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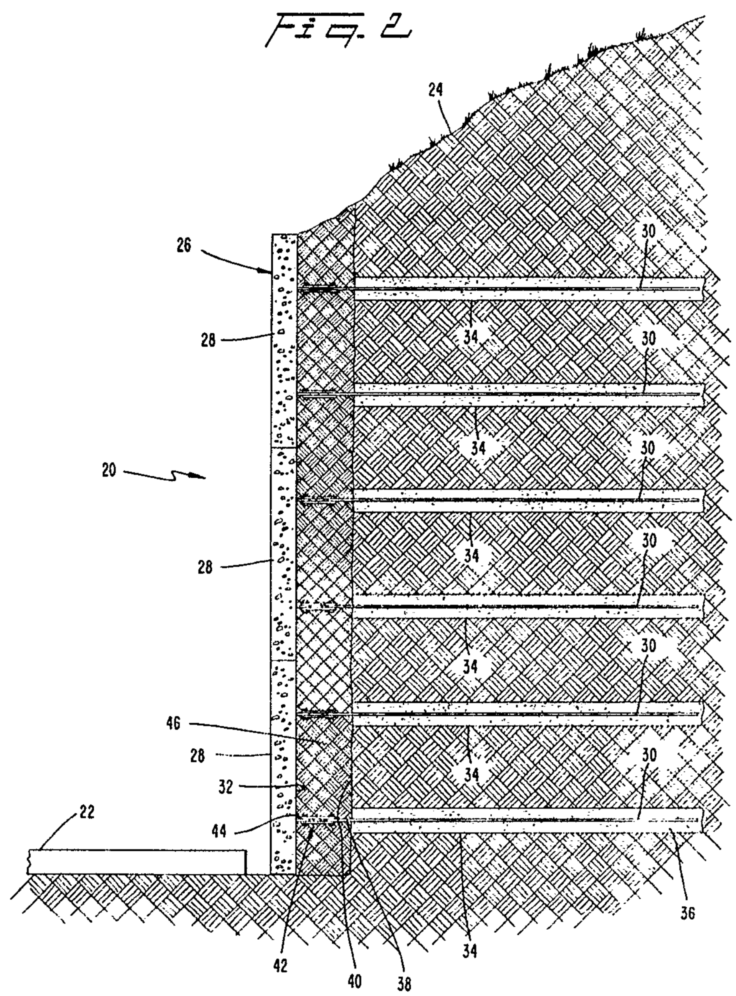
(71) Applicant
Henri Vidal,
6 bis Boulevard, Maillot
92200, Neuilly Sur Seine,
France
(72) Inventor
Henri Vidal
(74) Agents
Frank B. Dehn and Co.,
Imperial House, 15—19
Kingsway, London
WC2B 6UZ

(54) Constructing retaining walls

(57) A method is described of constructing an internally stabilized structure in situ which includes the steps of boring holes into the face of the earth mass and positioning reinforcing members 30 in the bore holes. Sand or other particulate material 36 is fed into the bore holes to surround the reinforcing member so as to transmit forces from the earth mass to the member. A tube is assembled with each reinforcing member when it is inserted in the bore hole. Sand is fed through the tube to fill the bore hole progressively from the inner end toward the face, as the tube is progressively withdrawn from the bore hole. To protect the face, a covering such as grouting may be applied, or wall elements 28 may be connected to the ends of the reinforcing members.

FIG. 2



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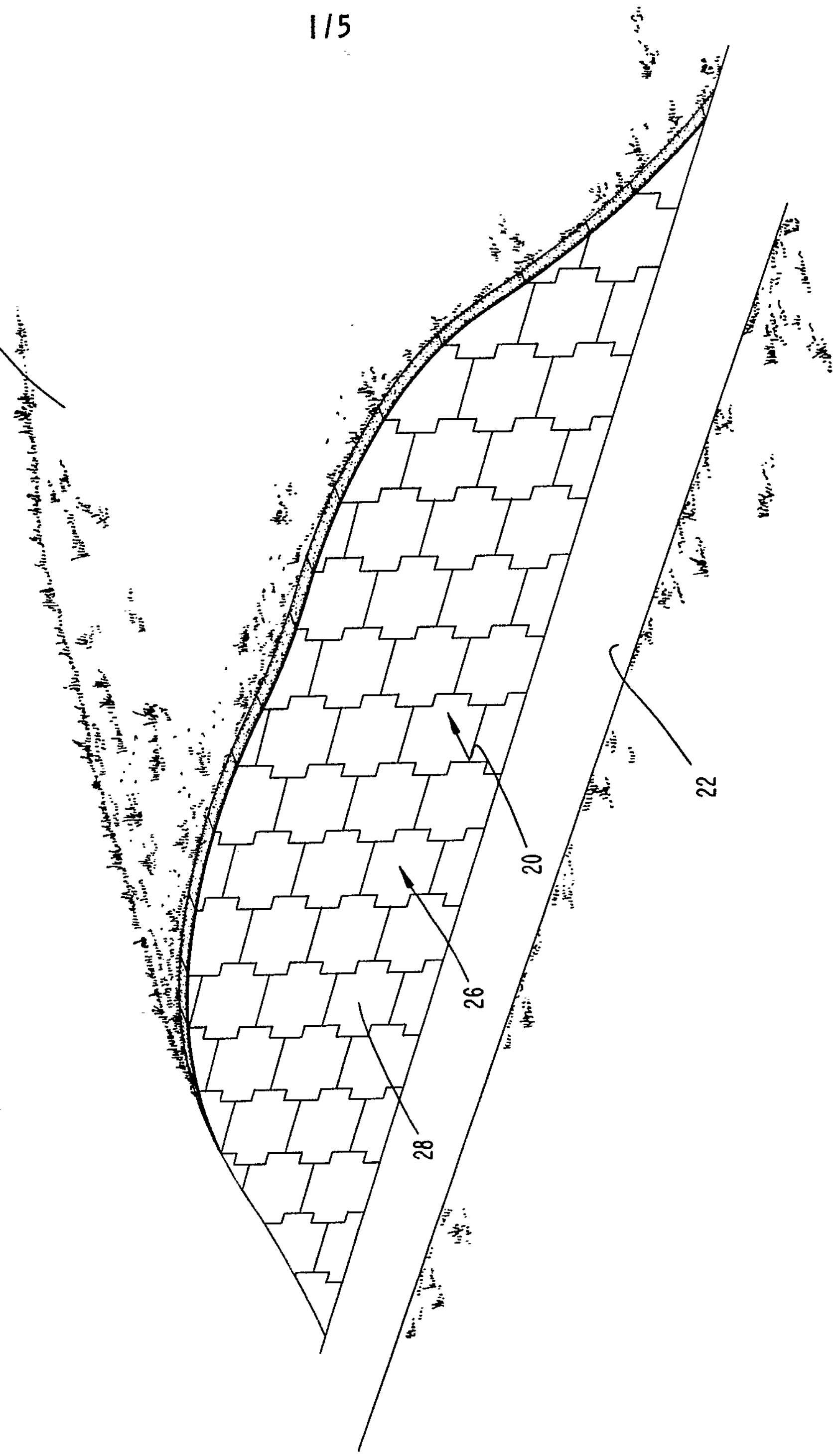


