CONSTRUCTION OF THE TOROID SECTION OF THE DRAFT TUBES
INSTALLED IN THE LOWER KAMA HYDROELECTRIC PLANT

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In building power plants with vertical large-diameter adjustable-blade turbines, the question arises concerning selection of the best industrial procedure for the molding of blocks when concreting the most complex section in the construction of a hydroelectric plant—the elbow of the draft tube, and especially its toroid section. The toroid sections of the Volga-Lenin and Volga-22nd Congress hydroelectric plants were built from construction timbers with lined fascia slabs.

For the first time in the construction of a hydroelectric plant, supporting reinforced girder-slabs, which have two planes of support, were used as forms for concreting the toroid section at the Dneprodzerzhinsk hydroelectric plant in 1962. Support was provided by a series of columns in the upper section and by the draft-tube cover in the lower section. Considering the inaccuracies that are possible during fabrication, the low lift capacities of the assembly cranes, and the correspondingly large number of assembly components, the effective reinforcement of the toroid was not included in the reinforced-concrete slab, and was placed in the block in the form of individual circular bars on the rear surface of the components. The reinforced girders were fabricated in a jig and were concreted on a wooden stand. The Dneprodzerzhinsk plant came under heavy scrutiny owing to the industrialization of work and reduction in labor outlays in concreting the blocks. The toroid sections of the Saratov, Rizhsk, Kegum, and Dnepr-II hydroelectric plants were built by a similar method on special matrices for a single component.

Considering the large number of units (16), the significant diameter of the turbine rotor (10 m), the high requirements placed on the accuracy of draft-tube fabrication by the Leningrad Metallurgical Plant (deviations of ±0.22, and localized irregularities of not more than 6 mm) at the Lower Kama hydroelectric plant, the Kuibyshev Branch of the All-Union Lenin Order S. Ya. Zhuk Scientific-Research Institute for Design and Exploration and the Kamgazenergostroi adopted a solution for the fabrication of the reinforced girder-slab of the toroid (GST) on a forming stand with a size equal to that of the entire toroid. The steep surfaces of the reinforced double-curvature girder-slabs, the limited thickness of the supporting reinforced-concrete slabs (18-24 cm), and the heavy saturation of the slabs with reinforcement (effective radial and circumferential reinforcement 32 mm in diameter and 40 cm on centers, peripheral and inclined reinforcement 9 mm in diameter in the form of a grid with a 10 x 10 cm mesh, and the lower collar of the flat supporting girders reinforced with two rods 60 mm in diameter with connection plates), virtually excluded the possibility of consolidating the concrete with a vibrator; the gravity method was therefore adopted for casting concrete with the installation of a rear form.

The forming stand (Fig. 1) is a closed, hot-air-heated, metallic form with an area of 200 m², and a fully recurrent configuration of the double-curvature surface of the plants-draft-tube toroid. The closed form is created by a stationary deck, which forms the smooth face of the toroid, and by removable panels, which shape the rear surfaces adjacent to the monolithic concrete. Deck 1 is fashioned from a metallic sheet 6 mm thick and stiffeners consisting of 8 x 160 mm strips. The form and position of the deck are fixed at 19 supporting marks 2 and by ties formed between these marks by 75 x 75 x 6 angle irons. The supporting marks are secured to reinforced-concrete slab 3. A working platform is arranged in the upper section of the forming stand for the delivery of concrete by a 1.6-m³ bucket. The space beneath the deck-pan of the stand is airtight and heated by hot air.
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Fig. 1. General appearance of forming stand.

Removable panels 4 and 5 are metallic and are equipped with bolts and band fasteners. The lateral and fascia formwork, which possesses cutouts for reinforcement, is sealed by strips of conveyer belt. The deck, replaceable panels, and fastener subassemblies are designed with allowance for the pressure induced by the 2.3-ton/m³ concrete, which reaches 0.12 MPa in the lower section.

The position of the deck of support subassemblies 6 and 7 for securing supporting girders 8 of the GST, and their design (upper hinged, and lower sliding with four bolts) and number were assigned the same as in the blocks concreted in the hydroelectric plant. Thus, the forming stand is an assembly for the fabrication of GST and a platform 9 for test assembly. The composition of the concrete with a special additive (bentonite clay), the heat-treatment regime, and the measures taken to create smooth internal and rough external surfaces were worked out at the scientific-research station and the Kuibyshev Branch of the S. Ya. Zhuk Institute.

In opting for the stand method for the fabrication of the reinforced toroid girder-slabs, it was assumed that work on their fabrication, transportation, and assembly in the block will be realized by the continuous method (separate payment schedule) by organizations having work experience with the fabrication and assembly of complex sectional reinforced-concrete components. The construction of an experimental-production installation for the fabrication of reinforced toroid girder-slabs — a forming stand — was completed in June 1976.

Special attention was focused on the accuracy of deck fabrication; with the significant deck area (200 m²) and induced temperature deformations, the workers assigned to the trust Gidromontazh were required to use special technological procedures. The actual position of the face of the forming stand (deck) was estimated at 342 points from measurements taken by the Division of Geodesic Surveys of the S. Ya. Zhuk Institute in accordance with the method of stereophotogrammetric land surveying. A position of 320 points was found to be within allowable limits and only 22 points, or 6% of the horizontal radii exhibited deviations of from 1 to 11 mm.

It was specified that the girder-slabs of the toroid (GST) be fabricated by assemblies. Each assembly was composed of 11 GST with maximum dimensions of 2.5 × 10 m = 25 m², and a weight of 16.7 tons. A total of 16 assemblies were involved. The work was carried out in the following sequence: a) reinforcing of the entire toroid with lower supporting reinforcement (Fig. 2) and casting the toroid with concrete of a special composition without vibration; b)