March 28, 1967 C. VEDER 3,310,952

METHOD FOR THE CONSTRUCTION OF A WALL IN THE GROUND

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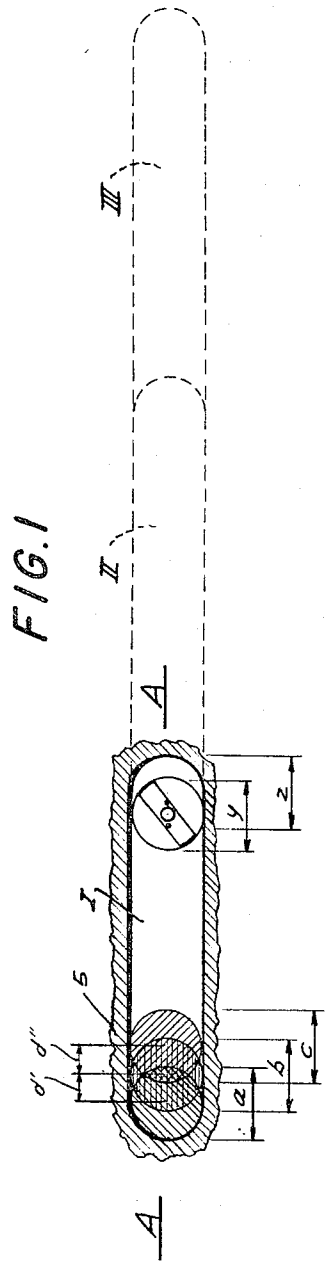


FIG. 1

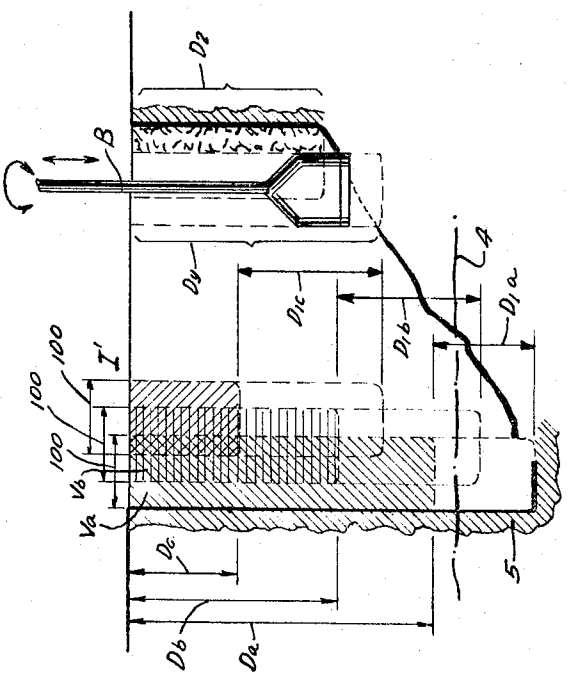


FIG. 3

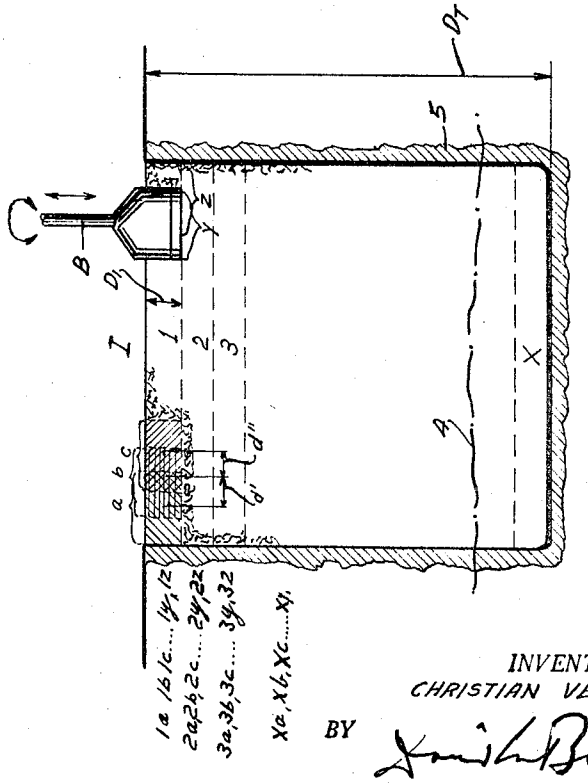


FIG. 2

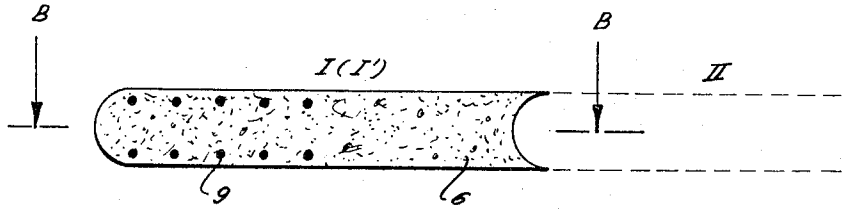
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FIG. 4



