Nov. 23, 1926. **C. O. TAPPAN** 1,608,258

METHOD OF BUILDING COREWALLS FOR DAMS AND SIMILAR STRUCTURES

Filed Jan. 10, 1922 4 Sheets-Sheet 1

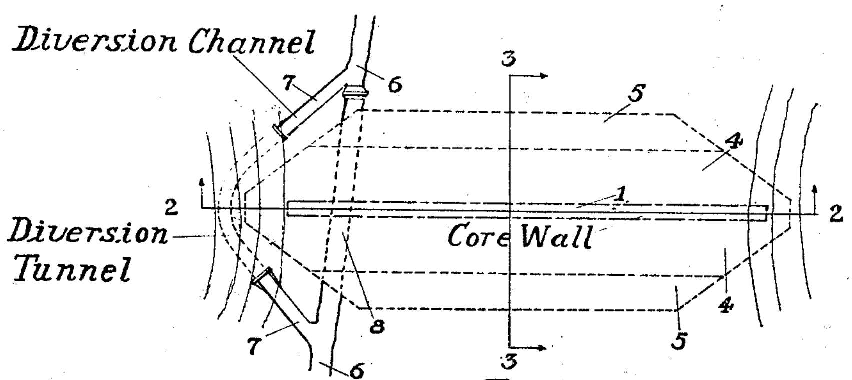

Fig. 1.

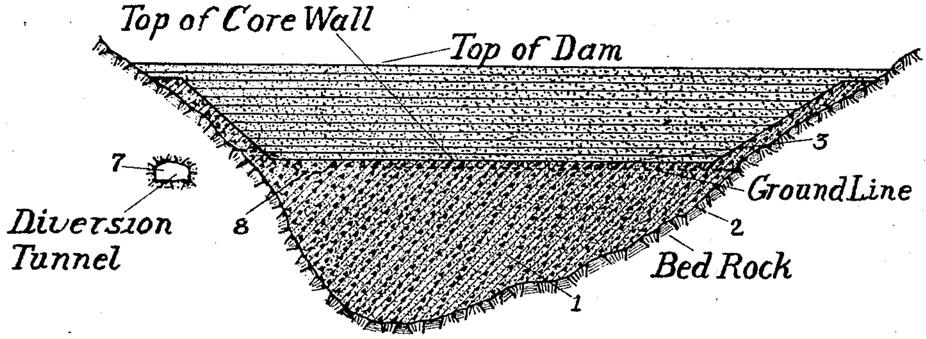

Fig. 2

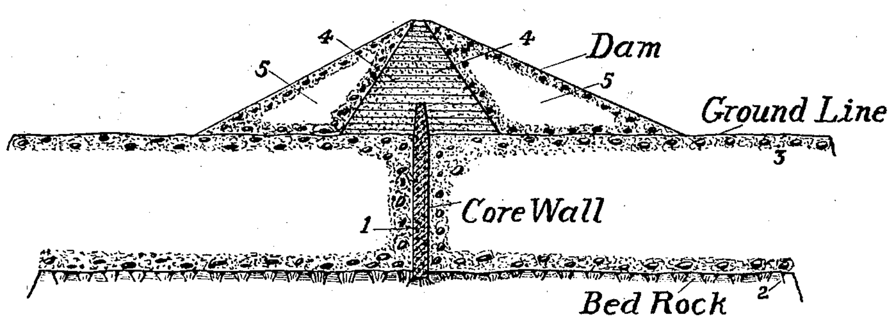

Fig. 3.

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Prindle, Wright and Small, ATTORNEYS.

