IOP Conf. Series: Materials Science and Engineering **775** (2020) 012051 doi:10.1088/1757-899X/775/1/012051

Specific features of diaphragm wall construction

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Abstract. The paper observes various technologies of diaphragm wall implementation as a shoring system in excavation pits. Protection of the adjacent existing buildings and structures and maximal removal of the impact to the existing city building system during construction process are considered as the key positive factor of the diaphragm wall technology. The consideration is made basing on the completed projects within dense existing building system of Saint-Petersburg where each free land plot is valuable and shall be used with the maximum benefit.

1. Introduction

In recent years, the construction of underground and buried structures has been increasingly developing in big and metropolitan cities. The main factors that contribute to the need for using the urban underground space are both the shortage of free areas in the conditions of historically formed housing system and the requirements for the development of urban infrastructure.

Structural solutions of underground and buried facilities, as well as methods for their construction, depend on space-planning solutions, their intended use, depth, engineering-and-geological conditions, climatic and seismic conditions of construction, surface loading, and the presence of neighboring buildings and structures.

Based on the method of construction, underground structures are divided into those built by closed, open and semi-closed methods. The great majority of urban underground and buried civil facilities that are compact in plan, as well as line facilities of shallow depths are constructed by the open or semi-closed methods in excavation pits. Certainly, technical capabilities to increase a depth of projected excavation pits and a number of underground floors do exist at the present time. However, the above parameters are constrained by such factors as: economic feasibility, comfortable conditions of staying in underground facilities. Impact on the surrounding buildings and hydrogeological conditions.

It is known that the shoring of excavation shall ideally combine the following principal functions: to take up lateral soil pressure, to serve as curtain grouting and to take up head of groundwater, if required, to absorb vertical loads, to minimize the impact of excavation pit on surrounding buildings. Facilities that are constructed by the diaphragm wall method correspond most completely to the combination of all these functions. The construction of shoring for excavation pits and foundations of buildings by the diaphragm wall method involves the construction of a narrow trench of the required depth in the ground using dedicated equipment.

2. Basic technological features of diaphragm wall design

Let us consider the technological stages of the diaphragm wall construction. For instance, when installing trench structures of the diaphragm wall, there are technological features associated with the need to provide the stability of the trench walls while trenching - to prevent soil from creeping and collapsing. It is especially relevant when excavating in soft soils below the underground water level.

Stage I.

Prior to starting the construction of the diaphragm wall, an auxiliary structure of guide wall is constructed. This structure performs two functions: it is a guide for the work tool of and excavating machine and it protects the trench wall against collapse in the top area.

The stability of deep and narrow trenches is provided by filling them with thixotropic clay (bentonite) slurry - a mixture of clay with water with density ρ = 1,15-1,25 t/m^3 - and continuously maintaining its level. There are several different points of view on the stability of the trench walls in silty-clayed water-saturated soils: these are osmotic phenomena in soil with the presence of bentonite slurry, these are the strength properties of forming film, this is the three-dimensional behavior of soil mass. In the modern approach, we are based on the interaction of the bentonite slurry in trench and the surrounding soil mass as an integrated geotechnical problem of providing the stability of excavation taking into account the technological parameters of the bentonite slurry and the lateral pressure of soil mass along the trench depth depending on a kind of soil and its initial stress-strain behavior.

Stage II.

Removing excavated soil from trench and filling excavated space with slurry at the same time. Excavation is divided into two groups according to the type of earth-moving equipment: a hydraulic cutter, which excavates soil transferring it to working slurry and lifting to the surface using a pump, and a grab, which is an excavating machinery that raises excavated soil to the surface using a grab bucket. (Figures 1,2). In the first case, reverse circulation of slurry is necessary with sludge removed from it, and in the second case, excavated soil does not foul slurry, but a number of operations increases that are associated with raising and lowering the working tool.

Stage III.

After the soil has been excavated within the next panel, slurry is additionally cleaned using an air-lift plant, which makes it possible to remove heavy impurities and soil residues from the trench bottom and to reduce the risk of defect occurrence in concreting.

Stage IV.

Installation of reinforcement cage (re-cage) in trench (Figure 3). When lowering the cage, the reinforcement shall be wetted with water, which reduces the risk of clay cake forming on the reinforcement. A specific feature of reinforcement cages for a diaphragm wall are concrete cover spacers that make it possible to form a 70-mm concrete cover, which ensures that the main reinforcement is protected against exposure. Also, at this stage, end stops are installed that form a tongue-and-groove joint between the panels of the diaphragm wall (Figure 4).

Stage V.

The diaphragm wall panels are concreted using the tremie pipe (vertically moving pipe) technology. In the process of concreting, care shall be taken to provide continuous concreting and to prevent slurry from entering the concrete conveying pipe. One panel should be concreted without interruption until pure concrete pours out onto the surface in order to prevent it from mixing with slurry [1].

3. Principle machinery used for construction of diaphragm wall

Here we give an overview of the equipment used in the construction of the diaphragm wall on construction sites at the present day.

Mechanical grabs (Figure 2) are suitable for hard soils, especially heavy ones. They are capable to excavate soil with the high content of gravel particles, but only by dropping from a height as they have the low closing force. The design of the mechanical grab is very reliable, its maintenance is simple. The speed of digging a panel for the diaphragm wall is quite high. However, when the mechanical of bentonite slurry on them, which leads to their thixotropic softening, thus increasing the risk factors of poor-quality construction and causing difficulties in construction of diaphragm wall (settlements of neighboring buildings and structures, formation of concrete fins during pit excavation, etc.). This circumstance requires that the negative construction properties of soft and low-plasticity soil should be taken into consideration in the development of the process procedure and the method statement.

