May 10, 1966 S. E. WEBB ETAL 3,250,075

METHOD OF RETAINING WALL CONSTRUCTION AND ANCHORING

Filed Sept. 26, 1963 5 Sheets-Sheet 1

FIG. 1.

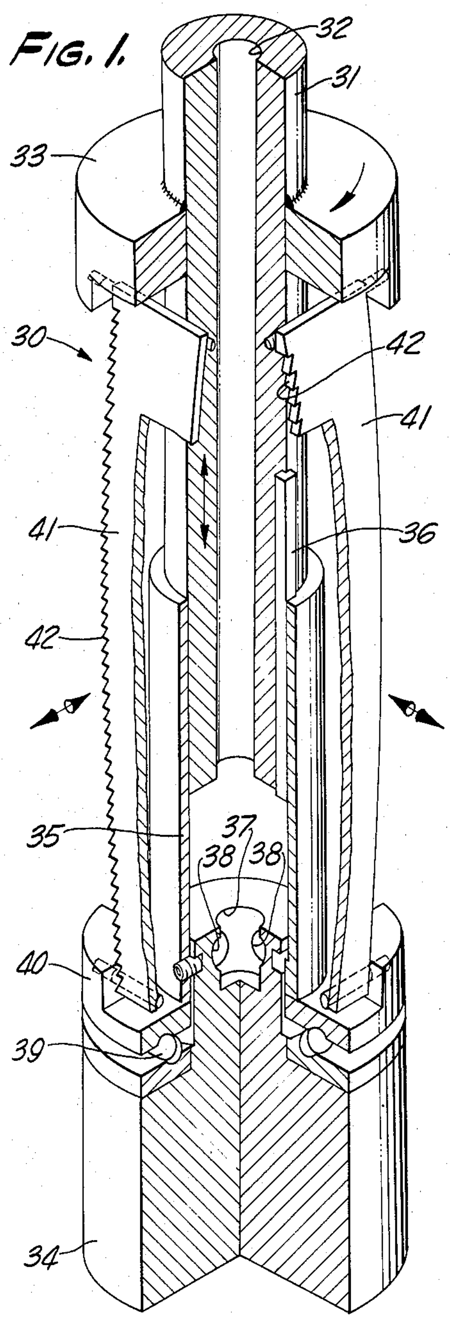


FIG. 2.

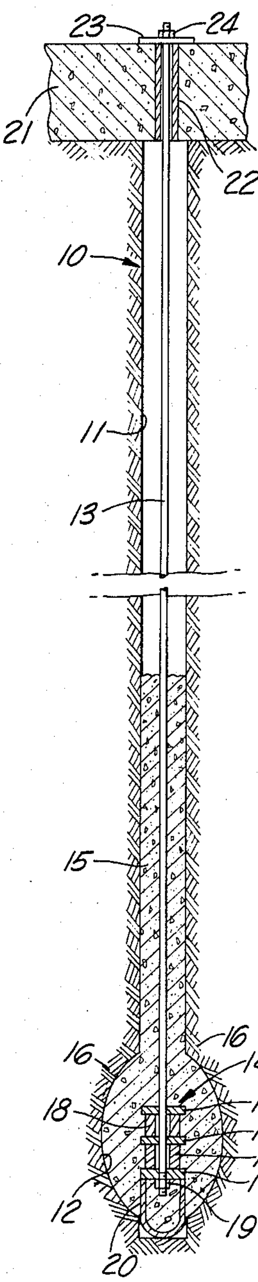
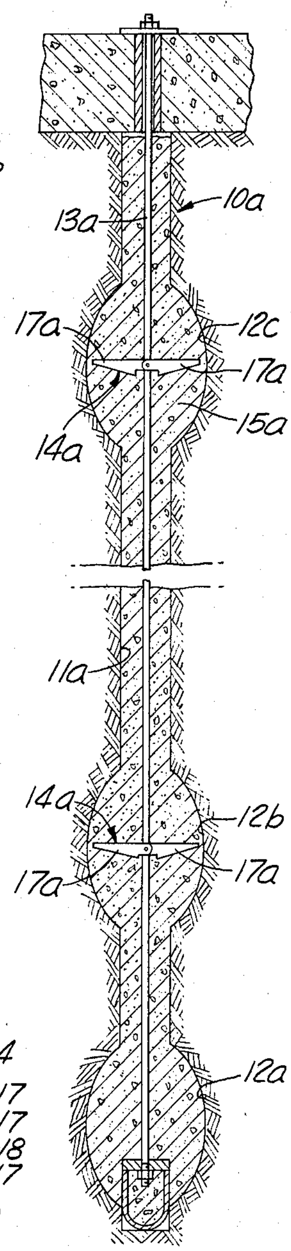