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METHOD OF BUILDING COREWALLS FOR DAMS AND SIMILAR STRUCTURES

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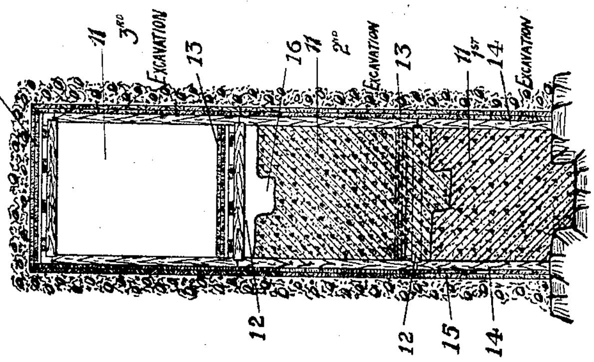

Fig. 5.

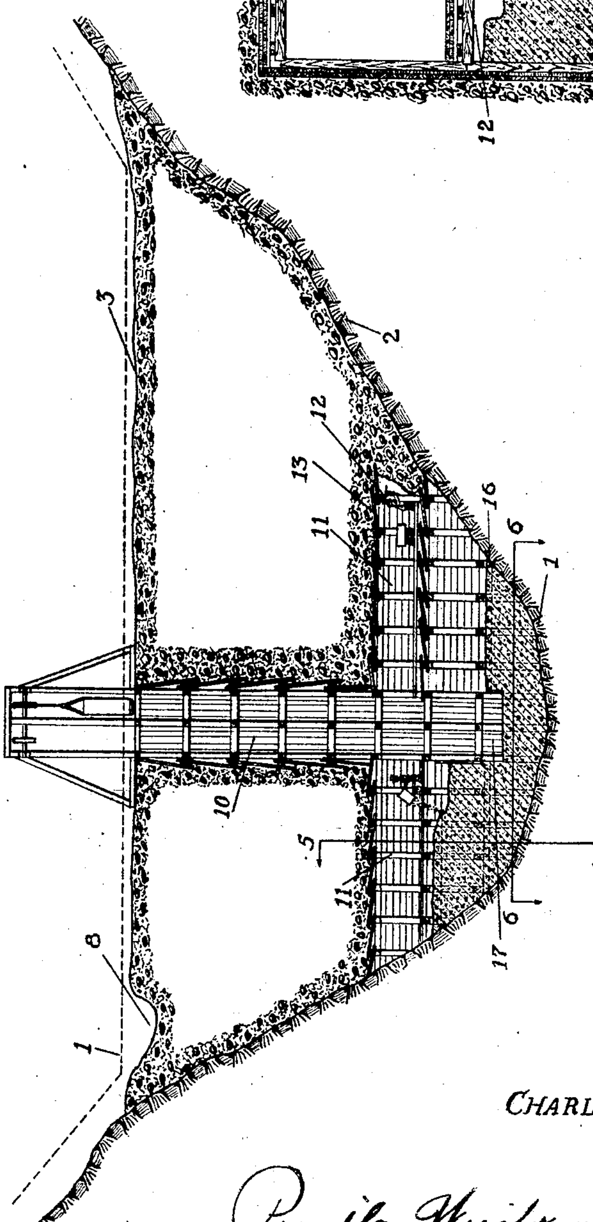

Fig. 4.

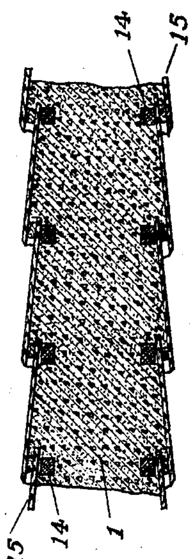

Fig. 6.