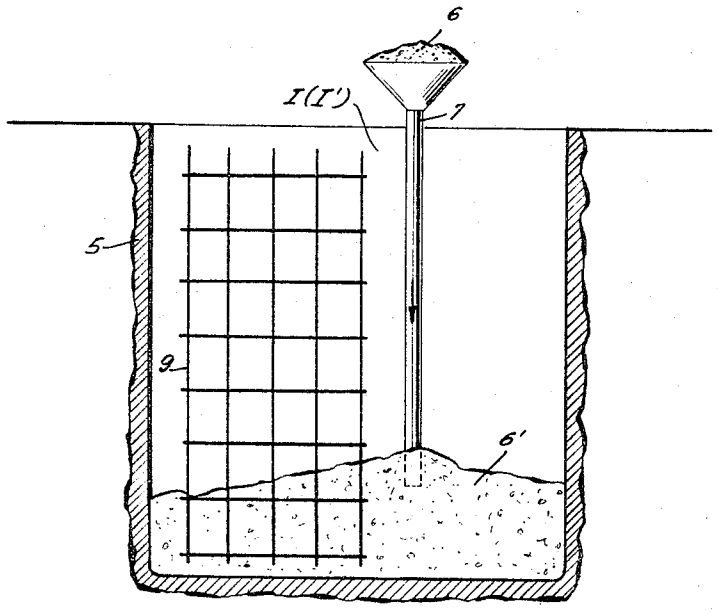


FIG. 5

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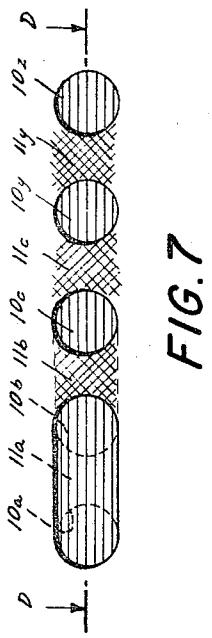


