Aug. 30, 1938. J. D. MADARAS 2,128,657

DAM

Original Filed April 10, 1933 3 Sheets-Sheet 1

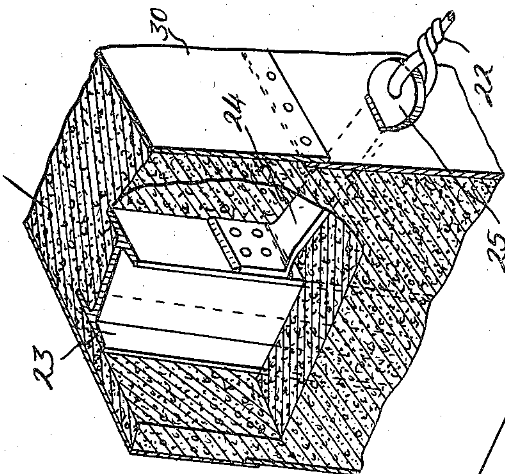

Fig. 2.

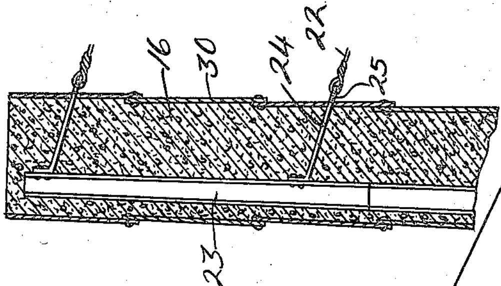

Fig. 3.

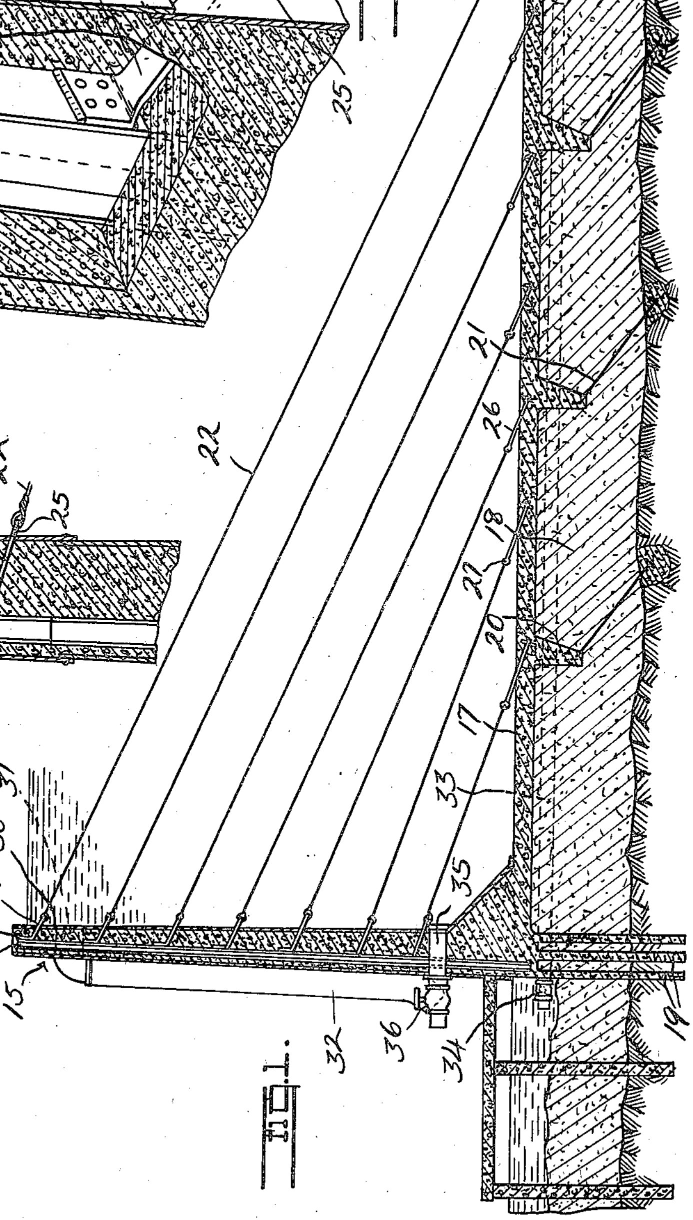

Fig. 1.

