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Settlement of soft rock under heavily loaded structures

Le tassement des roches meubles sous des structures très chargées

J.PALKA, Geotechnical Institute, Technical University, Cracow, Poland
 J.NABORCZYK, Geotechnical Institute, Technical University, Cracow, Poland
 A.SALA, Geotechnical Institute, Technical University, Cracow, Poland

SYNOPSIS: The results of investigations of soft rocks and settlements of heavily loaded structures founded on these formations are presented. These investigations have proved that geotechnical parameters of this type of rocks are smaller than those given in literature and settlement of objects situated on them is considerable. For a big furnace of the bearing pressure of the order of 530 kPa the settlement amounted to 63 mm. Agreement of prognosed and real settlement quantities was obtained.

1 GEOTECHNICAL PROPERTIES OF ROCKY SOIL

Practice shows that some kinds of rocks, the so called soft rocks, are subjected under the load of heavy structures to considerable and non-uniform deformations which can create some danger for a safe work of the object. In the discussed example the ground subsoil is shaped by Permian, Triassic and Quaternary period formations.

With the aim of structure foundation in view vast geotechnical investigations of the rocky grounds discussed were carried out. Within the framework of these investigations, apart from drillings and laboratory works, other studies were performed, such as: plate bearing tests in borehole, pressuremeter tests, static soundings. Distribution of boreholes and their profiles with test load places marked are presented in fig. 1.

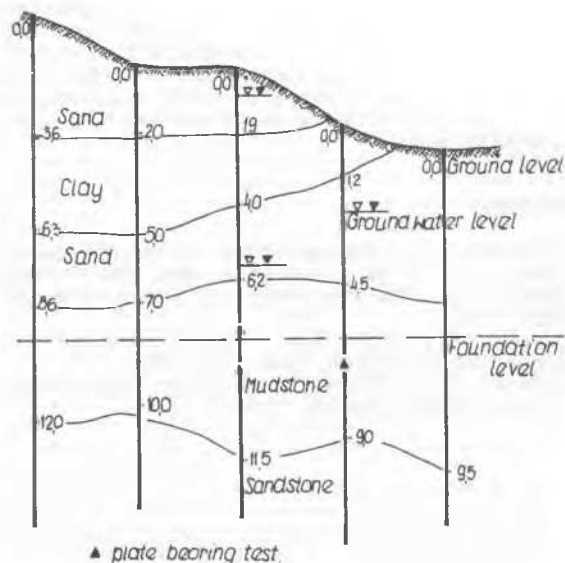


Figure 1. Section through boreholes

Test loads have been carried out with application of a stiff plate of cross-section, diameter circular equaling 0.276 m, and surface area to 0.06 m². Pressure on the plate was evoked by means of a hydraulic lift in stages 50, 100, 200, 400 and 800 kPa. Settlement observations were carried out on 3 gauges of accuracy up to 0.01 mm. Fig. 2 presents the curves of test loads. Mean values of geotechnical parameters of the rocky soil is shown in Table 1.

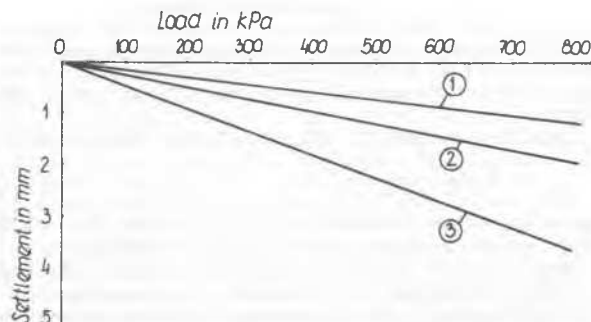


Figure 2. Results of plate bearing test

TABLE I
 Geotechnical properties of rocky soils

	Silty clay, clay	Soft rocks	Hard rocks
Water content, %	12.0-20.3	2.2-11.1	2.9-3.9
Unit weight, kN/m ³	20.2-20.8	20.2-25.2	21.3-25.8
Cohesion inter- cept in terms of total stress, MPa	0.06-0.07	0.7-1.2	2.2-18.0
Angle of internal friction in terms of total stress,	7°-12°	20°-24°	28°-31°
Modulus of linear deformation, MPa	9.3-12.5	56-99	136-251
Uniaxial compressive strength, MPa	-	1.21-1.32	11.7-92.0

The values obtained from these investigations

are distinctly smaller than the ones quoted in literature /Tomlison 1980, Kidybiński 1982/. Also pressuremeter test realized in 12 spots under the future foundations of the object at the depth of 0.7 to 0.9 m showed relatively small values of pressuremeter modulus within the range of 15.1 to 38.2 MPa. Ultimate stress defined by the pressuremeter were 1.36 to 2.3 MPa.