FIG. 7

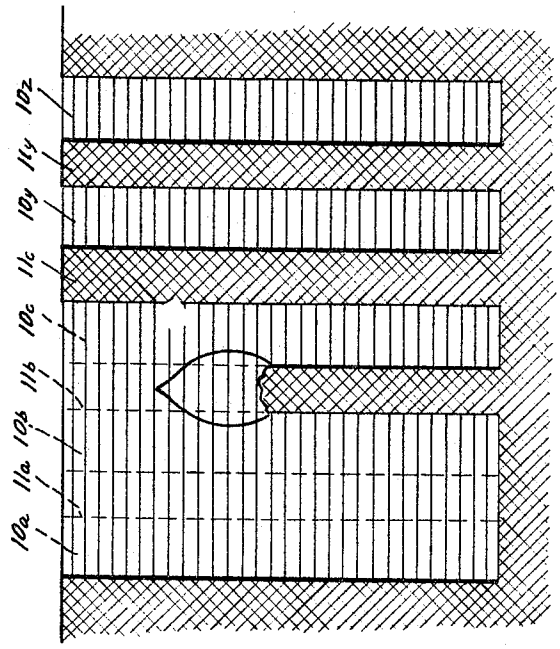


FIG. 7a

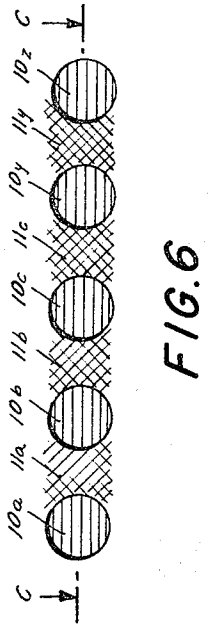


FIG. 6

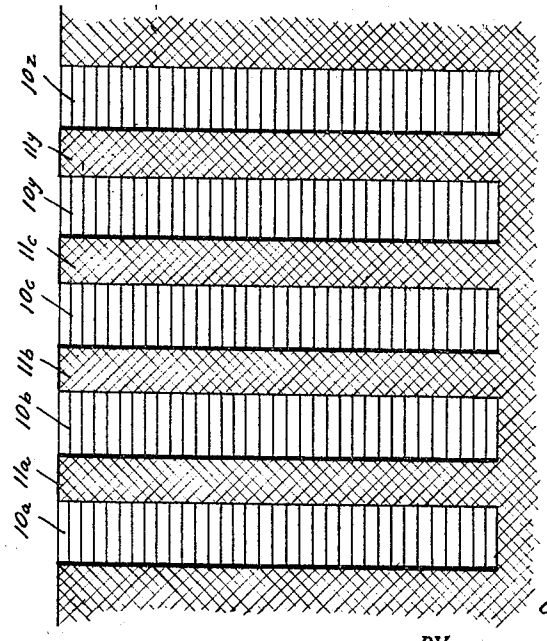


FIG. 6a

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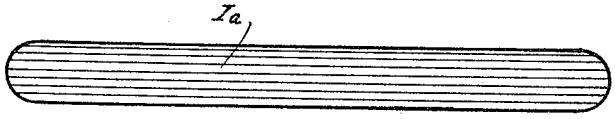


FIG. 8

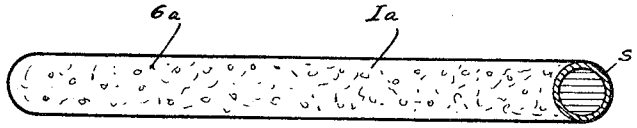


FIG. 9

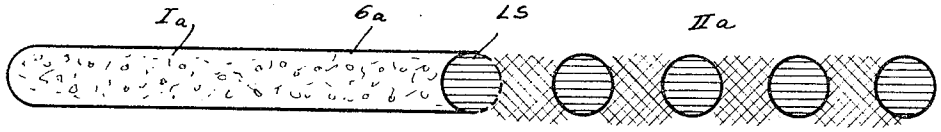


FIG. 10

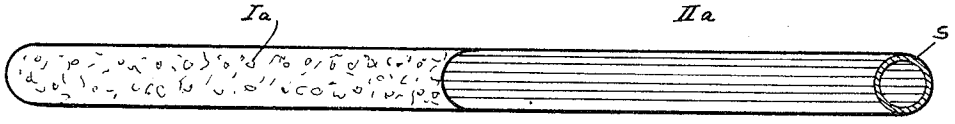


FIG. 11

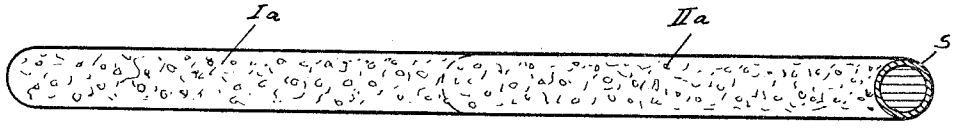


FIG. 12

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FIG. 13

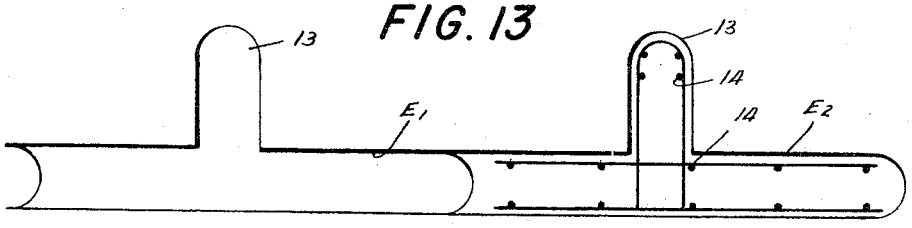


FIG. 14

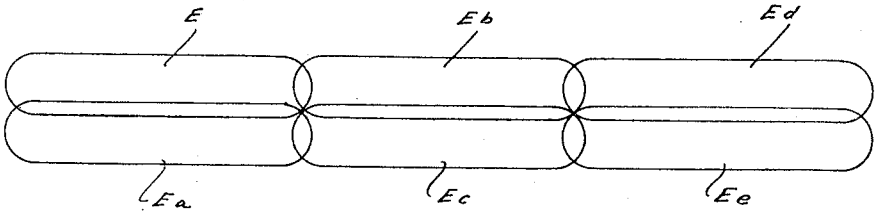
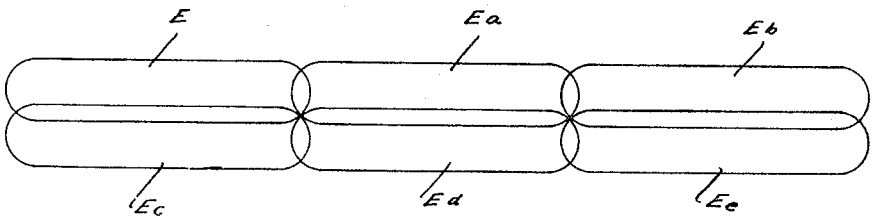


