April 5, 1932. F. A. NOETZLI 1,852,431

DAM

Filed Nov. 25, 1929

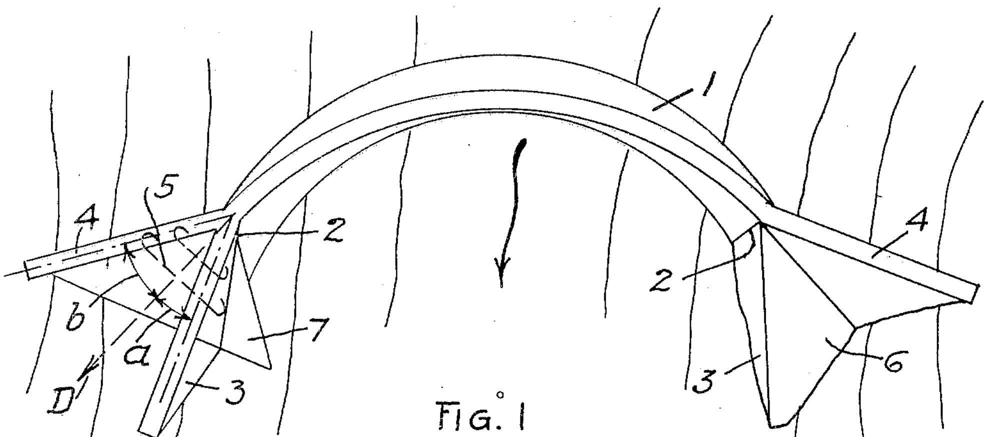

FIG. 1

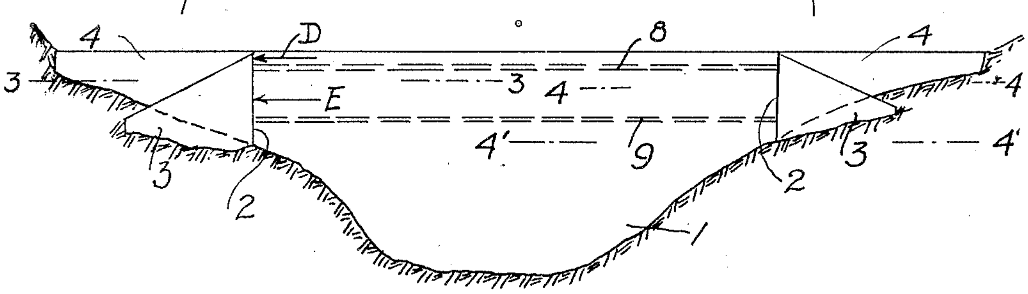

Fig. 2

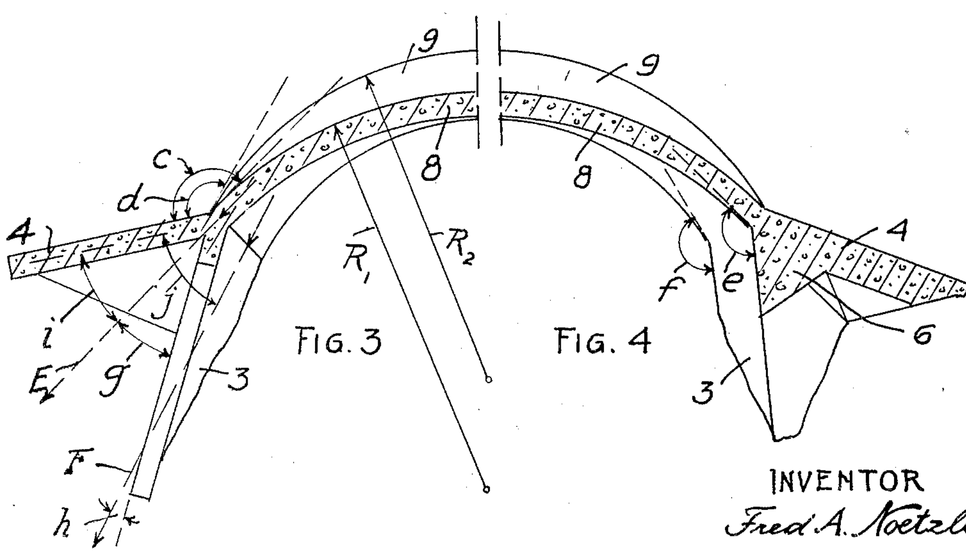

FIG. 3 FIG. 4

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Patented Apr. 5, 1932 **1,852,431**

UNITED STATES PATENT OFFICE

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DAM

Application filed November 25, 1929. Serial No. 409,489.

This invention relates to the construction of concrete dams and the primary object of the invention is to provide a dam of this type which will be less expensive and which can be built in a shorter period of time than dams such as heretofore constructed.

An object of the invention is to provide a dam of novel construction which is a combination of an arch dam with a forked abutment. This feature has been recognized in my co-pending application, Serial No. 319,205, filed, November 14, 1928, over which the construction disclosed in this application may be considered as an improvement.

Another object of my invention is to provide a dam having its central portion of arch construction and one or both sides or wings of gravity section construction, and having buttresses which cooperate with the wings of the dam in sustaining the thrust of the arched portion of the dam. The combination is highly advantageous in that the buttresses do not alone have to sustain the thrust of the arch but instead the portions of the dam which are of gravity section assist in weighting down the ends of the arch and in sustaining the thrust. The arch abutments comprising buttresses and gravity wing walls permit to make the arch of the dam shorter and also permit the use of shorter arch radii and smaller thicknesses of the arch in the highest portion of the dam. The abutments are of "forked" shape and offer large areas in shear and upon the foundation material for resisting the thrust of the arch.

With the foregoing and other objects in view which will be made manifest in the following detailed description and specifically pointed out in the appended claims, reference is had to the accompanying drawings for an illustrative embodiment of the invention, wherein:

Figure 1 is a schematic plan view of the dam embodying the invention.

Figure 2 is a view in elevation of the dam shown in Figure 1.

Figure 3 is a horizontal section through a portion of the dam shown in Figures 1 and 2 and may be considered as having been taken along the line 3—3 of Figure 2.

Figure 4 is a horizontal section through the dam shown by Figures 1 and 2 and may be considered as having been taken along the line 4—4 of Figure 2.