FIG. 1

Fig. 2

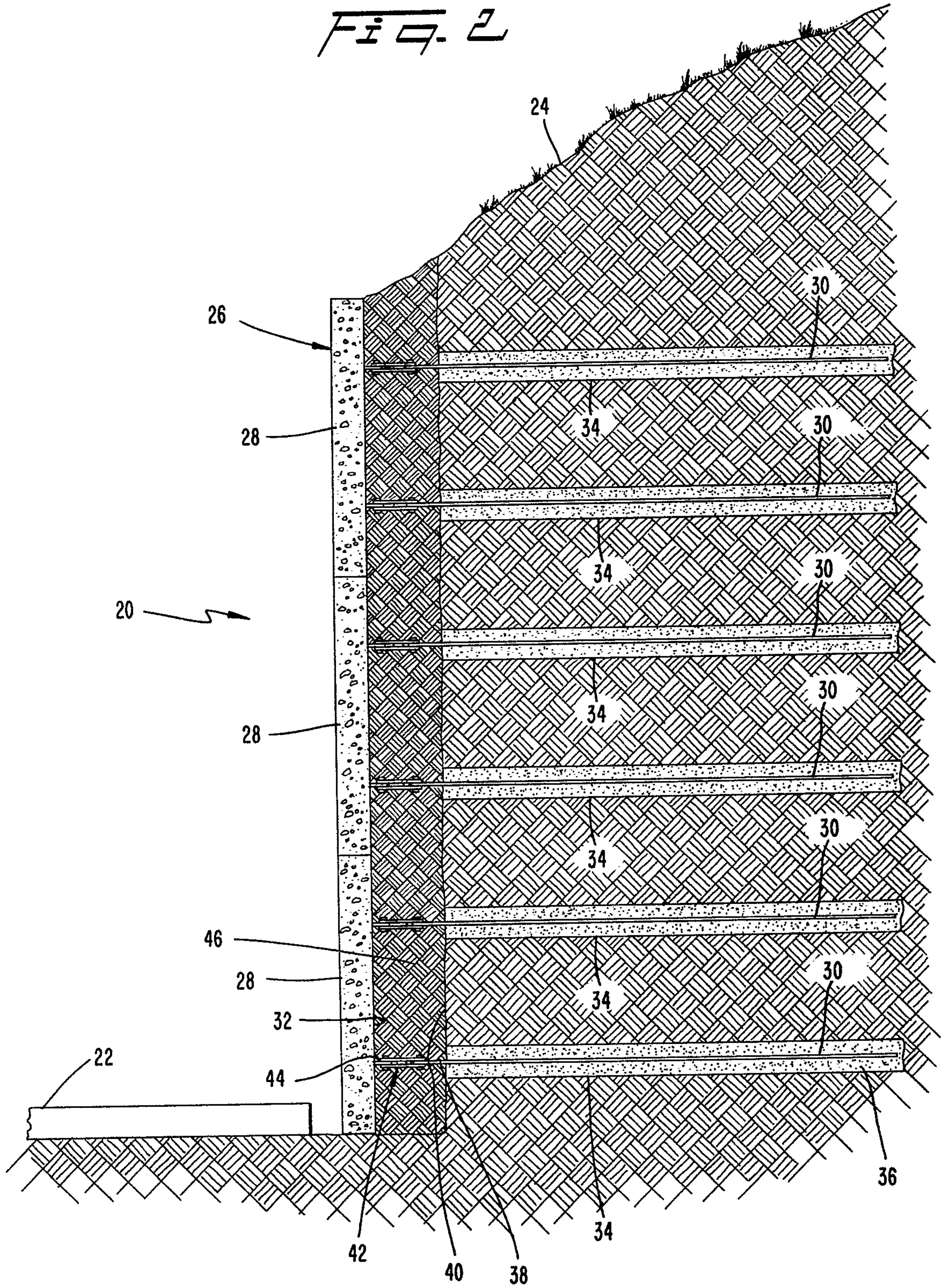


Fig. 3

