Feb. 21, 1933. F. A. NOETZLI 1,898,095

DAM

Filed Nov. 25, 1930

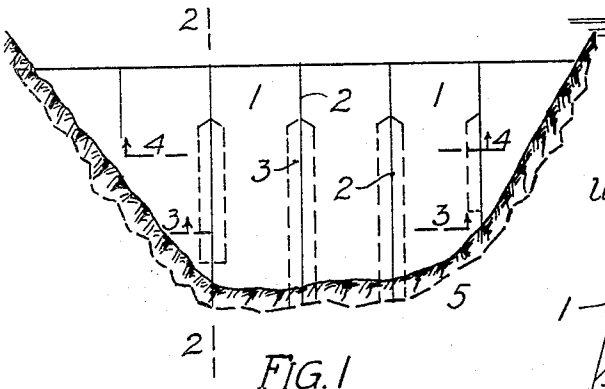


FIG. 1

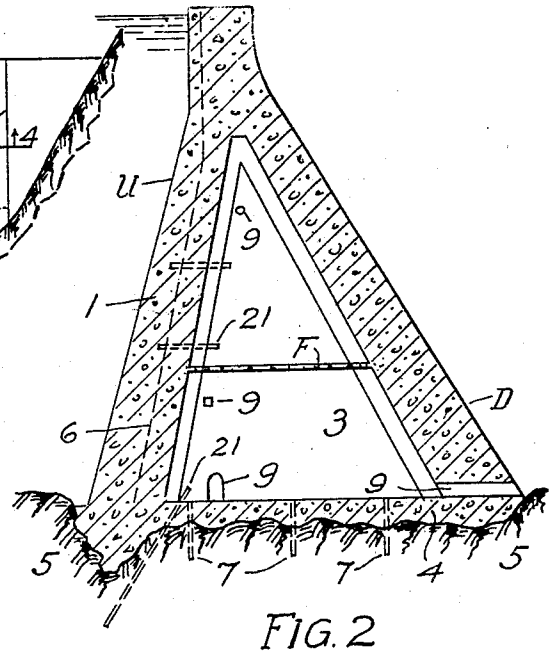


FIG. 2

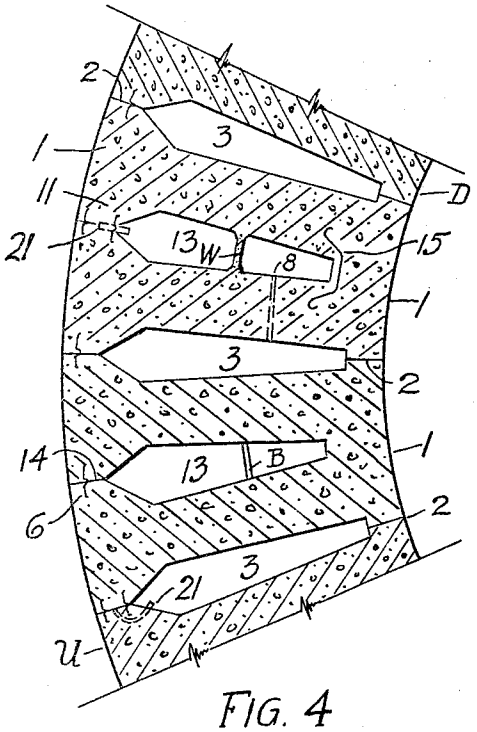


FIG. 4

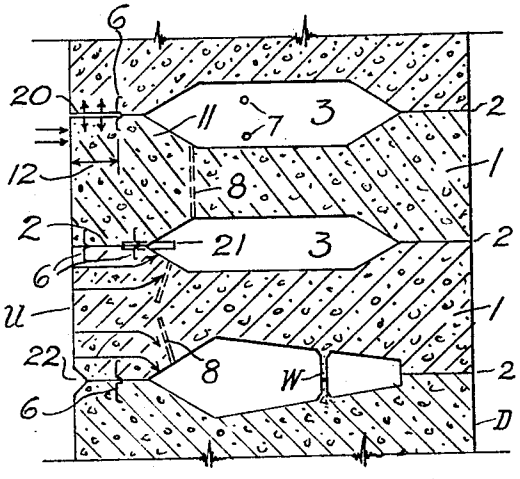


FIG. 3

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UNITED STATES PATENT OFFICE

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DAM

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This invention relates to dams, and the primary object of the invention is to provide a dam of the gravity type which will be less expensive and at the same time safer than gravity dams as heretofore constructed.

