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Anchorage of Retaining Walls and Antilandslide Structures

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Abstract

The article describes the experience of designing, arrangement and testing of anchors for fixing the protection of deep foundation pits in narrow urban areas on various construction projects during the reconstruction.

Keywords: retaining wall, anchor, trials.

There are various types of fencing when deep foundation pits are organized. The most widespread one is pile-beam-type fencing (so-called Berlin support). You can see such structure in Fig. 1. This fencing was used in Minsk in Shornaya street. Such structure provides steadiness through the organized inclined earthfill without anchorage from one side of the pit and through the possibility of shifting of the fencing in the direction of the excavation from the other side of the foundation pit.

Disadvantages of pile-beam-type fencing:

1. Heavy expenses of steel section in short supply for installation of support.
2. Heavy expenses of timber, which is used for horizontal sheeting between supports.
3. Adverse dynamic influence on surrounding buildings during the driving double tees. The driving double tees into boreholes helps to reduce this influence.

Fig. 1. Pile-beam-type fencing without anchors of deep foundation pit

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Fencing in the form of trench or pile walls haven't got disadvantages mentioned above. Moreover, such fencing can combine load-bearing and antifiltering functions during the embedding in aquifuge.

If the foundation pit is more than 7 meters deep the steadiness of trench walls is provided by setting-up of one or several tiers of strut rails or anchors for perception of horizontal stress of soil and for perception of vertical load. This makes it possible to reduce necessary jamming depth of walls lower the bottom.

Technology, which implements the injection of piles or anchors and which also strengthens soils in the foundation bed of buildings, has great importance to fix fencing of foundation pits and to preserve surrounding buildings.

Mastering this technology began in 1980 when trench walls were anchored in Minsk on Kharkov street [1]. Then the wealth of experience was stored during the construction of underground railway in Minsk and other projects. The biggest construction with anchoring was the building of huge foundation pit 18 meters deep (Fig. 2). This foundation belongs to the underground shopping centre under Independence Square in Minsk.

a) b)

Fig. 2. General view of foundation pit on Independence Square in Minsk with anchored containing walls

Geotechnical conditions in that place were represented by mixed grained sand, and also by moraine dry clay sand with gravel-pebblestoned inclusions under 30% stretching under the sands. Subterranean water was absent.

At first I-beams were driven to the depth of 23 metres in incremental step of 1.8 metres by jigger. But after such operation produced intensive vibration of soil and surrounding buildings forced to sink I-beams into the boreholes with next driving to designed depths.

Near the buildings of Capital Construction Board, Teachers' Training Institute and underground passages fencing was made of contacting CIDH piles. As the soil was excavated the fencing was fixed by CIDH (Cast-in-drilled-hole) anchors (Fig. 3) with control rods on roots in sleeves (Fig. 4) according to author's certificate No 1392203 [2].

a) b)

Fig. 3. Anchoring of containing walls: a) pile-beam-type, b) from cast-in-drilled-hole piles

a) b)

Fig. 4. Assembly of anchor bars according to author's certificate No 1392203 at the bottom of foundation pit (a) and sinking of bars into the hole (b)

Quality pressing of surrounding soil during the controlled process of mortar injection can:

1. Increase bearing capacity of anchors
2. Reduce cement consumption
3. Reduce term of increase in cement stone's durability even in clay soil.

Use of multimetallic water concentrate additive in mortar gave the possibility to strain anchors in 7 days after injection in moraine clay sand and 2,5 days in sand according to Standards of Belarus 1113-98.

Work in production and testing anchors being under scientists' observation and theirs calculations of deflected mode made it possible to decrease the number of anchors' tiers and to decrease total amount of anchors by 22,4%, i.e. from 2137 to 1659 pieces.

CIDH (Cast-in-drilled-hole) anchors were applied in the foundation of 120-metre-long arch cover in Vitebsk amphitheatre. Southern part across Gogol street near the location of foundation Fn1 has a scarp 5 meters high with a tip 30–45°. Geological feature was represented as fine sand, gravel sand, sandy clay and calcic dolomite. Subterranean water was detected near the ground surface.

There were applied bored and cast-in-place piles with injection pressing of soil under the pile's end. Part of the horizontal stress was taken by inclined prestressed cast-in-drilled-hole anchors. There were made vertical bored piles ø630 mm and inclined bored piles ø426 mm 11..12 metres long under each foundation.