FIG. 3.



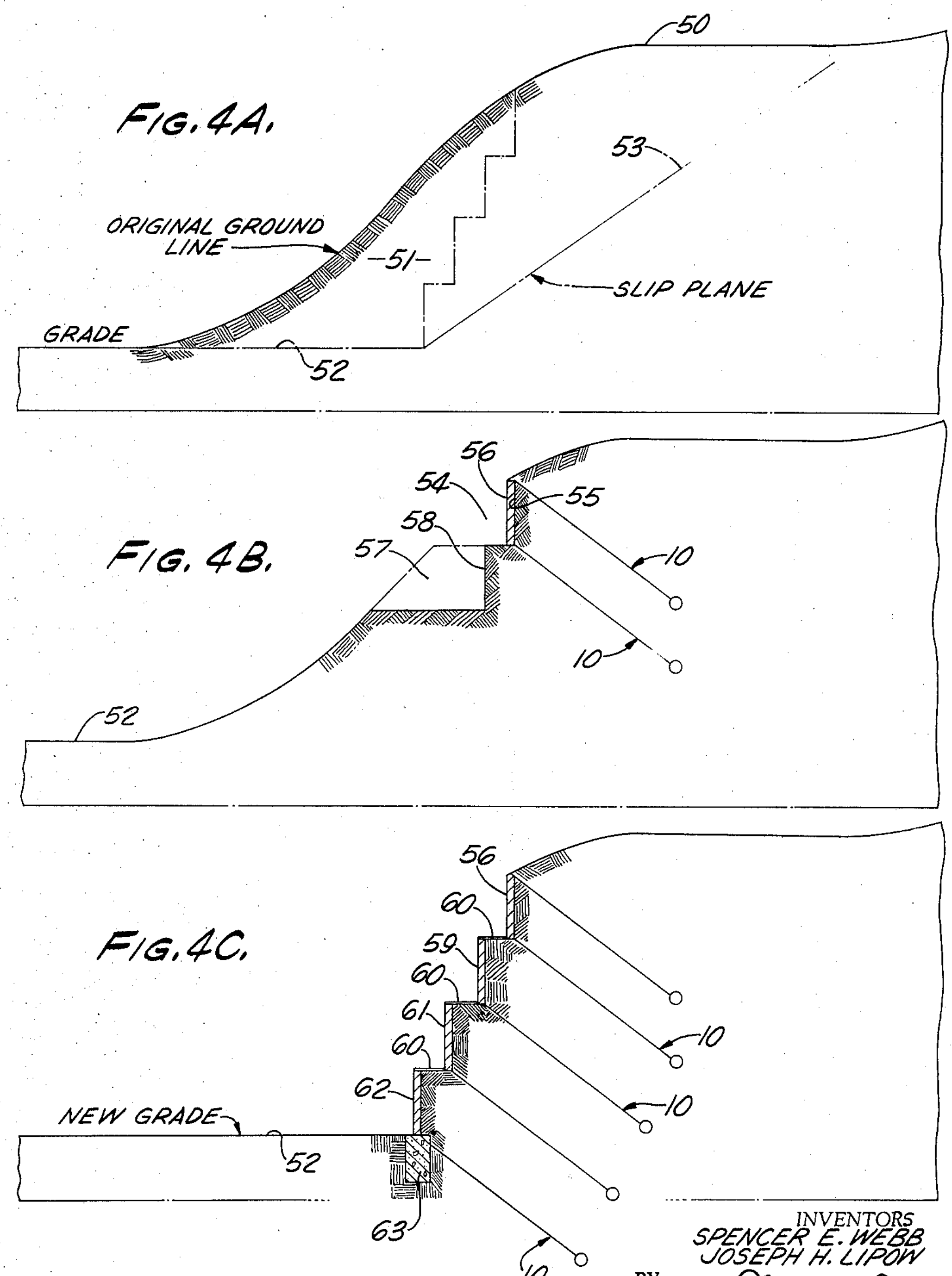
INVENTORS
SPENCER E. WEBB
JOSEPH H. LIPOW

BY Lyon & Lyon

ATTORNEYS

METHOD OF RETAINING WALL CONSTRUCTION AND ANCHORING

Filed Sept. 26, 1963 5 Sheets-Sheet 2



INVENTORS
SPENCER E. WEBB
JOSEPH H. LIPOW