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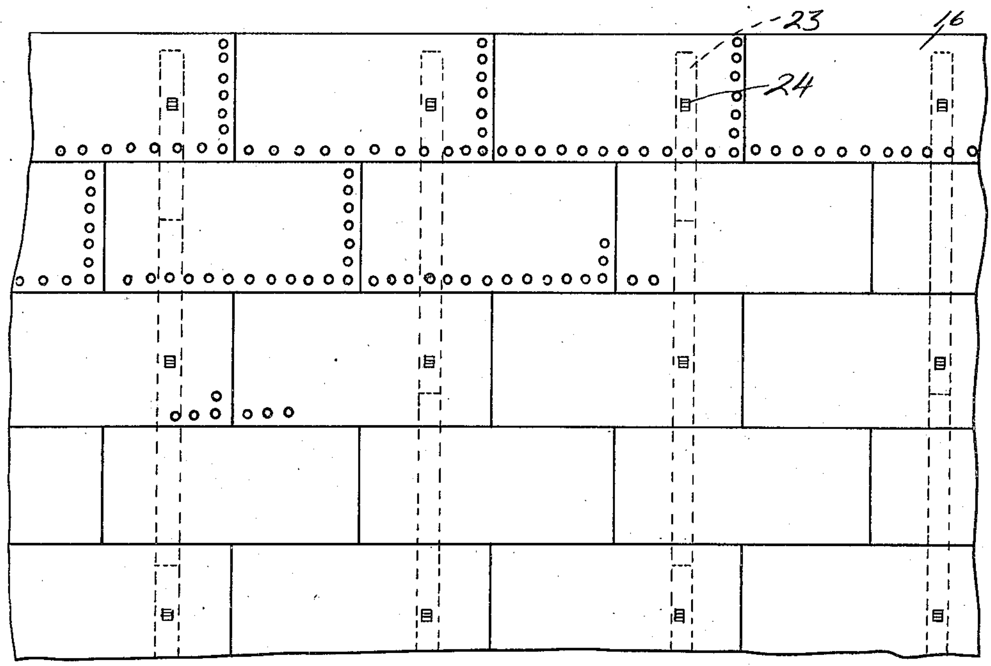


Fig. 7.

Fig. 8.

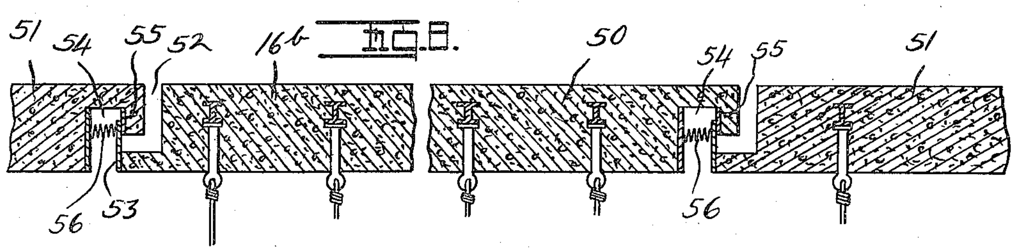
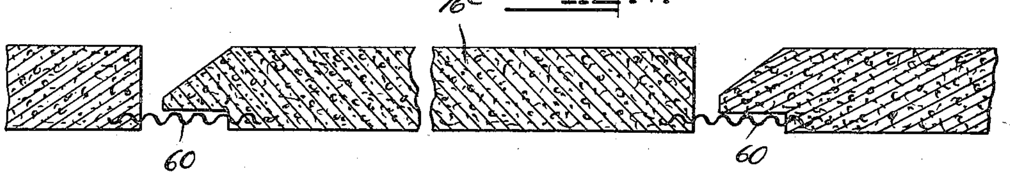


Fig. 9.