Referring to the accompanying drawings wherein similar reference characters designate similar parts throughout, the dam consists of an arch central portion 1, and arch abutments 2 for supporting the thrust of the central portion 1. The abutments 2 comprise buttresses 3 arranged on the downstream side of the arch 1, and wing walls 4 of gravity section, extending in a lateral direction and serving as a closure of the reservoir.

The buttress 3 and wing wall 4 form together a "forked" abutment 2 which is especially well adapted to support the thrust of the arch 1. While I have shown the arch 1 to be supported at each end by a forked abutment 2, it is understood that in certain cases one end of the arch may abut directly against the rock of the canyon walls or upon another structure. In such a case only one forked abutment 2 may be required for the arch 1. The buttress 3 and the adjacent wing wall 4 form an acute angle with each other and they are so arranged that the direction D of the arch thrust forms an acute angle a with the direction of the buttress 3, and forms another acute angle b with the direction of the wing wall 4, such as shown in Figure 1. By arranging the buttress 3 and the wing wall 4 at an acute angle with each other, these two structural members which together form the abutment 2 of the arch 1 are intimately connected with each other, and their foundation areas, as well as certain parts of these members themselves, overlap and are combined so that certain parts of the concrete are stressed in the direction of the buttress 3 and the wing wall 4, and at the same time help to support a part of the water pressure by gravity action in the wing wall 4. The thrust of the arch 1 is carried by the combined action of buttress 3 and wing wall 4, that is, by the abutment 2. It is therefore of importance that the buttress 3 and the wing wall 4 act properly together, and to improve and safeguard such monolithic action, I may place reinforcing bars 5 in the abutment 2 crosswise to the direction of the arch thrust, these bars 5 to extend from the buttress 3 into the wing wall 4, as shown in Figure 1. I may also add a body 6 of concrete material between the buttress 3 and the wing wall 4 as shown in Figures 1 and 4 to avoid re-entrant angles between buttress and wing wall, and thereby strengthen the abutment 2. Of course, the body 6 of concrete is built integrally and monolithically with the buttress 3 and the wing wall 4, and thus ties these two elements better together and also increases the mass and the cross sectional area subject to shear in the abutment 2, whereby its strength and safety to resist the thrust of the arch 1 is materially increased at a relatively small expense.

