CHAPTER III. FOUNDATION TREATMENT

12. GENERAL. The foundation treatment of Glen Canyon Dam consists of three parts: Grouting, drainage, and excavation of cutoff drifts and backfilling them with concrete. The cutoff drifts and the grouting will seal the cracks and joints. The drainage hole pattern will relieve the water that may seep through the massive sandstone.

13. GROUTING. The general plan for grouting the rock foundation beneath the dam provided for low-pressure shallow grouting of the upstream 60 feet of the foundation, to be followed by high-pressure deep curtain grouting from the foundation gallery. Grout holes were also provided for in the foundation tunnels which would complete the deep-curtain grouting in the vicinity of the tunnels and which could extend the grout curtain further into the abutment if desirable at a later date. The low-pressure shallow holes were to seal any near-surface cracks and were designated as B-holes. The main cutoff or grout curtain beneath the dam was to be formed by the high-pressure deep-curtain holes known as A-holes. In addition to the above foundation treatment for the dam, radial grouting was provided for in the spillway tunnels and around the diversion tunnel plugs, and periphery and perimeter grouting was provided for around the backfill and tunnel plug concrete placed in the diversion tunnels. Provisions were also included for grouting major seams, cracks, crevices, and channels, both under the dam and under the powerhouse.

Consolidation grouting of the near-surface rock by means of the B-holes was originally required to be completed prior to placing the overlying concrete. Because of the steepness of the abutments and the possibility of lifting the near-surface rock, this method was modified so that B-hole grouting above elevation 3110 was to be performed from the tops of concrete lifts in the abutment blocks. The B-holes were to be spaced at 20-foot centers in both directions, and were to be drilled and grouted to 25-foot depths. The upstream row of B-holes was located just inside the upstream face of the dam.

The A-hole deep-curtain grouting in the lower part of the dam was to be performed generally at 40-foot spacings to a depth of 250 feet, with intermediate holes at 20-foot spacing going to 150-foot depths, and with the final grout holes at 10-foot spacing going to 100-foot depths. This curtain varied uniformly from the above pattern to approximate 110-, 65-, and 45-foot depths for the 40-, 20-, and 10-foot spacings, respectively, at about elevation 3450. Above elevation 3480, the curtain decreased in depth to a 50-foot depth at the top of the dam, all holes to be at 10-foot spacings and drilled from the foundation tunnels.

Because of vertical and near-vertical joints encountered in the upper parts of the abutments, adits paralleling the abutments were constructed in the dam between elevations 3157.5 and 3630. These adits were constructed with a twofold purpose. The first was to provide a means of grouting the concrete-rock contact at any time in the future as the need required. The second purpose was to provide the means for extending the B-hole consolidation grouting so as to cover practically all of the abutment area in the steeper part of the abutments. Grout holes from these adits were to be drilled and grouted at 40-foot spacings along the profile of the abutment and at 80-foot spacings across the width of the abutment. All holes were to be 50 feet into rock.

One near vertical joint, called the A-joint, was observed in the right abutment above elevation 3120 and required special grouting. This was done through nearly horizontal holes drilled 30 feet beyond the A-joint and spaced at 20-foot centers horizontally. Pipes were caked into these holes and brought above the top of the next lift of concrete to be placed. After placement of the lift of concrete, similar holes 7 and 1/2 feet above the lower holes were drilled beyond the A-joint. The lower holes were then grouted using the upper holes as vents. After use as vents, the upper holes were washed and then used as grout holes for the next 7-1/2-foot lift. This procedure was repeated throughout the A-joint area. The A- and B-hole grouting patterns and layouts are shown on figures 14 and 15. The grouting performed from the special adits is shown on figure 16.

Two water-bearing seams were discovered in the foundation on the right abutment at elevations 3118 and 3070 and one on the left abutment at elevation 3080. The one on the left was treated by extending the B-hole grouting downstream in this area an additional 60 feet. The two on the right were treated by excavating drifts into the abutment at the upstream side of the foundation area and backfilling with concrete to increase the path of percolation (fig. 17). The lower drift was extended 160 feet and the upper drift 60 feet into the abutment. The extent of the drifts was determined by field inspection of the leakage in the water-bearing seams.

