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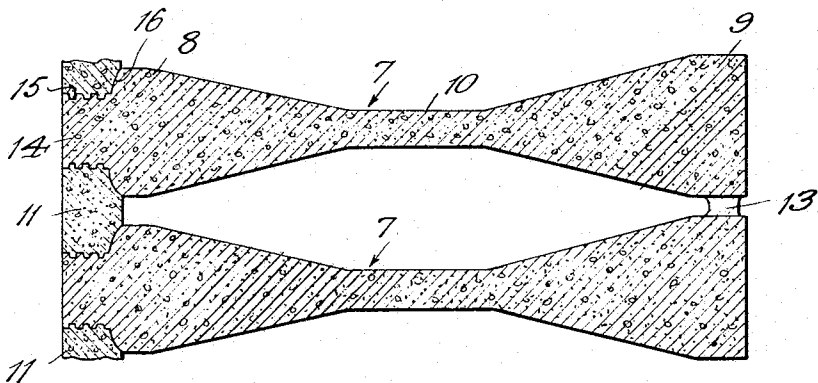
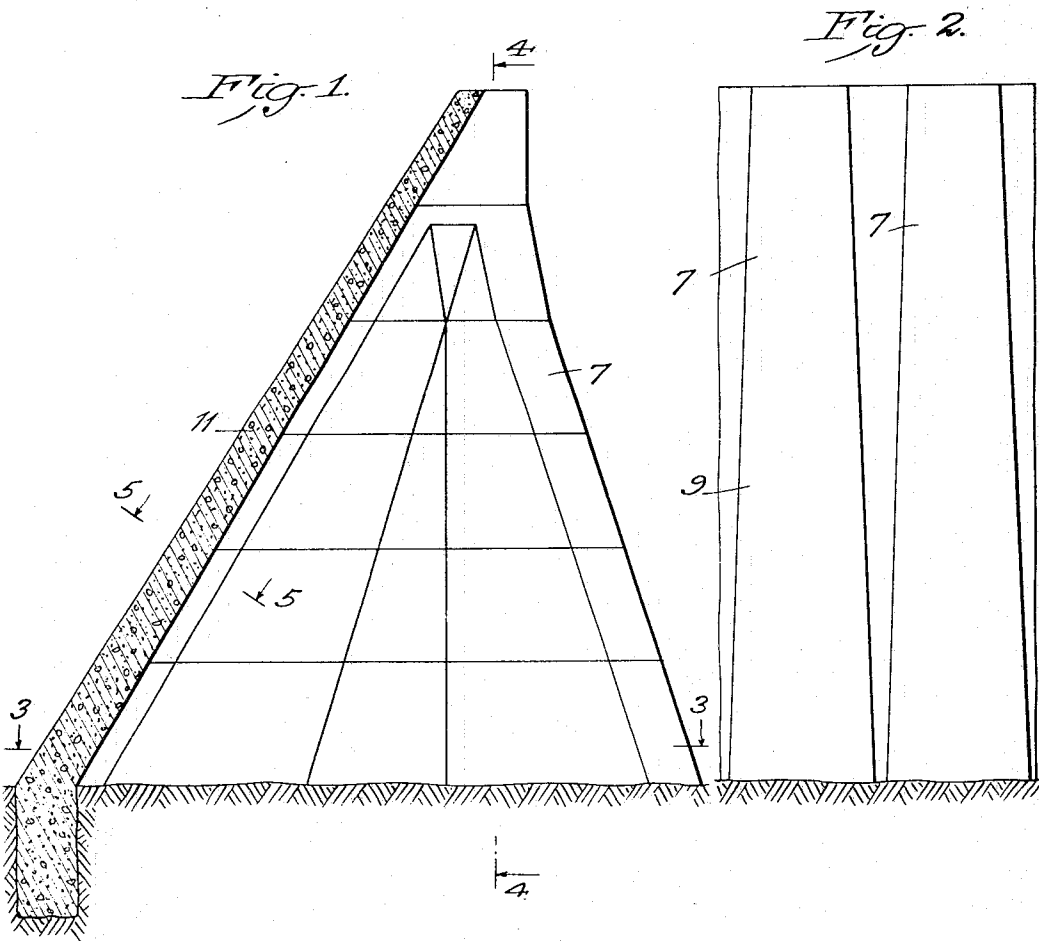
E. H. BURROUGHS ET AL