In the ordinary type of uniform section gravity dam the pressure of the water is resisted merely by the weight of the structure. Except in very high gravity dams the material is subjected to relatively small stresses and is therefore used rather inefficiently. This is especially true for the material in the interior of the dam. Furthermore, solid gravity dams are subject to up-lift pressure of water in the joint between dam and bed rock, or in joints between pours of concrete.

One object of the invention is to provide a gravity dam in which hollow spaces of suitable shape are substituted for some of the concrete in the interior of a solid dam. These spaces will also serve to reduce uplift pressure in the interior of the dam. Safety against overturning is provided in my improved structure by building it with a marked upstream slope and by increasing its thickness at the base.

Another object of the invention is to build my improved dam as a combination of walls which are structurally substantially independent of each other and which have their upstream and downstream portions enlarged laterally so as to form continuous upstream and downstream faces of the dam.

Another object of the invention is to eliminate tension stresses in a lateral direction in the enlarged upstream portions of the aforesaid walls.

Other objects of the invention are to provide novel and advantageous joint constructions and drainage systems.

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 drawing for an illustrative embodiment of the invention, wherein:

Figure 1 is a schematic elevation of the dam embodying the invention.

Figure 2 is a vertical section through the dam shown in Fig. 1 and may be considered as having been taken upon the line 2—2 of Figure 1.

Figure 3 is a partial horizontal section along the line 3—3 through the dam shown in Fig. 1.

Figure 4 is a partial horizontal section through a dam curved in plan, and may be considered as having been taken upon the line 4—4 of Fig. 1.

Referring to the accompanying drawing wherein similar reference characters designate similar parts throughout, the dam shown in Fig. 1 consists of concrete or masonry and is designed to withstand the water pressure in the reservoir by virtue of its weight and of the vertical component of the water pressure. Such a dam is usually called a gravity type dam. It may be straight or curved in plan.

The dam comprises vertical walls 1 between contraction joints 2. From the structural point of view the walls 1 are substantially independent of each other, and in the design are usually considered as structural vertical elements acting like cantilevers in supporting the water pressure against their upstream face.

Figure 2 illustrates how such a gravity type dam appears in section having a hollow drain space 3 in the interior extending substantially in the direction of a contraction joint 2 from near the base to a certain distance below the crest and from points near the downstream side D to points near the upstream side U of the dam. Such hollow spaces 3 may occur at different places in a dam and preferably in the planes or directions of some or all of the contraction joints. They serve for draining some of the water from the concrete which may enter from the upstream side into the pores of the concrete or into horizontal construction joints and thus they tend to reduce uplift pressure. At the same time they permit of the saving of a considerable quantity of material at places where in a solid gravity dam the stresses are relatively low and the material is used rather inefficiently.

The drain spaces 3 may be of any shape but preferably are elongated in an upstream

and downstream direction such as shown, for instance, in Fig. 3. They may extend from a certain distance below the crest down to a base slab 4 or completely down to the foundation material 5 as indicated in Fig. 1. In order to reduce underpressure under the dam and under the base slab 4 I may provide drain holes 7 reaching down into the foundation material 5.

Past experience in concrete dam construction has shown the necessity of providing in gravity dams transverse contraction joints 2 about 40 ft. to 60 ft. apart in order to prevent vertical cracks in the dam due to shrinkage of the concrete. It is common practice to place a water stop 6 across the joint near the upstream face. In my improved dam the drain spaces 3 will collect all water that may pass through or around the stops 6. I may also place drain conduits 8 leading from the interior of the walls 1 into the drain spaces 3, thus further reducing the tendency of uplift pressure in the concrete. In order to prevent excessive accumulation of water in some of the drain spaces 3 which might induce undue lateral pressure upon the adjacent walls 3, I provide openings 9 in the walls 1 for facilitating the circulation of air and water between adjacent spaces 3 and for the removal of excess water towards the downstream side.

