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EXPERIENCE OF IMPROVING THE OPERATING RELIABILITY OF DRILLING MACHINES AT THE INSTALLATION OF EXTRA DEEP WELLS IN COMPLEX GEOLOGICAL CONDITIONS

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Abstract.
Constructive and geotechnical solutions for the arrangement of bases and foundations of drilling rigs for the construction of wells up to 6000 m deep in complex engineering and geological conditions, as well as the results of approbation of these solutions are given. The thickness of non-building soils (soil-plant layer, peat, fluid-plastic and fluid loams) is 5.6 m, and the groundwater level is 1 m from the earth's surface. Different thicknesses of soil layers, as well as various layers and lenses were recorded within the massif. Geotechnical solutions of engineering preparation for prefabricated foundation slab from 5 rows of road slabs for a drilling machine with a capacity of 450 tons are analyzed, in particular: cutting weak soils with piles; improvement of the base under the machine by vertical reinforcement of weak soils with rigid elements and replacement of the top layer with a compacted sand cushion; improving the base with vertical gravel drains within water-saturated weak soils and replacing the top layer with a compacted sand cushion; improving the base with horizontal gravel drains and replacing the top layer with a sand cushion.

Keywords: drilling rig, foundation, base, subsidence, roll, weak soil, sand cushion, gravel drain, field test.

Introduction. A well is a complex innovative engineering project for mining. A modern well is an extremely complex system, which each time has an original trajectory in space, and sometimes it is a system of wells made from one point. (Fig. 1.1).

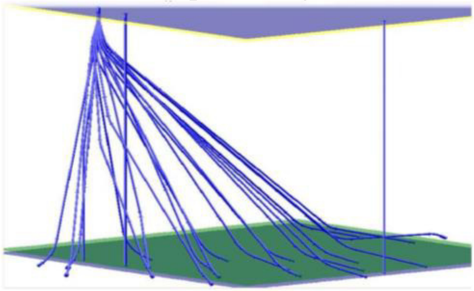


Fig. 1.1. Example of a modern well system (multi-well)

Modern powerful drilling rigs of various companies are used in the construction of deep and ultra-deep wells, including complex trajectories. This equipment is subject to extremely high requirements in terms of displacements and rolls in the process of their work, which can be caused by absolute and uneven subsidence of the base of their foundations. Very often (especially in the areas of the central part of Ukraine) drilling rigs have complex engineering and geological conditions (floodplains, swamps, weak soils, etc.). Due to the fact that the construction of the well is a temporary process (currently the leading companies have experience in drilling wells over 5,000 m deep for up to 4 months), to build under the drilling machine massive monolithic foundation slabs, reinforced concrete piles and other capital foundations provided on construction sites, impractical for many reasons (economic, environmental, the need for complete dismantling after completion of drilling, etc.).

1. Experience and problems of laying foundations for drilling rigs in complex engineering and geological conditions

Prefabricated foundation slabs are usually used as foundations. As a rule, they consist of road slabs in several rows. This design is not rigid and in the process of drilling may receive excessive deformation. Drilling rigs can lead to well construction accidents and significantly increase both the time and cost of the well drilling process. Therefore, the problem of improving the operational reliability of drilling rigs when installing ultra-deep wells in difficult geological conditions is extremely relevant. Some of the above problems are analyzed in scientific papers [1,2].

Studies of subsidence of the foundations of heavy and high equipment, which is intended to be temporarily operated (less than a year), in complex engineering and geological conditions were almost not conducted. Therefore, this issue requires the systematization of various experience in the operation of equipment in complex engineering and geological conditions under different geotechnical solutions [3-8], in particular with the improvement of the soil base, which is why this article is devoted.

2. Methods of research of the bases under drilling rigs

When constructing ultra-deep wells in Ukraine, and especially in the Poltava region, drilling contractors often use a drilling rig with a capacity of 450 tons (general types of equipment are shown in Fig. 2.1).

In Fig. 2.2 shows a photo of one of the sites where the installation of the drilling rig was planned.

Adverse physical and geological processes and phenomena for many sites include:

1) thick (from 4.5 to 5.6 m) thickness of non-building (soil-plant layer, peat on the base of the layer silty, rubberized, with organic residues, fluid, very heterogeneous) and weak soils (loam (bottom silt) light dusty, from fluid-plastic to fluid, with layers of sand, layered; modulus deformation of soil $E \leq 5$ MPa). When using them as a natural basis for foundations, excessive and uneven deformations of the soil mass are possible;

Fig. 2.1. General view of the drilling machine

Fig. 2.2. Engineering and geological conditions of the site for drilling machine installation

2) soils capable of thixotropic rarefaction in the case of dynamic loads;

3) significant heterogeneity of the soil mass - different thicknesses of soil layers, the presence of layers and lenses;

4) flooding of the territory.