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METHOD OF BUILDING COREWALLS FOR DAMS AND SIMILAR STRUCTURES

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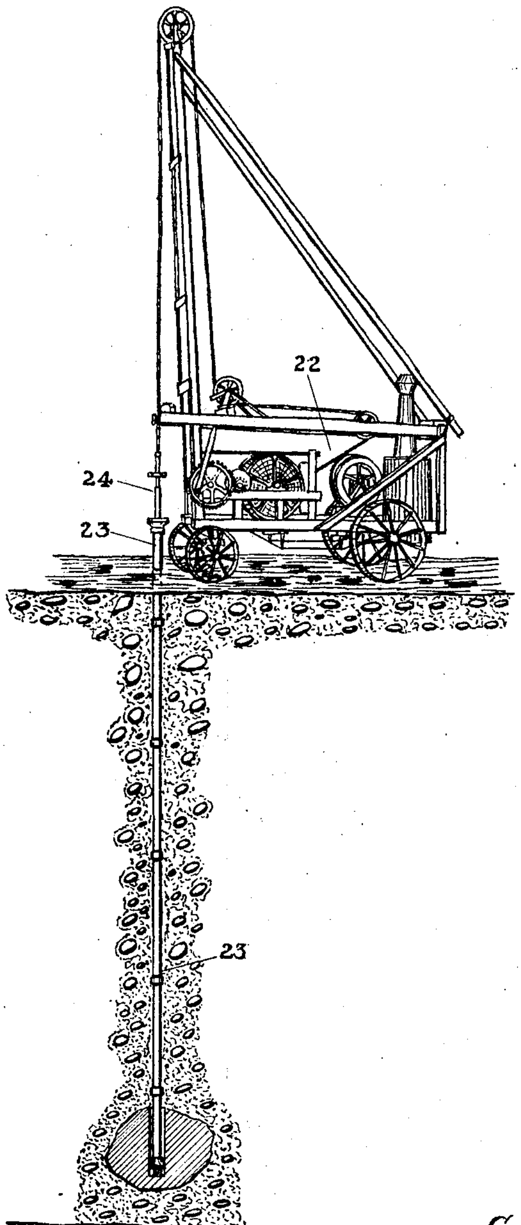

Fig.7.

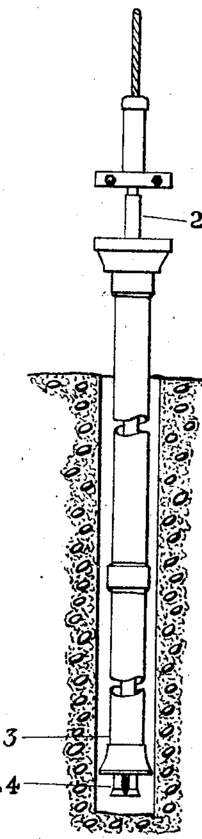

Fig.8.

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METHOD OF BUILDING COREWALLS FOR DAMS AND SIMILAR STRUCTURES

Filed Jan. 10, 1922 4 Sheets-Sheet 4

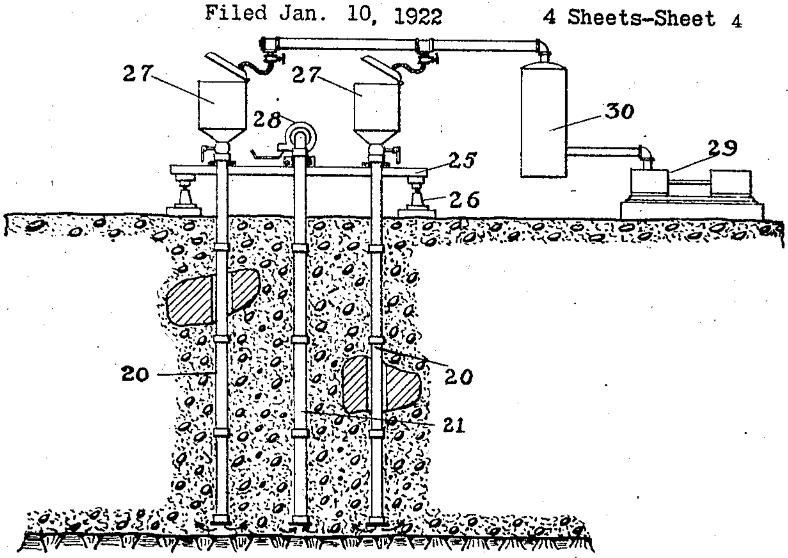

Fig. 9.