The contraction joints 2 and the hollow spaces 3 may be considered as dividing the dam into walls 1 resembling the buttresses of a buttressed type of dam. From the structural point of view the function of these structures is very similar indeed. In my improved dam the individual walls 1 are structurally independent of each other and they may be considered as walls having their upstream and downstream portions enlarged laterally so as to form continuous upstream and downstream faces of the dam. Thus, certain portions 11 of a wall 1 in a horizontal plane extend near the upstream face laterally beyond the face of the wall 1. The pressure of the water in the reservoir has therefore a tendency of producing a bending moment and tension stresses in a lateral direction in the portions 11 extending laterally beyond the face of the wall 1. If the upstream face of the portions 11 has such a shape that the water pressure acting upon these portions is transmitted by direct compression upon the wall 1 no such lateral bending moment and tension stresses will occur. This was recognized in Letters Patent No. 1,681,427 issued to me under date of August 21, 1928. An improvement over the construction described in the aforesaid Letters Patent is disclosed in the present application whereby special means are provided at small expense to produce such lateral pressure upon the portions 11 as to offset or compensate bending moments and tension in a lateral direction.

Referring to Fig. 3, I provide a seal or water stop 6 across the joint 2 a certain distance downstream of the upstream face. When the reservoir fills, water will then enter into the joint and produce lateral pressure upon the portions 11. The distance 12 of the water stop 6 from the upstream face of the dam should preferably be such that the tension stresses in the portion 11 due to the water pressure on the upstream face are materially reduced or entirely eliminated by the lateral pressure of the water in the joint 2.

In order to insure access of water into the joint 2 upstream of the stop 6 I may provide a notch 22. I may also provide an open slot 20 instead of a mere joint 2. Near the crest of the dam it will be preferable not to provide any drain spaces 3. In this portion the dam is then of the usual uniform section gravity type.

I may also force cement grout under pressure into the joint 2 by means of pipes 21 over all or a part of the area between upstream face and drain space 3. If the joint 2 is thus filled with cement grout no dangerous lateral bending can result in the portions 11. I may also use other means for producing lateral pressure in the joint 2 to reduce tension in the portions 11. In the case of gravity dams curved in plan the grouting of the joints 2 near the upstream face and in the upper portions of the dam may make horizontal arch action feasible in the dam over the grouted portions. The effective arch section would be relatively thin but nevertheless very efficient in transferring a portion of the water pressure laterally upon the canyon walls.

I may build my improved dam straight or curved in plane. In case of a curved dam the drain spaces 3 are preferably of such a shape that in certain horizontal planes the average width of the spaces 3 is larger near the upstream face of the dam than near the downstream face. This results in a better proportion of the walls 1.

In a curved gravity dam the thickness of the walls 1 is greater near the upstream side than near the downstream side of the dam. I may therefore place vertically extending hollow slots 13 in the interior of some or all of the walls 1 of the dam and provide short contraction joints 14 between the slots 13 and the upstream face. The joints 14 extend on the upstream side practically from the base of the dam or of the slot 13 to the crest, but on the downstream side they extend only part of the distance from the crest downward. I place reinforcing bars 15 in the lower parts of the dam to prevent the slots 13 or joints 14 from extending beyond the desired points.

Various changes may be made in the de-

tails of the structure herein described without departing from the spirit or scope of the invention as defined by the appended claims.

For instance, there may be at one or several points intermediate vertical walls W or floors F or both of any thickness across the hollow space 3 or there may be other braces B between the walls 1.

Joints 2 or open slots 20 in combination with other means for producing hydraulic or other pressure in a lateral direction upon the walls 1 may be used to accomplish objects of my invention.

I claim:

1. In a dam two walls each wall having a flat upstream face, certain portions of said walls near the upstream face extending laterally towards each other and being provided with a joint joining said portions, certain parts of said joint being open to water pressure from the reservoir, a water stop across said joint, the distance of said water stop from the upstream face bearing a definite relation to the lateral extension of said portions beyond the faces of said walls and to the pressure of the water acting thereon, substantially as described.