For drilling rigs as foundations, as a rule, use a foundation slab with dimensions in the plan of approximately 20x32 m and a thickness of 700 mm, which is arranged from 5 rows of road slabs with appropriate bandaging and which are combined with holders from the channels (Fig. 2.3).

Without proper engineering training, the above solution will not be able to ensure trouble-free operation of the drilling rig.

The following is an example of the arrangement of the drilling rig in the complex engineering and geological conditions of Poltava region.

Engineering and geological conditions of the site are represented by the following soils:

EGE-1 - loam gray, dark gray, light dusty, from hard to soft plastic, layered, with layers of sand, humus-bath, thickness 0.4-0.7 m;

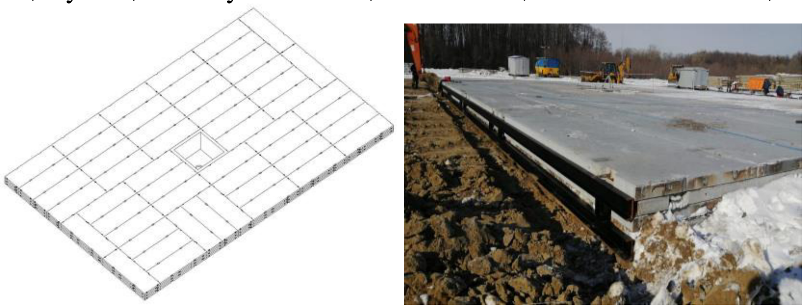


Fig. 2.3. Space image and photo of the foundation for the drilling rig

EGE-2 - sands loam gray, blue-gray, dusty, from plastic to fluid, heterogeneous, with layers of sand, thickness 1.0-2.1 m;

EGE-3 - sands gray, bluish-gray, dusty, from loose to medium density, with layers and lenses of sandy loam, thickness 1.5-2.5 m;

EGE-4 - sands blue-gray, shallow, medium density, saturated with water, with layers and lenses of sand, thickness 0.4-1.4 m;

IGE-5 - sands gray, shallow, medium density, saturated with water, thickness 1.2 m.

At the time of engineering and geological surveys (June 2020), the groundwater level was at a depth of 1 m from the earth's surface. This level was established after the installation of a ring drainage system with forced pumping around the site.

Thus, the unfavorable physical and geological processes include:

- man-made processes - the territory is under the influence of man-made factors and human engineering activities. At the time of the survey, the site was planned and the upper layers of soil to a depth of 1.0 m were cut and planned into a dump near the site;

- weak and heterogeneous soils – at the moment the territory to a depth of 2.8 to 4.4 m is composed of heterogeneous sandy or clay soils. Dusty sands are loose sandy layers with layers and lenses. Clay soils (loams and sands) are in a state from soft-plastic to fluid with layers and lenses of sand. When using them as the basis of foundations, non-uniform deformations of the soil mass are possible;

- flooding of the territory - the territory at the time of the survey is flooded. With a significant rise in water levels in rivers (seasonal or heavy rainfall), the area may be flooded.

In the given difficult engineering-geological conditions some geotechnical decisions of engineering preparation or effective bases under the prefabricated base plate for the drilling rig with a loading capacity of 450 t for construction of a well up to 6000 m deep (Fig. 2.4-2.7) are offered:

- cutting weak soils with pile foundations [9-11] (Fig. 2.4);

- improvement of the soil base for the drilling rig by vertical reinforcement of weak soils with rigid elements and replacement of the top layer with a compacted sand cushion [10-14] (Fig. 2.5);

- improvement of the base under the drilling rig by arranging vertical gravel drains within water-saturated weak soils and replacement of the upper layer with a compacted sand cushion [15] (Fig. 2.6);

- improving the soil base for the drilling rig by installing horizontal crushed stone drains and replacing the top layer with a compacted sand cushion [15] (Fig. 2.7).

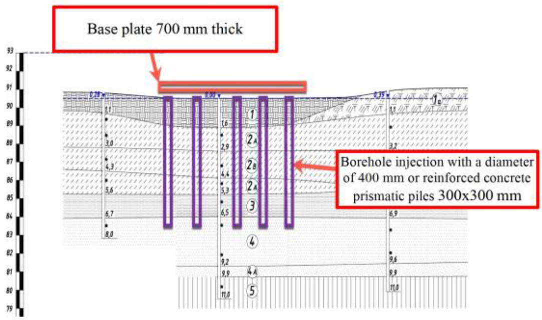


Fig. 2.4. Option of cutting weak soils with pile foundations

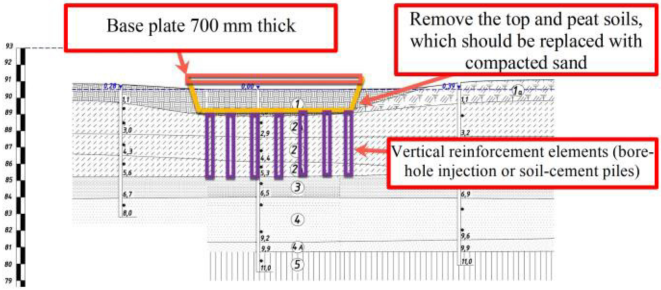


Fig. 2.5. Option to improve the soil base for the drilling rig by vertically reinforcing weak soils with rigid elements and replacing the top layer with a compacted sand cushion

