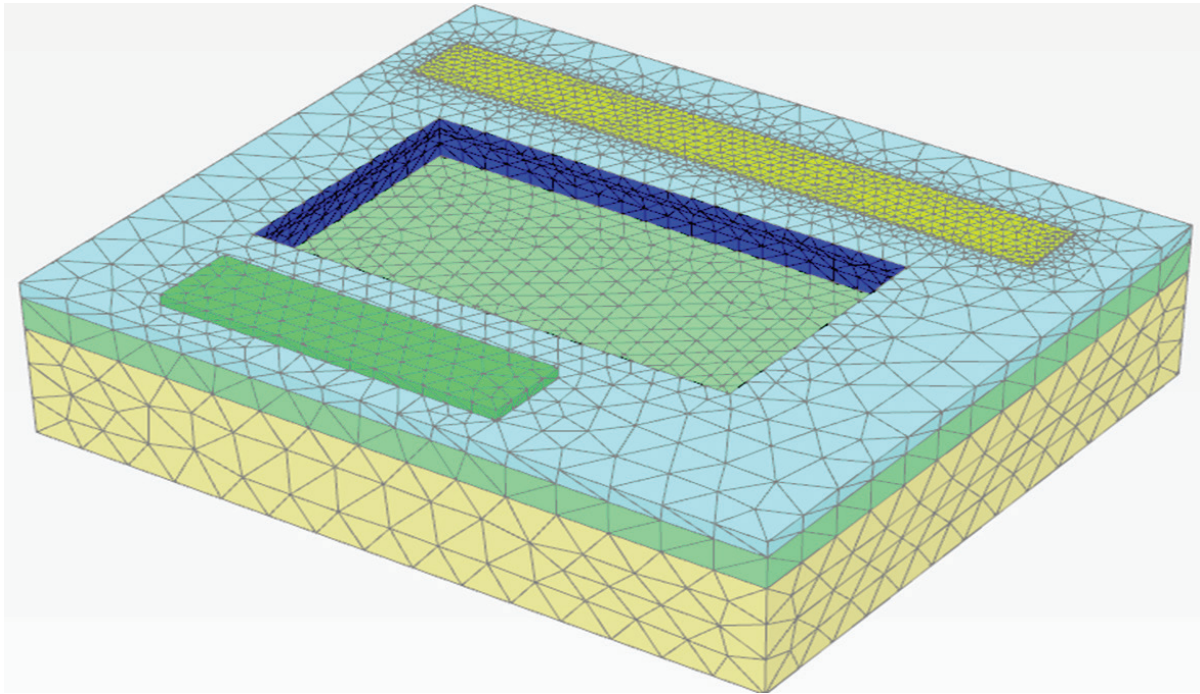


Fig. 6. Modelling of the enclosing structure

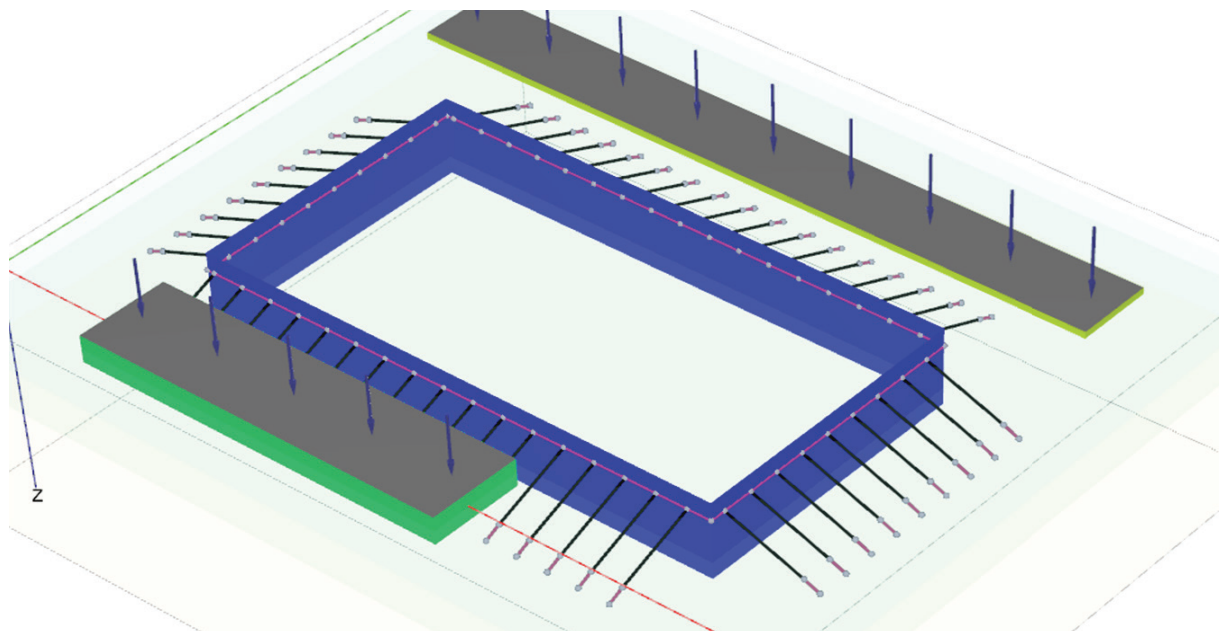


Fig. 7. Calculation model of anchor fastening of enclosing structure