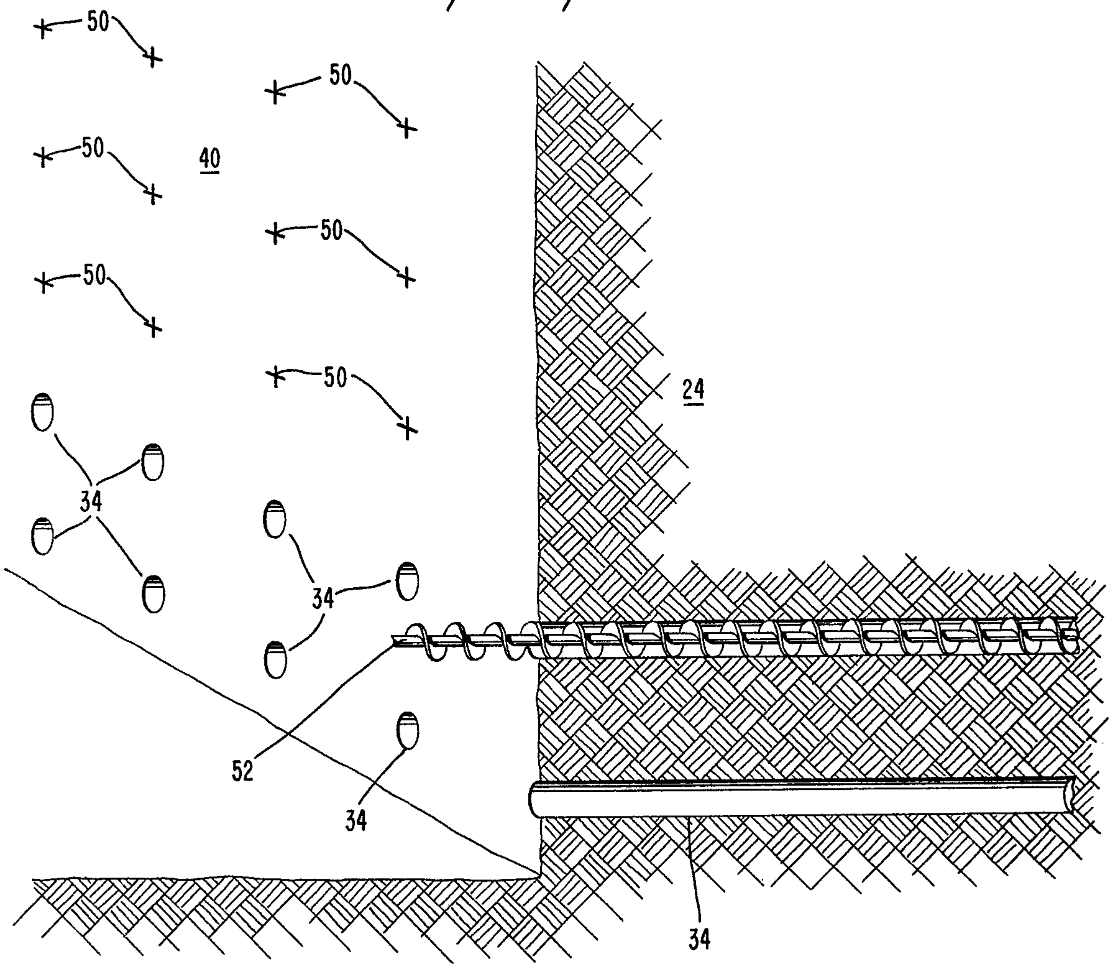
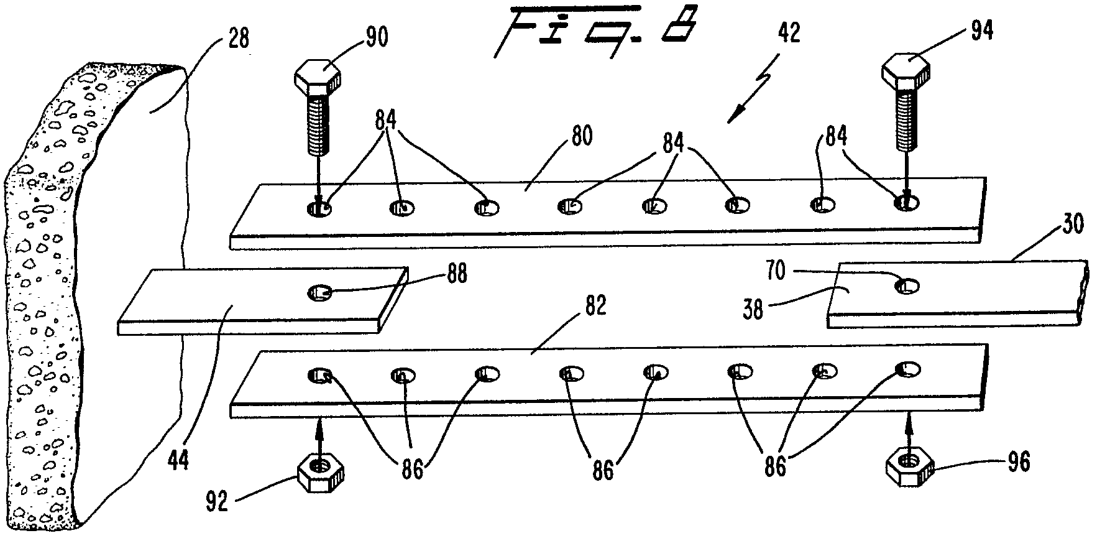