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Original Filed April 10, 1933 3 Sheets-Sheet 3

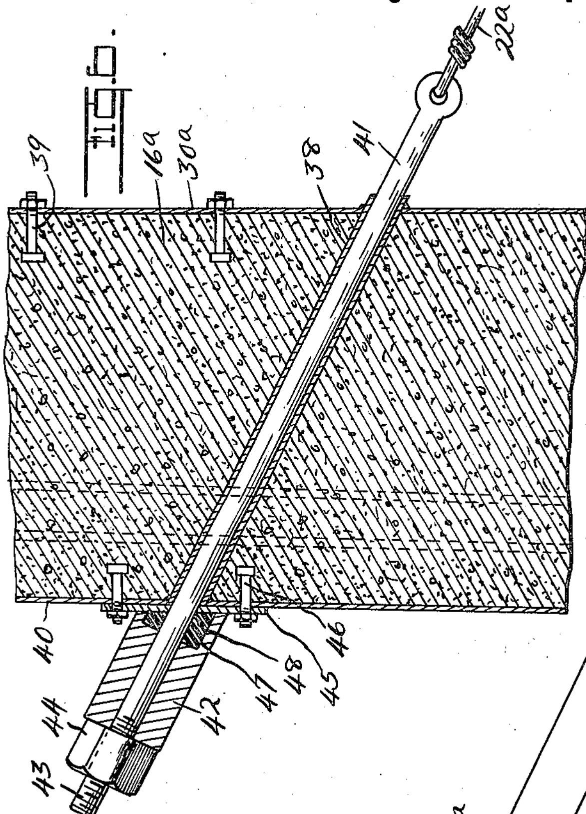

Fig. 6

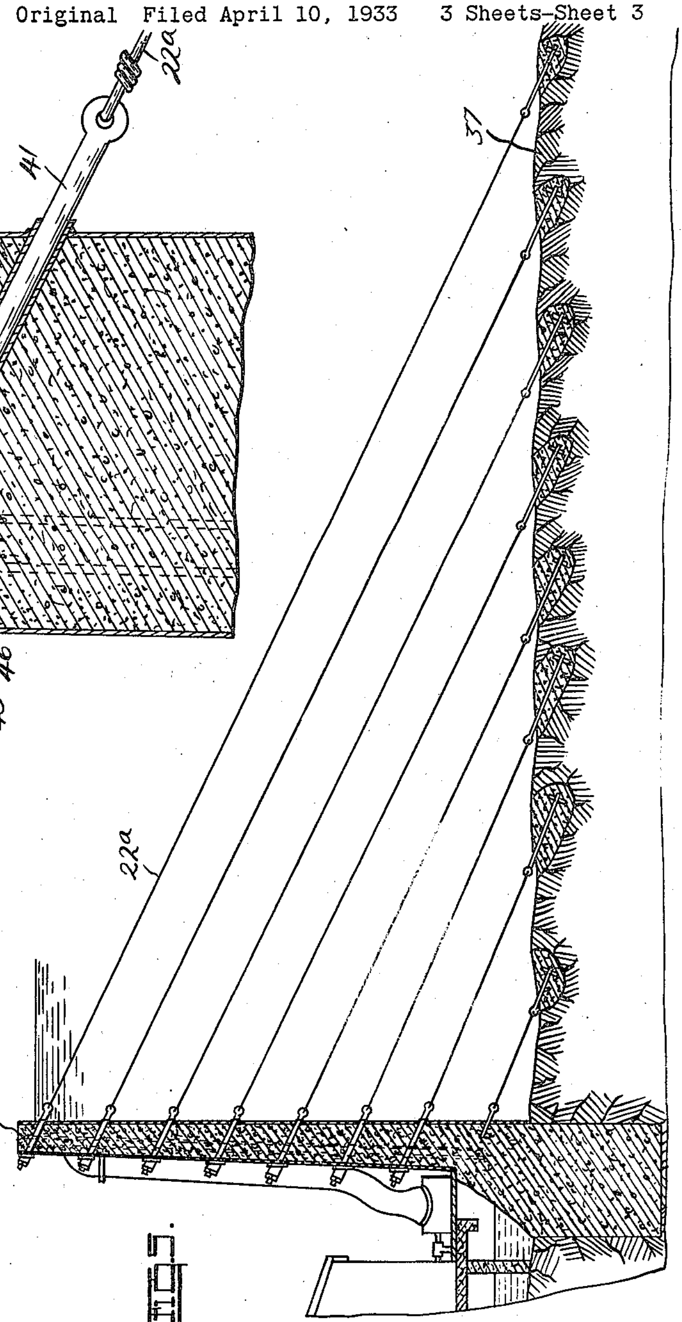

Fig. 5

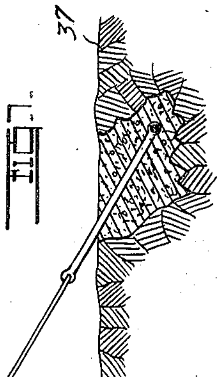

Fig. 7

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DAM

Julius D. Madaras, Detroit, Mich.

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12 Claims. (Cl. 61—33)

This invention relates to dam constructions and has as one of its objects to materially reduce the cost of installation of dams as well as to improve the construction thereof.

The cost of dams constructed in accordance with conventional practice is approximately proportional to the square of the height of the dam, and inasmuch as the latter dimension is usually calculated from the bed rock to the water level, the cost of installation may be expressed mathematically as approximately proportional to $K(h_1+h_2)^2+a$ where "K" is a constant, "h_1" is the distance from the river bottom to bed rock "h_2" is the effective height or, in other words, the distance from the river bottom to the water level, and "a" is a factor depending upon conditions existing at the site of installation.

The present invention contemplates materially reducing the cost of installation of dams by providing a construction composed of considerably less material than dams of the general character set forth in the previous paragraph and possessing at least the same strength as the latter dams. The foregoing is accomplished herein by a novel construction of dam wherein the amount of material necessary in its formation, instead of being proportional to the square of the actual height of the dam as is the case in present day practice, is more nearly proportional to the area of the dam or, in other words, is more nearly proportional to the linear dimensions of the dam.