FIG. 15



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METHOD FOR THE CONSTRUCTION OF A WALL IN THE GROUND

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Filed Mar. 7, 1957, Ser. No. 644,556
8 Claims. (Cl. 61—35)

This application is a continuation-in-part application of my co-pending U.S. patent application Ser. No. 392,401 filed on Nov. 16, 1953 and now abandoned for "Shut-off Walls, Sheet Piling and the Like, and Method of Making Same."

This invention relates to the erection of walls in the ground, and more particularly to the erection of walls in loose rocks.

An object of the invention is to provide a method by means of which cut-off walls, supporting walls or walls for draining purposes may be erected at low costs and in a short time.

Another object of the invention is to provide a method for the erection of a wall having uniform thickness over a great length.

A further object of the invention is to provide a method by means of which a wall of great depth may be erected even if large rocks are encountered and by means of which the wall may be bonded in a waterproof manner in compact stratum below the loose rocks.

Other objects and structural details of the invention will be apparent from the following description when read in conjunction with the accompanying drawings, wherein:

FIG. 1 is a top plan view illustrating in a somewhat diagrammatical manner the excavation of a plurality of holes in the ground according to the invention,

FIG. 2 is a vertical sectional view taken along line A—A of FIG. 1,

FIG. 3 is a vertical sectional view similar to that shown in FIG. 2, illustrating, however, a different method,

FIG. 4 is a top plan view illustrating in a somewhat diagrammatic manner the filling of an excavation with a filling material,

FIG. 5 is a vertical sectional view taken on line B—B of FIG. 4,

FIG. 6 is a top plan view illustrating in a diagrammatical way an intermediate step in the preparation of an excavation according to a different embodiment of the invention,

FIG. 6*a* is a vertical sectional view taken on line C—C of FIG. 6,

FIG. 7 is a top plan view illustrating in a diagrammatical way a further step of the method illustrated by FIGS. 6 and 6*a*,

FIG. 7*a* is a vertical sectional view taken on line D—D of FIG. 7,

FIG. 8 is a top plan view of an excavation made according to the invention,

FIG. 9 illustrates the excavation shown in FIG. 8 being filled with a filling material,

FIG. 10 is a top plan view diagrammatically illustrating the excavation of FIGS. 8 and 9 filled with a filling material and an intermediate step in the preparation of an adjacent excavation,

FIG. 11 illustrates the first excavation of FIGS. 8 and 9 filled with a filling material and the second excavation of FIG. 10 completed and provided with a shield,

FIG. 12 is a top plan view illustrating the first and second excavations of FIGS. 8–11 filled with a filling material,

FIG. 13 is a diagrammatical top plan view illustrating a different embodiment of an excavation according to the invention, and

FIGS. 14 and 15 illustrate diagrammatically two different methods for preparing a widened excavation according to the invention.

Referring now to FIG. 1, I indicates a hole, which is excavated in loose rocks by a boring tool B. In accordance with the invention, after the excavation of the hole I, the latter is filled with a suitable material, whereupon the adjacent hole II, indicated by dash lines, and thereafter the next hole III are excavated and filled respectively in a similar manner.

According to the embodiment of the inventive method illustrated by FIG. 2 being a section along line A—A of FIG. 1, the hole I is excavated by a successive excavation of horizontal sections 1, 2, 3 . . . X, until the full depth of the hole I is reached.

With a view to facilitating a better understanding, the depth of said sections is represented in the drawing on a scale which is vertically enlarged; in reality the depth of each section corresponds to the biting into the ground of the hammer boring tool B every time the tool, after having been lifted, is dropped in the ground by its own weight.