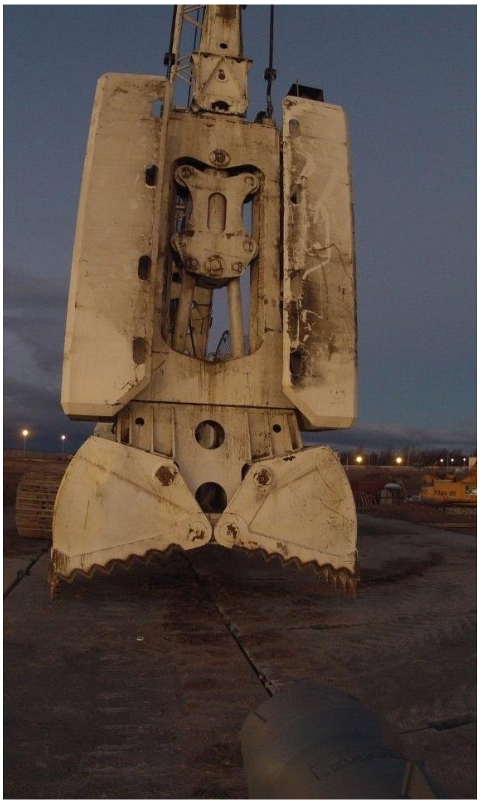

Figure 1. Hydraulic boom grab

Figure 2. Mechanical grab

Figure 3. Installation of re-cage **Figure 4.** end stops: metal - extractable, reinforced concrete - lost.

Hydraulic grabs (Figure 1) are used to excavate trenches in soft low-plasticity soils and non-cohesive loose and medium-density soils, both slightly wet and water-saturated (clay, sand). Due to the hydraulic force of the grab jaws, the dynamic impact on soil is minimized, and also provided is the minimum deviation of the location of the diaphragm wall panels from the design one. At the same time, the hydraulic grabs have rather complicated mechanical and hydraulic components. They are difficult to operate and service. The speed of digging a trench is relatively high, but lower than when using the mechanical grab. However, in this case, as practice shows, the safety of operations is much higher than when working with other systems, including mechanical ones, in the engineering-and-geological section of the central part of Saint Petersburg. Today, this design is most widely represented on the construction sites of the city.

Hydraulic cutter (Figure 4) is capable of excavating all layers of soil: from dispersed soil to half-rock. Soil is excavated by drilling out soil using two wheels with drill bits that are vertically mounted on the cutter body. Drilled solids are mixed with bentonite slurry and delivered to the surface using a powerful pump mounted above the drill wheels, after which bentonite slurry is cleaned. The hydraulic cutter has the high rate of trench excavation for the diaphragm wall. It eliminates the use of end cutoffs as the diaphragm wall sections are constructed staggered and the closing sections actually cut the previously completed elements, due to which the waterproofing of joints is provided. The hydraulic cutter has a very complicated hydraulic system and a dedicated design of attachments for each type of soil. It requires the use of properly sized equipment, additional cleaning facilities and pumps at the bentonite slurry plant. As practice has shown, the hydraulic cutter is not efficient in weak water-saturated soils with the inclusion of coarsely clastic rock.

Figure 5. Hydraulic cutter

The construction of a diaphragm wall of any type requires strict and thorough compliance with the requirements for the sequence and quality of work, as well as full-scale geotechnical monitoring of soil mass, conditions of trench located in the affected zone, and housing system during technological operations. It is believed that, during operations, the following parameters shall be monitored depending on the operations stage:

a) pre-excavation:
- location of wall;
- materials
  - reinforcement mesh and other elements to be installed in the structure;

b) construction of diaphragm wall structure:
  - excavation method, dimensions and leveling;
  - removal of sludge, cleaning of trench bottom;

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- formation of joints;
- placement of reinforcing and other elements;
- concreting [2].

4. Check calculations of trench stability under bentonite surcharge in water-saturated silty-clayed soils

Design of diaphragm wall depends on the engineering-and-geological conditions, operations technology and depth of excavation pit and stability system of excavation pit. When designing the diaphragm wall, its stability is calculated under the impact of the soil mass behind the wall, the impact of process loads, and process on the pit edge. The above calculations are made using the PLAXIS 2D or 3D program.

In our opinion, the calculation of the stability of the trench walls under bentonite surcharge is one of the most complicated calculations in conditions of diaphragm wall construction by the grab method to provide the stability of the trench walls using bentonite slurry in water-saturated silty-clayed soils of Saint Petersburg.

Let us consider some examples of trench stability calculations for diaphragm wall under a bentonite surcharge on one of the sites in the central part of Saint Petersburg. The calculations were made by the numerical method (FEM) in three-dimensional formulation using the PLAXIS 3DFoundation software system. Table 1 shows the initial data on the soil properties.

Table 1. Soil properties taken in calculations

EGE No.	EGE roof elevation	Thickness. m	Bulk density. $\gamma_{I.}$ kN/m3	Modulus of deformation E. MPa	Specific cohesion c_I kPa	Internal friction angle ω_I. deg	Dilatancy angle χ. deg
1a	2.000	1.0	20.6	54.0	2	38	8
1	1.000	0.7	20.7	59.0	2	36	6
2a	0.300	2.4	19.9	36.0	3	35	5
2b	-2.100	1.3	19.7	28.0	1	39	9
2	-3.400	0.8	17.2	3.6	8	7	0
3	-4.200	5.5	19.1	5.0	8	10	0
4a	-9.700	1.5	18.4	6.0	9	10	0
4	-11.200	1.9	17.9	8.0	8	7	0
5	-13.100	2.0	19.4	9.0	16	14	0
6	-15.100	1.9	22.3	13.0	19	23	0
6a	-17.000	4.7	22.6	17.0	28	25	0
7	-21.700	7.3	21.4	25.0	105	13	0
8	-29.000	20.0	22.1	90.5*	148	22	0

The groundwater level is taken at a depth of 1,0 m from DL. Ground surface elevation: +2.000 m. Trench bottom elevation: -30.000 m. Trench width: 1.2 m. Length of panel: 5.6 m. The guide wall is taken to be rectangular in the cross section, 0.8 m wide and 1.5 m deep. Load from the equipment: pressure under crane tracks: 91 kPa (it is assumed that a SoilmecSC-120 crawler-mounted crane would be used with the working weight of 130 t and track width of 1.0 m). A distance from the internal edge of the guide wall to the crane tracks is 2.8 m (2,0 m from the external edge).

