In 1971, the Rodina mine was placed in operation with an output of 3.3 million tons of ore per year, in the city of Krivoi Rog. At this mine, the main overground structure is a tower headframe equipped with a multiple-cable lifting installation.

The foundation of this large tower headframe was the first of its type to be constructed on a compressible bed in the Krivbass. The differential settlements and inclinations of tower headframes have strict limitations (i ≤ 0.002). Hence, data about the actual settlements of these structures are necessary for design of reliable and economical foundations.

The tower headframe consists of a tower measuring 21 × 24 m in plan and 97 m in height, and of an annex measuring 18 × 24 m in plan and 26 m in height. The tower is adjoined on two sides by a crushing building and by a building containing the transforming machines (Fig. 1).

The tower and adjoining structures have steel frames with cast-in-place and partially prefabricated reinforced concrete floors. The external walls consist of prefabricated reinforced concrete panels. The types of foundations were determined from the engineering-geologic conditions of the site, as well as from the overall-planning and constructional solutions used for the structures.

The total mass of the tall part of the tower headframe, including the dead and live loads, is 28,000 tons. The loads transmitted by the frame columns to the foundation lie in the range 5000-28,000 kN. The central columns, located near the shaft, transmit the maximum loads. The loads are distributed on the foundation bed by a rigid foundation consisting of a cast-in-place reinforced concrete mat measuring 26 × 27 × 3.8 m, with a square 8 × 8 m opening at the center for passage of the lifting elements.

Taking into account the presence of an operation basement at elevation −7.5 m, the foundation was constructed at a depth of 11.3 m. On three sides of the main foundation there are independent foundations for the crushers, transforming machines (GD group), and columns of the annexes.

The compressible foundation bed consists of dense clays of the Quaternary Period, containing inclusions of fine-grained gypsum and splices of crystals of different shapes and sizes, as well as a layer of fine sands of the Tertiary Period. These deposits are underlain by native crystalline rock (Fig. 2a). The index properties of the compressible soil layer are presented in Table 1.

To measure the settlements of the foundation of the tower headframe, instrumental observations were started in May 1970, after completion of the placing of the zero-cycle reinforced concrete elements. After the pit was excavated, the existing pressure decreased from 0.17 MPa to zero. This pressure was compensated by the mass of the zero-cycle elements over a period of several months.

Thus, the actual foundation settlements were determined from the additional pressure, that is, from the part of the pressure under the foundation which exceeds the existing pressure.

The foundation settlements were measured by means of a hydrostatic system installed in internal compartments in the foundation mat, as well as by geometric leveling on the basis of a Class II program, using a Koni 007 level.

The hydrostatic system consisted of 10 measuring piezometer tubes and two tanks connected into a closed circuit by means of rubber pipes and filled with colored, distilled water. The measuring tubes were secured at the investigated points of the foundations, and the feeding tanks were bolted to the mine shaft, which was used as fixed bench mark.
Fig. 1. General view of tower headframe.

Fig. 2. Geologic section through shaft (a) and settlement diagrams for corner points of headframe (b). 1) Fill layer; 2) light-yellow loesslike loam; 3) yellow-brown loam; 4) dark-brown loam; 5) chestnut-brown clay; 6) dense chestnut clay; 7) fine yellow-brown sand; 8) shattered native rock.

TABLE 1

<table>
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<tr>
<th>Names of soils in compressible layer</th>
<th>Density, kg/m³</th>
<th>Dry density, kg/m³</th>
<th>Liquid limit, %</th>
<th>Plasticity index, %</th>
<th>Water content by weight, %</th>
<th>Void ratio</th>
<th>Basic characteristics according to norms SNIIP 11-8. 1-62</th>
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<tr>
<td>Chestnut-brown clay</td>
<td>1850–1900</td>
<td>1500–1550</td>
<td>45–48</td>
<td>21–23</td>
<td>0,72–0,73</td>
<td>0,72–0,73</td>
<td>82</td>
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<tr>
<td>Fine sand</td>
<td>1600–1700</td>
<td>1500</td>
<td>26–28</td>
<td>15–19</td>
<td>0,6–0,7</td>
<td>0,7</td>
<td>18</td>
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The altitude base for measurement of the settlements by geometric leveling consisted of four bench marks located at the construction site. The settlement marks were established at elevation ±0,00 in the base plates of the corner columns.

The settlements were measured every 1–2 months. The final values of the foundation settlements, measured by the geometric and hydrostatic methods, differ from each other by not over 10%. From the results of the measurements, graphs representing the variations of the settlement with time for the corner points of the foundation were constructed (Fig. 3).

Loading of the foundation over the original existing overburden started in May 1970. In March 1971, when the total load was being transmitted to the founda-