The excavation of each horizontal section 1, 2, 3 . . . is subdivided into the excavation of a plurality of overlapping zones or sub-sections *a, b, c . . . y, z* which in the drawing are represented separately for a better understanding, but which in practice follow one after the other uninterruptedly, because the boring tool B is moved very slowly but continuously from one end to the other of hole I, while it is alternatively lifted and dropped. Anyhow, with reference to the drawing it can be said that first the zone 1*a* of the section 1 having a depth D_1, is excavated whereupon the boring tool is withdrawn and its longitudinal axis is shifted through the distance *d'* to the right, as viewed in FIGS. 1 and 2. Upon its displacement to the right through the distance *d'*, the boring tool is dropped and the zone 1*b* of the section 1 is excavated, which intersects the zone 1*a*. Thereafter, the boring tool is again withdrawn and displaced to the right through a distance *d''*, preferably, but not necessarily, equal to the distance *d'*, so as to make the boring tool ready for acting in the zone 1*c* of the section 1.

Thus, in the manner described above, at first the substantially horizontal section 1 is excavated by successive drilling operation in the zones 1*a*, 1*b*, 1*c* . . . 1*y*, 1*z* from left to right. Thereafter, the boring tool is returned into its extreme left hand position, whereupon the substantially horizontal section 2 having a depth D_2, equal to or different from the depth D_1, of the layer 1, is excavated by similar successive drilling operations from the left to the right in the zones 2*a*, 2*b*, 2*c* . . . 2*y*, 2*z*.

Thereafter, the substantially horizontal section 3 is excavated by successive drilling operations in the zones 3*a*, 3*b*, 3*c* . . . 3*y*, 3*z*.

Then, successively, one horizontal section after the other is excavated by successive zone drillings in each section. The excavation of the hole I is completed, when the last zone Xz of the last layer X is excavated.

The number of sections 1, 2, 3 . . . X depends on the total depth D_T of the hole I to be excavated.

This total depth D_T should always surpass to a fairly large extent, the irregular separating surface 4 of the rock or clay stratum, into which stratum the wall to be erected in the hole I should penetrate with a certain depth.

Furthermore, the successive excavating of the various zones of each section 1, 2, 3 . . . X may take place from the right to the left instead of from the left to the right as described above. Moreover, the successive excavating of the various zones may take place in some of the horizontal sections from the left to the right and in the other

horizontal sections from the right to the left; if desired, for example, the excavation in the section 1 takes place from the left to the right, in the successive section 2 from the right to the left, in the successive section 3 from the left to the right, and so on in alternating manner.

During the drilling operations a dense, preferably thixotropic, colloidal liquid or slime apt to gel, such as a thickish liquid known in the trade as "bentonite" is introduced into the excavation and circulated therein. A portion of said thickish liquid penetrates into the ground surrounding the excavation so as to form therein a zone 5 impervious to water and to consolidate the wall of the excavation for preventing a collapsing thereof. The remaining portion of the thickish liquid may be used for assisting in the removal of excavated material from the hole I or may be at least partially left in the excavation until the latter is filled with a suitable material for the formation of a wall. Furthermore, if a portion of the thickish liquid remains in the excavation, it may be diluted prior to the introducing of the filling material.

Owing to the before mentioned penetration of the thickish liquid into the wall of the excavation and the resulting formation of the zone 5, the hole I may be readily kept open without danger of collapsing, until the entire hole I has been excavated in the way of successive zones *a*, *b*, *c* . . . *z* in successive sections 1, 2, 3 . . . X.

After the hole I has been completely excavated it is filled with a suitable material, such as a cementitious material or a mixture of sand and gravel depending on the type of wall to be constructed. When the hole is filled with concrete, a cut-off wall capable of sustaining vertical loads can be obtained. A filling with sand and gravel may serve the construction of a vertical wall for drainage. If the filling is made of a plastic or formative material, the wall may follow deformations in the ground without causing the formation of cracks or fissures in the finished wall.

After the filling of the hole I with a suitable material for the formation of the first portion of a wall and in case of the use of cementitious material preferably before the completed setting thereof as long as the material is still somewhat soft an adjacent hole II is excavated in the same manner as described above in connection with the excavation of hole I, the first zone in each section of the hole II intersecting the end portion of the wall in the hole I. After the excavation of the hole II the latter is filled with a suitable material and thereafter an adjacent hole III is excavated and filled in the same manner as described above in connection with hole I. The number of adjacent holes depends on the length of the wall to be constructed.

Instead of withdrawing the boring tool B each time during a change from one zone, for example *a*, to the next zone, for example *b*, it would also be possible to displace the boring tool B sidewise, for example from left to right, during the drilling operation for the excavation of a horizontal section 1 or 2 or 3 . . . . In this case a milling cutter may be used and the depth of D_1, D_2 . . . of each section 1, 2 may be rather substantial.