The hydrostatic pressure of bentonite slurry on the trench walls was modeled by deactivating the soil in the corresponding clusters, while the water pressure in these clusters was replaced with the bentonite slurry pressure based on its density of 11 kN/m^3 (water pressure parameters in the trench clusters: $y_{ref}=2.000m$, $p_{ref}=0.000m$, $p_{inc}=11.000kN/m^2/m$).

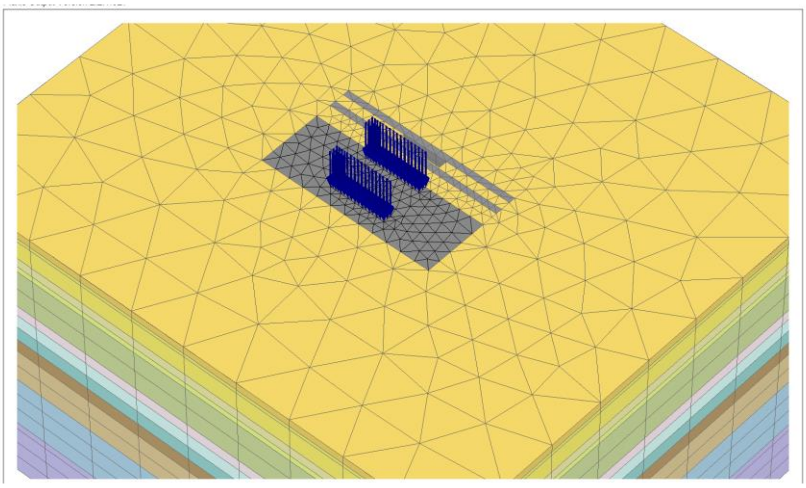


Figure 6. Crane travel parallel to guide wall

Calculation results:

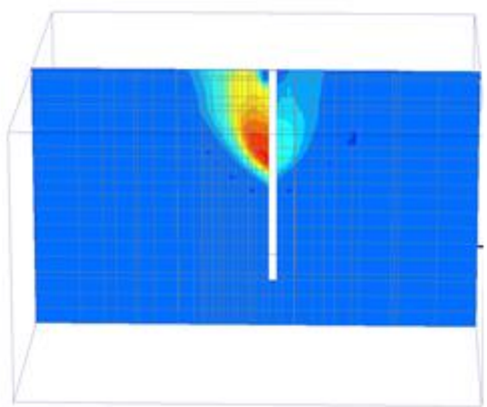


Figure 7. Stability calculation results based on "phi-creduction" method: area of potential collapse

Stability margin factor: 1,2 (calculation before clarification of the foundation soil properties)
We take the trench top elevation as equal to 4,000 m and keep the same initial data.
Calculation results:

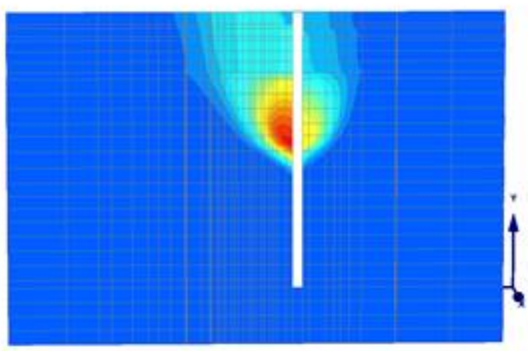


Figure 8. Stability calculation results based on "phi-creduction" method: area of potential collapse

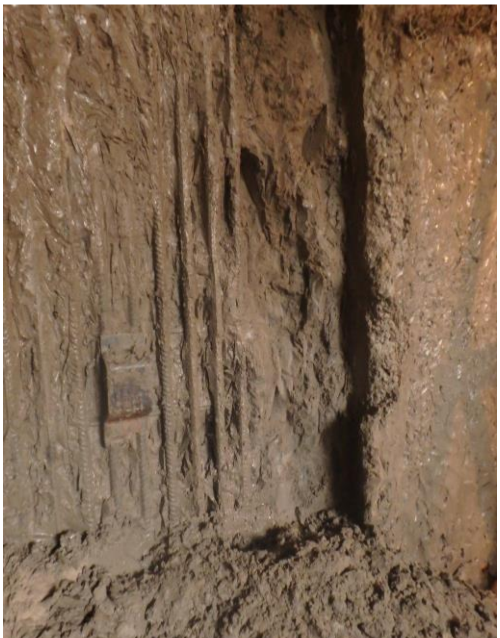
According to the results of the calculation made, the stability of the well walls is provided, and in

this case, the stability margin factor is 1.37.
Thus, based on the calculation made, it can be concluded that when the trench top elevation (working platform for crane) changes, the wall stability margin factor of the trench filled with bentonite slurry changes as well. After having completed all above calculations and taken action to eliminate the negative impact of weak water-saturated soil layers, it was possible to provide the quality of the constructed diaphragm wall, to significantly reduce the risk of water-saturated soil penetrating the excavation pit through the diaphragm wall, and to provide the safe excavation of the pit.
The completed calculation showed that, with an increase in a height of the working platform for equipment to construct the diaphragm wall, the wall stability of the trench filled with bentonite slurry also increases. Hence, the calculation determines the possibility whether it is safe to perform operations for the construction of the diaphragm wall from the day surface level, or whether an additional working platform is required, or a pilot pit may be excavated. We verified the calculation results based on completed and surveyed structures from various digging levels [3].

5. Examples of practical use of diaphragm walls for shoring of excavation pits in soil conditions of Saint Petersburg

To verify the calculations, let us consider materials for the construction of excavation pits with a diaphragm wall, for which hydraulic grabs were used. The examples under consideration have different soil conditions, which are characterized by the presence of weak silty-clayed water-saturated soils [4]. Given that, it should be noted that the same design parameters (thickness of structure, strength properties of concrete and reinforcement) were used in the computational models. In fact, when analysing the materials, visually inspecting the structures during excavation and studying the work of the structures during excavation, it was found that there are differences in the quality of the contact (peripheral) concrete layer, there are differences in the quality of the structure formation along the wall height depending on the presence of weak water-saturated soil interlayers. The above circumstances called for additional check calculations of the structure for stability. Figure 8 shows the defects of the diaphragm wall that may occur in the area of soft soils: formation of concrete fins at a depth of 1,5-2,0 m from the surface under the guide wall base, distortion in formation of protective cover layer due to interaction of concrete with contact layer of silty water-saturated sand mass.

a)



b)

c)

d)

Figure 9. Defects of the diaphragm wall in silty-clayed water-saturated soils: a) Formation of concrete fin in weak silty-clayed soils; b) Distortion in formation of surface protective cover layer; c) clay sticking resulting from poor cleaning of bentonite slurry, d) incomplete concreting of panel in the top area.