1,933,092

DAM

Filed April 30, 1930

2 Sheets-Sheet 1



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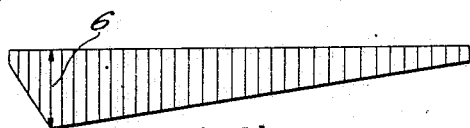
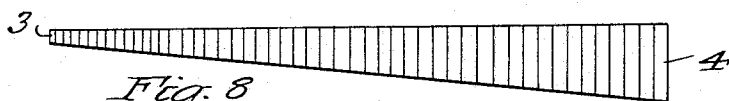
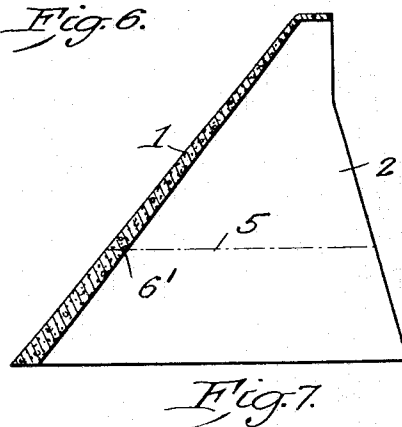
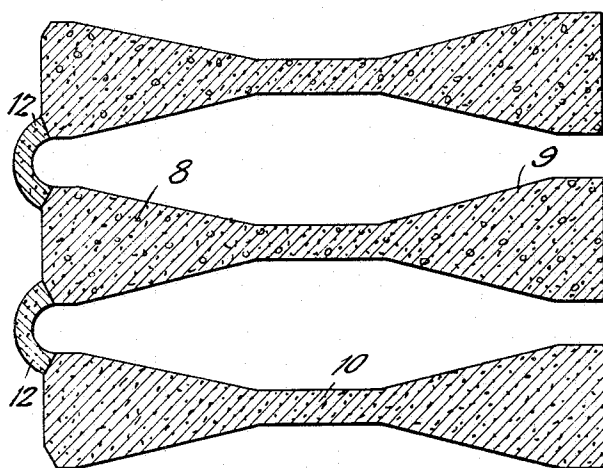
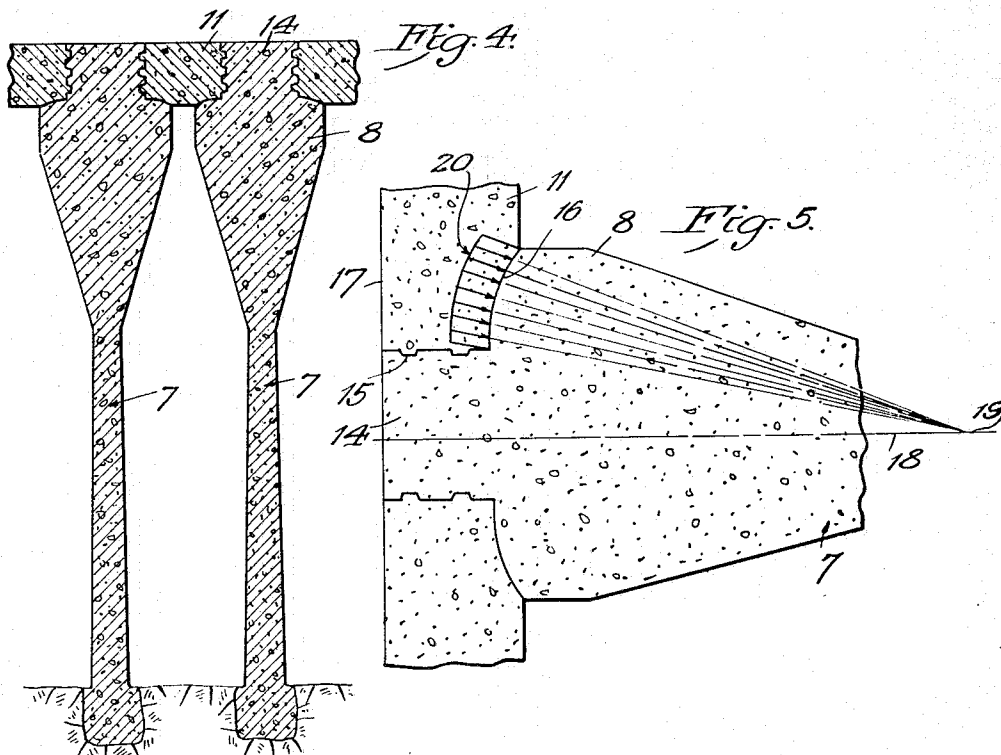
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2 Sheets-Sheet 2



