HYDROTECHNICAL CONSTRUCTION

EXPERIENCE IN OPERATING THE STRUCTURES OF THE MANSOUR EDDAHBI HYDROPOWER DEVELOPMENT

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The Mansour Eddahbi hydropower development was constructed on the Draa River in Morocco between 1969 and 1973 according to the design of the All-Union Planning, Surveying, and Scientific-Research Institute (Gidroproekt). The development includes an arch dam with a bottom outlet, power-canal hydroelectric station with a capacity of 10 MW, and a transmission line (Fig. 1).

The arch dam [1, 2, 9] with a height of 70 m and crest length between bank abutments of 245 m has a double curvature. In plan the dam is drawn from three centers. The central part of the dam is described by axial radii varying from 103.7 m at the crest elevation to 39.5 m at the base of the dam. The side parts of the arch of the dam are described by various radii from two centers. The thickness of the cross section of the arch is variable over the height and changes from 16 m at the base to 5 m at the crest. The upper part of the arch of the dam is supported on massive bank abutments, which provide reliable adjoining of the dam to the banks in the zone of increased jointing. The dam is divided lengthwise into 17 sections by vertical contraction joints. Stainless-steel contour waterbars are installed in the section joints for providing impermeability and for performing sealing grouting. The dam is constructed on a rock foundation with a modulus from deformation from 70 to 200 MPa.

Two galleries were constructed for performing grouting works and installing the monitoring equipment in the dam body. One is in the foundation part and measures 3 × 3.5 m, and the second is in the upper part of the arch with dimensions 2.2 × 3 m and has exits in the abutments and serves as a means of communication between banks.

To reduce seepage losses and increase the stability of the dam, cutoff measures were taken, consisting in the construction of a grout curtain and curtain drain. The single-row grout curtain with a depth of 50-60 m and length along the front of 700 m is located under the dam foundation on the upstream side and on bank stretches, into which it penetrates 160 m in the right bank and 300 m in the left bank.

Two drainage galleries are constructed at elevations 1060 and 1077 m in the lower pool of the dam. The drainage system is made in the form of wells drilled from the surface with outflow into the drainage galleries.

Consolidation grouting was carried out to increase and equalize the modulus of deformation of the rock in the dam zone.

At elevation 1104 m of the dam there is an overflow aerated spillway with a length of 190 m. Owing to the asymmetric configuration of the dam site, the spillway bucket is divided into right- and left-bank parts. On the 113-m-long right-bank part the bucket has a ski-jump deflecting the jet 46 m from the base of the dam. The water from the 77-m-long left-bank spillway falls into a reinforced-concrete "ladle" flume located along the slope and directing the flow into the river channel.

The dam creates a reservoir with a capacity of 536 million m^3 of water, which permits irrigating 25,000 ha of land and generating 20 million kWh of electric energy per year. The main purpose of the reservoir created by the dam is to regulate the streamflow to meet the irrigation needs in the Draa River valley.

For systematic monitoring of the behavior of the dam, 885 various monitoring devices were installed in the structure [3, 4].

For sanitary releases and discharge of water for irrigation, the dam has a bottom outlet, which consists of an intake, two 1.6-m-diameter steel pipelines, and the bottom-outlet building in which the cone and butterfly valves are located. The equipment of the bottom outlet was delivered from the USSR and was assembled by Soviet specialists.

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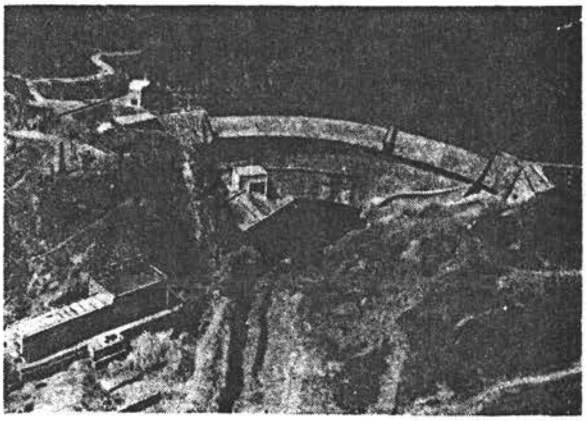

Fig. 1. Mansour Eddahbi hydropower development.

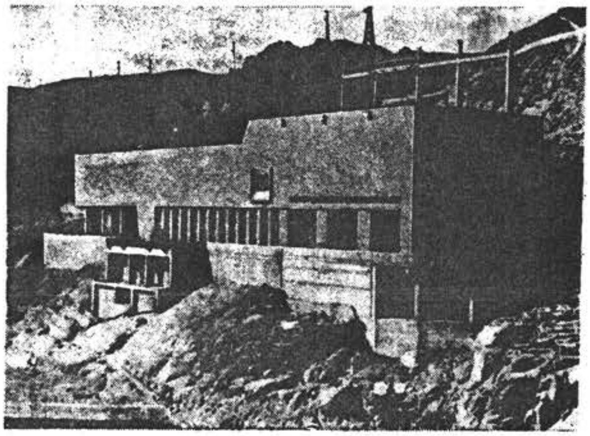

Fig. 2. General view of powerhouse.