Let us consider the experience in using the diaphragm wall technology on some sites in Saint Petersburg:

Site No.1: At an industrial machine-building factory in Kolpino district of Saint Petersburg, it became, during the factory renovation, to construct a technological pit 13.5 meters deep for equipment installation (Figures 9 and 10). In geomorphological terms, the renovation site is confined to the lacustrine-and-glacial plain within the limits of Prinevskaya Lowland. The following formations are represented in the geological structure of the site from the surface: technogenic deposits with a thickness of about 1.2-1.5 m, which are underlain by the thick layer (9.0 to 11.5 m) of banded silty clayey loams from flowing to high-plastic consistency with the low strength characteristics (angle of internal friction φ is 5 to 17 degrees, specific cohesion is 7 to 15 kPa, consistency index c is 0.66 to 1.37, general deformation modulus E is 3 to 4 MPa). Lower along the section, glacial deposits occur that are represented by silty moraine clayey loams with the inclusion of gravel and pebbles up to 15%, with lenses and interlayers of sand of different fractions from high-plastic to hard consistency. At the bottom of the section, silty and gritty sandy loams of hard consistency occur with gravel and pebble up to 20% and sand lenses of various fractions (W=0.11; specific gravity ρ=2.28 g/cm^3, porosity coefficient e=0,304, consistency index I_L= - 0.27, internal friction coefficient $\varphi=29^0$, specific cohesion c=22 kPa, general deformation modulus E=16 MPa). In hydrogeological terms, it should be noted that the site is characterized by the presence of underground water with free surface. The second aquifer with head water (a head is 2.7-3.4 m according to the surveys data) was found in drilling the exploratory holes at depths of 17.6-24.8 m and confined to the lenses and interlayers of glacial and interglacial marine Mikulin sands of various fractions; underground water of sporadic distribution also have a head of 3.3-3.7 m. Thixotropic properties of clayey loams are noted as unfavorable building properties, which excludes active dynamic impact on soils during construction works

The design provided for the construction of a diaphragm wall 600 mm thick and 23 meters deep.

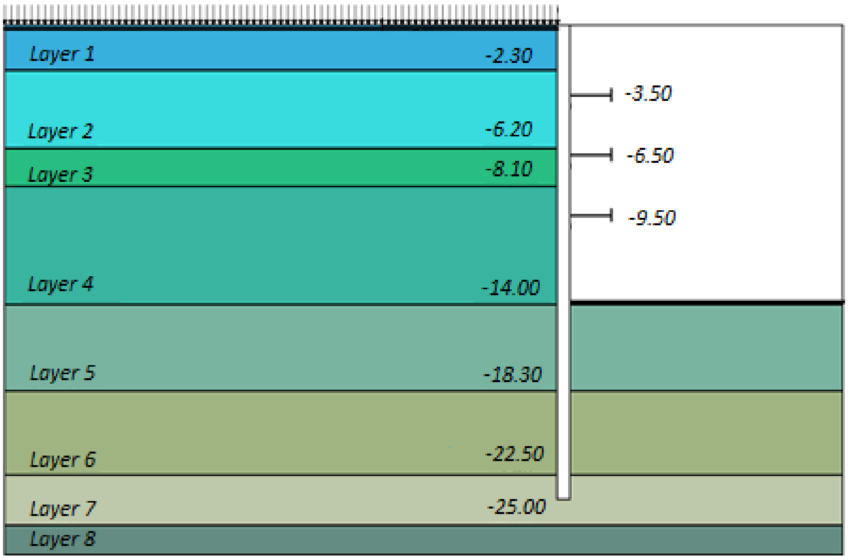
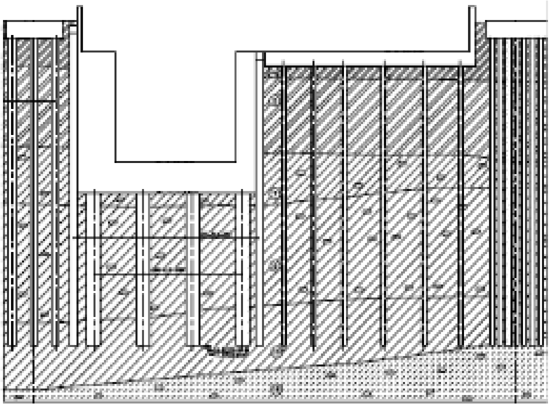


Figure 10. Computational model of diaphragm wall with three rows of braces



a)

b)

Figure 11. Structural section of the technological pit (a). View of excavated pit in diaphragm wall structures (b). The bracing system of the excavation pit is made in the form of pipes.

The diaphragm wall was constructed using a SoilMec R 870-based set of equipment and a Russian-made bentonite plant. When digging the pit to the design depth, we carried out monitoring of the diaphragm wall conditions in various soil layers with the study of the colmatation zone size of mudding in the contact layer and the surface layer conditions of the structure. The distribution of bentonite slurry was observed to a depth of 15-47 mm in the mass of surrounding soil, while we established, in the “wall-soil” contact zone due to complex mechanical and physical-and-chemical processes, the presence of a cement-bentonite layer 9 to 21 mm thick, which had to be removed to clean the concrete surface of the wall.

The calculation determined the need for installation of three levels of bracing metal structures along the depth of the excavation pit, which was implemented when the pit was constructed. Instrumental monitoring of the horizontal displacement of the pit walls during excavation showed the maximum horizontal displacement of 18 mm inwards the pit at the calculated value of 35.6 mm, which indicated the high reproducibility of the calculation results based on the proposed computational model with the actually obtained data.