Moreover, excavating tools of the rotatable or hammer type or any other suitable type could be used as boring tool for the excavation of the holes in accordance with the method according to the invention.

According to the embodiment illustrated by FIG. 3 the hole I' is excavated in a somewhat different way. In this case, at first a vertical bore V*a* of a diameter 100 is drilled to a depth D*a*. Thereafter, a second vertical bore V*b* of the same diameter 100, partly intersecting the first bore V*a*, is drilled to a depth D*b*. Then a third vertical bore V*c* of the same diameter 100, likewise partly intersecting the second bore V*b*, is drilled to the depth D*c*. Thus, a plurality of intersecting vertical bores is drilled successively by the boring tool B from left to right, the last two bores being the bores V*y* and V*z* having the depths D*y* and D*z* respectively. The depth D*a*, D*b* . . . D*z* depends on the nature of the ground. In the embodiment shown in FIG. 3, the depth D*b*, D*c* . . . D*z* of each successive bore V*b*, V*c* . . . V*z* is shorter than the preceding one.

After the completion of one row of intersecting bores V*a*, V*b* . . . V*z* of the depth D*a*, D*b* . . . D*z* respectively the boring tool B is returned from its extreme right position into its extreme left position for continuing the drilling of the bore V*a* through the length D_1a. Thereafter, the drilling of the bore V*b* is continued through the length D_1b, then the drilling of the bore V*c* is continued through the length D_1c, and so on in successive operations from the left to the right. If, after this second excavating operation the hole I' is not yet fully excavated, the vertical bores V*b*, V*c* . . . are still more deepened in successive manner as described before.

Preferably, the excavating of a hole I' in vertical sections and successive order as described above in connection with FIG. 3 is carried out when the ground is so hard that the progressing in horizontal sections as described above in connection with FIG. 2 is impossible for technical reasons. Moreover, the excavating of the hole I' by means of vertical intersecting sections, which are deepened successively if necessary, has the advantage that the wall to be erected in the excavation may be very effectively bonded in a highly inclined profile of the compact stratum in the ground.

It is understood that during the drilling operations for the excavation of the hole I' of FIG. 3 a thickish, preferably thixotropic colloidal liquid or slime is introduced into the respective bore being drilled, and that a portion of said thickish liquid penetrates into the wall of the excavation so as to form an impermeable zone 5, which also prevents the excavation from collapsing so that the excavation can be kept open until after completion of the excavation the desired material is filled into the latter.

If the length of the excavation shall be longer than the length of the hole I' shown in FIG. 3, one or more additional holes are excavated in succession as described above in connection with the holes II and III shown in FIG. 1, the ends of adjacent holes interesecting each other.

FIGS. 4 and 5 illustrate the filling of an excavation I or I' prepared in accordance with a method described in connection with FIG. 2 or in connection with FIG. 3. The concrete or other suitable material 6 is filled into the hole I or I' in any known manner, for example in accordance with a system described in the Swedish Patent 33,675 to A. Gundersen and known in the trade as the "Contractor-System" according to which the material is filled into the excavation under water. For example, according to such a method the concrete or other material is introduced into the excavation I or I' through a steel tube 7. Care should be taken that at all times the lower end of the steel tube 7 remains within the heap 6' of concrete or material filled into the excavation so as to avoid a washing away of the concrete or other material. The slowly rising heap 6' of concrete or other material pushes upwardly the amount of the preferably diluted thickish liquid being above said heap. The operation is terminated when the concrete or other filling material reaches the surface of the ground.

If desired, a metal or iron reinforcement 9 may be brought into the excavation I or I' prior to the filling in of the concrete 6, so that a concrete wall reinforced by a metal or iron respectively is obtained which in addition to vertical loads may sustain horizontally acting loads and moments. It is known from experience that bentonite being a thickish liquid used according to the invention in the manner described above does not combine at all with a metal reinforcement so that the concrete may tightly surround said metal reinforcement as in the case of a normal reinforced concrete support, so that a perfect joint effect of strength is obtained.

After the filling of the excavation I (I') the adjacent

excavation II is excavated and filled and so on as described above.

A different method of excavation illustrated by FIGS. 6 and 6*a* may be useful for certain types of soil. According to this modified method at first a plurality of spaced bores **10***a*, **10***b* . . . **10***z* is excavated by suitable boring tools of the rotary type, hammer type or other type, whereupon the columns **11***a*, **11***b* . . . **11***y* left over between the bores **10***a*, **10***b* . . . **10***z* are removed by a grab G (see FIG. 7*a*) or another suitable device such as a dredger, milling cutter, or the like. Additional amounts of a thickish, thixotropic, colloidal liquid or slime are filled into the excavation corresponding of the volume of the columns **11***a*, **11***b* . . . **11***y* or parts thereof as they are removed in the course of the excavating operation, so that the excavation is filled with such thickish liquid at all times.