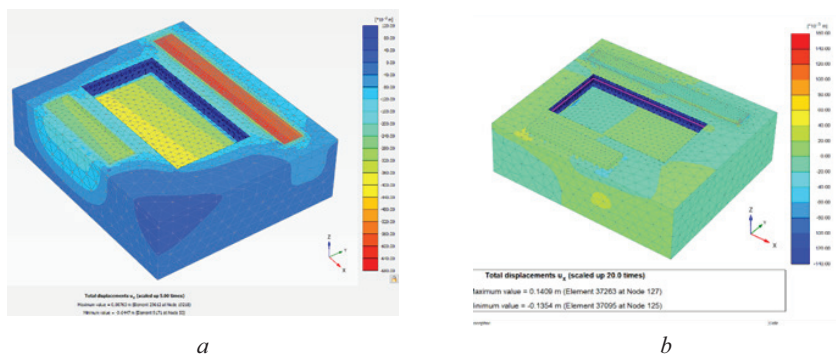


Fig. 8. Vertical deformation of the foundation soil

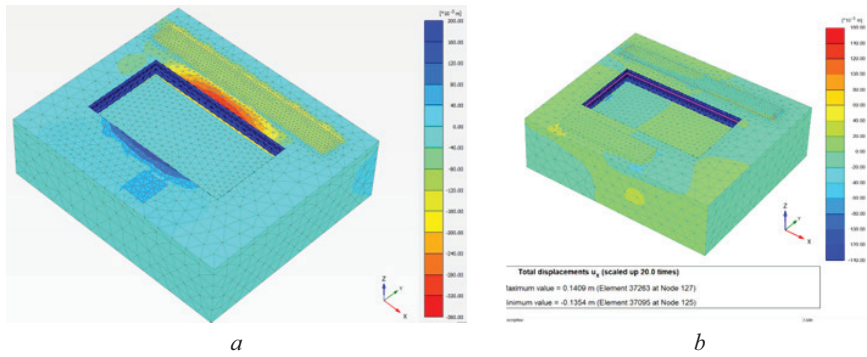


Fig. 9. Horizontal soil movements: *a* — in the *Y* direction; *b* — in the *X* direction