Site No.2: Financial and credit centre with built-in indoor spaces and underground parking in Khersonskaya Street (Figures 10 and 11). The project design and construction were carried out by Renaissance Construction Company, the structural part of the design was made by KTISIS-PROEKT LLC. The proposal for the diaphragm wall construction, the design-basis justification and the execution of the work were carried out by Geostroy CJSC.

The site is located in the Central District of Saint Petersburg in the built-up part of the city, in place of the regional historical monument - Pravda Newspaper Publishing House, whose facade is to be preserved. In geomorphological terms, the survey site is confined to the lacustrine-and-marine terrace adjacent to the Gulf of Finland. The engineering-and-geological conditions are characterized by the following formation of soils in depth from the ground surface: the upper part of the section is represented by recent Quaternary technogenic deposits in the form of filled soils, which are underlain by biogenic deposits in the form of peat, and lacustrine-and-glacial deposits, which are represented by silty sand. Lower along the section, Upper Quaternary lacustrine-and-glacial deposits occur that are represented by high-plastic clayey loams, which are underlain by glacial deposits: low-plastic clayey loams with high-plastic interlayers, layers of silty sand, and plastic gritty sandy loams and plastic silty sandy loams. The hydrogeological conditions of the construction site are characterized by the presence of two underground water horizons, which are confined to the Quaternary deposit system. Thus, underground water of the first aquifer from the surface is confined to lacustrine-and-marine deposits: silty sands, as well as to lenses and interlayers of sand in Upper Quaternary lacustrine-and-glacial deposits and glacial sandy loams and clayey loams. According to the data provided by LENTISIZ CJSC survey company, underground water was encountered at depths of 1.70-1.80 m during the survey period (May 2008). Water is non-artesian. Underground water of the second horizon was encountered at depths of 16, 20-18.7 m, they have a head of 7.2 – 8.7 m. The upper and lower confining beds are glacial sandy loams and clayey loams.

According to TSN 50-302-2004, Geotechnical Category 3 is taken for this construction project.

The design provides for the construction of a diaphragm wall 600 mm thick and 14 meters deep.

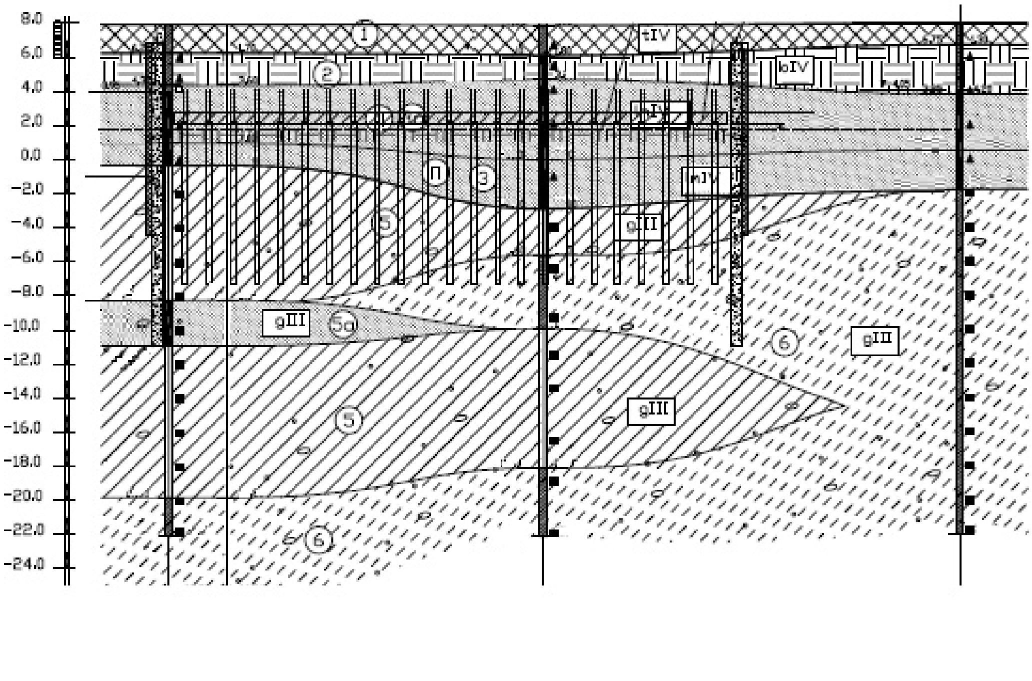


Figure 12. Engineering-and-geological profile of construction site

Figure 13. View of diaphragm wall structure and bracing system

Site No. 3: Apartment building with built-in indoor spaces, built-in child care centre, underground parking. Address: Russia, Saint Petersburg, Institutsky Pr. 16, Bldg. 1A.