BY
Lyon & Lyon
ATTORNEYS

METHOD OF RETAINING WALL CONSTRUCTION AND ANCHORING

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FIG. 5A.

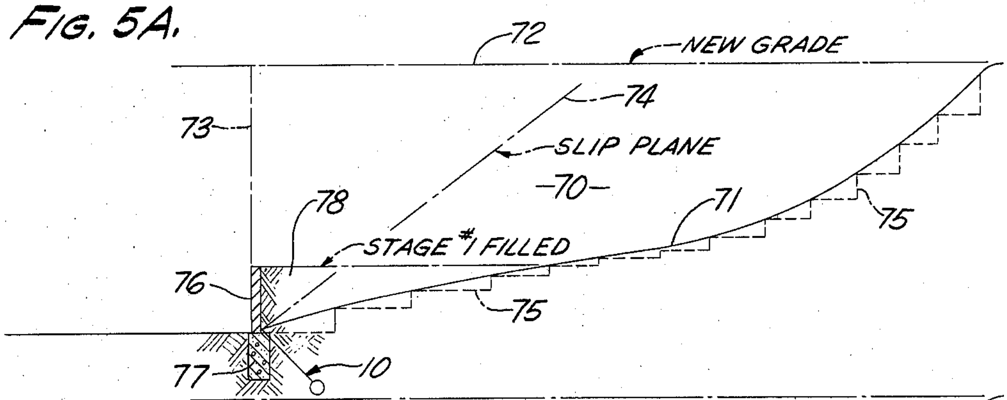


FIG. 5B

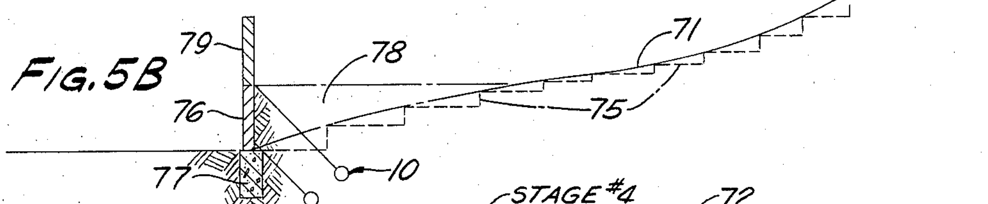


FIG. 5C.