Another advantageous feature of this invention which contributes materially to reducing the cost of the dam resides in the provision of a construction which does not necessarily extend beyond the river bottom to bed rock so that the actual height of the dam may be calculated from the river bottom instead of bed rock or, in other words, is the same as the effective height referred to above in discussing conventional types of dams. As a consequence, the cost of a dam constructed in accordance with the foregoing may be expressed mathematically as proportional to Kh_2+a+b where b is a factor peculiar to the cable structure of this invention instead of the expresison $K(h_1+h_2)^2+a$ employed in calculating costs of the present constructions of dams. The saving in material and consequent saving in the cost of installation effected by the invention will be apparent upon comparing the two aforesaid mathematical expressions.

The foregoing as well as numerous other structural features will be made more apparent as this description proceeds, especially when considered in connection with the accompanying drawings, wherein:

Figure 1 is a sectional view through an installation of a dam constructed in accordance with this invention;

Figure 2 is an enlarged fragmentary perspective view featuring one type of cable connection;

Figure 3 is an enlarged sectional view through the upright wall of a dam featuring the reinforcing means for the concrete and the manner in which the cable brackets are secured in place;

Figure 4 is a side elevation of the upstream face of the dam;

Figure 5 is a view similar to Figure 1 showing a modified form of construction;

Figure 6 is an enlarged sectional view through a portion of the upright wall of the construction shown in Figure 5 illustrating the adjustable cable connection with said wall;

Figure 7 is a detail sectional view showing the manner in which the cables are anchored in the foundation rock;

Figure 8 is a horizontal sectional view through another modified form of the invention;

Figure 9 is a similar view illustrating still another modification of the invention.