2 CHARACTERISTICS OF THE OBJECT AND THE COURSE OF ITS SETTLEMENT

Due to technological reasons a big metallurgical furnace was founded at the depth of 8.0 m below the macronivelation level on the building site. At this depth of the foundation soil Triassic and Permian silty clays and mudstones 1.0 m and 0.8 to 2.5 m thick respectively, are deposited. At lower levels hard mudstones with inter-layered low condensed, brittle and hard sandstones changing into mudstones are found.

Bearing pressures under the foundation lies in the interval 0.45 to 0.55 MPa in dependence on the furnace being filled with charge. The foundations of the object were designed in form of a reinforced concrete steel cylinder 20.0 m in diameter and 8 m height including the circular foundation slab of a diameter 38.0 m, thickness in its center and circumference 4.5 and 2 m respectively.

In order to measure the settlement of foundations of the big furnace during building and exploitation first bench marks were placed symmetrically on the circumference of the foundation slab and in the second stage of realization on the circumference of the shaft of the furnace.

Basing upon the results of geotechnical studies and the quantities of transmitted loads were elaborated by means of prognosis of soil behaviour during building and exploitation of the object. Foreseen settlement quantities were determined:

1. From the relation /Terzaghi and Peck 1948/

$$s = s_0 \left(\frac{2B}{B + B_0} \right)^2 \quad /1/$$

where: s_0 - settlement of test plate, B_0 - diameter of test plate, B - width of foundation

2. Basing upon the consolidation model /Terzaghi 1943/ adopting the linearly increasing consolidation load and thickness of the consolidation layer equaling the foundation width. The obtained settlement values were:

$s = 66.0$ from the formula /1/ and

$s = 59.9$ acc. to the consolidation model.

Measurement results of maximum settlement are presented in fig. 3. Foundation settlement was non-uniform in the first period and differences reached the value of 10.3 mm. During further observations settlement differences of individual bench-marks did not increase.

As follows from the settlement diagram a considerably intensive settlement of the foundations, reaching 25 mm was taking place for 1.5 month from the beginning of concreting and loading the subsoil with the foundation dead load. Further settlements proceeded in a slower way and only after 2 months they reached 30 mm. Hence, further settlement by 5 mm at load increase by 30 kPa required 2 months. A further settlement process proceeded regularly with load increase, settlement increase at load increase being expressed in terms of a bigger inclination of the tangent to the settlement curve. Total settlement of the big furnace from the dead load of its foundations and structure equaled after 22

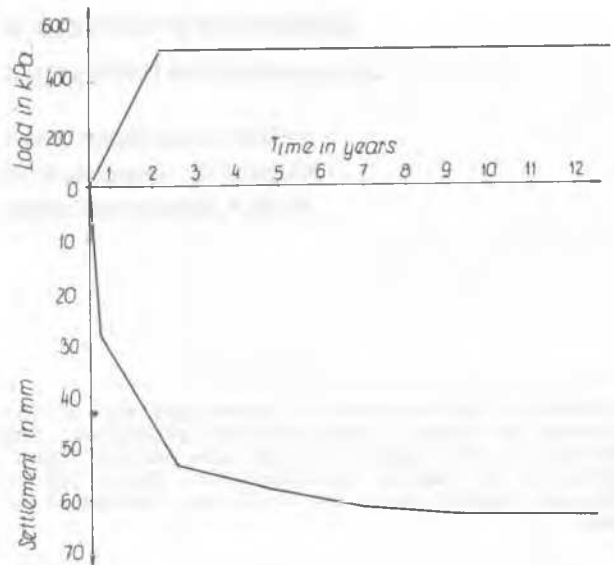


Figure 3. Diagram of settlement of the smelting furnace

month of building works 53 mm at a load increase to 460 kPa. After further loading with furnace charge to 530 kPa the settlement increased to 63 mm.

3 CONCLUSIONS

1. Rocksoil, especially that formed of soft rocks at load from heavy structures shows a considerably high settlement which is to be considered when designing these structures.
2. For designing heavy structures on soft rocky soils geotechnical parameters of these soils must be examined each time. These parameters given in literature are, as a matter of fact, determined in a large interval and depart from the quantities established in investigations.
3. Real settlement of the structure established on the basis of a long term geodetic measurements are in good agreement with values prognosed obtained from an experimental relation for test loads and with values obtained for the consolidation model.

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