Fig. 8



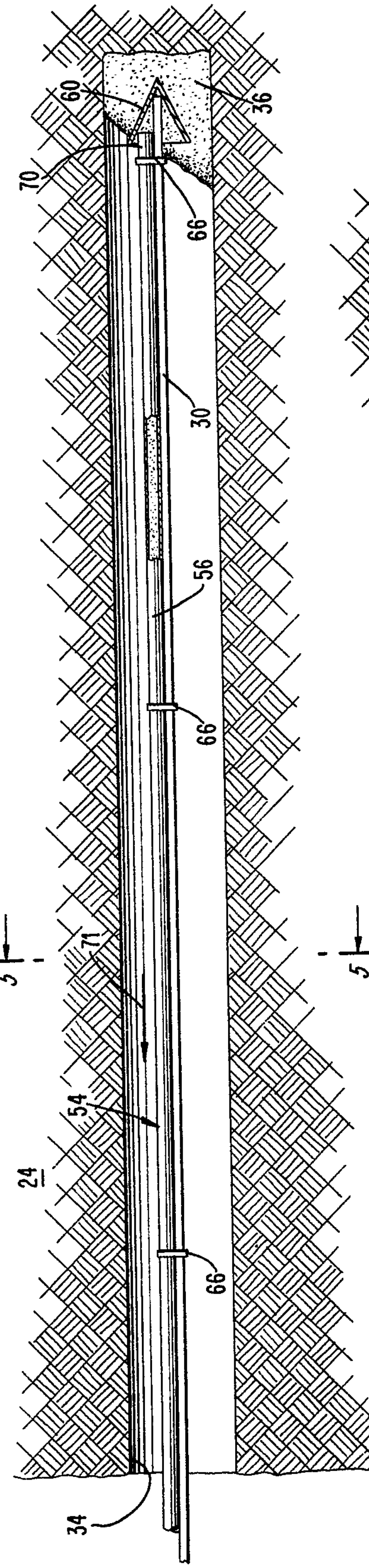


FIG. 4

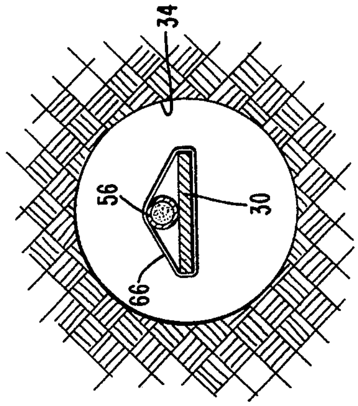


FIG. 5

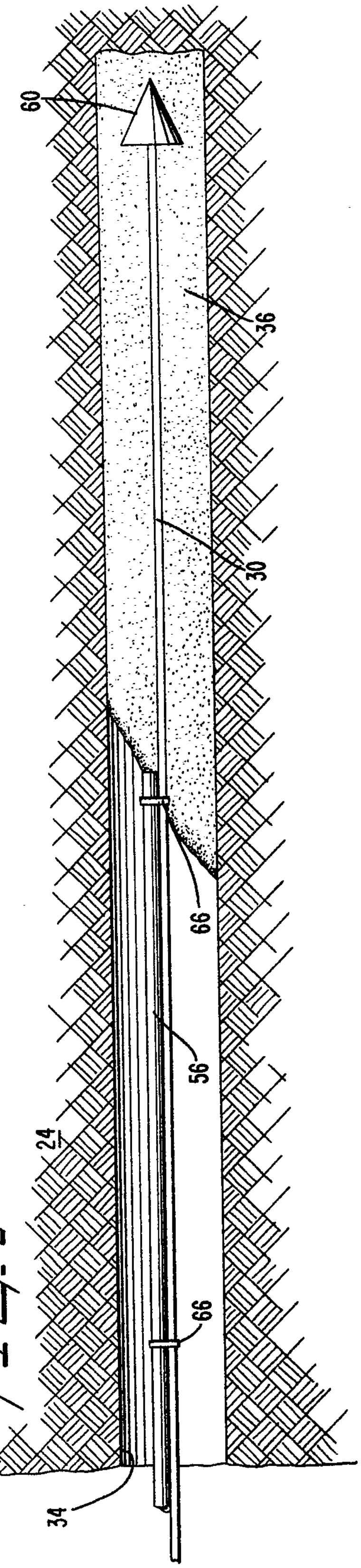
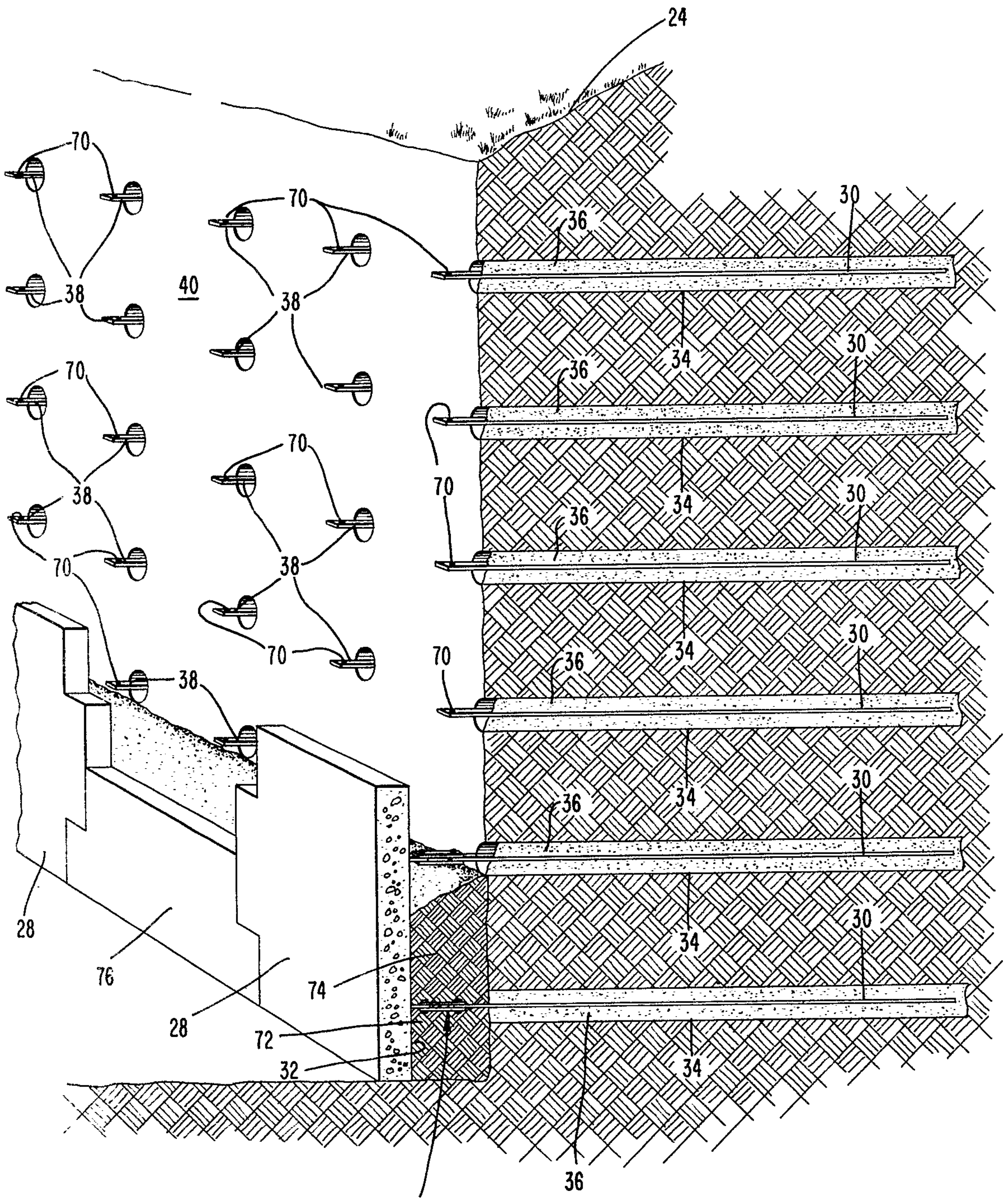


FIG. 6

Fig. 7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SPECIFICATION

Retaining wall and in situ method of construction

The present invention relates to internally stabilized earth structures and methods of constructing them. More particularly, the present invention deals with an internally stabilized earth structure and its construction is essentially unexcavated environments.