Referring now to the several specific embodiments of the invention featured herein and with special reference to the installation shown in Figure 1, it will be noted that the latter comprises a dam 15 formed principally from concrete and steel beams. The dam 15 is provided with an upright wall section 16 for obstructing the stream and is formed at the lower end thereof with a horizontally disposed apron 17 extending laterally from the upstream side of the wall 16. The apron 17 has a width substantially equal to the length of the wall 16 of the dam, and while the length of the apron may vary in dependence upon the installation, nevertheless, it is preferably about twice as long as the height of the wall 16.

In the embodiment of the invention shown in Figure 1, the apron 17 is seated upon the river bottom designated in the above figure by the reference character 18 and is anchored in the foundation rock below the river bottom by suitable piling designated by the reference character 19. In the present instance, the piling 19 is located directly below the upright wall 16 of the dam and at the upstream end of the apron 17. Under ordinary condtions, the above piling should be sufficient to prevent skidding of the dam, but in the event it is desired to more effectively anchor the dam, the action of the piling may be supplemented by forming ribs 20 at spaced intervals on the underside of the apron 17 and by anchoring these ribs to bed rock through the medium of suitable cables 21. By reason of the above construction, it is not essential to extend the upright wall 16 of the dam into bed rock as is the usual practice, and, as a consequence, a saving in material is not only realized, but a saving in labor is also effected. In other words, the actual height of the wall 16 of the dam shown in Figure 1 is equal to the distance from the river bottom to the water level as distinguished from the conventional dam construction wherein the actual height of the wall is represented by the distance from the foundation rock to the water level.

In accordance with this invention, the force of the water upon the upstream side of the wall 16 is resolved into different components, and this is accomplished herein by bracing the wall 16 from the apron 17 through the medium of a plurality of cables 22 varying in number in dependence upon the length and depth of the wall 16 exposed to the water pressure. In general, the upper ends of the cables 22 are anchored in the concrete wall 16 at spaced intervals, and the lower ends of the cables are suitably anchored in the apron 17. In detail, the concrete wall 16 is reinforced by steel beams 23 embedded in the wall and suitable anchors 24 are welded or otherwise suitably secured to the upstream sides of the beams 23 as shown particularly in Figure 2 of the drawings. As will also be apparent from the above figure, the anchors 24 project through the upstream side of the wall 16 and terminate in suitable eyes 25 to which the upper ends of the cables are rigidly secured. In order to provide for anchoring the lower ends of the cables in the apron 17, I provide additional anchors 26 secured within the concrete apron 17 and terminating at the upper ends thereof in suitable eyes 27 to which the lower ends of the cables are suitably secured. The anchors 26 as well as the anchors 24 are inclined in directions coincident to the angle of inclination of the cables connected thereto so that the bending stresses on the anchors will be reduced to the minimum.

With the above construction, it will be apparent that the water pressure on the dam is equalized by the horizontal component of the force applied to the cables, and the upright wall 16 of the dam carries only the vertical component of the resultant force on the cables plus the weight of the dam. In other words, the overturning moment exerted on the wall 16 by the water pressure is resisted by the cables 22 instead of by the weight of the wall itself as is the conventional practice. Moreover, with the above type of dam construction, the weight of the water supported by the apron serves to balance the upward force components on the cables or, in other words, the weight of the water exerting the overturning force against the wall 16 of the dam is utilized for resisting this force by counteracting any tendency for the apron to move upwardly under the action of the same. It necessarily follows, therefore, that the material contained in the upright wall 16 of the dam need not be proportional to the square of the height of the wall as is the case in conventional installations, but may be considerably less since the wall is not depended upon to withstand the overturning moment. Perhaps the outstanding fundamental difference between the present dam construction and conventional practice may be more readily understood upon comparing the mathematical expressions governing the construction of the walls of both types of dams. The material necessary and the cost of installation of dams constructed in accordance with conventional practice is approximately proportional to $K(h_1+h_2)^2+a$ where "K" represents a constant, "h_1" is the distance from the river bottom to bed rock, "h_2" is the effective height or in other words the distance from the river bottom to the water level, and "a" represents a factor determined in accordance with the conditions at the point of installation. On the other hand, the material as well as the cost of installing the wall 16 is substantially equal to Kh_2+a+b wherein "K" represents the constant, "a" and "b" represent factors depending upon conditions existing at the side of installation, and where "h" represents both the effective and actual height of the dam since the latter dimensions are the same in the installation shown in Figure 1. By comparing the two aforesaid mathematical expressions, it will be apparent that the thickness of the wall in the present instance is considerably less than the corresponding dimension of the wall in conventional installations, and, as a consequence, considerably less material is required in forming the same. While the saving in building costs effected by materially reducing the amount of material to be handled is somewhat offset by the cost of the cable equipment necessary in the formation of the dam shown in Figure 1, nevertheless, when everything is considered, the total cost of building the dam featured in this figure would be considerably less than a dam of equivalent strength constructed in accordance with the usual practice.

