Translation No. 9

DAMS

IRRIGATION AND WATER POWER IN ALGERIA
(A translation)

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Public Works and Colonization in Algeria

Regime of Algerian Streams

One of the essential characteristics of Algeria is the fact that this country is particularly poor in forests and that its soil, very often argillaceous, hardly retains the rain water; consequently the run-off is heavy.

In summer, at the time of the lowest water level, the flow of the Chelif is so weak that one may refer to it as a dry "oued" (stream). In winter, the rate of flow of flood water is often higher than 100 m^3 per second, and sometimes reached 1000 m^3 per second. The safety devices built on this stream are large enough to permit a much higher discharge (spillway accommodation of the Ghrib dam: 2000 m^3 per second). The total annual flow varies considerably also. In the Chelif, which is the most typical Algerian stream, the volume of water in a wet year may be as much as 25 times greater than in a dry year.

Another characteristic of the Algerian streams is the large quantity of sediments they carry, due to the nature of their bed which is particularly

liable to erosion, and to the heavy rate of their flood discharge. As a result, the Algerian reservoirs are almost entirely filled at flood time, and they silt up surprisingly fast. For example, the mud deposited in the artificial lake of the Oued Fodda is about 30 m. thick at present. The capacity of the Cheurfas reservoir was reduced two-thirds due to the silting up. Other lakes of lesser importance, such as the Relizane reservoir on the Mina, or the Kef on the Tafna stream, are entirely silted up.

Considering the nature of the streams which distribute the necessary water, the only logical solution to the irrigation problems of Algeria was to build storage dams of a capacity sufficient to properly control the streams on which they were built and to allow the development of the irrigable areas before the reservoirs were silted up. This is the solution that was adopted at the end of World War I by the Service of Irrigations of the General Government of Algeria. Eleven main storage dams were built in Algeria.

Dams and Reservoirs in Algeria

The first and one of the most important problems in the construction of a large dam concerns the foundation. In this, there is a primary and essential difference between the Algerian and the Swiss dams. As the Swiss dams are built on sound rock showing little fracturing, foundation conditions are quite different from those of Algerian structures. This difference stems from the fact that the terrain where the Algerian dams are erected is more recent and less stable than the granitic rock which generally serves as foundation for dams in the Alps. Marl, shale, more or less heterogeneous sandstone, and limestone are generally found in Algeria. The limestone is harder than the other types but is always much fractured. Consequently, the problem of dam foundations is often connected with the watertightness of the reservoir basins.

The statements made about the regime of the Algerian streams show the need for a second essential in the construction of dams in Algeria: namely, the fact that the possibility of important floods during construction is never excluded. Consequently all temporary diversion construction, as well as the structures controlling the discharge of flood water of the completed dams, should be of ample size.

The main Algerian dams, as seen when crossing the country from west to east, are shown on the following table:

Dam	Type	Height in meters	Impounded capacity in $10^6 m^3$	Regulated volume in $10^6 m^3$
Beni-Bahdel	Multiple arch	54	73	50
Cheurfas	Gravity dam, rubble-masonry reinforced by vertical stays	27	6	6
Bou-Hanifia	Rock-fill dike	54	75	100
Oued Fergoug	Gravity, rubble-masonry; failure in 1927. Reinforced by stays.			
Bakhadda	Rock-fill dike	45	37	50
Oued-Fodda	Gravity dam, concrete	90	225	100
Ghrib	Rock-fill dam, concrete	65	280	140
Hamiz	Gravity, raised with concrete	45	23	28
Oued Ksob	Multiple arch	32	12	30
Foum-el-Gueiss	Rock-fill dike	23	2.5	6
Zardezas	Gravity, concrete	35	11.2	30

The old Oued Fergoug dam which is 40 m. high and impounded 30 millions m^3 of water, was transformed into a diversion structure after its spillway was partly filled and strengthened by stays. The storage reservoir created by the Hanifia dike, 30 km. upstream, replaces the destroyed reservoir of the Oued Fergoug dam.

One dam representative of each type constructed in Algeria is described below.

Gravity Dam of Oued Fodda

This dam is located in the Department of Algiers, upstream from Lamartine. It is a simple concrete wall of triangular cross section which resists the water pressure solely by its own weight. The foundations rest on strong limestone of questionable impermeability. The injection of 6,700 tons of cement and chemical products, however, has made the reservoir satisfactorily watertight. The dam, started in 1928, was completed in 1932. The total height, foundations included, is 100 m., the width at the base is 68 m. The volume of concrete is about 30,000 m^3. Its two spillways together can discharge a volume of 1,100 m^3 per second. The storage capacity is 225 million cubic meters for an average annual discharge of 80,000,000 m^3.