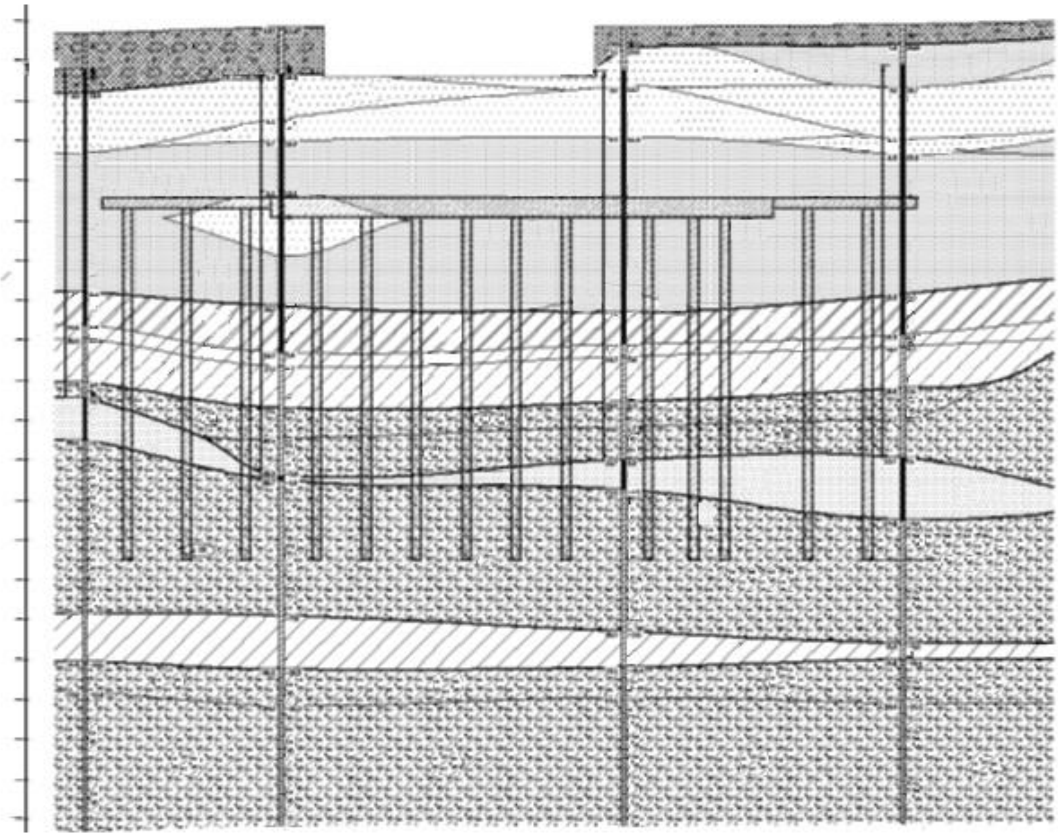


Figure 14. Siting plan of building substructure

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The site is located in a quarter limited by 2nd Murinsky Prospekt and Akademik Likhachev Alley on the south and north, Orbeli Street and Institutsky Avenue on the west and east. In accordance with the technical report on the engineering-and-geological conditions of the site, the site in question is classified as Difficulty Category II (medium difficulty). Geologically, the site is formed, to a depth of 40.0 m, by recent technogenic deposits; Upper Quaternary lacustrine-and-glacial and glacial deposits, Upper Quaternary undivided lacustrine, lacustrine-and-glacial and fluvio-glacial deposits; Middle Quaternary lacustrine-and-glacial and, at the base of the section, glacial deposits.

The hydrogeological conditions are characterized by groundwater with free surface encountered on the site; artesian aquifer confined to undivided lacustrine, lacustrine-and-glacial and fluvio-glacial deposits; artesian water of sporadic distribution that are confined to Middle Quaternary glacial deposits. When calculating the water inflow into the excavation pits, it is recommended that the filtration coefficients should be taken as follows: for EGE 1 filled soil, 20 m/day; for EGE 2 coarse-grained dense sands, 35 m/day; for EGE 2a coarse-grained medium-density sands, 45 m/day; for EGE 3 medium-grained dense sands, 20 m/day; for EGE 3a medium-grained medium-density sands, 25 m/day; for EGE 4 fine-grained dense sands, 6 m/day; shoring of excavation pit is cast-in-situ reinforced concrete trench diaphragm wall: thickness is 800 mm; elevation of diaphragm wall top is +21.550 m; elevation of diaphragm wall bottom is -5.000 m; material: concrete of Class B35; W12; F150.

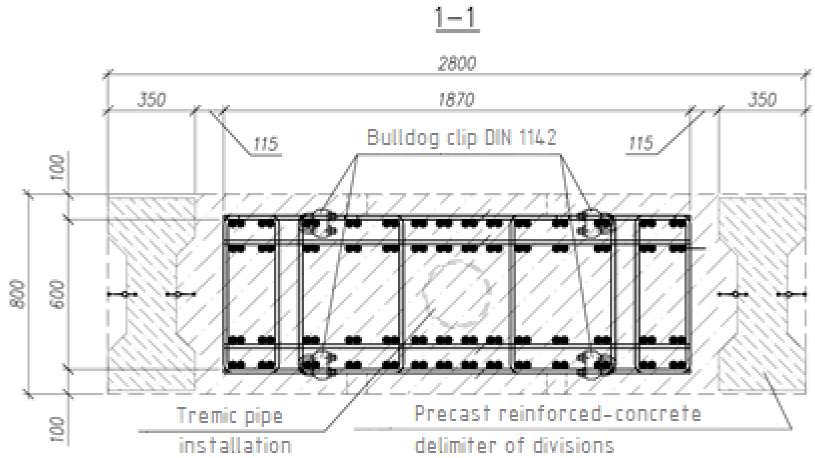

Figure 15. Siting plan of building substructure

The calculation determined the need for installation of two levels of bracing metal structures along the depth of the excavation pit, which was implemented. Instrumental monitoring of the horizontal displacement of the excavation pit walls during excavation showed the maximum horizontal displacement of 18 mm inwards the pit at the calculated value of 35,6 mm, which indicated the high reproducibility of the calculation results based on the proposed computational model with the actually obtained data.

<u>Site No. 4:</u>

The construction footprint almost coincides with the boundaries of the construction site. As a result, no free area was actually left to arrange driveways, temporary construction camp, places to store building materials and to install construction equipment. At a distance of 15 meters to the north of the site, the River Moika flows, 10 meters to the east, there is the Kryukov Channel. In addition, the construction conditions are complicated by the proximity of the existing buildings: At a distance of 13 meters to the west, the operations area is adjacent to the residential building at Moika River Emb, 104, Bldg A and to the residential building at Matveyev Lane 1. At a distance of 18 meters to the northwest at Matveyev Lane 1, Bldg A, the operations area is adjacent to the building of the Rimsky-Korsakov College of Music. On the south at a distance of 6 meters, the operations area is adjacent to the non-residential two-storey building at Dekabristov Str. 29, Bldg C, the 6-7-storey residential building at

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Dekabristov Str. 29, Bldg B, and, at a distance of 30 meters, to General Education School No. 259 at Kryukov Channel Emb. 3, Bldg A. Additional difficulties in the design and construction are created by the sewage header with diameters of 1840x1200 mm located at a depth of ≈11.5 m along the Kryukov Channel Embankment.

According to drilling data to a depth of 45.0 m, the geological structure of the site is represented by recent technogenic formations (tIV) and lacustrine-and-marine deposits (lmIV), Upper Quaternary deposits of lacustrine-and-glacial (lgIII) and glacial (gIII) genesis that are underlain by Vendian deposits (Vkt).