In the past, various methods and apparatus have been used for stabilizing volumes of soil. For example, two-dimensional arrays of stone columns or sand columns have been used to stabilize surface areas in order to support various structures such as a building, highway or the like. With the stone column concept, a multiplicity of generally vertical cylindrical holes are drilled into the earth. Each hole is then filled with crushed stone and compacted. With sand columns, sand is substituted for the crushed stone. The presence of these particulate masses (crushed stone or sand) is useful to create a composite soil structure that stabilizes, for example, silt deposits, marine clay, loess material and the like. See, for example, International Conference on Soil Reinforcement: Reinforced Earth and Other Techniques, Volume 1, 211—16, 249—54.

The stone column and sand column stabilization technique is not, however, well adapted to use in stabilization of embankments or slopes. The reason for this is that stone columns and sand columns enhance compressive strength of the surrounding material but do not enhance the tensile and shear strength, of the surrounding material. Accordingly, failure of the slope material, which typically is a shear failure, is not resisted by horizontally disposed stone columns or sand columns.

Methods have, however, been established for stabilizing slopes, embankments, and the like. One such approach involves ground anchors. With ground anchors, deep inclined bores are provided, each of which has considerable length. An anchor is positioned in each bore and secured therein by grouting or the like. Subsequently, the face of the slope is shotcreted, or a concrete or steel facing is applied to the slope face. Thereafter, the ground anchors are stressed by creating tension therein. This tension retains the shotcreted, steel or concrete face and, as a result, the material of the underlying slope. See, for example, International Conference on Soil Reinforcement: Reinforced Earth and Other Techniques, Volume II, 552—53.

Variations of the ground anchor method involve the concepts of root pilings and soil nailing. One form of the root piling method involves using a plurality of steel members which extend generally perpendicularly to the face of a slope into the soil to be retained. The exposed ends of the steel members are covered with suitable reinforcement members. Then the exposed ends of the steel members along with the reinforcement are shotcreted. The resulting gravity structure is effective to retain the slope in its desired position. See, for example, International Conference on Soil Reinforcement: Reinforced Earth and Other Techniques, Volume II, pages 301—03.

The soil nailing concept provides a sequential slope reinforcement which can be used during the excavation process itself. Initially, an excavation is made to a predetermined depth. Then, the exposed face of the excavation is given an appropriate reinforcement and shotcrete is applied thereto. Next, special nailing equipment places nails at predetermined intervals through the reinforced shotcrete face and into the soil embankment to be retained. Typically, the annular space between soil nails and the surrounding soil is grouted with a cement mortar. When a first application of a shotcrete and nailing has been completed, further excavation can take place and subsequent applications of reinforced shotcrete and soil nailing are made until the excavated face has its desired final configuration. See, for example, International Conference on Soil Reinforcement: Reinforced Earth and Other Techniques, Volume II, pages 469—74.

The processes of soil nailing, root piling and ground anchors, as can be seen from the foregoing, each involve the application of surface treatment of shotcrete. Accordingly, these construction methods are relatively expensive and require a great deal of labor in order to provide the necessary slope stabilization. The shotcrete technique requires not only special equipment but also the concomitant expense of a large volume of cement type material. In addition, these methods are not generally useful for obtaining and stabilizing embankment surfaces having generally vertical faces. Moreover, embankment stabilization is not effective until these methods are complete.

Internally stabilized earth structures utilizing a plurality of strips attached to generally vertical wall facing elements have been known for many years. This construction technique is ordinarily used in fill areas where extensive excavation is not required. Heretofore, this construction method has not been used in stabilization of existing embankments because of the volume of excavation required. For example, the excavation behind the wall must extend for a distance approximately equivalent to the wall height. Accordingly, the required excavation in typical highway construction makes the cost of the internally stabilized gravity structure impractical as compared with other methods where slopes only require excavation to, for example, a 2:1 incline.

Where an existing internally stabilized earth structure has been standing for a long period of time, it occasionally happens that soil constituents have corroded the metal strips providing the reinforcement to such a degree that additional reinforcement of the wall is necessary. One possible method of accomplishing this repair involves drilling a hole completely through the affected facing element and into the stabilized volume therebehind. A steel reinforcement strip is then placed in the bore and bound to the adjacent earth by an injection of cement-and-sand mortar. The exposed end of the strip is secured to the exposed face of a wall facing element itself. Such methods are not, however, adapted for use in the construction of walls because the wall facing panels are not positioned or retained in place during the construction process and because the additional expense of the grouting material required for injection into bores is impractical on a large scale wall.

Generally, the difficulties with prior art methods for stabilization of slopes and embankments can be summarized as (a) requiring too much excavation; (b) requiring expensive materials in large quantities; or (c) requiring special machinery and handling techniques that necessitate the use of skilled workmen. Moreover, the slope or embankment is not stabilized by the method during intermediate construction steps.

According to the present invention we provide a method of internally stabilising an existing earth mass comprising boring into one face of said earth mass an array of stabilizing element receiving boreholes characterised by positioning each of a plurality of reinforcing element in a corresponding one of said boreholes and essentially filling the boreholes with particulate material around the elements to transfer forces in the earth to said elements through frictional engagement with the particulate material.

The method of the present invention provides in general a gravity structure and method of erecting that structure which uses generally available construction equipment and do not require the use of skilled labor forces. In particular, the new technique is capable of providing a generally vertical face on the exposed surface of a stabilized embankment.