At certain dam sites it will be desirable to make the angle $a+b$, that is the angle between the directions of the buttress 3 and the wing wall 4, relatively small so that the base of the gravity wing wall 4 extends materially beyond the base of the buttress 3, such as shown in Figure 1. In such a case, I may construct the gravity wing wall 4 with its full cross-section at its junction with the arch 1 such that the portion 7 of the wall 4 extends beyond the buttress 3 on the downhill side. Thus, the base of the portion 7 extends beyond the base of the buttress 3 and is of value in supporting the water pressure acting upon the upstream face of the wall 4.

I may construct the dam such that the buttress 3 extends substantially in the direction of the total thrust E of the upper portion of the arch 1. Thus, the buttress 3 will have to carry most, if not all of the arch thrust E. The gravity wing wall 4 may then be disposed at an acute angle i with the direction of the arch thrust and towards the side of the reservoir. According to the size of the angle i a smaller or larger proportion of the arch thrust will be thrown upon the wall 4 and this one may be built in a direction which takes the best advantage of the topography of the dam site.

In some arch dams built heretofore the thrust of the arch is carried by a wing wall of gravity section, whereby this wing wall extends in the direction of the tangent to the arch at its junction with the wing wall. These so-called gravity tangents must often be rather long in order to fit properly into the hillside. In my improved dam the gravity wing wall 4 extends at an angle with the tangent to the arch, as shown in Figs. 1 and 3, and this angle may be chosen within wide limits so as to best suit the topographic conditions of any site, inasmuch as the buttress 3 helps the support the arch thrust.

The arch 1 of the dam may have an upstream face of constant radius of curvature, or it may be of the variable radius arch type in which the arch radius decreases from the crest towards the base of the arch. The arch 1 may be assumed as consisting of a series of arch elements or elementary arches, each confined between two parallel planes, generally horizontal or normal to the spring lines, and extending from one abutment to the other. In a variable radius arch dam the up-stream radius R_1 of an upper arch element 8 near the crest is greater than the up-stream radius R_2 of a lower arch element 9, as illustrated in Fig. 3. Therefore assuming a given direction of the wing wall 4 the tangent to the up-stream face of the upper arch element 8 at its junction with the wing wall 4 forms a certain angle c with the up-stream face of the wing wall 4, and the tangent to the up-stream face of a lower arch element 9 forms a smaller angle d with the up-stream face of the wing wall 4. On the other hand, the tangents to the intrados of the arch elements form angles e and f with the inner face of the buttress 3, which angles decrease in size from the base of the buttress 3 upwards towards the crest, so that angle e is smaller than angle f.

For relatively thin arch elements like those at or near the crest of arch dams the arch thrust coincides very nearly with the center line of the arch. In the upper arch element 8 the direction of the arch thrust E forms a larger angle g with the direction of the buttress 3 than the angle h which the direction of the arch thrust F in the lower element 9 forms with the direction of the buttress 3. The angle i which the arch thrust E of the upper element 8 forms with the direction of the wing wall 4 is smaller than the angle j between the direction of the arch thrust F of the lower element 9 and the direction of the wing wall 4.