The hydrogeological conditions of the operations area are characterized by the presence of underground water confined to the Quaternary deposit system. Underground water is confined to filled soils, lacustrine-and-marine sands, sandy interlayers and lenses in clayey soils of lacustrine-and-marine, lacustrine-and-glacial and glacial genesis. During the survey period, they were encountered by all wells at a depth of 2.0-2.6 m (elevation 0.2-1.0 m). Water is non-artesian. The observed level is close to the annual average one. During periods of rains and intensive snow melting, the maximum level should be expected ~ 1.0 m higher than the observed one (~ elevation 2.0 m). In addition, underground water is hydraulically connected to the waters of the River Moika and the Kryukov Channel, which has effect on the horizon regime. During the period of storm surge phenomena from the Gulf of Finland when the water level rises in the River Neva and the associated waterways, there may be a short-term rise in the underground water level.

- Criticality rating of the projected building is II (normal) in accordance with the provisions of the technical regulation on safety of buildings and structures (Federal Law No. 384 dated 30.12.2009). - Based on Appendix B, SP 11-105-97, Part I, the engineering-and-geological conditions of the site are classified as Difficulty Category II.

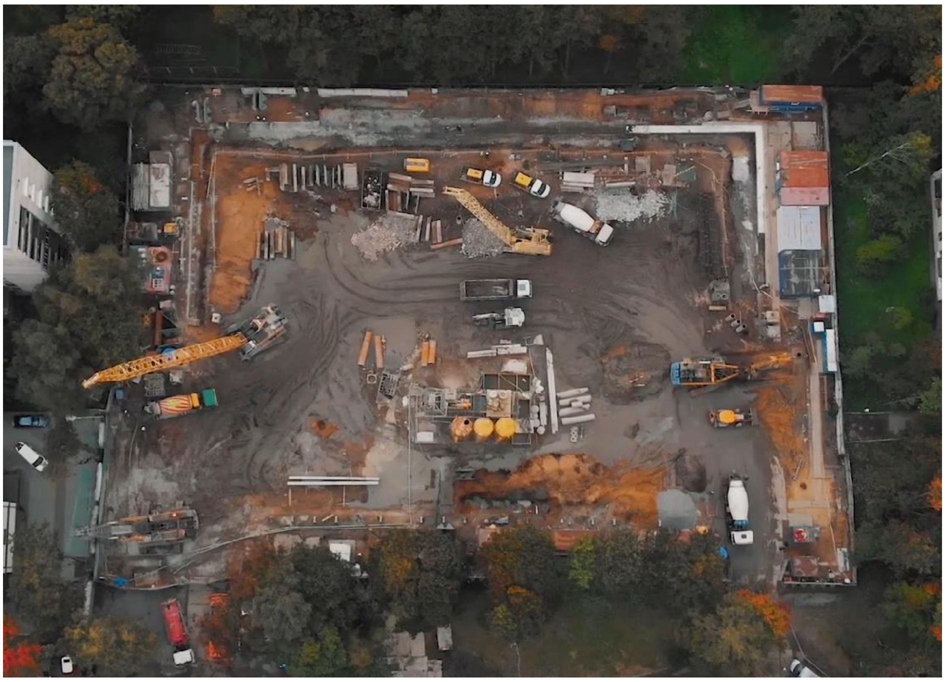

Figure 16. Site No. 4 Apartment building with built-in indoor spaces and underground parking. Address: Saint Petersburg, Admiralteysky District, Moika River Emb. 102, Bldg A.