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UNITED STATES PATENT OFFICE

1,933,092

DAM

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Application April 30, 1930. Serial No. 448,503

14 Claims. (Cl. 61—30)

This invention relates to a novel and improved form of dam, the novel features of which will be best understood from the following description and the annexed drawings, in which are shown 5 selected embodiments of the invention and in which:

Fig. 1 is a vertical sectional view through a dam constructed according to our invention.

Fig. 2 is a down-stream elevation of the dam 10 shown in Fig. 1.

Fig. 3 is a section on the lines 3—3 of Fig. 1 but showing a slight modification.

Fig. 4 is a section on the line 4—4 of Fig. 1.

Fig. 5 is a section on an enlarged scale, on the 15 line 5—5 of Fig. 1, and showing the distribution of stresses at the bearing surface between an up-stream slab and one of the buttresses upon which it rests.

Fig. 6 is a view similar to Fig. 3 but showing a 20 different form of up-stream construction.

Fig. 7 is a diagrammatic vertical cross-section through a dam of the general type covered by this application.

Fig. 8 is a diagram showing the distribution of 25 foundation pressures in a dam of the type shown in Fig. 7.

Fig. 9 is a diagram showing the distribution of principal stresses in a dam of the type shown in Fig. 7.

Referring now to Figs. 7, 8 and 9, Fig. 7 shows a dam of the so-called "buttress type", having an up-stream deck 1 supported by buttresses 2 which extend up- and down-stream. In such a type of dam the vertical pressure exerted by the dam, as constructed according to present practice, is shown in Fig. 8, the amount of the pressure being measured by the vertical ordinates of the diagram. From this diagram it will be seen that the pressure at 3, which is the pressure at the up-stream end or heel of the dam, is a minimum, while the pressure at 4 which represents the down-stream or toe of the dam is a maximum, the pressure varying substantially uniformly from heel to toe. This means that the foundation near the toe of the dam is more severely stressed than that portion near the heel or up-stream side. The pressures are obtained from the following formula:—

$$P(\max) = P(av) + \frac{My}{1}$$

$$P(\min)$$

in which P (max) and P (min) = the maximum and minimum pressures at the toe and heel respectively. 55

P (av) = the average of maximum and minimum pressures.

M = the moment about the horizontal section or the product of the resultant vertical load by the eccentricity or distance between the point of 60 application and the center of gravity of the section.

Y = the distance from the center of gravity of the horizontal section to the most remote fibre.

While the pressures on horizontal planes is 65 determined from the above formula, as shown on the diagram of Fig. 8, and are the critical ones which govern foundation design, they do not govern the design of the superstructure. In this part of the dam the critical stresses are 70 those known as principal or maximum inclined stresses. In dams of the type under discussion, these principal stresses in the superstructure are distributed as indicated in Fig. 9, this diagram showing the distribution on the line 5 of Fig. 75 7. The maximum stress is represented by the vertical ordinate 6 which represents the stress approximately at the point 6' in Fig. 7. From this diagram it will be seen that the maximum stress in the superstructure occurs near the up- 80 stream side of the dam.