2. In a dam two adjoining vertical structural elements disposed substantially perpendicularly to the axis of the dam, certain portions of said elements near the upstream face extending laterally from said elements, and being joined by a substantially open joint between said portions, certain parts of said joint being open to water from the reservoir, water pressure acting upon the upstream face of said elements tending to produce tension stresses in said portions in a lateral direction, a water stop placed across said joint at such a distance from the upstream face that the lateral pressure of water entering from the reservoir into the joint upstream of the water stop substantially eliminates said tension stresses.

3. A dam of the character defined by claim 2, in combination with a uniform section gravity type dam extending along the crest and from the crest downward for a portion of the height of the dam.

4. In a dam two adjoining walls extending transversely to the direction of the dam and having substantially flat upstream faces, certain portions of said walls near the upstream face extending laterally from said walls and being provided with an open slot between said portions, a water stop near the downstream end of said slot, the distance of said water stop from the upstream face bearing a definite relation to the lateral extension of said portions.

5. In a dam two walls extending transversely to the direction of the dam, certain portions of said walls near the upstream face extending laterally and being provided with an upwardly extending open slot approximately one to six inches wide extending from the upstream face rearwardly, and means for confining water from the reservoir over certain portions of said slot.

6. In a dam a wall extending substantially transversely to the direction of the dam and having portions near the upstream face extending laterally, the upstream face of said portions extending in a horizontal plane substantially perpendicularly to the direction of said wall, pressure means acting in a lateral direction upon said portions producing stresses in said portions to the exclusion of tension stresses.

7. In a dam a wall having a head with an uptream face extending in a horizontal plane substantially perpendicularly to the direction of said wall, certain portions of said head near said upstream face extending laterally beyond said wall, means for producing pressure of such a size in a lateral direction upon said portions whereby said head is compressed to the exclusion of tension stresses in a lateral direction.

8. In a dam a plurality of walls having heads joined with each other and forming a continuous upstream face extending in a horizontal plane substantially perpendicularly to the direction of said walls, the pressure of the water in the reservoir acting upon the upstream face of said heads tending to produce tension stresses in the heads in a lateral direction, and means interposed at the juncture between said heads substantially eliminating said tension stresses.

9. In a dam a plurality of buttress walls having buttress heads near the upstream face extending laterally beyond said buttress walls and being joined by vertically extending joints, the upstream face of said buttress heads in a horizontal plane extending substantially perpendicularly to the direction of said buttress walls, means in said joints for producing pressure upon said buttress heads to the effect that the pressure of the water in the reservoir acting upon the upstream face of the buttress heads in combination with the said pressure in the joints produces substantially only compression stresses in said buttress heads.

10. In a dam two adjoining walls extending substantially transversely to the direction of the dam, certain portions of said walls near the upstream face extending laterally and being joined by an upwardly extending joint, said joint admitting water from the reservoir, means for confining the water over a certain area of the joint, the upstream face of said walls having such a configuration that the pressure of the water in the reservoir acting upon the laterally extending portions of said walls tends to produce tension stresses in a lateral direction in said portions, said certain area of said joint being of such a size

that the pressure of the water in said joint at least eliminates said tension stresses.

11. In a dam two walls, certain portions of said walls near the upstream face extending towards each other and forming a continuous upstream face but being separated by an open joint, said upstream face having such a shape that the water pressure in the reservoir tends to produce tension stresses in a lateral direction in said portions, means for confining water from the reservoir over such an area of said joint that the pressure of the water in the joint substantially eliminates said tension stresses.

12. In a dam two walls, certain portions of said walls near the upstream side extending towards each other and being joined by a joint which in part is subjected to water pressure, the pressure of the water in the reservoir acting upon the upstream face of said portions tending to produce tension stresses in a lateral direction in said portions, the combined pressure of the water upon said upstream face and in said joint stressing said portions to the exclusion of tension stresses in a lateral direction.

In testimony whereof I have signed my name to this specification.

FRED A. NOETZLI.