When installing a dam constructed in accordance with Figure 1 wherein cables are employed to brace the upright wall 16, it is desirable to make some allowance for the expansion of the cables due to stretching or temperature variations. In the present instance, expansion of the cables is compensated for by inclining the entire wall 16 from the vertical toward the upstream side of the dam a distance predetermined in dependence upon the normal stretch or expansion of the particular cables employed. With this construction, the wall will give more readily under the action of the water to take up any slack in the cables without fracture.

In order to prevent any possibility of the water on the high pressure side of the wall to escape through a crack or other aperture in the wall to the low pressure side thereof, the upstream side of the wall may be covered with sheet metal designated generally herein by the reference character 30. The latter may be fabricated in the manner shown in Figure 4 and is secured to the wall 16 by welding the sheets to the portions of the anchors 24 extending therethrough as shown particularly in Figure 2.

As is usually the case, the dam 15 is provided with a number of spillways in the form of openings 31 through the upper regions of the wall 16 so as to provide for the escape of water from the high pressure side of the dam to the low pressure side thereof. In the present instance, the water escaping through the openings 31 is collected by suitable conduits 32 fixedly secured to the front side of the dam and communicating at the lower ends with suitable power means (not shown herein).

In construction of the type shown in Figure 1 wherein the apron 17 of the dam is seated upon the subsoil or river bed above the foundation rock, it is highly desirable to prevent the water from building up a pressure against the underside of the apron since such a condition would reduce the effect of the water above the apron to anchor the dam. In the present instance, the piling 19 at both ends of the dam is in the form of a wall anchored in the bed rock so as to minimize the escape of water into the space between the bed rock and apron 17. However, in order to insure maintaining the aforesaid space relatively free from water under pressure, I provide a drain 33 establishing communication between the said space and low pressure side of the wall 16. If desired, a suitable pressure relief valve 34 may be fixed within the front end of the drain so as to prevent any tendency for the water on the low pressure side of the dam to flow through the drain into the space between the bed rock and apron.

In certain types of installations, it is frequently desirable to provide relief gates in the lower regions of the wall 16 of the dam, and this may be accomplished herein by extending a conduit 35 through the lower portion of the wall 16 having the rear end welded to the sheet metal facing 30 and having a manually controlled valve 36 positioned for convenient manipulation at the front side of the wall 16 to control the flow of water through the conduit. The conduit 35, as well as all of the other metallic parts of the dam which are exposed to the water, is preferably galvanized or formed of stainless steel so as not to corrode and become ineffective for accomplishing their respective functions.