In general, the structure will be constructed in situ by excavating a natural earth slope to provide a generally vertical earth face to a predetermined depth. A plurality of generally horizontal bores may then be made in the earthen face. A reinforcing element is then positioned in each of the bores and secured in that corresponding bore by the injection of particulate material which is free of binding agents but surrounds the reinforcing member and essentially fills the hole i.e. as completely as possible. In this manner, expensive grouting materials and procedures are not required. Moreover, the earth face is stabilized merely by the presence of the reinforcing members.

Subsequently, further excavation of the face may be done. The next portion of the face is then stabilized with reinforcing strips in the manner described above. The excavation and stabilization steps are repeated until the earthen face has attained the required height.

Next, wall facing elements are positioned in front of the exposed earthen face. Each wall facing element is attached to one or more reinforcing members and the space between the rear of the wall facing element and earthen face is filled with compacted particulate material. Accordingly, the excavation required for erecting the wall only needs to provide adequate space behind the wall to allow connection of the reinforcing members to the wall facing elements.

To accommodate lateral misalignment between the reinforcing members and connecting points on the wall facing elements or panels, a connector assembly may be provided which accommodates that lateral degree of freedom. In addition, the connector assembly may be longitudinally adjustable to accommodate the variations in spacing between the reinforcing members and the panels.

Brief Description of the Drawings

The above, as well as many other objects of the present invention, will be apparent to those skilled in the art when this specification is read in conjunction with the attached drawings wherein like reference numerals have been applied to like elements and wherein:

FIGURE 1 is a perspective view of an internally stabilized earth structure erected in situ in accordance with the present invention;

FIGURE 2 is an enlarged cross-sectional view taken through the wall of Figure 1 to illustrate details of the wall assembly;

FIGURE 3 is a perspective view of the exposed face of an earth structure during construction which illustrates a suitable method of boring;

FIGURE 4 is an enlarged partial cross-sectional view of a bore illustrating the method of reinforcing member placement and the method of filling the bore with a particulate material;

FIGURE 5 is a cross-sectional view taken along the line 5—5 of Figure 4;

FIGURE 6 is a view similar to Figure 4 illustrating the filling of the bore with a particulate material;

FIGURE 7 is a perspective view showing reinforcing members in cross section as well as illustrating the placement of a first row of wall facing panels; and

FIGURE 8 is a detail view in perspective of the connecting assembly for attachment of a reinforcing member to a wall facing panel.

Description of the Preferred Embodiment

A wall 20 (see FIGURE 1) constructed according to the present invention may be built in a topological area through which a structure 22 such as a road is designed to pass and which requires that the existing earth contours be excavated, or cut away, in order to provide a specified slope for the road 22. It is to be recognized, of course, that the wall 20, according to the present invention, may also be used in connection with other civil engineering structures as well as any situation calling for slope stabilization. For example, retaining walls, slope stabilization structures adjacent highways, paths, railroads, excavation of buildings and the like are suitable uses. Moreover, the slope of the finished face may be vertical as well as any larger angle measured from a horizontal surface projecting from the front of the wall at the bottom.

The wall 20 is constructed in situ in the ground 24 from which a portion must be cut to make way for the structure 22. The wall 20, as illustrated, provides a generally vertical exposed, or front, face 26. A vertical face essentially minimizes the volume of earth which must be excavated to prepare for the wall. This, in essence, effects a significant cost saving in comparison to inclined embankments since the excavation of material to provide 2:1, 3:1, 4:1 or lower slopes is significantly greater than the amount of excavation required to provide a vertical exposed face.

The vertical face 20 is composed of a plurality of wall facing panels or elements 28. These wall facing panels may be generally cruciform-shaped, as illustrated in FIGURE 1, or may have any other suitable configuration. It is contemplated that the panels 28, as illustrated, are precast in reinforced concrete and delivered to the job site. In this fashion, highly uniform wall panels can be used, each of which is designed for interconnection with adjacent wall panels in a known manner. See, for example, U.S. Patent No. 3,686,873, which describes one type of wall panel suitable for use in this wall. The details of the wall panel as specified in U.S. Patent No. 3,686,873 are incorporated herein by this reference thereto. The wall panels 28 may be made of other suitable materials, such as metal or plastics.

Each wall panel 28 (see FIGURE 2), comprises the vertical face 26, is retained in position by one or more reinforcing members or strips 30 which extend from a rear face 32 of the wall panel 28 into the in situ mass of earth 24. Typically, each reinforcing member 30 is fashioned from steel and has a generally rectangular cross-sectional shape. The reinforcing members frictionally engage the surrounding material and, thereby, are retained by that material. In some instances, it is desirable to provide a suitably textured surface to increase the frictional engagement between the strips and the adjacent material.

Each reinforcing member 30 is positioned within and retained within a corresponding generally cylindrical bore 34 having a generally circular cross section as formed by the hole forming tool. Each bore 34 is shown in the drawings to be horizontal and extending generally perpendicularly to the plane of the wall facing panels 28, but the bores need not be horizontal or parallel to each other. The bores 34 may be inclined either upward or downward from the face of the wall.

In order to retain each reinforcing member in its associated bore or hole 34, a suitable particulate material 36 is placed in the bore 34 surrounding the reinforcing member 30. In this manner, frictional engagement between the member 30 and the particulate material 34 imposes tensile forces on the member 30 to resist any tendency for the earth mass to fail, as described more fully in my patent, No. 3,421,326. In addition, by completely filling the bore 34 with the particulate material 36, the bore 34 is prevented from collapsing and weakening the stabilized earth structure constructed according to this invention.

While different materials may be suitable for use as the particulate material 36, it is envisioned that sand is the best combination of an inexpensive yet widely available particulate material which would be suitable for use. It is significant to note that no binding agent such as cement is combined with the particulate material 36. Accordingly, the particulate material 36 does not constitute a cohesive mass surrounding the strip-like reinforcing member 30, but rather, maintains its particulate character.

One end 38 of each reinforcing strip 30 projects beyond the generally vertical exposed earthen face 40 of the wall excavation. A connector assembly 42 is attached to the projecting end 38 of the member 30 and is also attached to a connecting point 44 at the back face 32 of a wall facing panel 28. The connecting assembly 42 accommodates partial lateral misalignment between the connecting point 44 of the panel and the projecting end 38 of the reinforcing member 38 by virtue of the pin-like connections and the parallel spaced axes thereof. It may be interjected at this point that the connecting point 44 may constitute a strap portion extending rearwardly out of the wall facing panel 28 and being generally horizontal.