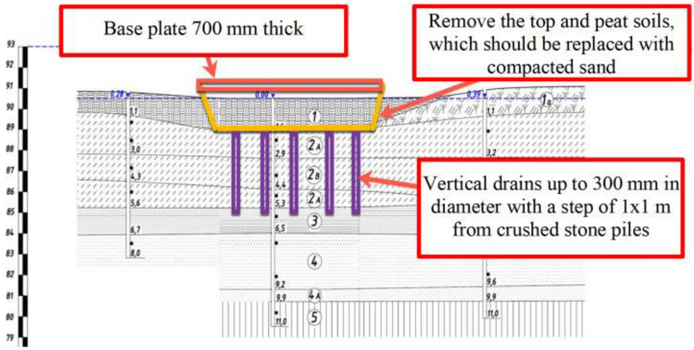


Fig. 2.6. Option to improve the base for the drilling rig by arranging vertical gravel drains within water-saturated weak soils and replacing the top layer with compacted sand cushion

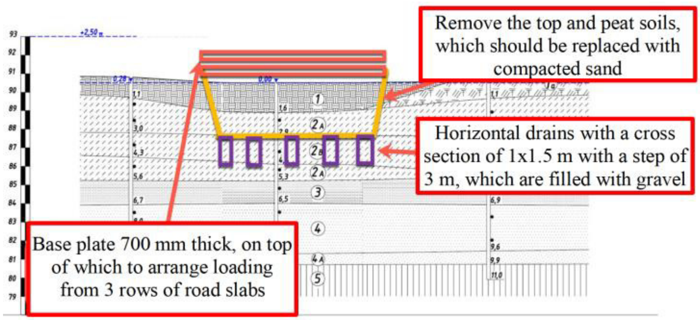


Fig. 2.7. Option to improve the soil base for the drilling rig by installing horizontal crushed stone drains and replacing the top layer with a compacted sand cushion

3. Results of research of the arrangement of the foundations for the drilling rig in complex engineering and geological conditions

The main option was to improve the soil base for the drilling rig by installing horizontal crushed stone drains (Fig. 2.7). Upon completion of the work, the gravel drains were replaced with a solid gravel base. The work was performed as follows: first, an excavator performed a trench 1.5 m wide to the maximum depth (almost to the design mark) and immediately filled it with gravel and sand to the groundwater level; then a retreat was made and a new trench was arranged according to the same method and so on over the entire area of the foundation slab; further trenches were made between the already arranged ones, but the design depth of these trenches could not be reached by 0.4-0.6 m. The trenches were flooded rather quickly, but it was almost immediately filled with rubble, and the entire area of the excavation was covered with sand. From the mark approximately 20 cm above the groundwater level, the sand cushion began to be compacted in layers.

As a result of monitoring the technology of earthworks for the construction of the pit with partial replacement of gravel and sandy soil, it was found that in general the contractor achieves design solutions.

The control of the sand cushion arrangement was carried out by sampling of compacted soils from the pits. At the same time, soil samples and monoliths were taken from different horizons with an interval of 0.3 m. The average value for the mass of compacted soil is ρ_d=1,667 t/m^3, which is in the range of normalized values of dry soil density for compacted bases (ρ_d=1,65-1,7 t/m^3).

The main task of the reinforcement was to ensure the maximum subsidence of no more than 10 mm at the worst combinations of loads and impacts when drilling a well.

Therefore, in order to confirm the calculated data, field tests were conducted by loading the paved slab with road slabs to achieve the design loads and impacts when drilling a well. The experimental loading on the foundation slab was selected from the conditions of the most unfavorable combinations of loads and influences during the operation of the drilling rig.

The weight of the drilling rig according to the passport data in total with technological loads when drilling wells is 680 tons (6800 kN).

The weight of the foundation slab is 260×4.2+208×0.0184=1096 tons (where 4.2 tons is the weight of the road slab; 260 is the number of road slabs in the foundation; 208×0.0184=4 tons is the weight of the clip made of channels).

Thus, the total weight of the foundation with technological equipment will be 680+1096=1776 tons.

During the tests it was decided to use the maximum number of available road slabs 156 pieces. At the same time their placement is provided similarly to the scheme of transfer of loadings from the drilling rig. The total weight during the tests was 156×4.2=655.2 tons, which is 96% of the maximum possible value.