Referring now to the modification of the invention shown in Figure 5, it will be noted that the same differs essentially from the construction shown in Figure 1 in that the apron 17 is omitted and the wall 16^a is anchored in the rock foundation. This construction is particularly applicable to localities where the river bottom is formed of rock, and when installed in such localities, is less expensive than the dam shown in Figure 1. The formula for forming the wall 16^a is approximately the same as the formula hereinbefore set forth in connection with the first described form of the invention with the exception that the actual height of the wall is calculated from the bed rock. The wall 16^a is also supported by a plurality of cables 22^a differing from the construction shown in Figure 1 in that the lower ends of the cables are embedded directly in the bed rock as at 37 and the upper ends of the cables are adjustably secured to the wall 16^a in the manner shown in Figure 6. In detail, a plurality of sleeves 38 are extended through the concrete wall 16^a at an angle coincident to the angle of inclination of the associated cables, and the end of the sleeve at the upstream side of the wall is preferably welded to the sheet metal facing 30^a on the wall 16^a. The facing 30^a may be identical to the facing 30 shown in Figure 1 with the exception that it is preferably secured to the concrete by suitable bolts 39 in the manner clearly shown in Figure 6. In the present construction, the rear face of the wall $16a$ is covered with sheet metal as indicated by the reference character 40, and the rear ends of the sleeves are welded in suitable openings formed in the facing 40. Slidably mounted within each of the sleeves 38 is a bolt 41 having the rear end projecting beyond the upstream side of the wall 16^a and terminating in an eye for attachment to the cables 22^a. The forward ends of the bolts 41, on the other hand, project beyond the facing 40 a sufficient distance to receive suitable washers 42 and are threaded as at 43 at the extremities thereof to receive clamping nuts 44. The clamping nuts 44 engage the front ends of the washers 42, while the rear ends of the latter are provided with bearing plates 45 fixed to the facing 40 through the medium of bolts 46 embedded in the concrete. While the eye-bolts snugly engage the sleeves 38, nevertheless, there is a possibility of the water escaping through the sleeves to the low pressure side of the wall 16^a, and in order to prevent such a condition, the ends of the washers engaging the bearing plates 45 are recessed as at 47 for receiving suitable packing glands 48. With the above construction, it will be apparent that expansion and contraction in the cables due to stress and temperature changes may be compensated for by adjusting the nuts 44 on the eye-bolts 43. It is to be noted that this form of cable connection may be employed with equal facility in the construction shown in Figure 1 if desired, and such an arrangement is contemplated by this invention.

In the construction shown in Figure 8, expansion and contraction of the cables due to stress and temperature changes is compensated for by permitting the major section of the wall 16^b to move in accordance with changes in cable length. In the specific embodiment of the invention shown in Figure 8, the wall 16^b is divided into three sections comprising a central section 50 and end sections 51. The central section 50 extends for the major length of the wall 16^b and has the low pressure side thereof rabbeted at opposite ends as shown by the reference character 52 for receiving the adjacent ends of the end sections 51. The extreme ends of the section 50 have secured thereto suitable plates 53 extending rearwardly into suitable recesses 54 formed in the adjacent ends of the end sections 51. The plates 53 extend for the full height of the central section 50 and slidably engage corresponding plates 55 fixed to the end sections 51 in the recesses 54 thereof. Inasmuch as the recesses 54 in the end sections are open at the high pressure side of the wall 16^b, it will be apparent that the water pressure acting upon the plate 53 will tend to maintain the same in tight frictional engagement with the cooperating plate 55 so as to prevent escape of the water between the plates. In order to insure maintaining a sufficiently tight joint between the plates to prevent escape of the water therebetween, I provide springs 56 suitably anchored within the recesses 54 in the end sections between the plates 55 and opposite walls of the recesses. With this construction, it is not necessary to adjustably secure the upper ends of the cables to the wall 16^b since a substantial part thereof is permitted to float in effect and thereby take up any variations in cable lengths.

The construction shown in Figure 9 is similar to the construction shown in Figure 8 in so far as forming the walls 16^c in sections is concerned, but differs therefrom in that the opposite ends of the central section are adjustably connected to the end sections through the medium of corrugated sheets 60. The corrugated sheets 60 also extend for substantially the full height of the wall 16^c and are flexible so as to permit the desired movement of the central section in order to compensate for variations in cable length. It will also be observed from Figure 9 that the sheets 60 positively prevent escape of the water from the high pressure side of the dam to the low pressure side thereof.

What I claim as my invention is:

1. In a dam installation, an upright wall forming an obstruction for a stream and having a slab extending from the upstream side thereof at the lower end of the same whereby the weight of the water on the slab resists the overturning force exerted on the wall by the water, and means for resolving the overturning moment into different force components including cables having the upper ends anchored to the wall and having the lower ends anchored at longitudinally spaced points in said slab.