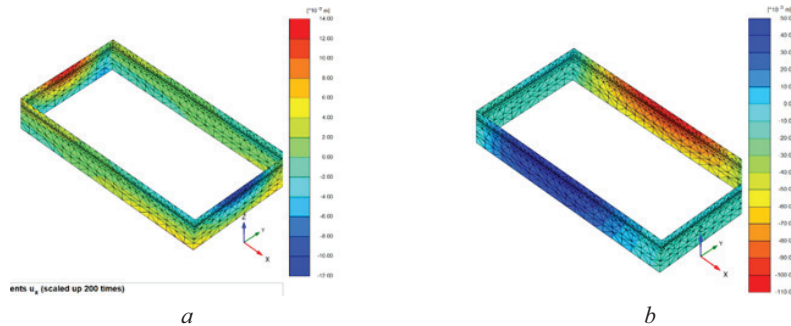


Fig. 10. Horizontal displacements of the structure in the *Y* and *X* directions

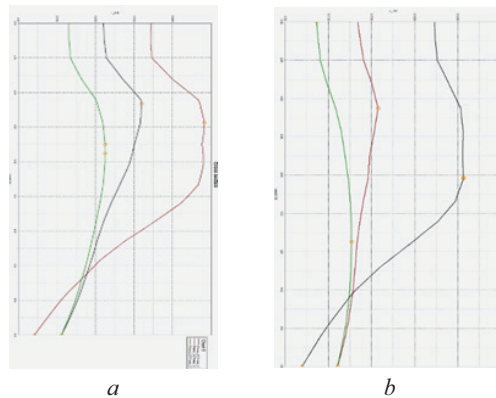


Fig. 11. Graph of horizontal deformations of the enclosing structure in the *Y* and *X* directions

Calculation model. The numerical calculation of the enclosing structure was modeled on the PALAXIS 3D programme using the finite element method (Fig. 6), taking into account the load from the building and the road located in the zone of influence of the new building (Fig. 7).

Horizontal and vertical displacements, as well as deformations from bending moments of enclosing structure, caused by loads from horizontal pressures of excavation pit soils and also from the adjacent building and road after excavation of excavation pit and construction of enclosing structure of excavation pit, are shown in Fig. 8–11.

Maximum settlement caused by the adjacent building $S = 2.9$ cm, relative deformation value $\Delta S = 0.003$.

The maximum value of horizontal displacement in the *Y* direction is $\Delta y = 9$ cm and is greater than the permissible value, based on this, there is a need to design an enclosing structure.

The horizontal displacement of the pile enclosing structure is: $\Delta X_{\max} = 1.0$ cm; $\Delta Y_{\max} = 1.7$ cm

The strength calculations of the enclosing structure are carried out depending on the magnitude of the bending moment. Fig. 12, *a* shows the values of the bending moments, and Fig. 12, *b* shows the maximum value of the bending moment $M_{\max} = 509.3$ kNm. M_{\max} is the support moment, based on this condition, the strength calculations are carried out based on the values of the non-support moment.

Calculated value of bending moment $M_{\max} = 250$ kNm. In this case, when calculating the strength of a mono-

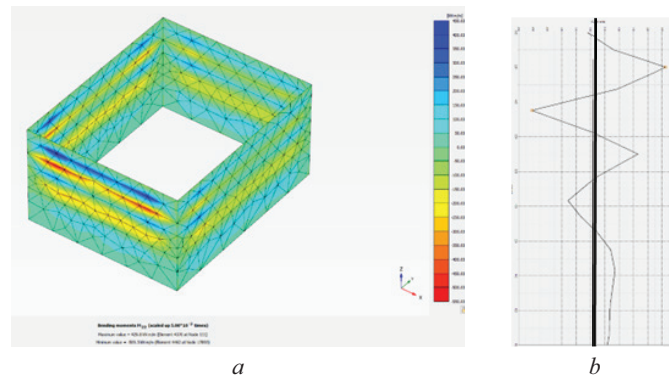


Fig. 12. Moment diagram arising in enclosing structures

lithic reinforced concrete pile in the tension zone, the obtained value of the cross-sectional area of the working reinforcement $A_s = 19.078 \text{ cm}^2$ was obtained, therefore 8D18 with an area $A_s = 20.36 \text{ cm}^2$ was selected, and for the full cross-section of the pile, working reinforcement 16D18A400 was selected.

CONCLUSIONS

The pile-enclosing structure of a deep pit is designed from monolithic reinforced concrete piles with a diameter of 700 mm and a length of 15.0 m, the anchor traction structure of the wall is carried out at a distance below 2.6 m from the pile head. The calculation results confirmed that the horizontal displacement of the enclosing structure of a deep pit will not exceed the maximum permissible value under the action

of the load from the building and the road located in the influence zone.

The calculation results confirmed that, provided that the enclosing structure of the pit wall of a newly constructed building is designed and implemented with the established dimensions in the calculation results, then horizontal displacements and additional settlements for a building located at a distance of 8.0 m from the upper cliff of the pit will not occur in excess of the permissible value.

Depending on the regional characteristics of Mongolia, it is necessary to take into account the influence of horizontal and tangential forces from possible soil freezing under conditions of seasonal deep freezing during construction work and develop a calculation method.

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