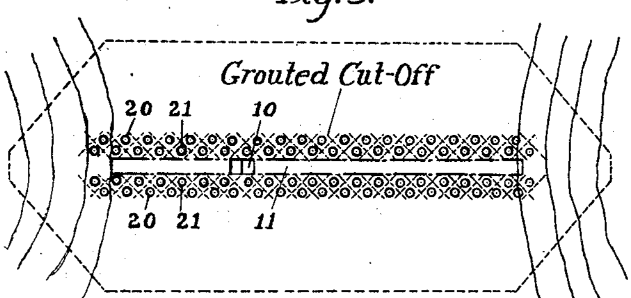

Fig. 10.

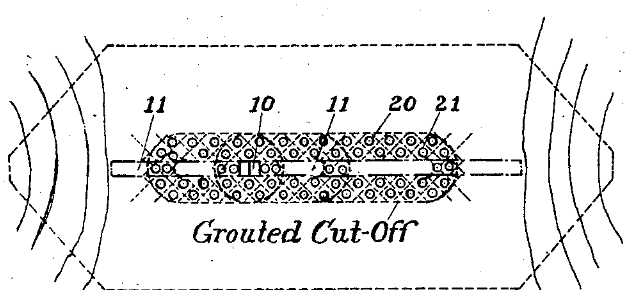

Fig. 11.

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Patented Nov. 23, 1926. **1,608,258**

UNITED STATES PATENT OFFICE.

CHARLES O. TAPPAN, OF NEW YORK, N. Y.

METHOD OF BUILDING COREWALLS FOR DAMS AND SIMILAR STRUCTURES.

Application filed January 10, 1922. Serial No. 528,213.

My invention relates to an improved method of building corewalls for dams, foundations, bulkhead walls, and other similar structures and has for its object to provide an improved method of building corewalls or cut-off walls for dams, foundations, bulkhead walls, or other structures in the construction of which it is necessary to excavate through the material overlying the bedrock in order that the structure may be built on the bedrock.

Other and further objects of my invention will be apparent from the following description and from the accompanying drawings of illustrative embodiments thereof, in which—

Figure 1 is a general plan of a valley showing outline of dam in dash lines and outline of corewall in dot and dash lines;

Figure 2 a vertical section taken on the line 2—2 of Figure 1 looking in the direction of the arrows;

Figure 3 a vertical section taken on the line 3—3 of Figure 1 looking in the direction of the arrows and showing completed corewall and dam;

Figure 4 a cross-section of illustrative valley showing excavation and working shaft and method of completing corewall by progressive excavating, timbering, and filling;

Figure 5 a cross-section taken substantially on the line 5—5 of Figure 4 looking in the direction of the arrows and showing method of filling the excavated portions with sections of concrete bonded together to form a continuous water-tight structure and showing in dot and dash lines former position of removed cap timbers and top lagging;

Figure 6 a fragmentary horizontal section of the corewall taken substantially on the line 6—6 of Figure 4 looking in the direction of the arrows and showing the excavated portion filled with concrete.

Figure 7 a side elevation of a conventional drilling machine (such, for example, as a "Keystone well driller") showing the drill in operation sinking a hole through miscellaneous material overlaying bedrock and surrounded by a casing;

Figure 8 an enlarged detail of the bottom of the drill hole showing the drill and casing;

Figure 9 the method of applying void filling material in connection with the embodiment illustrated;

Figure 10 a plan of one embodiment of process utilizing the void filled cut-off for complete length of corewall; and

Figure 11 a plan of one embodiment of process utilizing progressive void filled cut-offs for working shaft and drifts.

Similar reference characters refer to similar parts throughout the drawings.