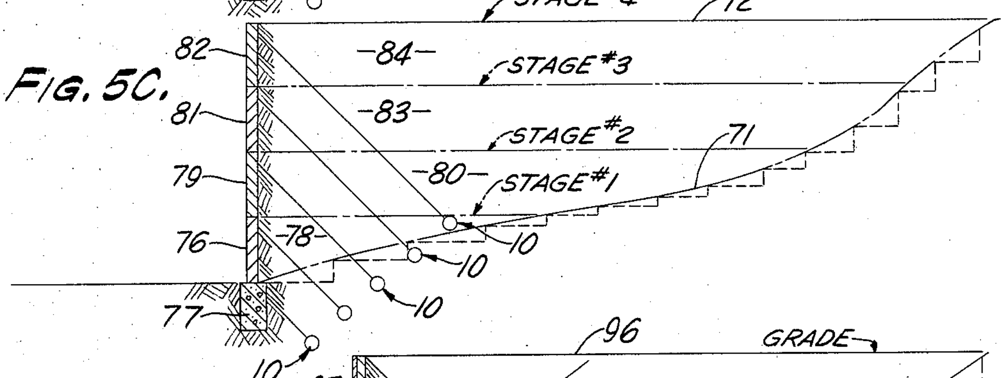
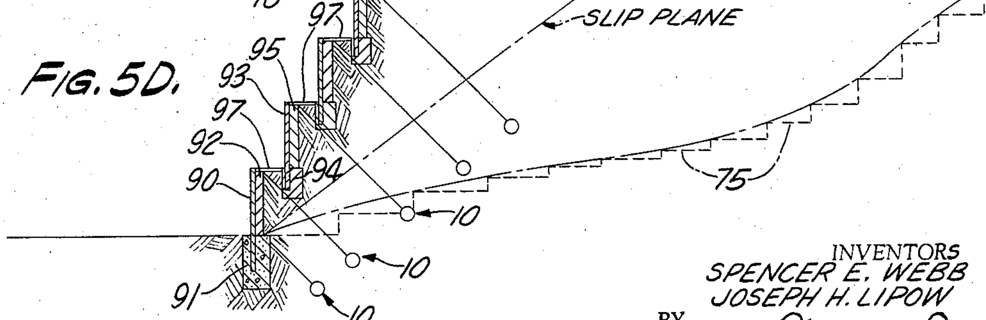


FIG. 5D.



INVENTORS
SPENCER E. WEBB
JOSEPH H. LIPOW
BY
ATTORNEYS

May 10, 1966 | S. E. WEBB ETAL | 3,250,075

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FIG. 6A.

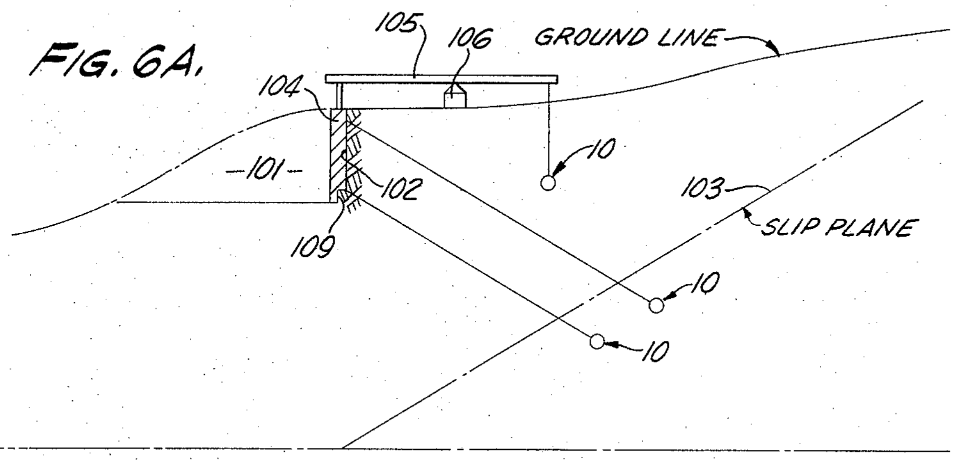


FIG. 6B.