According to FIGS. 7 and 7*a* the column 11*a* is already entirely removed while the column **11***b* is only partially removed by the grab G and the columns **11***c* . . . **11***y* are not yet removed. When the excavation is completed it is filled subsequently with a suitable material as will be described hereinafter.

When, as illustrated by FIG. 8, the section I*a* of an excavation is completed a shield S is inserted at the right hand and thereof as illustrated by FIG. 9, said shield being in the shape of a cylinder or any other suitable form. Thereafter, concrete **6***a* or other filling material is filled into the space of the excavation I*a* outside the shield S, the filling material engaging the wall of the excavation I*a* and the left hand outer surface of the shield S.

After setting of the concrete **6***a* the shield S is withdrawn as indicated by the dash lines in FIG. 10, so that a bore LS filled with a thickish liquid introduced into the excavation during the drilling operation as described above remains. Thereafter, the excavation II*a* is prepared in the same manner as described above in connection with excavation I*a* by drilling consecutively spaced vertical bores and removing thereafter the columns left between them. Now, when excavation II*a* is completed as shown in FIG. 11 and, thereafter, concrete or other suitable filling material is introduced into the excavation II*a* as shown in FIG. 12, the filling material engages at the left hand end the semicylindrical surface of the wall previously prepared in excavation I*a* and at the right hand end the shield S now inserted into the excavation II*a*.

Thereafter, upon removal of the shield S, a third and if necessary a series of additional excavations is made and filled with suitable material in the same manner as described above in connection with FIGS. 6–12, it being understood that the insertion of the shield S is omitted in the last excavation.

While it has been described above in connection with FIG. 1, that the first zone *a* of the second hole II intersects the last zone *z* of the first hole I, of course a shield S as described in connection with FIGS. 9–12 could be inserted into the last zone *z* of the first hole I—be it prepared according to FIG. 2 or according to FIG. 3—before the filling material is filled into the hole I, whereupon after filling the hole I with the filling material and after a subsequent removal of the shield the second hole II is prepared in accordance with the method described in connection with FIG. 2 or FIG. 3. In the same manner the transition between each two successive excavations II, III etc. or wall portions could be made.

FIG. 13 illustrates a different form of excavations E_1, E_2, which may be prepared in accordance with any of the methods described above and illustrated by FIGS. 2–12. According to FIG. 13 each excavation E_1 or E_2 is provided with a lateral extension **13**, whereby the drain path parallel to the wall to be erected in the excavation is extended as may be desirable under certain circumstances for hydraulic reasons. Furthermore, as shown in the right hand portion of FIG. 13, a metal reinforcement **14** may be inserted into the excavation E_2 including the lateral extension **13** thereof, so that the completed wall acts as a T-support or T-beam in accordance with the rules pertaining to the science of reinforced concrete.

FIGS. 14 and 15 illustrate two different methods for preparing an excavation being wider than the diameter of a rotary boring tool irrespective of the fact whether the method according to FIG. 2 or FIG. 3 or FIGS. 6, 6*a*, 7, 7*a* is used. According to FIGS. 14 and 15 adjacent individual excavation making up the total excavation intersect each other partially.

According to FIG. 14 at first the excavation E is prepared, whereupon the excavation E*a* adjoining the excavation E at a longitudinal side thereof is prepared. Thereafter, the pair of excavations E*b*, E*c*, then the pair of excavations E*d*, E*e*, and so on in dependence on the desired length of the wall to be erected, are prepared. Thus, the total excavation is prepared by successively preparing excavating sections E, E*a*–E*b*, E*c*–E*d*, E*e* widened to the desired width.

According to FIG. 15 at first the excavation E is prepared, whereupon the excavation E*a* adjoining the excavation E at an end thereof and, thereafter, the excavation E*b* adjoining the excavation E*a* at an end of the latter are prepared. Then, the series of excavations E*c*, E*d*, E*e* is prepared in a similar way. Thus, the total excavation is prepared by successively preparing an excavating section E, E*a*, E*b* having the total length and thereafter widening same by preparing another excavating section E*c*, E*d*, E*e* of the total length.