The improved method of construction will be described in connection with the building of corewalls for earth dams. An illustrative design of such a structure is shown in Figures 1, 2, and 3 of the drawings in which the corewall is shown as a continuous concrete corewall 1 bonded into the bedrock 2 to prevent the flow of water under the dam and extending continuously across the valley to a point above the ground line 3 and bedded into the impervious section or core 4 of the dam proper (comprising impervious section or core 4 and pervious outer sections 5), the corewall and dam proper forming in conjunction a water-tight impervious structure completely closing the valley to a predetermined level for the purpose of storing water. Figure 1 shows an illustrative plan of a valley in which the dam is to be built and indicates the location of corewall 1, the limits of the dam proper (comprising impervious core 4 and pervious outer sections 5), the original river 6, diversion tunnel 7, and original river bed 8. Figure 2 illustrates a cross section of the valley at the site of the proposed dam and indicates the location of the bedrock 2, ground line 3, top of corewall 1, location of original river bed 8, and diversion tunnel 7, through which the flow of river 6 is to be diverted during construction. Figure 3 illustrates a vertical cross section through the dam and indicates the location of bedrock 2, ground line 3, and cross section of the dam and relation of corewall 1 thereto.

The methods heretofore used for constructing such a corewall or similar structure in general are as follows:

Where bedrock is encountered at a moderate depth and is overlaid with loose material either dry or containing an amount of water that can be controlled with pumps, two lines of sheet piling commonly are driven parallel to the axis of the dam and the material enclosed by the piling excavated so as to form an open trench for the corewall. When the trench is completed to bedrock, the concrete corewall is constructed and on its completion the piling is withdrawn and the remaining space in the open trench is refilled with carefully compacted earth. The heavy timbering required to support the sheet piling obstructs the work of excavation and the placing of the concrete for the corewall, and also is expensive both as to time and material. By this old method, moreover, to provide for strains resulting from unequal settlement of the refilled ground and the surrounding material, a much thicker corewall is required than is the case with the improved method hereinafter described, where the concrete is placed so as to fill completely the excavation without disturbing the surrounding material. This results in a material saving, both in excavation and in concrete.

Where the bedrock is overlaid deeply with loose, water-bearing material or with quick sand, it has been the practice heretofore to use caissons with compressed air. The caisson consists of a heavy box-like structure, the bottom having cutting edges and containing a working chamber provided with airlocks so that air pressure can be maintained to keep out the water and the material excavated and removed. The top of the caisson is formed generally of a heavy timber frame upon which the concrete corewall gradually is built, so that, as the material is removed from the working chamber, the cutting edges of the caisson are forced into the ground by the superimposed weight. Sufficient air pressure is carried in the air chamber to prevent the inflow of the surrounding material and water, and as a result of the excavation in the working chamber and the addition of concrete on the top, the caisson is forced through the overlying material to bedrock, and the working chamber and shafts then filled with concrete. Where the bedrock is irregular much difficulty is experienced in building the cutting edges of the caisson to conform to it. In the case of a long corewall such as the structure shown in Figures 1, 2, and 3 of the drawings, a series of caissons driven side by side would be necessary and the separate sections would have to be connected with some form of water-tight joint after completion. This method of construction is extremely costly and slow.