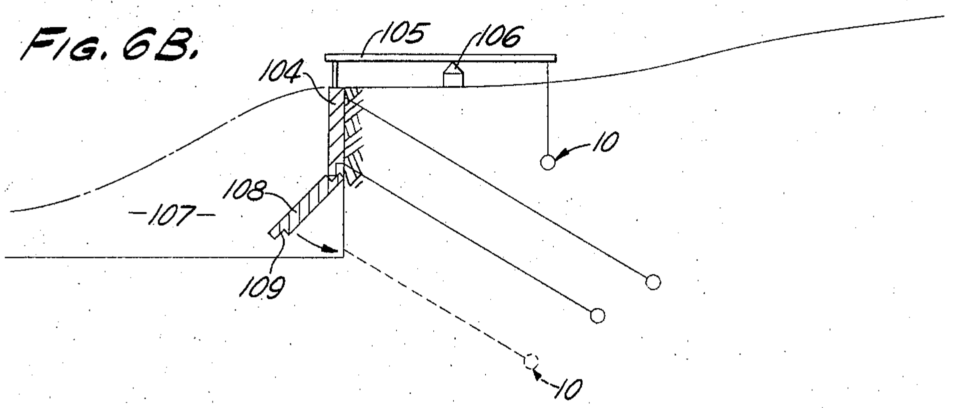
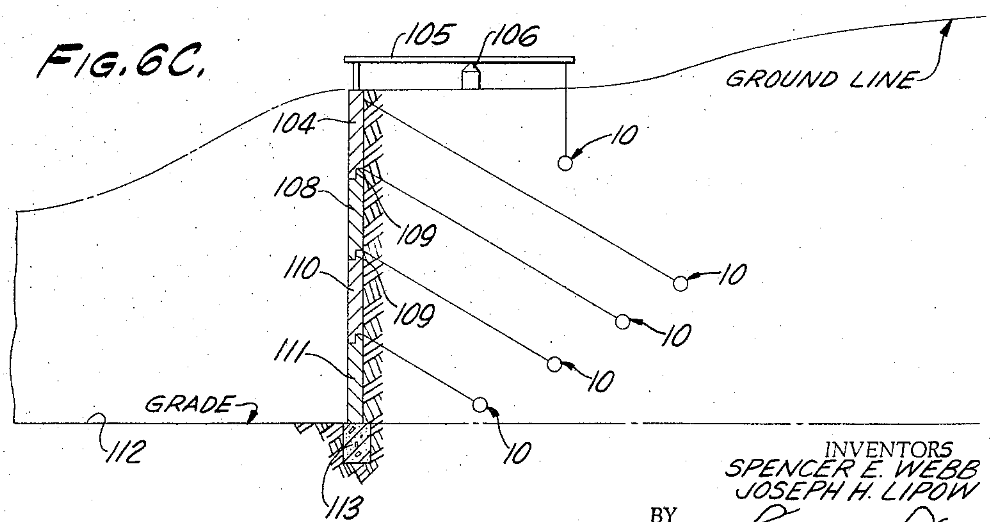


FIG. 6C.



INVENTORS
SPENCER E. WEBB
JOSEPH H. LIPOW

BY Lyon & Lyon

ATTORNEYS

METHOD OF RETAINING WALL CONSTRUCTION AND ANCHORING

Filed Sept. 26, 1963 5 Sheets-Sheet 5

FIG. 7A.

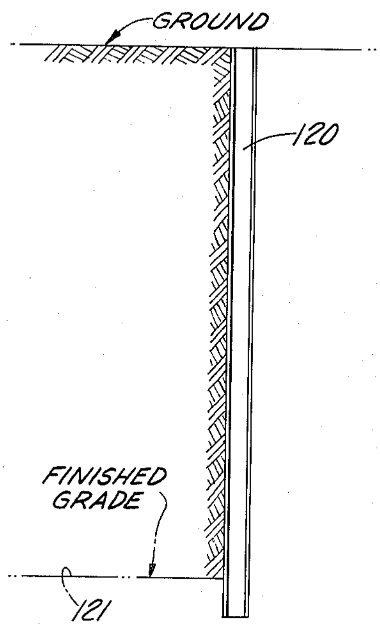


FIG. 7B.