In the usual prior art construction which is under discussion the buttresses 2 are usually of uniform thickness substantially throughout their length up- and down-stream, and the water bear- 85 ing surface of the dam is formed by slabs supported on brackets or short cantilever beams projecting from the sides of the buttresses and this invention relates particularly to an improvement upon this type. In this type of construction the 90 bracket or cantilever beam must be designed to take care of stresses caused by moment, shear, and diagonal tension, all of which requires a large amount of reinforcing steel which, in turn, makes it difficult to obtain a sufficiently dense 95 concrete in this portion of the dam. It should be remembered that this portion is that which forms the water bearing surface and thus the concrete must be absolutely water-tight, sound and durable. Placing of concrete about rein- 100 forcing steel increases the liability of the formation of pockets and provides a chance for poor workmanship.

With the above discussion of the prior art in mind, this invention aims to provide a dam hav- 105 ing a substantially uniform distribution of stresses in both the foundation and superstructure, at the same time providing for maximum economy and safety of the entire structure. This object is achieved in this embodiment by the 110

structure which will now be described in detail.

Referring first to Figs. 1 to 5 inclusive, the invention is shown herein as embodied in a dam having a plurality of buttresses 7 extending up- and down-stream. In this application we shall refer to the dam as if it were built across a stream, although of course by that language we do not intend to limit the structure to one which must necessarily be built across a water course.

Each buttress is shown as flared at its up-stream edge as indicated at 8, and at its down-stream edge as shown at 9, these flared portions being connected by a portion 10 of reduced thickness. The flared ends 8 and 9 are preferably joined to the reduced portion 10 by tapered portions of gradually varying thickness rather than by abrupt changes. We have found that by constructing the buttresses in this manner, both the principal stresses in the superstructure and the stresses in the foundation are more uniformly distributed. This is probably because of the fact that the up-stream flaring portion 8 is beneath the water bearing up-stream face of the dam, thus providing a larger section of masonry directly under the application of the load, than would be the case if the buttresses were of the usual uniform thickness throughout their lengths. This arrangement therefore appears to reduce the intensity of the principal stress at the point of application of the loading and by properly designing the transition or intermediate portion between the maximum and minimum widths of a buttress, nearly equal intensities of stress may be attained throughout the portions 8 and 10 of the buttress, that is to say, for approximately the up-stream half of the buttress. The down-stream flare 9 of the buttress will of course decrease the intensity of any principal stress occurring therein and serves to draw the center of gravity of the buttress section down-stream or nearer the point of application of the resultant loading. This in turn reduces the eccentricity of the resultant loading, thus tending to equalize the foundation pressure as well as the stresses in the superstructure.

Aside from the above advantages, the flared buttress construction makes it possible to space the buttresses further apart than under present practice and to span the space between the up-stream flares by slabs or beams 11, or by arches 12, as shown in Fig. 6. The relative spacings of the different portions of the buttresses may conveniently be defined by stating that the clear span between the narrow portions 10 of the buttresses is greater than or at least as great as the lengths of the members 11 or, in other words, as the distance between the portions of the buttresses with which the ends of the members 11 contact. This construction is plainly shown in Fig. 3.

Th wider spacing makes it possible to decrease the number of buttresses, thus saving a large expense for form work. Moreover, the placing of a relatively thick or massive section of concrete near the up-stream portion of the dam, adds a stabilizing effect against overturning of the dam and makes it possible to place less dependence on the water load acting on the water bearing up-stream surface of the dam. This, in turn, allows the placing of this up-stream water bearing surface more nearly perpendicular than would otherwise be possible, thereby saving masonry and forms.

If desired, the rigidity of the structure may be greatly increased by connecting the adjacent down-stream flared portions of the buttresses by

walls 13, as shown in Fig. 3, although these walls may be omitted if desired. These walls may be placed between each two buttresses or between alternate buttresses or at other selected locations as desired.