My improved method of construction, an embodiment of which is illustrated in Figures 4, 5, and 6 of the drawings, comprises excavating a working shaft 10 to bedrock 2 approximately on the center line of the proposed corewall 1 preferably at the point where the rock is deepest below the surface of the ground. The first excavation 11 next is run along the bedrock from working shaft 10 on the line of the proposed corewall. The sinking of the working shaft and the excavating may be done in any desired manner as, for example, by the methods of sinking, excavating, and timbering ordinarily used in mining operations. A second excavation 11 then is made on the level immediately above the first excavation and timbered in usual manner, the horizontal cap timbers 12 and top lagging 13 which have formed the roof of the first excavation serving as the floor of the second excavation. After the second excavation is completed or simultaneously with its excavation, the concrete of the concrete corewall 1 is placed in the first excavation starting at bedrock and suitably bonded thereto. The vertical posts 14 and side lagging 15 of the first excavation may be left in place and the entire excavation filled with concrete. A third excavation then is made on the level immediately above the second excavation and timbered in usual manner, the horizontal cap timbers 12 and top lagging 13 which have formed the roof of the second excavation serving as the floor of the third excavation. When the first excavation has been filled to a convenient height its roof is removed, a suitable water-tight bonding channel 16 (Figure 5) is made on the top of the concrete, and when the third excavation is completed, the horizontal caps 12 and top lagging 13 which have formed the floor of this third excavation are removed and the second excavation filled completely with concrete. The working shaft is filled progressively from the bottom as the work progresses, and suitably bonded to the adjacent concrete. By this method, step by step, commencing at the bedrock, an impervious concrete cut-off wall is formed to the surface of the ground, each portion of the concrete placed in the excavations being bonded to adjacent sections thereof so as to form a continuous water-tight cut-off.

The method above described is applicable to conditions where bedrock is encountered at a moderate depth and where the overlaying material does not contain more water than can be handled conveniently by pumps drawing from a sump 17 (Figure 4) at the bottom of the working shaft.

To permit the method of construction above described to be applied to conditions where the bedrock is overlaid deeply with pervious water bearing material or quicksand, I use in combination therewith, compressed air or void filled cut-offs or both. These cut-offs are built up from the bedrock to the surface of the ground surrounding the site of the excavation for the corewall and either completely surrounding the entire length of the proposed corewall, as shown in Figure 10, or constructed so as progressively to surround first the working shaft and thereafter the drifts as shown in dash lines (Figure 11).

Where cut-offs surrounding the excavation are required, my improved method of forming such cut-offs is as follows:

A series of cased holes 20 and 21 (Figures 9, 10, and 11) suitably located with reference to each other and the limits of the excavation first is sunk to bedrock by means of any suitable drilling apparatus, such for instance as a "Keystone well drill" 22 similar to that illustrated in Figures 7 and 8 of the drawings and adapted to penetrate rock and boulders or other obstructions clear down to the bedrock. In this manner a casing 23 consisting of wrought iron pipe or other suitable material may be forced down, preferably simultaneously with the drilling, to surround the hole excavated by the action of the drill 24 as shown. When a series of such cased holes have been carried to bedrock, as shown in Figure 9, a suitable number are fastened to a platform 25 provided with suitable lifting devices 26. Containers 27 for applying the void filling material under pressure are attached to the cased holes 20 through which it is desired to force the void filling material, and the suction of a suitable pump 28 is attached to cased holes 21 through which it is desired to withdraw water, so that by means of forcing in said material through cased holes 20 and by withdrawing water through cased holes 21 suitably located with reference thereto, preferably until said material begins to appear in the discharge from suction hole 21, a circulation is set up and any voids in the water bearing material or quicksand are filled.

Before commencing the void filling operation the casings are withdrawn a certain predetermined distance above the bedrock. The void filling mixture then is placed in containers 27, the covers closed and compressed air applied by compressor 29 through compressed air receiver 30, and by means of pump 28 suction is applied to cased holes 21. When the void filling mixture begins to be drawn through cased holes 21, work is suspended, the casings raised to a higher level, and the process repeated. In this manner, step by step, from the bedrock, a continuous series of impervious or semi-impervious zones are formed surrounding the proposed excavation for the purpose of reducing or preventing the flow of water into the excavation and of facilitating the work of excavation by the consolidation of material adjacent to its boundaries.

By the above described method a cut-off is constructed either entirely surrounding the site of the proposed excavation before the work is commenced as illustrated in Figure 10, or is constructed first around the working shaft 10 and next extended progressively along the line of the proposed excavation so as to surround portions of the working drifts 11 as illustrated in Figure 11 by short dash lines.