To keep a slope in its position there was made a wall from bored piles ø630 mm 10 metres long which was used as formwork for the foundation Fn1. 136 vertical driven piles were made for it with a cross-section 35×35 centimeters 8 metres long. Tubes were put in the body of foundation Fn1 (Fig. 5). Through these tubes boreholes drilled after the pour with installation of 26 injection anchors.

78 piles were applied in the foundation Fn2 (18 vertical piles in 2 ranks and 60 piles inclined 20° to vertical plane in 4 ranks) 7 и 8 metres long.

Fig. 5. Pipe arrangement in Fn1 in Vitebsk

Pressing of soil under the foundation was performed by injection of cement mortar through injection tubes, installed in the slab.

Some of anchors had low bearing capacity according to tests. Therefore additional pumping of mortar had to be produced between roots and free part along the length of rod. It ensured opportunities for perception of designed load and gave the possibility not to install additional anchors.

Anchoring of retaining wall was used when restoring outhouses built in Minsk on International street. This wall was intended for keeping of soil during the construction period and during further maintenance. Two tiers of anchors were provided for wall's stabilization. Total height of retained slope was 6,4 metres. At the top of the steep slope a building was situated with thick communications network.

a) b)

Fig. 6. International street, Minsk: a) excavation near the pile wall on the first tier; b) on the second tier

The site consisted of lower stratum was medium sand of low durability, medium-strength, durable, and also pulverescent durable sand. Level of subsoil water was 1–1,5 metres lower the bottom.

Rated designed force on anchors of upper tier was N_a = 200 kN under live load during the period of construction (footing excavation) and N_a = 160 kN under dead load during the working life of building (after backfilling).

Check test revealed that anchors No 5 and No 6 had deficient carrying capacity near the channel for conduits. It became the reason of soil's decompaction and decrease of clenching pressure in roots during the excavation. Carrying capacity of anchors No 15 and No 16, which was situated in the central part of retaining wall, corresponded design value. According to approval tests, only 7 of 14 anchors could bear rated force 300 kN, the rest of anchors – 200–280 kN. But corrections in calculations revealed decrease of maximum force in forces, that's why it made possible to use anchors with lower carrying capacity without additional anchors. It helped to reduce terms of construction.

a) b)

Fig. 7. Fencing of foundation pit for PLC "Priorbank": a) anchoring of monolithic reinforced concrete banding girt before excavations of foundation pit; b) General view of foundation pit

When the foundation pit was fenced for the building PLC “Priorbank”, there was applied fixing in one tier by anchors “Titan” in open cut on the slope between the nearest building on Winners avenue. Here was applied jetting technology when installing anchors and piles.

One tier of stressed injection anchors with roots in capsules according to author's certificate No 1392203 [2] (Fig. 8) was designed for fixing of foundation pit’s fencing, where foundation was made of piled sheets for high-rise building on Winners avenue. But design decision failed, because roots of anchors appeared in peat strata and piled sheets was bad (Fig. 9). Finally slabby-piled foundation was installed on anchor’s fixing.

Injection anchors and piles were designed and made according to author's certificate No 1392203 [2] as foundation for Г-shaped support of abat-jour during the reconstruction of stadium in Borisov (Fig. 8).

a)

b)

c)

Fig. 8. Fencing of foundation pit for high-rise administrative commercial centre: a) cast-in-drilled-hole piles; b) soil- cement piles; c) anchor bars according to author's certificate No 1392203

a)

b)

Fig. 9. Well boring (a) driving anchor bars in textile membrane according to author's certificate No 1392203; (b) Borisov

In cushion blocks anchors were tested for pulling and piles were tested for jacking. Jacking effort on pile base was transmitted by inner tube to the building-in hole outer tube, which was support together with foundation for loading jack. Thus, double testing load became total strength of pile was 550 kN, which provided perception of designed load.

In some cases if the pace of construction is high it has to refuse an anchoring and to do fencing of foundation pits by walls from piles with big diameters. To reduce the depths of jamming lower the bottom of foundation pit it need to resort to cementation hardening of soil before piles under the bottom due to jetting technology. Such decisions was applied for subsurface station of water purification in Belorussian metallurgical works in Zhlobin and also for plate polished glass manufacturing line on PLC “Gomelsteklo” in Kostyukovka of Gomel region.

Conclusions

1. Trench walls and piled sheets are effectively used in deep foundation pits.
2. Anchoring fixations of walls, which fence helps to reduce their thicknesses and the length of building-in lower the bottom, but increase period of works execution.
3. In some cases next measures help to accelerate erection of retaining walls:
   - using of inclined struts
   - increasing of piles’ diameters
   - hardening of soils (especially soft) by cementation lower the building-in under the bottom of foundation pit.

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