The up-stream edge of each buttress is provided with a tongue portion 14 extending lengthwise of the buttress and having on opposite sides thereof recesses 15 to interlock with projections on the slabs, in order to form expansion joints. As a measure of the relative dimensions of the buttress, it may be noted that the width of a tongue 14 between adjacent slab ends is greater than or at least as great as the minimum thickness of the buttress at the reduced portion 10. At the down-stream end of each portion 14 is provided a bearing surface 16 here shown as cylindrical in form and adapted to contact with a corresponding cylindrical surface on a slab 11. It will be noted that this portion 16 is inclined down-stream with respect to the water bearing surface 17 of the slab, and this inclination is to such an extent that the lines of pressure on the surface 16 all intersect the center line 18 of the buttress and when the surface 16 is cylindrical, as is the preferred construction, all of these lines intersect as at a point 19. It will be noted that the lines of pressure fall entirely within the flared portion 8 of the buttress.

The arrangement just described provides in effect rocker bearings for the slabs 11 and, consequently an even distribution of pressure throughout the entire surface 16, the distribution of pressure being indicated by the diagram 20 in Fig. 5. Thus, we avoid concentration of loading on the outer edge of the bearing for the slab, which has been objectionable in the prior art construction of the type referred to above. As before pointed out, such construction requires a great amount of reinforcement which tends to create rock pockets and to give a porous and unsatisfactory concrete at the very part of the structure which ought to have the densest and most reliable concrete.

The use of a cantilever beam or bracket is thus entirely eliminated and the loads are transmitted directly to the buttress from the slabs in compression, bending moments and diagonal tension being eliminated, thereby eliminating the necessity for reinforcing steel in this part of the structure. The flared portion 8 is designed as an integral part of the buttress and does not take any stresses corresponding to those carried by the brackets or cantilever beams of the prior art. The expansion joints which include the recesses 15 may be made water-tight by any suitable means, and preferably the bearing surface 16 is also made water-tight by being coated with suitable asphaltic material or the like.

While we have shown the invention as embodied in certain specific forms, it is to be understood that various changes in details may be made without departing from the scope of the invention, and we therefore do not intend to limit ourselves except by the appended claims.

We claim:

1. In a dam, a plurality of buttresses extending up- and down-stream, and an upstream face comprising members extending between adjacent buttresses and bearing thereon, with the bearing surfaces on the buttresses extending laterally of the buttresses and the distance of each surface from the plane of the upstream edge of the buttress increasing from a minimum at the edge of the surface nearest the center of the buttress

to a maximum at the edge remote from said center, said buttresses having tongues extending upstream between said members from said edges of the bearing surfaces nearest the center of the buttress and contacting with the ends of said members.

2. In a dam, a plurality of buttresses extending up- and down-stream; an upstream face comprising slabs extending between adjacent buttresses and bearing thereon, with the bearing surfaces on the buttresses substantially cylindrical and extending laterally of the buttresses and the distance of each surface from the plane of the upstream edge of the buttress increasing from a minimum at the edge of the surface nearest the center of the buttress to a maximum at the edge remote from said center.

3. In a dam, a plurality of buttresses extending up- and down-stream, and with the upstream edge of each buttress forming part of the water bearing surface, the remainder of said surface being formed of slabs bearing on said buttresses, with the bearing surface between each buttress and a slab supported thereon being so disposed that all lines of pressure normal to the bearing surface intersect the center line of the buttress.

4. In a dam, a plurality of buttresses extending up- and down-stream, with the up-stream end of each buttress forming part of the water bearing surface, the remainder of said surface being formed of slabs bearing on said buttresses, with the bearing surface between each buttress and a slab supported thereon being so disposed that all lines of pressure normal to the bearing surface intersect the center line of the buttress, and with the water bearing surface of the slab flush with the water bearing surface of the buttress.

5. A dam comprising a plurality of buttresses extending up- and down-stream, slabs extending between said buttresses and presenting water bearing surfaces, and bearing surfaces between said slabs and buttresses, said surfaces being approximately cylindrical with the center of the cylinder within the buttress.

6. A dam comprising a plurality of buttresses extending up- and down-stream, slabs extending between said buttresses and presenting water bearing surfaces, and bearing surfaces between said slabs and buttresses, said surfaces being approximately cylindrical with the center of the cylinder within the buttress and on the center line of the buttress.