The void filling material applied by the process described above to fill the voids in the material and thereby form an impervious or semi-impervious cut-off may be composed of an inert, void filling substance, or of a bonding substance and a void filling substance, combined in proportions to suit the conditions encountered so as to form a slow setting, free flowing, void filling mixture slightly heavier than water. The substances used for the bonding element may be cement, natural cement, slow setting cement, hydrated (slacked) lime, dry powdered clay, calcined gypsum (plaster of Paris), or native gypsum. The void filling elements may be sawdust, wood pulp, bran linseed husks, or husks from other seeds or cereals, manure, fine sand, or loam selected and combined with the bonding elements or used separately, as may be required by the character of the voids of the particular material to be treated and in such a manner as to form a void filling mixture slow setting, easy flowing, and slightly heavier than water. The nature of the void filling substances selected makes it possible to control the specific gravity of the void filling mixture.

Numerous attempts have been made to apply grout composed of cement paste to pervious gravel and similar water bearing materials, both for the purpose of reducing the flow of water and to facilitate excavation. All such attempts in the past have been unsuccessful due to the fact that the grouting mixture was not sufficiently slow setting and easy flowing and was not properly distributed through the voids in the material, with the result that large mushroom shaped zones were formed and no continuous homogeneous cut-off was obtained capable of forming an efficient cut-off for reducing or preventing the flow of surrounding water.

By the improved method herein described it is evident that by the use of cased holes starting from the bedrock and raised step by step as the void filling operation proceeds, and that by the introduction of the void filling material under pressure through one series of such cased holes and the application of suction to other cased holes suitably placed with relation to the pressure holes so as to create a circulation of the material, and that by the use of a void filling mixture or a mixture suitably compounded of bonding substances and void filling substances designed to form a slow setting, smooth flowing mixture slightly heavier than water, the voids in the material treated can be so filled, and the cut-off zones so joined, that a continuous cut-off can be created surrounding an excavation and reducing or entirely cutting off the flow of water into said excavation and facilitating the removal of material from the excavation by the consolidation of the material surrounding it.

Many modifications of my invention will be apparent to those skilled in the art without departing therefrom or from the scope of the claims, my invention not being limited to the embodiments chosen for purposes of illustration but comprising a method of building corewalls or cut-off walls by drifting and filling and of using therewith under certain conditions a method of forming protecting cut-off walls wholly or partially impervious to water.

What I claim and desire to secure by Letters Patent is:

1. The process of building underground foundations, corewalls, and cut-off walls for dams, bulkhead walls, and similar structures which require to be carried to bedrock through earth, gravel, or other soft material to form a water-tight cut-off, which comprises sinking a working shaft to bedrock, excavating a first excavation along the bedrock from this shaft and timbering said first excavation, removing material above said first excavation and timbering said second excavation, filling said first excavation through the second excavation with concrete bonded to the bedrock, removing material above said second excavation and timbering said third excavation, filling said second excavation through the third excavation with concrete bonded to the concrete of said first excavation, and step by step excavating, timbering, and filling with concrete to build a continuous bonded concrete wall from the bedrock to the desired height.

2. The process of building underground foundations, corewalls and cut-off walls for dams, bulkhead walls, and similar structures which comprises making a first tunnel to be filled with the wall material to form a layer of the wall, timbering the roof of the first tunnel sufficiently to support the weight necessary during the making of a second excavation having as a floor the roof of the first excavation, making such second excavation having as a floor the roof of the first excavation, timbering the roof of the second excavation sufficiently to support the weight necessary during the making of a third excavation having as a floor the roof of the second excavation, filling in the first excavation through its roof from the second excavation, and step by step excavating, timbering and filling in with concrete to build a continuous bonded concrete wall.

In testimony that I claim the foregoing, I have hereunto set my hand this 28th day of December, 1921.

CHARLES O. TAPPAN.