As seen in FIGURE 2, the rear face 32 of the wall facing panels is spaced away from the exposed face 40 of the excavation during construction. This allows the workmen to reach behind the wall panels 28 during erection of a wall to assemble the connector assemblies 42 between each connection point 44 and each corresponding reinforcing member 30. As each connecting assembly 42 is completed, a layer of particulate material 46 is backfilled between the exposed face 40 of the earth mass 24 and the rear face 32 of the wall facing panels 28. Accordingly, as each generally horizontal row of connector assemblies 42 is attached, the wall facing elements 28 can be backfilled to the elevation of the next row of attachment points 44. Thus, the wall is completed by simply backfilling the small space defined behind the wall panels.

The details of constructing the internally stabilized gravity wall in situ will now be described in detail. With reference to FIGURE 3, an excavation has been prepared which leaves an exposed earthen face 40 that may be generally vertical as illustrated. The height of the exposed face is predetermined at the distance which may, for example, correspond to that height where the wall can support itself without collapse or failure. It is noted, of course, that the exposed face 40 may be inclined at a suitable angle from the vertical to prevent failure of the earth mass 24 during construction. Alternatively, supports for upper portions of the face may be provided if desired.

With the excavation completed, the desired location for reinforcing members is then marked or otherwise indicated on the exposed face 40 of the earth mass 24. For example, a two-dimensional array of marks 50 may be identified on the face. The horizontal spacing between the marks 50 and the vertical spacing between the marks 50 is selected to coincide with the corresponding horizontal and vertical spacing between attachment points on the wall facing panels to be used in erection of the wall. Depending upon the preference of the contractor, all of the marks 50 may be placed on the wall at one time or portions of the wall may be suitably marked until the boring process is complete.

After the earthen face 40 is marked, a suitable conventional boring tool 52 is used to drill bores 34 preferably horizontally to a predetermined length in a direction generally perpendicular to the earthen face 40. The length of the bore is selected to define the boundaries of a finished internally stabilized gravity earth structure of the size and proportions desired. The boring tool 52 may be driven by any suitable conventional apparatus (not shown).

When the bore 34 has been completed (see FIGURE 4) a reinforcing member 30 is positioned in the bore. In order to position the reinforcing member 30 in the bore, a tube assembly 54 is used. The tube assembly 54 preferably includes a tube 56 which may be formed of plastic. The tube 56 is more flexible than the member 30. The tube 56 is loosely tied by a band 58 to the member 30 to hold them together as shown in FIGURE 5 while the assembly 54 is being inserted within the bore 34. A cone 60 is secured by suitable means to the end of the member 30 to facilitate the insertion of the assembly 54 and to guide it over any debris that may be lodged in the lower side of the bore 34. The band 58 holds the tube assembly 54 together, but allows the tube to slide axially relative to the reinforcing member 30.

When the reinforcing member 30 (see FIGURE 4) is positioned in the corresponding bore 34 with the tube assembly 54, the inner or buried end of the reinforcing member is positioned so that it projects beyond the end 70 of the tube 56. Thus, the cone 60 is spaced from the end of the tube 70. In order to secure the member 30 in the associated bore 34, sand or other suitable particulate material is blown through the hollow tube or the tube assembly 54 and out the end thereof. The sand accumulates around the end of the member 30 and the cone 60, and surrounds the member thereby retaining its position. At that point in time, the tube 56 is withdrawn from the bore 34 in the direction of the arrow 71. While the tube assembly 54 is being withdrawn (see FIGURE 6), sand or other particulate material is continually blown therethrough to essentially fill the horizontal bore 34 around the reinforcing member 30. In this fashion, it will be appreciated by those skilled in the art that the tube assembly 54 can be rapidly withdrawn while completely filling the horizontal bore and retaining the reinforcing member 30 therein.

When all of the reinforcing members 30 have been inserted in their corresponding horizontal bores 34 (see FIGURE 7), the outer end portion 38 of each reinforcing member will project beyond the exposed earth face 40 of the earth mass 24. The projecting end 38 of each reinforcing member 30 is provided with an aperture 70 for use in attaching the connector assembly 42.

The presence of the reinforcing members 30 in the in situ earth mass 24 stabilizes the earth mass against failure and/or collapse. Accordingly, if further excavation is necessary to lower the elevation of the bottom of the wall, the procedure above can be repeated in increments of wall height as necessary. Then the wall facing panels are installed.

When the first course of wall facing elements 28 has been positioned with its back face 32 spaced horizontally in front of, and generally parallel to, the front face 40 of the earth mass 24, a layer of particulate backfill material 72 is positioned and compacted up to the level of the first row of reinforcing members 30. Generally speaking, when the connector assemblies 42 for each of the first row of strips 30 has been attached, a second layer of particulate material 74 is deposited and compacted to bring the level of backfill up to the subsequent layer of reinforcing strips 30 and additional rows of wall facing elements are applied as needed. In this fashion, by attaching each row of strips to the wall facing panels 28 and successively backfilling and placing wall panels until the next adjacent layer is reached, the wall is completed as the compaction process proceeds.

It will be noted, moreover, that the use of full panels 28 spaced apart by half panels 76 in the first row of panels facilitates the attachment of the connector assemblies 42. More particularly, it is easy for workmen to attach the connector assemblies behind the half panels themselves. And, it is easy to reach over the half panels 76 to make the appropriate connections at the lower attachment points behind the full panels. Subsequently, when full panels are positioned over the half panels, the converse situation becomes true. For example, workmen can bend over the first row of full panels to make the upper connections to those panels and reach behind the first full panels positioned above the half panels 26 to make the lower connections with reinforcing members 30 for those full panels. In this fashion, the connection of the reinforcing members of the panels in conjunction with the convenient use of panels and half panels facilitates the connection of the facing elements to the reinforcing members as the wall facing is applied. Thus, in the illustrated embodiment, a row of panels is made up by a plurality of panels spaced apart by upwardly projecting parts of panels already in the wall in an interdigitated manner.