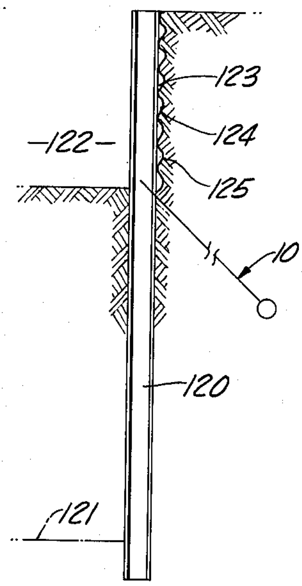
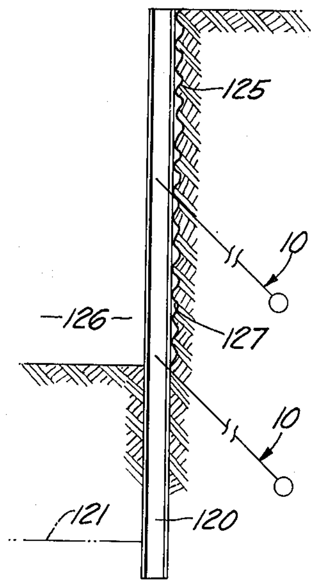


FIG. 7C.



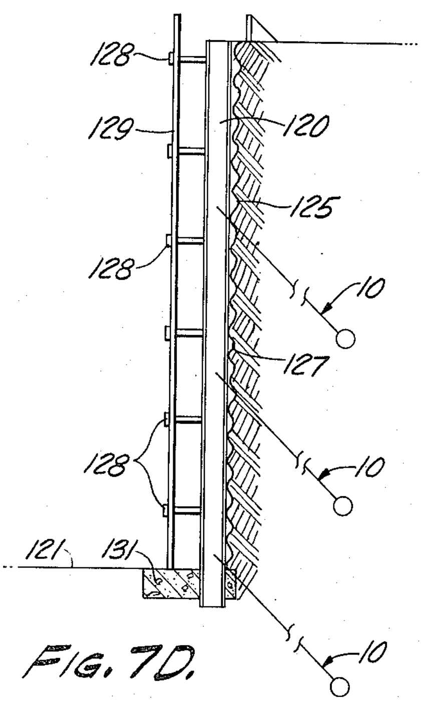
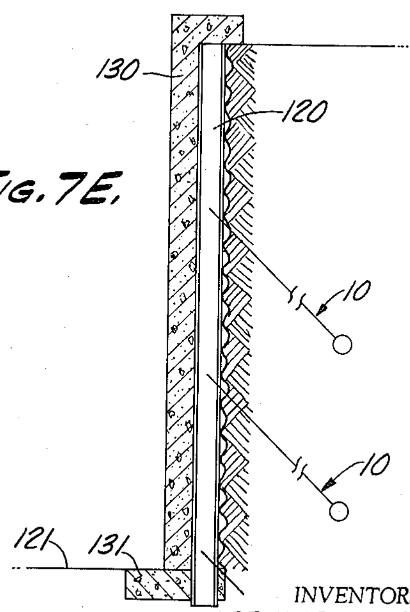


FIG. 7D.

FIG. 7E.



INVENTORS
SPENCER E. WEBB
JOSEPH H. LIPOW
BY
Lyon & Lyon
ATTORNEYS

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3,250,075
METHOD OF RETAINING WALL CONSTRUCTION AND ANCHORING

Spencer E. Webb, Los Angeles, and Joseph H. Lipow, Inglewood, Calif.

Filed Sept. 26, 1963, Ser. No. 311,897
1 Claim. (Cl. 61—39)

This invention relates to a system for producing a ground-mounted tension anchor and systems for constructing retaining walls with tension anchors.

Retaining walls may be classified in two broad categories; first, the type installed against cut banks of ground to retain the cut bank from falling into the excavated portion, and second, the type where the wall is constructed and the area behind and uphill from the wall is filled to produce, for example, a large level plot than could otherwise be obtained. Each of these types of walls conventionally employ a footing of substantial size for supporting the weight of the wall and a cantilever portion for resisting the overturning moment of force produced by the retained ground. When the height of the retaining wall is relatively limited the conventional means for construction are generally adequate and no unusual procedures need to be used that would incur unusual construction or material costs.

