IMPROVING ARCH ACTION IN ARCH DAMS*

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THE fact that arch dams, and mainly those of heavy sectional area, do not develop arch action before considerable load has been applied to them, is generally known, but, to a great extent, has not been especially considered in their design.

At present, working stresses of about 25 tons per square foot, as used in ordinary dam practice, are sufficiently low to produce a safe structure, even in spite of the fact that the formulas used for the design do not consider everything.

It is obvious, however, that if the practical arch could be constructed in such a way as to coincide more nearly with the ideal arch—that is, one which acts as an arch from the very start, and in which the load is mainly carried by pure arch action—a still safer structure would result. Higher unit stresses than are now common could be used with safety, if arch action could be made more definite from the start. The factor of safety to be used would depend on the importance of the particular structure in each case.

The two main reasons for the phenomenon that an arch dam does not act as an arch before considerable load has been thrown on it are, as is well known: First, the shortening of the arch rib due to shrinkage; and, second, because the arch is fastened to the foundation.

The shortening of the arch rib is caused by the natural shrinkage of the concrete as it sets, the dissipation of the chemical heat, the permanent set after the reservoir has filled once, and the fact that dams are of necessity almost always built during the season of highest temperature.

This shortening of the arch rib is plainly visible on dams provided with contraction joints. With an empty reservoir, during cold weather, these joints will have opened up from ¼ in. to perhaps as much as ⅜ in., where spaced, say, 60 ft. apart. If not provided with contraction joints, a dam of heavy cross-sectional area will undoubtedly show cracks at more or less regular intervals from 40 to 80 ft. apart. A dam of slim cross-sectional area may not always crack, as it is somewhat flexible, and the crown can often be pulled in a down-stream direction without developing excessive tension in the arch.

In cases where the contraction joints have opened up, the water level in the reservoir will have to rise a certain distance in order to throw sufficient load on the structure to force the dam, acting as a cantilever, to deflect in a down-stream direction, before the voussoirs—that is, the bodies between the contraction joints—come into contact with one another. Only from that moment does the remainder of the water load divide up between the arch, the curved beam, and the cantilever.

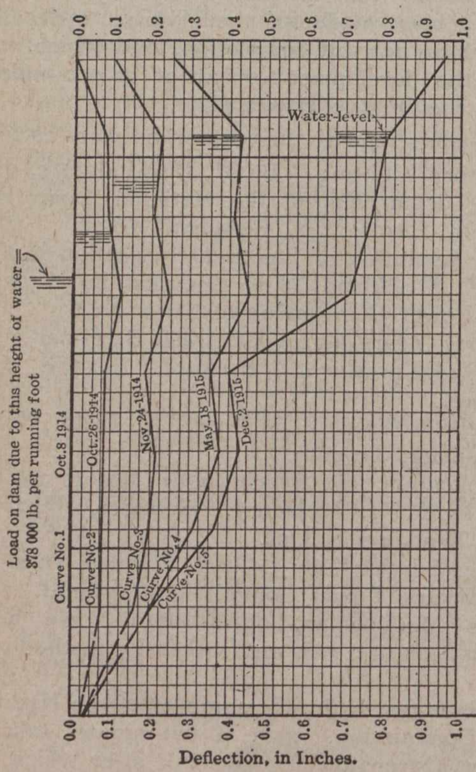

Fig. 1

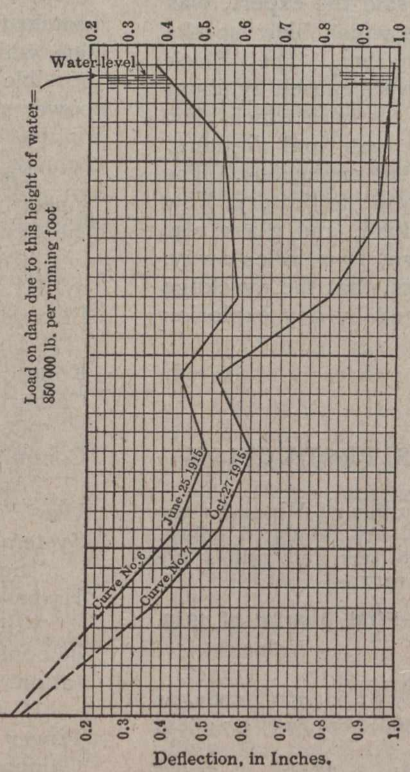

Fig. 2

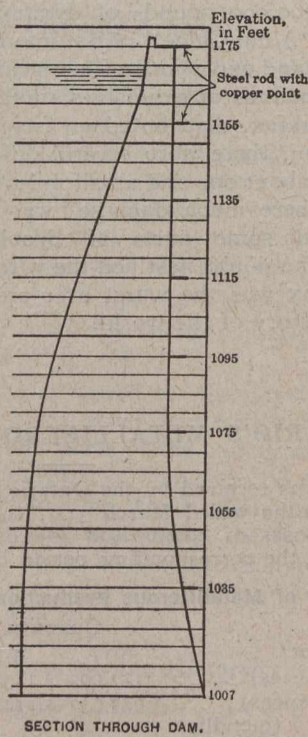

Fig. 3

In the case where the arch has not cracked, although under the influence of tensile stresses, the water level in the reservoir will have to rise until this tension has been compensated for by pressing back the cantilever. The remainder of the water load is then divided up between the arch, the curved beam, and the cantilever, according to their relative capacities for sustaining load.

The fact that the arch is fastened to the foundation prevents any considerable arch action from taking place at or near the latter; this, however, is not detrimental to the safety of the structure, such as would be the shortening of the arch due to shrinkage. The load on the lower portion of the arch causes shearing stresses in the concrete next to the rock and for some distance above and below. These shearing stresses, in turn, cause an elastic deformation, of both the dam and the rock foundation, to take place in a down-stream direction, especially at the crown of the arch, where the movement in that direction is the greatest. Ordinarily, the rock bottom has a higher modulus of elasticity than the concrete; it is well supported laterally from all sides, and therefore offers

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