The scheme of loading of a base plate and a photo of the loaded plate is given in Fig. 3.1 and Fig. 3.2 respectively. The results of the corresponding geodetic measurements are given in Table. 3.1. The leveling results are presented in Fig. 3.3.

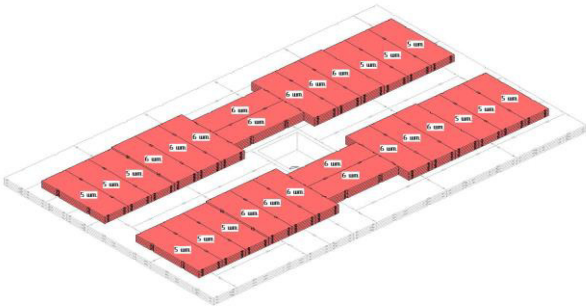


Fig. 3.1. The scheme of loading of a base plate

Fig. 3.2. A photo of the loaded plate

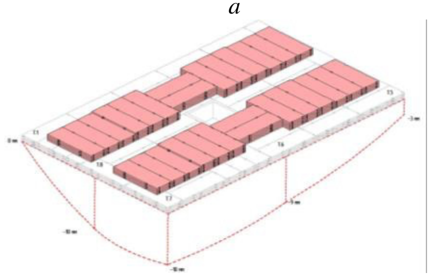
Table 3.1

The results of geodetic measurements in field tests of the base plate on an improved soil basis by arranging horizontal crushed stone drains

№ points	Measurement date (load percentage) / Sedimentation value in mm									
	15.02 (0%)	16.02 (65%)	17.02 (100%)	18.02 (100%)	19.02 (100%)	21.02 (100%)	22.02 (100%)	23.02 (100%)	26.02 (51%)	28.02 (0%)
T1	–	+4	0	-1	0	0	0	0	-1	-1
T2	-2	+2	-2	-2	-2	-1	-1	-2	-2	-2
T3	+3	+5	+3	+2	+2	+3	+3	+3	+3	+2
T4	-2	-3	-8	-7	-7	-6	-4	-6	-4	-3
T5	-3	0	-6	-6	-4	-3	-3	-3	-3	-2
T6	-8	-4	-10	-10	-10	-9	-9	-9	-9	-8
T7	-7	-4	-11	-11	-10	-10	-10	-10	-11	-10
T8	-6	-5	-10	-10	-10	-10	-10	-10	-9	-8

Field tests recorded a maximum vertical subsidence of 6 mm, with the rise of the plate did not exceed 4 mm, and the roll - 3.3×10^{-4}. These values are less than the maximum allowable requirements for the operation of the drilling rig, the roll will also not affect the normal trouble-free operation of the rig. In the process of unloading the elastic component of deformations was fixed, the rise of the plate was 1 mm.

a



b

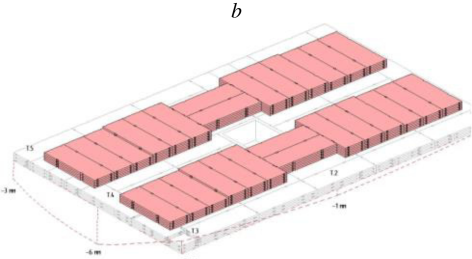


Fig. 3.3. Results of geodetic measurement of loadings by road plates of the basis and the base plate of the drilling rig: *a* - for marks 1, 5, 6, 7, 8;*b* - for points 2, 3, 4, 5

Very often, under similar conditions, it is rational to arrange a system of embankment of geogrids and geotextiles. The technology of works includes the following stages:

1) cutting of the top soil and its separate assembly outside the area where the embankment is arranged;

2) backfilling with clay soil up to 30 cm thick with surface compaction by rollers (vibration-free mode); the function of this layer is to reach the surface above the existing groundwater level and for ease of installation of the next layer of geotextile;

3) laying geotextiles, which are attached with pins to the previously poured clay soil;

4) installation of a spatial geogrid 20 cm high, the cells of which are covered with fine-grained rubble;

5) erection of the embankment body from layer-by-layer compacted sand by rollers in the vibration mode (the thickness of the embankment depends on the required level of its top: under the foundations of the drilling rig – up to 0.5 m; under the other part – up to 1.2 m);

6) laying geotextiles, which are attached to the embankment with pins;

7) installation of a spatial geogrid 20 cm high, the cells of which are covered with fine-grained rubble;

8) arrangement of the site (installation of road slabs) – construction of the foundation for the drilling machine.

Conclusions. All the above solutions provide the necessary operational requirements for drilling rigs with a lifting capacity of 450 tons, and have proven themselves in the construction of deep wells in complex engineering and geological conditions.

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