However, for relatively high walls of the first type, i.e., cut bank retaining walls, it is generally necessary either to slope the bank or to use shoring for restraining the cut bank during continued excavation and before the wall is erected. This shoring is in itself expensive and also interferes with the continued excavation and final wall construction. Further, an extremely high cut bank retaining wall must be of such extreme size proportions, for example, the wall thickness at the base, that the cost of materials for such a wall often is prohibitive.

With relative high retaining walls of the second type, i.e., back filled retaining walls, it is conventional to use tie-backs for assisting in supporting the wall to thereby obviate the necessity of the wall being of the extreme size proportions mentioned above. These tie-backs, also commonly known as "dead men," are usually comprised of a post or the like anchored in a ground a substantial distance behind the retaining wall and a cable or the like extending between the post and the wall. Since there may be a series of these tie-backs horizontally spaced along the wall and each generally positioned above the orginial ground level, the tie-backs substantially interfere with the operations of back filling with earth and properly compacting the backfill. Good construction practice and many building codes require that the fill earth be placed in layers of limited depth and compacted between layers and, therefore, the filling and compaction of earth behind a retaining wall using these tie-backs becomes rather a tedious and difficult operation. Where necessary the tie-backs have also been used on cut bank type retaining walls by digging trenches back from the wall, setting an anchor member, running a cable in the trench from the wall to the anchor member, and then filling and compacting the trench.

It is an object of this invention to provide a novel system for producing a ground anchored tension member and employing such tension member in novel systems of retaining wall construction.

Another object of this invention is to provide an inexpensive and consistently effective method and apparatus forming an anchor in the ground to which tension may be applied.

A further object of this invention is to provide novel systems for constructing relatively high retaining walls in multiple stages wherein novel type anchors are employed but do not interfere with or require back filling and compacting and the need for shoring excavated walls is usually eliminated.

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Still another object of this invention is to provide a novel system for anchoring temporary shoring to an excavation wall for minimizing the obstructions formed by shoring and assisting in construction of the final wall.

Other and more detailed objects and advantages of this invention will appear from the following description and the accompanying drawings.

In the drawings:

FIGURE 1 is a perspective view with portions broken away and shown in section of a tool for creating the cavities in the ground that are employed in the systems of this invention.

FIGURE 2 is a sectional elevation view of the anchor system of this invention although the view is not necessarily oriented in the most common angular position with respect to a vertical plane.

FIGURE 3 is a sectional elevation view similar to FIGURE 2 illustrating a modified form of the anchor arrangement of this invention.

FIGURES 4A, 4B and 4C are diagrammatic elevation views of the progressive steps of our system for constructing a cut bank type retaining wall.

FIGURES 5A, 5B and 5C are diagrammatic elevation views of the progressive steps of our system for constructing a bank fill type retaining wall. FIGURE 5D illustrates a modified form of this type of retaining wall.

FIGURES 6A, 6B and 6C are diagrammatic elevation views of the progressive steps of our modified form of system for constructing a cut bank type retaining wall.

FIGURES 7A, 7B, 7C, 7D and 7E are diagrammatic elevation views of the progressive steps of our system for shoring the walls of an excavation and constructing a retaining wall for the excavation.

Referring now more particularly to FIGURE 2, the tension anchor assembly, generally designated **10**, of this invention is constructed by boring a hole **11** in the ground in the desired direction and to the proper depth and then creating an enlarged cavity **12** at the desired location in the hole **11** which is generally at the bottom. A tension member such as a rod **13** of the proper length and having an enlarged assembly, generally designated **14**, mounted on the lower end thereof is then lowered into the hole **11**. Fluid concrete **15**, or any other suitable fluid material that hardens to a mass having substantial compressive strength, is then introduced into the hole **11** in a sufficient quantity to fill cavity **12** and at least a portion of hole **11**. After the concrete **15** has hardened and is thereby secured to the rod **13**, an upward tension force may be applied to rod **13** causing the mass of concrete within cavity **12** to compress the portion **16** of the ground above the cavity thereby transmitting the load to the surrounding ground.