7. In a dam, a plurality of spaced buttresses extending up- and down-stream, and an upstream face comprising members extending between adjacent buttresses and bearing thereon, with the bearing surfaces on the buttresses extending laterally of the buttresses, said buttresses being so proportioned and constructed with relation to the bearing surfaces that all pressures exerted on said bearing surfaces follow lines entirely within the buttresses.

8. In a dam, a plurality of spaced buttresses extending up- and down-stream, and an upstream face comprising members extending between adjacent buttresses and bearing thereon, with the bearing surface on the buttresses extending laterally of the buttresses, said buttresses being so proportioned and constructed with relation to the bearing surfaces that all pressures exerted on said bearing surfaces follow lines entirely within the buttresses and intersecting the longitudinal center lines of said buttresses.

9. In a dam, a plurality of spaced buttresses

extending up- and down-stream, an upstream face comprising members extending between adjacent buttresses and bearing thereon, with the bearing surfaces on the buttresses extending laterally of the buttresses and so constructed with relation thereto that all pressures exerted on said surfaces follow lines entirely within the buttresses, said buttresses having tongues extending between said members, and said tongues for at least a substantial portion of the height of the dam being greater in thickness than the minimum thickness of the buttresses.

10. In a dam, a plurality of spaced buttresses extending up- and down-stream, said buttresses having relatively narrow portions intermediate their lengths and having relatively wide portions adjacent their up-stream ends, said up-stream ends of the buttresses having laterally extending bearing surfaces and inclined down-stream from the centers of the buttresses to cause substantially all pressures exerted on said surfaces to follow lines substantially entirely within the buttresses, and water bearing members supported on said surfaces, the clear span between said narrow portions of two adjacent buttresses being at least as great as a parallel overall distance between the ends of the water bearing member supported by said two buttresses.

11. In a dam, a plurality of spaced buttresses extending up- and down-stream, and an upstream face comprising members extending between adjacent buttresses and bearing thereon, with the bearing surfaces on the buttresses extending laterally of the buttresses and inclined down-stream from the centers of the buttresses to cause substantially all pressures exerted on said surfaces to follow lines substantially entirely within the buttresses, said buttresses gradually decreasing in width down-stream from said bearing surfaces at such a rate as to render the intensity of principal stress in one of said buttresses approximately uniform along its up- and down-stream axis for a substantial distance down-stream from said face.

12. In a dam, a plurality of spaced buttresses extending up- and down-stream, and an upstream face comprising members extending between adjacent buttresses and bearing thereon, with the bearing surfaces on the buttresses extending laterally of the buttresses and inclined down-stream from the centers of the buttresses to cause substantially all pressures exerted on said surfaces to follow lines substantially entirely within the buttresses, said buttresses gradually decreasing in width down-stream from said bearing surfaces at such a rate as to render the intensity of principal stress in one of said buttresses approximately uniform along its up- and down-stream axis for a substantial distance down-stream from said face and gradually increasing in width adjacent the down-stream end thereof.

13. In a dam, a plurality of spaced buttresses extending up- and down-stream, and an upstream face comprising members extending between adjacent buttresses and bearing thereon, with the bearing surfaces on the buttresses extending laterally of the buttresses and inclined down-stream from the centers of the buttresses to cause substantially all pressures exerted on said surfaces to follow lines substantially entirely within the buttresses, said buttresses being so proportioned as to render the intensity of stress therein approximately uniform for approximately the up-stream half thereof.

14. In a dam, a plurality of spaced buttresses

extending up- and down-stream, and an up-
stream face comprising members extending be-
tween adjacent buttresses and bearing thereon,
with the bearing surfaces on the buttresses ex-
tending laterally of the buttresses and inclined
down-stream from the centers of the buttresses
to cause substantially all pressures exerted on
said surfaces to follow lines substantially en-
tirely within the buttresses, said buttresses be-
ing so proportioned as to render the intensity
of stress therein approximately uniform for ap-
proximately the up-stream half thereof and to ap-
proximately equalize the foundation pressure
throughout the length thereof.

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15	90
20	95
25	100
30	105
35	110
40	115
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50	125
55	130
60	135
65	140
70	145
75	150