Rock-fill dam of the Ghrib

The Ghrib dam on the Chelif, upstream from Dollfusville, is the most important one of North Africa. It rises 65 m. above its foundations. The foundation ground consists of alternate benches of soluble marl, and poorly sorted heterogenous sandstone, which is generally soft and friable. The Ghrib dam is a stone wall strengthened on the upstream side by an impervious cover that is sufficiently flexible to follow the irregular settling of the wall. The wall is made of various size blocks, some weighing as much as 10 tons, set in place by crane so as

to obtain a cyclopean masonry. The impervious cover was made of bituminous concrete composed of a well-graded mixture of broken stones, gravel, sand, and fine dust coated with a bituminous binder. The great advantage of this bituminous mix is its flexibility which permits it to follow the deformations of the upstream side of the wall without cracking. The bituminous coating is composed of 2 layers, each 6 cm. thick, which are applied on a base coat of porous concrete which forms a generalized drain. A second coating of porous concrete, to serve as protection against the heat, covers the outside. Foundation conditions of the Ghrib dam required extensive construction to avoid the risk of the supporting ground washing away. To this end, a cutoff wall was built upstream from the dam. It is 40 m. deep and is extended into the ground by a grout-curtain which in places is 100 m. deep.

The flood control work is particularly important because the Ghrib dam can have a discharge of 2,000 m^3 per second. Theoretically, floods of the order of 10,000 m^3 per second could reach the Ghrib. Fortunately, it was possible to control the course of the Chelif upstream from the Ghrib by means of a small earth dam about 10 m. high, which can impound a volume of 1,000,000,000 m^3. The reservoir of the Ghrib has a capacity of 280,000,000 m^3 and the controlled discharge to be distributed yearly is 140,000,000 m^3.

Multiple-arch dam of Beni-Bahdel

This structure has 11 full-centered arches, inclined at about 45° each, with a 17 m. span. It is located on the Oued Tafna (Tafna stream) southwest of Tlemcen, in the Department of Oran. The dam is set on shaly sandstone formations, sandstone predominating on the right bank, shale on the left bank. The dip of the strata downstream is steeper

than the gradient of the river, so that the beds are beveled across the valley bottom. The multiple-arch dam was chosen because of the shale which underlies the left bank. Since this shale weathers rapidly in contact with the atmosphere, large excavation such as is required for the foundations of a gravity dam could not be considered. Moreover, the multiple-arch dam has the advantage of producing lower pressure, due to compression, on the foundation ground. Finally, the uplift pressure also has a less important effect in the case of the multiple-arch dam.

The total length of the dam is 320 m., 220 m. of which is the multiple-arch dam and 100 m. is a gravity dam on the sides. The buttresses supporting the inclined arches of the multiple-arch dam are vertical concrete (not reinforced) walls of triangular cross-section, 20 m. apart from axis to axis; their thickness varies from 3 m. at the crest to 5 m. at the base. Their maximum height is 57 m. above the foundations. The foundations of the buttresses are connected upstream by a cutoff-wall 6 m. thick. Their bases are connected downstream by a toe wall in order to reduce the hydrostatic pressure on the ground.

The buttresses are braced at different heights by beams, alternately fixed or hinged in the buttresses.

The inclined arches are of concrete, reinforced with sectional steel and round iron rods. The thickness of the arches varies from 70 cm. at the top to 1.30 m. at the bottom.

The structure, which was planned to reach an altitude of 647 m. was raised another 7.25 m. before completion. To provide sufficient stability in spite of the increase of water pressure, a large concrete block was

built at the foot of each buttress. Each block was divided by an expansion joint in which jacks were placed in order to create large counterthrusts amounting to thousands of tons. Due to the deformability of the bearing ground, these artificial thrusts had a tendency to disappear; therefore, they had to be restored several times during the first three years of the war. In 1943, the expansion joints were finally filled up and from then on became solid joints. The margins of the Beni-Bahdel reservoir showed two depressions having elevations of about 640 m. These low places were also blocked by multiple-arch dams 5.50 m. high; one of them was used as a spillway of a very special type called "bec-de-canard" (duck-beak). It was necessary for this spillway to be designed to handle an especially large overflow in order to discharge 1,200 m^3 per second by losing a minimum height of water over a fixed weir. This was obtained by the construction of about 20 hanging channels 30 m. long, which were designed to permit overflow along their sides.

The Beni-Bahdel reservoir has a storage capacity of 73 millions m^3, the regulated volume being 50 millions. The areas irrigated by it are mostly in the Marnia region. The main purpose of this reservoir, however, is to supply water to the town of Oran through a water main which is now under construction.