EXPERIENCE WITH CONSTRUCTION AND OPERATION OF "DINAMO" STADIUM ON FILL SOILS IN MINSK

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The "Dinamo" stadium in Minsk was constructed on fill soils up to 8.5 m thick, using the natural and filled bank slopes of the Svisloch' River.

The project for the stadium was prepared by the Belpromproekt Institute during 1950-1952, with assistance from the Scientific-Research Institute for Foundations. The stadium, which covers an area of 9 ha, was constructed by the Minsk Construction Trust and was commissioned in March 1955. Its stands, which are 40 m wide and 18.2 m high, can accommodate 41,000 spectators. The spaces under the stands, which cover a total area of 2346 m$^2$, are used for sport chambers and service rooms.

During the period of operation the main structure of the stadium has been subjected to major repairs (partial replacement of the waterproofing elements), partial reconstruction (widening of the stands at the expense of the entrances), and many routine repairs.

In recent years, cracks with maximum widths of 30 mm have appeared in the brick walls and the arcades of the stadium. At the request of the directors of the sport combine, the author carried out long (since 1970) observations and investigations on the causes of the formation of cracks and on the degree of influence of the cracks upon the suitability and durability of the structure.

The cracks in the walls could have been caused by unstabilized differential settlement of the fills and nonuniformly compressible natural soils, temperature fluctuations attended by "loosening" of the masonry in the crack zone, weathering of the masonry in the vicinity of the contraction joints, and the adverse effects of water and frost, which led to the development of a "wedging effect" [1].

During the design stage the designers contemplated the possibility of the development of large and differential settlements, owing to nonuniform compaction of a fill layer ranging in thickness from 0.4 to 7 m and to different compressibility of the natural soils, which consist of weak flood-plain alluvial deposits under the eastern stand and of moraine loams at the top of the bank slope of the Svisloch' river valley near the western stand. According to data from the explorations conducted by the Belpromproekt Institute, the fill soils consist of material from excavations from pits at other construction sites (sandy loams, common loams) mixed with construction debris, wood remnants, and heterogeneous dump material. The normative pressure on the fill soils was taken as 1.25 kg/cm$^2$, but after consultation with the Scientific-Research Institute for Foundations it was increased to 1.5 kg/cm$^2$.

The fill soils underwent surface compaction applied by means of platform vibrators; 40-cm thick sand layers were placed under the foundations. A 10-cm thick compacted leveling course, consisting of granite rubble mixed with 1:4 cement mortar, was placed over the sand layers.

The foundations under the stands were designed in the form of intercrossed cast-in-place reinforced concrete strips located at a depth of 1.7-3.5 m (Fig. 1). The load-bearing structures of the stands and the rooms under the stands consist of transverse reinforced concrete frames supported on the intercrossed foundations, longitudinal beams, and cast-in-place roof slabs. This rigid spatial structure is divided by contraction joints into separate blocks (at 40-m spacings); the entrances to the stands, whose roofs consist of freely supported beams and slabs [2], are located between the blocks.
Fig. 1. Intercrossed foundations of the stadium. 1) Earth fill; 2) compacted fill; 3) sand layer; 4) rubble course; 5) intercrossed foundation; 6) column or wall.

The contraction joints are highly complex, owing to the lack of an open arcade.

The state of the foundation bed was investigated by means of test pits, penetration tests, and soundings.

The dynamic soundings, carried out at three points along the front of the eastern stand, confirmed the presence of relatively weak soils at a depth of 7-13 m below the lower surface of the foundations.

The test pits made it possible to discover fill soils having different ages and compositions, including an old cellar pavement over a base course, and flood-plain deposits in a low-humidity condition.

The graphs obtained from the dynamic soundings permitted determining the modulus of deformation of the fills, whose value (460 kg/cm²) confirmed the fact that during operation of the structure the fill layers became compressed, so that they could be regarded as soils of medium density (void ratio ε = 0.65).

From compression tests on a recovered flood-plain alluvium block the following values were determined: modulus of deformation E = 100 kg/cm², angle of internal friction φ = 28°, and cohesion C = 0.15 kg/cm². The normative pressure on this soil, according to formula (12) of the SNiP norm [3], ranges from 1.25 to 2.8 kg/cm², and the limiting pressure (according to V. G. Berezantsev’s formula [4]) is \( P_{lm} = 10.3 \text{ kg/cm}^2 \).

The normative pressure on the foundation bed exceeds the mean pressure by a factor of 2.3, and the limiting pressure exceeds the mean pressure by a factor of 8; this means that the first limiting state of the foundation bed cannot be reached.

The deformability of the foundation bed was evaluated by applying approximate procedures from the handbook [5]; a mean settlement \( S = 3.5 \text{ cm} \) was obtained, which indicated that a second limiting state of the foundation bed (S = 8 cm) was not possible.

The actual settlements during the first two years of the observation period ranged from 3.5 to 7.6 cm; further measurements of these settlements were interrupted. The settlement measurements carried out during 1970-1972, in accordance with the handbook [6], confirmed the practically final stabilization of the settlements.

The state of the foundations was investigated by excavation of test pits, control measurements, verification of the strength of the concrete with the aid of a Kashkarov’s hammer, and visual inspection of corrosion in the concrete. After 17 years of operation the foundations were found to be in good condition.

Thus, it was established that in the past the settlements of the foundations took place in a nonuniform manner and probably did not exceed 100 mm [7]; however, they could lead to the initial formation of cracks in the walls.

The effect of the cyclic variations of the ambient temperature upon the development of cracks was studied by means of analyses and full-scale measurements on over 30 pronounced cracks at different times of the year.