A joint opened up between the rock-contact line at the right abutment, block 26. This break in contact between the concrete and the rock extended about 30 feet down the upstream and downstream faces of the dam. Since the upper grout lift in the dam is ungrouted, no arch action was transmitted to the abutment. It was necessary to grout this joint to
14. DRAINAGE. Drainage of the foundation rock was provided for through 3-inch-diameter holes drilled into the rock foundation from the foundation and drainage galleries in the dam and from the foundation tunnels in the abutments. To prevent plugging the drainage holes during grouting operations, the drilling of drainage holes was delayed until all grouting within 250 feet was completed.

The main purpose of the drainage holes drilled from the drainage gallery was to reduce uplift and percolation of water near the downstream toe of the dam and in the powerplant area. In the drainage
Figure 14.—Dam foundation grouting—A-holes. (Sheet 2 of 2.) From drawing No. 557-D-1638.
Figure 15.—Dam foundation grouting—B-holes.
Figure 16.—Dam foundation grouting from adits. (Sheet 2 of 2.)
In the foundation gallery, the holes were spaced at 10-foot centers and extended into rock approximately 85 feet in the lower part of the dam, gradually reducing to 20 feet at the top of the dam. The drainage holes in the central portion of the dam were vertical holes, but the pattern fanned out so that all drainage holes in the abutments were self-draining. Drainage holes in the central portion of the dam were vertical holes, but the pattern fanned out so that all drainage holes in the abutments were self-draining. Drainage
holes drilled from the foundation tunnels at 10-foot centers supplemented the holes drilled from the foundation gallery in the drainage curtain. Other drainage holes from the tunnels extended the curtain in the abutment areas, and were to be drilled from both the floor and ceiling of the tunnels, the “down” holes being limited to about 75 feet. These holes were to be spaced at 30-foot centers, although intermediate drainage pipes were to be embedded in the floors of the tunnels at 10-foot centers in case additional holes were needed. Drainage holes from the foundation gallery and foundation tunnels are shown on figures 19 and 20.

The design of the drainage system for the dam foundation was based partially on the results of electric-tray analogy studies.¹

15. CANYON WALLS. In its report to the Bureau of Reclamation dated October 12, 1961,² the Glen Canyon Dam Board of Consultants made the following observations and recommendations:

“In view of the stress-relief joints that have developed, or may develop, in the abutment rock downstream of the dam, particularly in the right abutment, and the increase in the rock stresses that will result from the arch thrust, the Board is of the opinion that extensive anchorage and drainage should be provided to insure the stability of these rock masses. The more critical areas of the abutment appear to be those below about elevation 3450 in the right abutment and somewhat below elevation 3350 in the left where the intrados of the arch at the abutments lies close to the surface and where the relief jointing is most noticeable. Of special importance is the rock mass lying riverward of relief joint “A” where, in the right abutment in the lower part of the keyway, the intrados is riverward of this joint. (Quote continued.)

Figure 19.—Left abutment foundation drainage.
Figure 20.—Right abutment foundation drainage system.
Figure 21.—Left and right canyon walls—Rock anchorage and drainage holes.
“The Board recommends that the Bureau conduct studies to determine the details of the anchorage treatment between about elevations 3190 and 3450 in the right abutment and about elevations 3190 and 3350 in the left abutment extending downstream for a distance approximately 200 feet from the keyways. The Board is of the opinion that the anchorage in the right abutment should extend back of the "A" joint for a distance of at least 25 feet. It would be desirable to use high-carbon steel bars prestressed to say one-half their yield strength and to grout them in after prestressing. It would be prudent to install the anchorage at the earliest practicable date."

To implement this recommendation, studies were made of the extent, depth, and details of anchorage and drainage necessary to allay concern for stability of the rock masses involved.

The anchorage and drainage of the slabs are shown on figure 21. Two-inch anchor bars in 3-inch-diameter holes were grouted in rock beyond the A-joint. After grouting the lower ends, the bars were tensioned with a hydraulic ram to 20,000 pounds per square inch (63,000 pounds total load). The nuts were then tightened to a torque of 3,500 inch-pounds.

Because the concreting of the powerplant was scheduled to begin, the area between the powerplant d- and m-lines and below elevation 3240 was anchored with 1-1/2-inch torque-tensioned bolts similar to those used in the spillway outlet portal area (see fig. 22). These were on hand and allowed the contractor to begin installation of the bolts immediately.