In order to connect the reinforcing member 30, the connector assembly 42 (see FIGURE 8) preferably is designed to accommodate lateral misalignment between the projecting end 38 of the reinforcing member 30 and the attachment point 44 from the wall panel 28. One particular connector assembly 42 which is well adapted for use in this environment, includes a pair of elongated metal strips 80, 82 each of which is provided with a plurality of spaced apart holes 84, 86, respectively. One hole or aperture 84 of the upper strip 80 is aligned with a hole 88 provided in the attachment member 44 of the wall facing panel 28. Similarly, one of the apertures 86 at the end of the other strip 82 is positioned in alignment with aperture 84 and positioned therebelow. A suitable conventional bolt 90 and nut 92 may then be used to secure the two strips 80, 82, to the projecting end 44 so that the end 44 is sandwiched between the two strips. Of course, the pattern of holes in the strips 80, 82 may be varied from that shown in Fig. 8 to give the desired adjustability. For example, the holes may be arranged in two longitudinal rows spaced between holes of the adjacent row.

The connector assembly 42 may be attached to the wall facing panel 28 before it is positioned in the wall itself. Alternatively, the connector assembly 42 can be attached after the wall facing panel 28 has been positioned in the wall. In either event, the connector assembly 42 is also connected to the end 38 of the reinforcing member 30 in a similar fashion. More particularly, one of the holes 84 of the upper strip 80 is brought into general vertical alignment with the aperture 70 in the end 38 of the reinforcing member 30. Similarly, an aperture 86 of the lower strip member 82 is also brought into generally vertical alignment with the aperture 70. A second suitable conventional bolt 94 and nut 96 are then used to connect the two strips 80, 82, in sandwiching relationship to the end 38 of the reinforcing member 30 and complete the connection between the wall facing panels 28 and the reinforcing strip 30.

The connector assembly 42 described above provides lateral adjustability to accommodate misalignment between the connection points of the wall panels and the reinforcing members 30. For example, the bolts 90, 94 define two vertical axes that are spaced apart in the horizontal direction to accommodate unexpected offsets. Moreover, the plurality of holes 84, 86 in the strips 80, 82, respectively, provide longitudinal adjustability for the connector assembly 42. This feature avoids problems of critical positioning for the reinforcing members 30 when placed in the associated bores 34. More particularly, the longitudinal adjustability allows the end of one reinforcing member 30 to project a different distance from the earthen face than other reinforcing members 30 without introducing construction difficulties.

When the foregoing sequence of steps has been completed and repeated for each row of reinforcing elements and when each layer of compacted particulate material is positioned behind the wall panels, the resulting wall assembly will appear as illustrated in FIGURE 1.

It will be apparent to those skilled in the art that during the excavation process (see FIGURE 7) the reinforcing members 30 may be positioned as the excavation is being made, that is, from the top down. Alternatively, the reinforcing members 30 can be installed from the bottom working up.

From the foregoing, it will be appreciated that the amount of excavation required for a wall is considerably reduced. For example, an essentially vertical cut can be made to the desired grade without worrying about the potential for cave-in on sides of the cut. When the cut has reached the desired depth, the exposed wall faces are entirely ready for positioning and erection of the wall facing panels and backfilling of the small space behind them, without the need for placement and removal of forms and associated bracing. Moreover, the ability to use a vertical face significantly increases the desirability of this construction technique.

It will now be apparent to those skilled in the art that this specification describes a new in situ retaining structure as well as a method of erecting that retaining wall structure and that the wall and the method overcome problems of retaining wall constructions heretofore known. Moreover, it will be apparent to those skilled in the art that numerous modifications, variations, substitutions and equivalents exist for steps and features of the invention as described hereinabove which do not materially depart from the spirit or scope of the invention. Accordingly, it is expressly intended that all such modifications, variations, substitutions and equivalents for features of the invention as defined in the appended claims, which do not depart from the spirit and scope thereof, be embraced thereby.

CLAIMS

1. A method of internally stabilising an existing earth mass comprising boring into one face of said earth mass an array of stabilising element receiving boreholes characterised by positioning each of a plurality of reinforcing elements in a corresponding one of said boreholes and essentially filling the boreholes with particular material around the elements to transfer forces in the earth to said elements through frictional engagement with the particulate material.

2. The method of claim 1 including applying a covering to said earth face that is secured to said plurality of elements.

3. The method of claim 2 wherein said covering is applied by applying grouting cement on said earth face.

4. The method of claim 2 wherein said covering is applied by:

attaching each of a plurality of wall facing elements to a plurality of reinforcing elements while leaving a space between each wall facing element and the earthen face; and

filling and compacting particulate material in the space so that the facing elements define the front of the wall.

5. The method of claim 4 wherein said

attaching step includes:

securing a connector assembly to a connection point of the wall facing elements; and

connecting the connector assembly to the protruding end of a corresponding reinforcing member.

6. The method of claim 1 wherein the positioning step includes the steps of:

assembling each reinforcing element with a tube extending parallel, said tube being spaced from the end of said element;

inserting the tube and reinforcing element together into the corresponding bore;

feeding particulate material through the tube at a sufficient rate to fill the end of the bore around the protruding end of the reinforcing member; and

withdrawing the tube while continually feeding particulate material therethrough to essentially fill the bore around the reinforcing member with particulate material.

7. An internally stabilized earth structure for in situ construction in an excavation having an in situ earth mass with a plurality of bore holes projecting into the earth mass from a face characterized by a plurality of reinforcing members, each reinforcing member being received in one of said holes and extending substantially the entire length of said bore hole, each bore hole being filled with particulate material sufficiently to transmit forces from said earth mass to said reinforcing members.

8. The structure of claim 7 wherein the covering includes:

a plurality of facing elements spaced from the earth face on the in situ earth mass and defining a space, each facing element being attached to at least one of the reinforcing members; and

a generally vertical layer of compacted particulate material filling the space between the facing elements and the earthen face.

9. The structure of claim 7 wherein the covering is grouting applied to said face and being bonded to said reinforcing members.

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