2. In a dam installation, an upright wall forming an obstruction for a stream and being insufficient in itself to withstand the overturning moment exerted thereon by the water, a slab formed integral with the lower end of the wall and extending from the upstream side of the wall whereby the weight of the water on the slab serves to assist the wall in resisting the overturning force, and means for resolving the latter force into different components including cables having the opposite ends respectively anchored to the wall and slab.

3. A dam comprising a concrete upright wall of relatively thin cross section insufficient to withstand the overturning moment exerted thereon by the water, a lateral concrete apron extending upstream from said upright wall and a series of cables between vertically spaced portions of said upright wall and horizontally spaced portions of said lateral apron.

4. A dam comprising a concrete upright wall of relatively thin cross section insufficient to itself withstand the overturning moment exerted thereon by the water, a lateral concrete slab resting on the river bed and extending upstream from said wall for a distance greater than the height of said wall and a series of cables anchored to said wall at spaced points over the entire area thereof, the cables anchored to the lower portions of said wall being anchored in said slab, the cables anchored at higher points in said wall being also anchored in said slab at greater distance from said wall, projections extending downwardly from said slab to resist horizontal movement and means for anchoring said projections to bed rock.

5. A dam comprising a concrete upright wall and an integral concrete slab resting on the river bed, said slab being extended upstream for a greater distance than the height of said wall and a series of cables extending between said wall and said slab, said cables being anchored to said wall and said slab at a series of points spaced substantially uniformly over the entire surface of said wall and of said slab.

6. A dam comprising a concrete upright wall of relatively thin cross section insufficient to itself withstand the overturning moment exerted thereon by the water, a lateral concrete slab resting on the river bed and extending upstream from said wall, and a series of cables anchored to said wall at spaced points over the entire area thereof, the cables anchored to the lower portions of said wall being anchored in said slab and the cables anchored at higher points in said wall being also anchored in said slab at a greater distance from said wall.

7. A dam comprising a concrete upright wall of relatively thin cross section insufficient to itself withstand the overturning moment exerted thereon by the water, a lateral concrete slab resting on the river bed and extending upstream from said wall, a series of cables anchored in said wall and said slab respectively, and projections extending downwardly from said slab to resist horizontal movement.

8. A dam comprising a concrete upright wall of relatively thin cross section insufficient to itself withstand the overturning moment exerted thereon by the water, a lateral concrete slab resting on the river bed and extending upstream from said wall, a series of cables anchored in said wall and said slab respectively, projections extending downwardly from said slab to resist horizontal movement, and means for anchoring said projections to bed rock.

9. A dam comprising a concrete upright wall of relatively thin cross section insufficient to withstand the overturning moment exerted thereon by the water, a lateral concrete slab extending upstream from said wall, a series of cables extending in a vertical plane between said wall and said slab, and a beam structure in said wall in the vertical plane of said cables to hold the vertical force component of tension in said cables in the same plane and the weight of wall and structure on it, and also hold the horizontal pressure of water in the section.

10. A dam comprising a concrete upright wall of relatively thin cross section insufficient to withstand the overturning moment exerted thereon by the water, a lateral concrete slab extending upstream from said wall, a series of cables anchored respectively to said wall and said slab, and means on the downstream side of said upright wall to control the tension in each cable.

11. A dam comprising a concrete upright wall of relatively thin cross section insufficient to withstand the overturning moment exerted thereon by the water, a lateral concrete slab extending upstream from said wall, a series of cables anchored respectively to said wall and said slab, and means to provide a differential static pressure between the upper and lower sides of said slab.

12. A dam comprising a concrete upright wall of relatively thin cross section insufficient to withstand the overturning moment exerted thereon by the water, a lateral concrete slab extending upstream from said wall, a series of cables anchored respectively to said wall and said slab, a drain establishing communication between the underside of said slab and the downstream side of said upright wall, and a pressure relief valve for preventing flow from the downstream side of said wall to the underside of said slab.

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