SELF-LIFTING CANTILEVER FORMWORK FOR DAM CONSTRUCTION

AT THE TOKTOGUL'SK HYDROELECTRIC PLANT

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At the present time, several high concrete dams are being constructed in the Soviet Union: gravity, Tokto-
gul'sk, Ust'-Ilimsk; gravity-arch, Sayano-Shushensk; arch, Ingursk, Chirkeisk. In this connection, investigations
and tests are being carried out on the most rational types of formwork for the different types of dams and climatic
conditions. Now in the testing and introduction stages are cantilever formwork for the dams at the Ust'-Ilimsk and
Ingursk hydroelectric plants, a perimetric self-lifting formwork for the Chirkeisk hydroelectric plant, and a canti-
lever self-lifting formwork for the Toktogul'sk hydroelectric plant [1].

Cantilever formwork is widely used for arch dams in foreign countries because of the ability of this type of
formwork to produce with sufficient accuracy the required orientation and rigid fixing of the complex shapes of arch
dam surfaces, which vary with their height [2, 3]. The favorable characteristics of the use of cantilever formwork
are the following.

1. Design of the formwork permits varying in a simple manner the dimensions of the sheathing in the longi-
ditudinal direction immediately after its position is established in the block; as a result, a large proportion (95% and
over) of the concreted structure having variable cross sections can be covered with stock formwork.

2. For convenience in carrying out the construction work at the hydraulic development, under the restraints
of mountain conditions, the possibility of repeated turnover, and utilization of a single set of forms for several hy-
draulic projects, the cantilever formwork is fabricated and assembled using sheathing having the required dimensions
and made from simple flat elements which can be easily stored and transported. These elements are the following:
cantilever braces, brace planking, flat ribless formwork panels, embedded anchor parts, and trestle elements. These
elements, transported in sets to the assembly area in the concreting block, are used to erect formwork of the re-
quired dimensions, with different numbers of braces. The maximum number of braces is limited by the lifting ca-
pacity of the crane. During the concreting process, the edge (comer) sheathing in the formwork can be easily short-
ened or lengthened, depending upon the changes in the dimensions of the blocks to be concreted when passing to the
upper tier. Each cantilever brace, secured at two points to the concrete of the lower tier, and constructed with suf-
cient rigidity also in the plane of the formed surface, is a three-dimensionally invariable component which does
not require any additional connection to withstand the load transmitted by the concrete. However, for displacement
of the formwork in the vertical plane from tier to tier, it is sufficient to connect several cantilever braces together
by the planking and trestle elements, and by means of quickly demountable connections. In addition to the excel-
lent adaptability of this formwork to the variable shape of the blocks being concreted, there is the possibility of
quickly replacing the formwork panels, which are the parts most subjected to wear, as well as of using different types
of panels, including heated and unheated, according to the climatic and construction conditions.

3. Cantilever formwork produces concrete surfaces of high quality and good appearance, which do not require
additional treatment.

At the Dworshak arch dam, in the USA, use was made of a self-lifting cantilever formwork with an automated
anchoring system which saved manpower and eliminated the need for constructing trestles [4].

For construction of the dam at the Toktogul'sk hydroelectric plant, the Kazakhstan branch of the Gidropreaukt
Institute designed 10 sets of SKO-1 self-lifting cantilever forms, with a 3 x 6 m maximum dimension of the form-
work panels (Fig. 1). Each of these panels consists of four cantilever lattice braces placed at 1.5-m spacings, one

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Fig. 1. Variations in dimensions of panels for self-lifting formwork, a, b, and c) Formwork panels for two, three, and four braces. 1) Cantilever braces for boards; 2) brace planking; 3) formwork panels; 4) brace for lifting the formwork; 5) anchoring connections for braces.

Fig. 2. Types of marquees in self-lifting formwork, a) With movable cover; b) with cloth-rope cover. 1) Cantilever braces for panels; 2) lifting brace; 3) heating covers; 4) suspended truss with gangways; 5) rope compensator for varying dimensions of blocks; 6) cloth curtains for concrete-pouring openings.

Central formwork panel measuring $3 \times 3 \times 0.1$ m, two lateral panels (right and left) measuring $3 \times 1.5 \times 0.1$ m, and braces for lifting the formwork elements, $0.6 \times 0.6$ m in cross section and $11$ m long. Thanks to the erection joints, this panel can have the following four dimensions: $3 \times 6$ m; $3 \times 4.5$ m with the third brace at the right; $3 \times 4.5$ m with the third brace at the left; and $3 \times 3$ m.

Because of the possibility of simultaneous movement of the self-lifting formwork to the next concreting tier over the entire perimeter of the concreted block, it is possible to install marquees which are moved together with the formwork (Fig. 2). For the tests on the dam at the Toktogul'sk hydroelectric plant, a $12 \times 6$ m cloth-rope marque with curtain-covered concrete-pouring openings was designed (Fig. 2b). It is possible to use a self-lifting formwork with marquees in the form of rigid movable covers, equipped with curtain-covered concrete-pouring openings ($6 \times 6$ m), which were designed by the Gidroproekt Institute for a cantilever formwork at the Ingursk dam (Fig. 2a).

Because of the fact that by the time the experimental self-lifting formwork was ready at the Toktogul'sk hydroelectric plant dam, large blocks had been already constructed by using multispans and multirow light marquees, the SKO-1 formwork was tested without marquees, since the latter had been designed for spans of not over $18-20$ m. Each brace in the self-lifting formwork was independently secured to the concrete in the first lower tier at two points located in the same vertical, within the limits of the upper ends of the two concreting tiers (Fig. 3). For support on the concrete, the cantilever braces have supporting tables in the middle portion, and a supporting jack with a rocking roller at its end, in the lower portion. The lower jacks with the rollers are used for separating the formwork and for adjusting the inclination of the braces and of the formwork panels when the surfaces of the blocks being concreted are modified. When the position of the formed face of the block was vertical or inclined outward, the brace was anchored to the concrete only at the elevation of the brace supporting table. When the formed face was inclined toward the block, each brace was anchored to the concrete at its lower end also, to prevent overturning of the formwork panel during the period of preparation of the blocks for concreting. For installation of the embedded anchors during the concreting process, each brace had at its upper end a seat for an erection bolt which pressed the embedded anchor firmly against the formwork panel. Bolted connections at the upper ends of the braces were used for securing the $3 \times 3$ formwork panels to the two middle braces, and the $3 \times 1.5$ m panels to the two outer braces. The middle panel was secured to the outer panels also by means of bolted connections. In order to provide access