greater resistance to this movement (perhaps three times) than the concrete, but there is nothing to warrant the assumption that the rock bottom is immovable, and measurements also seem to indicate that it is not although measurements of such movements are very difficult to make correctly, as they are so small in this region.

A trial calculation will ordinarily indicate very low unit shearing stresses at the foundation, even assuming that shear alone carried all the load on, say, the lower fifth of the dam.

The unit shearing stresses, in most cases (perhaps in all cases), will be less than the unit weight multiplied by the coefficient of friction; but, in any case, the weight of the structure will exert considerable unit compression perpendicular to the horizontal plane of shear, and thereby improve the ability of the concrete to withstand shearing stresses along horizontal planes.

Deflection Curves

The curves shown on Figs. 1 and 2 are typical for the deflection of the crown of an arch dam due to different water loads and different temperatures of the dam body.

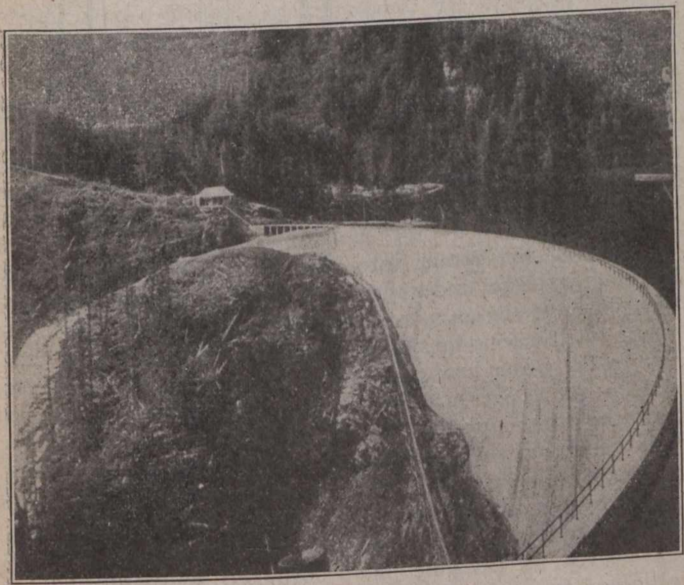

Fig. 4—Salmon Creek Dam, Near Juneau, Alaska. 168 Feet High

The curves are plotted from measurements taken on the Salmon Creek dam, near Juneau, Alaska. This dam (Fig. 4) is of the constant-angle arch type, 168 ft. high, with a crest span of 550 ft.

Fig. 3 shows the maximum cross-section at the crown. On this cross-section is indicated a number of horizontal steel rods embedded in the masonry, 20 ft. apart. These steel rods are provided with copper points on the downstream end for weather-proofing purposes. The different readings were obtained by sighting these points through a transit and determining their position in regard to fixed bench-marks.

It is very difficult to measure the deformation close to, or at, the foundation. It is so small that a transit reading would not be accurate enough, and if a stationary measuring apparatus was arranged on the ground, down stream from the dam, it would have to be at least 50 ft. distant in order to be on ground which does not take part in any movement caused by the load on the dam. The measuring tape or rod then becomes so long that all measurements taken must be compensated for temperature changes, and even a small error in such calculations or estimates will be sufficient to make this method of doubtful value. The best thing to do seems to be to extend downward, in a uniform direction, the curve obtained from observations at higher elevations.

The measurements on the Salmon Creek dam were commenced on October 8th, 1914, when the reservoir was filling for the first time, and the position of all the copper points on that date is taken as zero for all curves shown on Figs. 1 and 2. The actual zero will lie a little to the left; it may be some time before the water will be low enough to determine it by measurements.

The load due to the water level shown for Curve No. 1 was sufficient to keep the contraction joints (only two) closed.

Construction Features Cause Peculiarity

There is not much that need be explained about the results of the first and second deflection measurements—those taken on October 26th, and November 24th, 1914. The water kept rising, deflecting the crown in a downstream direction, about as might have been expected. The fourth measurement, Curve No. 4, taken on May 18th, 1915, begins to show some peculiarity about this dam, that is, the knee in the deflection curve at Elevation 1,095, which is still more apparent on the three following curves. This peculiarity is caused by construction features which must be known to be appreciated.

As it was necessary to stop construction work late in the fall of 1913 at about this elevation, the zone of the dam in this vicinity was built during the coldest portion of the fall and the coldest portion of the following spring. The total shrinkage of the concrete in this zone, therefore, has been less than the average, and the arch, therefore, takes a greater proportion of the total load than it does either above or below; in fact, some load is transferred through the vertical beam (the cantilever) to this zone from both above and below. Such transference of load also takes place through the vertical beam at the crest, as shown by Curve No. 4, but this would be expected in any case.

Curve No. 5 shows considerably more excess deformation of the dam than Curve No. 4, although the water load is only slightly higher, but Curve No. 5 was plotted from measurements taken on December 2nd, 1915, at a time when the days had been short and cold for some time, compared with the long, warm days around May 18th (Curve No. 4). Curve No. 5 also indicates that the outside temperature has been lower than that of the water and the dam body below the water level for some time, as the portion of the dam above the water level is forced downstream to a greater extent than the lower loaded portion as a result of the greater shortening of the arch (rib) in the upper region, produced by a lower temperature in the upper exposed portion of the dam.

Deformation Due to Temperature Changes

Curves Nos. 6 and 7 give an idea of the magnitude of the deformation due to temperature changes alone. The water load is the same in both cases—that due to reservoir full—but the average temperature of the dam body was high when the measurements for Curve No. 6 were taken, on June 25th, 1915, and low when the measurements for Curve No. 7 were taken, on October 27th, 1917. The days, of course, are still shorter and colder in January (Juneau, Alaska) than in the latter part of October, but October 27th was the last day the reservoir was full to the spillway crest.

Both curves are of the shape expected, except for the knee at Elevation 1,095, but low temperatures at the time of construction were responsible for that, as already explained.