The excavations prepared in accordance with the invention may be filled with concrete; if desired, as described above, an iron reinforcement may be inserted into the excavation before the concrete is filled in.

Instead of concrete, however, a plastic or formative mass, such as a mixture of gravel, sand, clay, bentonite and cement or a mixture of gravel, sand, bitumen and asphalt in predetermined proportions may be used.

Furthermore, the thixotropic colloidal slime may be directly hardened by chemical or physical means or simultaneously by chemical and physical means, so that a filling with concrete or another suitable material may be omitted.

The method according to the invention may be readily used for the erection of porous walls for the purpose of draining. In such a case it is sufficient to fill the excavation with gravel and sand of a size of grain adapted to the condition of the ground and to take care of a simultaneous washing out of the walls of the excavation so as to remove the impermeable zone 5 having a sealing effect. Preferably, in such a case the mixture of gravel and sand is brought into a permeable net-like enclosure, so as to prevent the penetration of the gravel into the surrounding soil.

I have described preferred embodiments of my invention, but it is understood that this disclosure is for the purpose of illustration, and that various omissions and changes in shape, proportion and arrangement of parts, as well as the substitution of equivalent elements for the arrangements shown and described may be made without departing from the spirit and scope of the invention as set forth in the appended claims.

What I claim is:

1. A method of making a horizontally elongated vertical wall excavation comprising the steps of excavating substantially vertically a bore hole until a desired initial depth has been achieved, making a series of similar overlapping bore holes extending horizontally to form an initial zone of predetermined depth, simultaneously, as the excavating proceeds, circulating therein a thixotropic fluid in order to cause consolidation of the vertical walls upon penetration of the thixotropic fluid therethrough, thereafter repeating the excavation to a greater depth in order to form a second zone while maintaining the excavation full of thixotropic fluid, and repeating the steps until the final depth has been reached.

2. A method of making a horizontally elongated vertical concrete wall element comprising the steps of making a horizontally elongated vertical wall excavation as defined in claim 1, and after completion of said excavation displacing the said thixotropic fluid by filling the excavation with concrete.

3. The method of making a wall as defined in claim 2 including the step of inserting horizontally elongated reinforcing members extending substantially from end-to-end of said excavation prior to the filling thereof with concrete.

4. A method of constructing a wall as defined in claim 2 including the formation of at least one lateral extension of said wall element.

5. A method for the construction of a waterproof wall formed by interlocked, horizontally elongated, vertical concrete elements comprising the steps of excavating a series of spaced apart holes along the line of the wall, each hole having a width equal to the thickness of the vertical elements and being substantially vertical, consolidating the walls of each hole of the series by introducing therein, simultaneously as the excavation progresses, a thixotropic liquid, removing the material between successive holes as defined by substantially parallel planes commonly tangent to the walls of adjacent holes to form a horizontally elongated excavation, consolidating the walls defined by said planes by maintaining the excavation substantially full of said thixotropic liquid, placing a vertical tubular shield at one end of said excavation, filling the horizontally elongated excavation thus formed, except the volume enclosed by said shield with concrete and removing said shield after the concrete has set before proceeding to the next and adjacent vertical concrete wall element and preparing the next said adjacent vertical concrete wall element in the same manner as the first utilizing as the first hole thereof the unfilled volume of the preceding horizontally elongated excavation to complete the wall.

6. A method of constructing an underground wall as defined in claim 5 including the step of inserting horizontally elongated reinforcing members in each excavation before filling said excavation with concrete to form reinforced horizontally elongated vertical concrete elements.

7. A method of constructing a wall as defined in claim 5 including the formation of at least one lateral extension of said concrete wall.

8. A method for the construction of a waterproof wall formed by interlocked vertical concrete elements comprising the steps of preparing an excavation by excavating substantially vertically a bore hole until a desired initial depth has been achieved and thereafter making a series of similar overlapping bore holes of decreasing depth and extending horizontally to form an initial horizontally elongated excavation zone and as the excavation proceeds simultaneously circulating therein a thixotropic fluid in order to cause sealing and consolidation of the vertical walls of the elongated excavation upon penetration of the thixotropic fluid therethrough, thereafter excavating said bore holes to a greater depth while maintaining the excavation substantially full of thixotropic fluid in order to form a second zone, repeating the process until the final depth has been reached and continuing to maintain the excavation substantially full of thixotropic fluid filling said excavation after the excavation of all of said zones with a cementitious material to displace said thixotropic fluid before proceeding to the next and adjacent vertical concrete element interlocked with the preceding one.

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