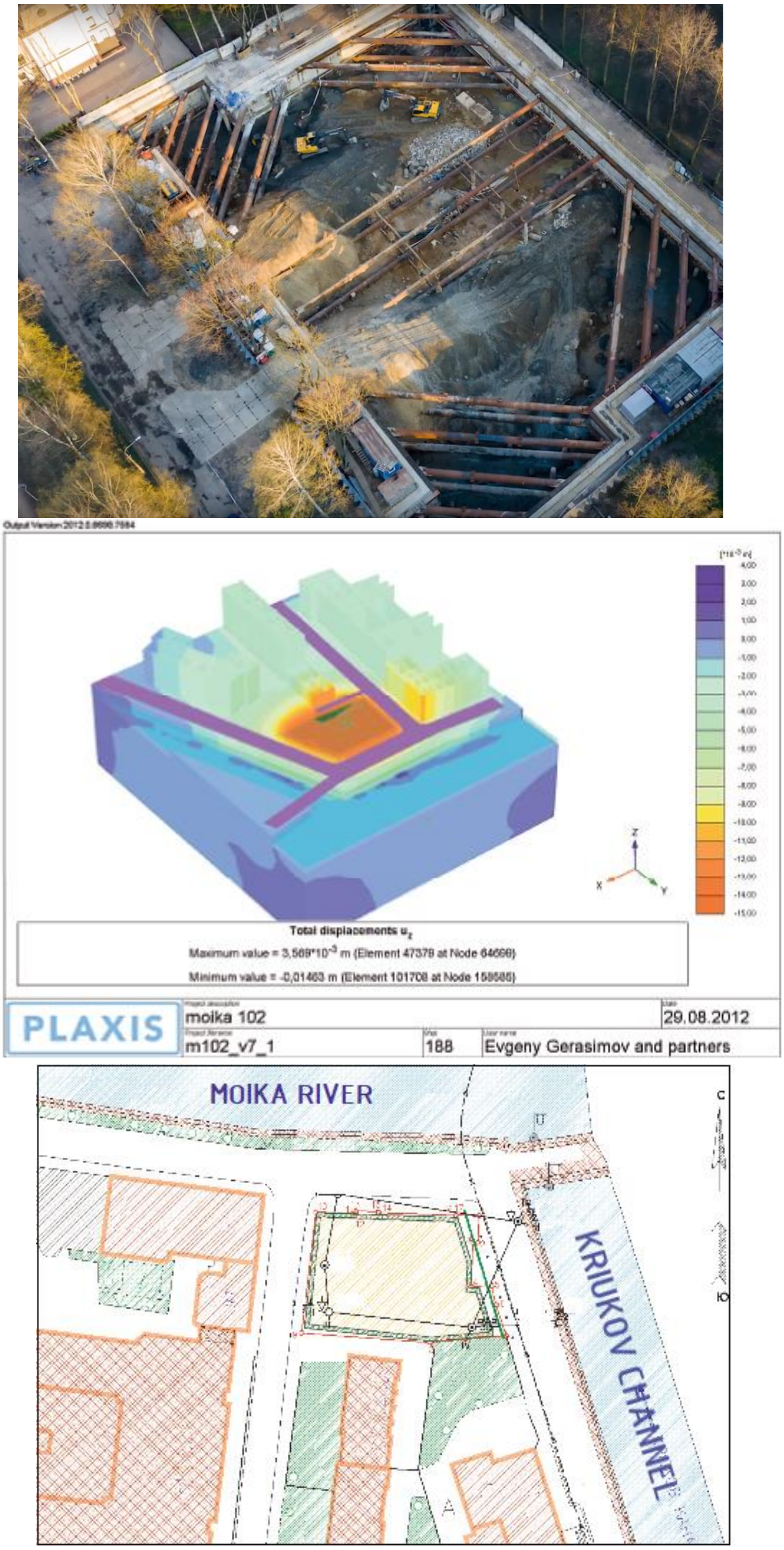

Figure 17. Plot plan

- Shoring of excavation pit shall be made in the form of a cast-in-situ reinforced concrete trench wall 1000 mm thick, concrete of Class B35W12F150 with internal waterproofing, and the wall shall be load-bearing wall at the same time. A depth of the trench walls was specified such that they are buried into moraine deposits (EGE-10 hard clayey loam) with the modulus of deformation equal to 20 MPa. The trench is excavated using hydraulic grab equipment under the protection of bentonite slurry with work areas 2,5 m long. The connection quality of the trench walls is provided by the angular L-shaped and T-shaped work areas. The reinforcement of the trench diaphragm wall was selected according to the strength and crack resistance in full compliance with the design stages associated both with the features of soil excavation in the pit and with the construction sequence of load-bearing reinforced concrete structures.

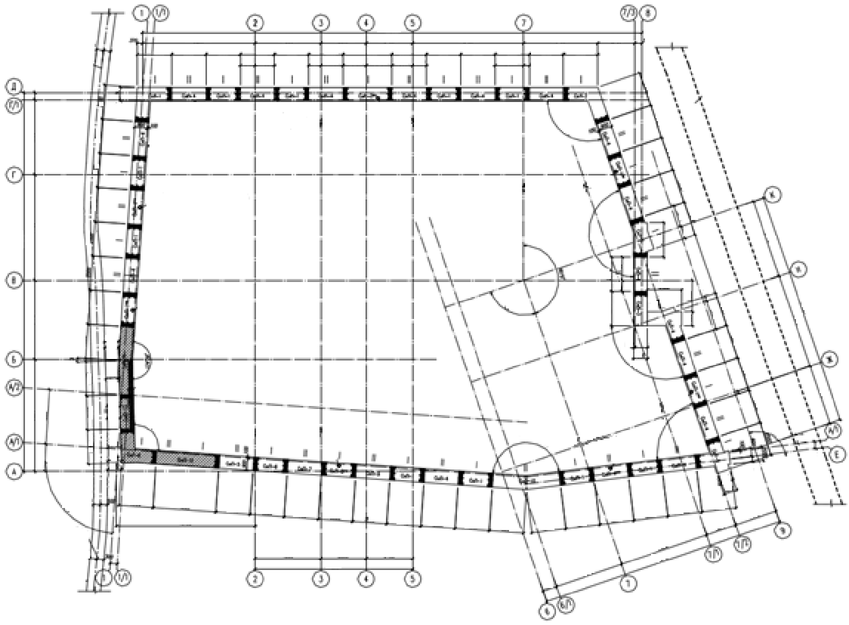

Figure 18. Shoring elements layout

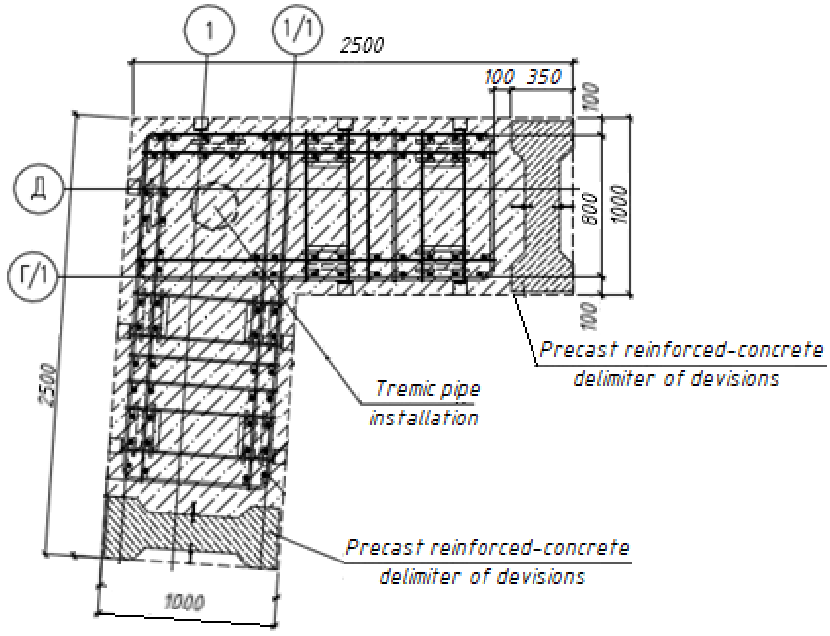

Figure 19. Corner Technological scheme.

Based on the experience of the implemented objects with the use of the technology " diaphragm wall", it can be argued that on the example of difficult ground conditions in St. Petersburg, this technology has proven itself as the safest for work in conditions of cramped urban development. The comparison of the calculated parameters of technological precipitates during the production of works coincides with the actual values, which allows predicting the negative impact of new construction and minimizing the risks at the design stage. The diaphragm wall as much as possible provides a solution to the problem of preservation from the negative effects of new construction, and at the same time allows more extensive development of underground space. Variability of technologies of the device allows carrying out works in practically any ground conditions, and to carry out works qualitatively and safely.

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