I claim:

1. A concrete dam comprising an arch subjected to water pressure, and means for carrying the thrust of the upper portion of said arch, comprising a buttress and a wing wall, the direction of the thrust of said arch at the junction of the arch with the buttress forming an acute angle with the direction of the buttress and forming another acute angle with the direction of said wing wall, the base of the buttress extending downstream beyond the base of said wing wall.

2. A concrete dam comprising an arch, an abutment for resisting the thrust of the upper portion of said arch, said abutment comprising a buttress wall extending substantially in the direction of the total thrust of said upper portion of the arch, and a gravity wing wall being disposed at an acute angle with the direction of said arch thrust and being disposed towards the side of the reservoir, the base of the buttress extending down-stream beyond the base of said wing wall.

3. In a concrete dam the combination of an upper and a lower arch element with an

abutment comprising a gravity wing wall disposed laterally relative to said arch elements, the tangent to the up-stream face of the upper arch element at the junction with the wing wall forming an angle with the up-stream face of the wing wall, the tangent to the up-stream face of the lower arch element forming a smaller angle with the up-stream face of said wing wall.

4. In a concrete dam the combination of a series of arch elements with an abutment comprising a buttress and a gravity wing wall, the tangents to the intrados of said arch elements forming angles with the inner face of said buttress, said angles decreasing in size from the base of said buttress upwards.

5. A concrete dam construction comprising superposed arch elements, and means for carrying the thrusts of said arch elements comprising a buttress and a wing wall of gravity section, one upper of said arch elements being located near the crest of said dam, and one lower arch element being located a certain distance below the crest of the dam, the directions of the thrusts of said arch elements at the spring lines forming angles with the direction of said buttress, said angle between the direction of the thrust of the upper arch element with the direction of the buttress being larger than the angle between the direction of the thrust of the lower arch element with the direction of said buttress.

6. A concrete dam construction comprising superposed arch elements of different thickness and different radii of curvature, means for carrying the thrust of said arch elements comprising a buttress and a wing wall, the directions of the thrusts of said arch elements at the spring lines forming angles with the direction of said buttress, said angles being larger for said arch elements located near the crest of the dam than for said arch elements located a certain distance below the crest.

7. A concrete dam comprising superposed arch elements of different radii of curvature, means for carrying the thrust of said arch elements comprising a buttress and a wing wall, the directions of the thrusts of said arch elements forming angles with the direction of said wing wall, said angles being smaller for said arch elements located near the crest of the dam than for said arch elements located a certain distance below the crest.

8. In a concrete dam the combination of an arch with an abutment comprising a buttress and a gravity wing wall being disposed at an acute angle with each other the slope of the down-stream face of said buttress being flatter than the slope of the downstream face of said wing wall, and material added to and between said buttress and said wing wall tending to promote improved combined action of said buttress and said wing wall for supporting the thrust of said arch.

9. A concrete dam construction comprising superposed arch elements, means for carrying the thrust of said arch elements comprising a buttress and a wing wall disposed at an acute angle with each other, the base of the buttress extending down-stream beyond the base of said wing wall, and reinforcing steel bars extending between said buttress and said wing wall and cross-wise to the direction of said thrust tending to promote monolithic action between said arch, said buttress and said wing wall.

10. A concrete dam construction comprising an arched portion and means for carrying the thrust of the upper part of said arched portion including a buttress and a wing wall of gravity section disposed at an angle with each other such that the base of said wing wall extends beyond the area of the base of said buttress towards the down-hill side substantially as described.

11. In a dam the combination of an arch with a buttress and a wing wall arranged at an acute angle with each other and in such a position relative to each other that the thrust of a certain portion of said arch is supported in part by the buttress and in part by the wing wall, the slope of the rear face of said buttress being flatter than the down-stream slope of said wing wall, and means interposed between said buttress and said wing wall tending to improve their ability to support said thrust.

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