Hydroelectric Station. Its structures include [10] a shaft-type intake, headrace pressure tunnel, hydroelectic station with an installed capacity of 10 MW with two vertical units of 5 MW each, and indoor electrical equipment (Fig. 2).

The shaft-type intake is located on the right bank in the upper pool of the reservoir and includes the intake works and the shaft of the intake. The intake works are made in the form of a concrete headwall equipped with an inclined trashrack measuring 7.25 × 8 m. The rack is cleaned by a rack-cleaning machine. The elevation of the intake sill is 1066.2 m and the drawdown level of the reservoir is 1076 m.

In the intake shaft located 71 m from the headwall, a 2.7 × 3.5-m emergency-guard gate is installed. Under the shaft is a 10-m-high building in which the hoisting and other mechanisms servicing the intake are located. The building is made of monolithic reinforced concrete. From the intake the water flows along a 206-m-long pressure tunnel to the units of the hydrostation.

The powerhouse and indoor electrical equipment adjacent to it are made in a single rectangular block. The surface room of the hydroelectric station has dimensions of 12.5 × 26.5 m; the height of the room above the assembly area is 12 m. An elliptical shaft is located in the floor of the surface room. The dimensions of the shaft with respect to the axes of the ellipse are 12.5 and 19.5 m; the depth of the shaft is 26 m. Two units are installed in the shaft. Beneath the floor of this room are located the generator and turbine rooms with two butterfly valves and the pump room. All rooms are connected by an elevator and spiral staircase.

Between the surface room of the hydroelectric station and indoor electrical equipment is a four-story room containing the cable room, control board, ventilation equipment, and storage batteries.

The indoor electrical equipment is located in a two-story building. The transformers are installed in separate rooms in the front on the first story. The office building abuts the powerhouse from the side of the assembly area. It is separated from the powerhouse by a construction joint. The supporting structures of the office building, walls, and columns are made of mass concrete. The design did not provide for monitoring equipment for observing the structures of the hydroelectric station.

All equipment of the hydroelectric station (turbine, spiral casing, butterfly valves, generator, etc.) were supplied from the USSR and installed by Soviet specialists.

Observations of the Behavior of the Structures during Operation. After the dam was accepted for operation in April, 1972, systematic control observations of the structure were carried out by means of monitoring equipment. In 1975, 1978, and 1982 the dam was inspected with an examination of the monitoring equipment, and control measurements were taken with respect to it

During the period from 1972 to 1975 the water levels in the reservoir varied within 1085-1092 m, and during the period from 1975 to 1978 they varied from 1083.5 to 1091 m. In January-March, 1978 the reservoir level increased from elevation 1091 m to 1100.2 m. In this case the maximum rise of water was 3 m/day. During the period from 1978 to 1982 water

TABLE 1

Indices	Joint between sections				
	12—14		14—16	16—18	
Elevation of transducer location, m	1076,4	1101,3	1101,3	1097,5	1108,8
Increase of opening of the joint after grouting, mm	1,04	0,53	1,26	0,51	0,95

TABLE 2

Joint	Consumption of cement grout, liters, by levels				
	III	IV	V	VI	VII
12—14	280	230	270	520	—
14—16	—	230	272	778	—
16—18	—	—	—	458	396
18—20	—	—	—	—	210

TABLE 3

Equipment	Number	Number operating satisfactorily	Number that failed
Piezometers in dam foundation	20*	—	—
Piezometers in bank abutments	41	41	—
Pressure transducers in dam foundation	26	20	6
Linear displacement transducers	103	89	14
Linear deformation transducers	186	168	18
Temperature transducers	91	86	5
Gap-gauge marks	20	20	—
Pressure transducers in concrete	32	30	2
Direct plumb line	4	4	—
Switches	20	19	1
Triangulation points	9	9	—
Survey monuments	6	6	—
Sighting marks	20	20	—
Permanent bench marks	6	6	—
Surface bench marks	82	79	3
Temporary bench marks	28	25	3
Side marks	21	20	1

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*The piezometer columns and filters are in satisfactory condition. The values and stopcocks, which have been operating since the time of installation without repair, need to be replaced.

was noted. A vertical crack was noted in the upper extreme block of the rock mass. No changes were noted in the condition of the rock of the left-bank abutment.

The drainage galleries of the bank abutments are in good condition. No rock falls or cracks in the linings were observed in them during operation.

The monitoring equipment installed in the dam and bank abutments has been operating satisfactorily since 1972.

Table 3 gives data on the monitoring equipment as of March, 1982.

Individual string-type transducers (pressure, linear displacements, linear deformations) failed owing to deterioration of the waterproofing of the cable connections. The number of satisfactorily operating string-type transducers is about 90%. A new system of measuring the displacements of the dam crest by means of direct plumbing by sighting the plumb line was installed on the dam in 1980. There is no doubt about the stability of the geodetic network. The condition of the survey monuments is satisfactory.

Temperature Regime of the Dam Concrete and Rock Foundation. In the operating period this was governed by the ambient temperature. Temperature variations had a seasonal character. The temperature regime over the length and height of the dam was different and depended on its structural characteristics, levels and temperature of the water in the upper and lower pools, orientation of the structure relative to the sun, and other factors. The maximum temperatures of the concrete reached 35°C and the minimum reached 11.8°.

The temperature regime of the surface layer (to 1 m) of the rock foundation under the central section stabilized after filling the reservoir to elevation 1062 m. Seasonal temperature variations occurred in a 2.5-m-deep layer of rock under the dam and were within 1.0-1.5°C [7].

Deformation of the Section Joints. The condition of the joints between sections was assessed by comparing the opening of the joints when the water level in the reservoir reached the maximum elevation and at low temperatures of the dam concrete with the values of their opening at the time of grouting. Taken as such a time was March, 1980, the coldest of the past 10 years when water flowed over the dam crest and the temperature of the concrete at the majority of points of the dam was minimum and was close to it at the remaining points. The majority of section joints of the dam after their grouting did not open or their opening did

Seepage Regime in the Foundation and Bank Abutments of the Dam. At the majority of measurement points located in the zone of consolidation grouting under the upstream face of the dam and in the ungrouted foundations in front of the grout curtain, the seepage heads changed practically synchronously with variations of the water level. The absolute heights of the piezometric heads at these points are close to the height of the water level in the reservoir. Data on head losses in the foundation show that the effectiveness of the grout curtain along the front of the dam is different. Losses of the seepage head on the grout curtain under the channel sections are 30-49% and under the bank section 15-22%. Such a difference in the effectiveness of the grout curtain is due to the different permeability of the foundation rocks. The residual heads beyond the grout curtains of the channel sections of the dam are 12-30 m (24-59%) and for the bank sections 29-39 m (57-80%). The large residual heads behind the grout curtain indicate a feeble outflow of seepage water from the rock mass into the lower pool, in connection with poor permeability of the rocks under the downstream face of the dam and longer seepage paths behind the grout curtain.

Despite this there are no signs of discharge of seepage waters on the bank slopes in the lower pool of the dam, with the exception of discharges of seepage waters in a ravine of the lower pool at a distance of 150-200 m from the bank curtain with a total discharge of 15-20 liters/sec. These discharges were observed during filling of the reservoir above elevation 1100 m.

Seepage in the bank abutments has a complex character. The seepage flow is formed due to percolation of water from the reservoir and inflow of groundwaters from the banks. According to the data of observations of the formation of the seepage flow in the bank abutments of the dam, it follows that half of the length of the grout curtain in the right-bank abutment and two-thirds of the length in the left-bank abutment participate in reducing the bypass seepage head.

A rise of the reservoir level to 1104.7 m in 1979 and 1104.4 m in 1980 led to a negligible increase of the seepage discharges in the left-bank drainage gallery; from 8.4 to 14.1 liters/min. In the right-bank drainage gallery the seepage discharge hardly changed and was 0.24-0.8 liter/min. The maximum seepage discharges at the maximum upper-pool level of 1104.7 m do not exceed the design values. The given data indicate normal operation of the cutoff works (deep grout curtain, drainage system) [8].

According to the data of the weather station, the relative humidity in the region of the hydrostation changed with increase of the reservoir water level. The relative humidity during the daytime of hot months (July-August) changed from 25-30% during construction to 32% in 1979, to 37% in 1980, and to 42% in 1981. Precipitation began to fall more frequently in the region of the dam, which is indicated by the following data:

Years	1974	1975	1976	1977	1978	1979	1980	1981
Precipitation, mm/yr	12,8	42,6	113,1	139,2	117,3	136,1	147,9	53,2

The equipment of the dam has been operating from the start without repair. The cable controlling the gates of the outlet was replaced during the time of operation. The glands of pump No. 2 for pumping out the drainage waters in the lower gallery and the seals of the butterfly valve of the left pipeline of the bottom outlets are in need of replacement in connection with water leaks through them. The remaining equipment of the dam (electrical equipment, butterfly and cone valves, and hydromechanical equipment of the outlet) is operating satisfactorily.

The structures of the hydrostation are in good condition. During the time of operation not one structure has been repaired. All rooms of the shaft of the station are dry; no discharges of seepage water through the shaft walls have been observed.

The equipment of the hydrostation has operated satisfactorily since the start. Owing to the great hardness of the water and its corrosiveness, the water-cooling pipes of the generator were destroyed by corrosion and replaced by new ones. The equipment of the hydrostation operates reliably.

CONCLUSIONS

1. The 10-yr experience of operating the structures and equipment of the hydrostation showed that the reservoir created by the arch dam provides streamflow regulation for meeting

the irrigation needs of 25,000 ha in the Draa River valley and the hydrostation provides the design production of electric energy.

2. The data of inspections of the hydrostation indicate a satisfactory condition of the structures and equipment.

3. The monitoring equipment installed in the dam permits operative monitoring of the safe operation of the dam. About 90% of the installed equipment is operating satisfactorily after 10 years.

4. An analysis of the data of long-term observations shows that at the design head the stresses, strains, displacements, and seepage stability of the dam foundation and bank abutments correspond to the design assumptions.

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