The depth of hole **11** and thus the distance between cavity **12** and the surface of the ground will vary for the particular use that is to be made of the anchor assembly **10** and the condition and type of soil encountered. It has been found that if the cavity **12** is relatively near the surface then an applied tension load will cause a cone of earth to be sheared from the surrounding ground and lifted thereby resulting in the anchor assembly failing to sustain any further tension load. While the actual shape of such cone of earth will be irregular, in general it will be a cone having an axis aligned with the tension rod **13** with the angle between the tension rod **13** and the conical surface substantially equal to the shear angle of the soil. The tension required to produce this type of failure is approximately equal to the weight of the volume of earth within the cone plus the shear forces. However, it is specifically contemplated by this invention that the cavity **12** of the anchor assembly **10** be at a depth greater than that which would result in failure by lifting this cone of earth. At such a depth the application of excessive tension forces on rod **13** will result in the "ball" of concrete formed within cavity **12** moving upwardly and compressing the earth outwardly and upwardly thereabove to create an enlarged bore having a diameter equal to the diameter of the concrete ball. Thus, the tension force that may be applied before the ultimate strength of the anchor is achieved far exceeds that which may be applied when failure occurs in the form of the lifting of a cone of earth. By way of illustration it has been found that in most soil conditions a depth of about 15 feet is the minimum preferred depth. Also by way of example and not limitation, a tension anchor assembly **10** was constructed wherein the bore **11** was of five-inch diameter and 16 feet deep, the cavity **12** was of 19-inch diameter, and sand and three-eights inch pea-gravel were used in the concrete. This anchor assembly was able to withstand a continuously applied tension load of 50 tons for 24 hours and a tension load of 75 tons applied for a short duration before the load test was discontinued.

The enlarged assembly **14** may be of any convenient form capable of adequately transmitting the load between the concrete mass and the rod. For example, it has been found adequate to employ three flange plates **17** spaced from each other by heavy ribs **18** with the lowermost plate **17** engaging a nut **19** on the tension rod **13**. A spacer **20** may be used to properly position the assembly **14** from the bottom of the hole. The wall **21** or the like that is to be secured to the ground by the anchor member may be provided with a sleeve **22** through which rod **13** passes and an appropriate plate **23** is used to transmit the force from the tension adjusting nut **24** to the wall.

In the modified form of tension anchor assembly **10*a*** illustrated in FIGURE 3, a plurality of cavities **12*a*, 12*b*** and **12*c*** are provided at different depths for increasing the tension that may be applied on the rod **13*a***. This modification is particularly useful where extreme tension forces on the rod **13*a*** may be anticipated or the soil conditions are such as to be easily compressible. The use of a plurality of cavities results in distributing the tension load applied to the rod **13*a*** over a plurality of areas and strata of ground. FIGURE 3 also illustrates a modified form of enlarged assembly **14*a*** which may be employed wherein arm members **17*a*** are hinged to the rod and spring biased to extend outwardly into the adjacent cavity for adequately transferring the load from the surrounding concrete **15*a*** to the rod **13*a***. FIGURE 3 also illustrates completely filling the hole **11*a*** with concrete to the surface which while not structurally necessary is preferred for preventing caving in of the walls of the hole or water filling the hole to weaken the compressive strength of the earth above the cavity.

Referring in detail to FIGURE 1, a cavity tool, generally designated **30**, is illustrated for creating the heretofore described cavity **12**. The physical construction of tool **30** forms no part of this invention and is illustrated and described merely for purposes of disclosing one manner in which the cavity **12** may be created. It will readily appear to those skilled in the art that other devices may be used instead of tool **30** for properly creating cavity **12** without departing from this invention. Tool **30** includes a mandrel **31** adapted to be attached to an appropriate drill string for lowering into the hole **11**. Mandrel **31** has a central bore **32** and a flange **33**. A lower mandrel **34** has an upwardly extending tube **35** for closely surrounding the downward extension of mandrel **31** and a key **36** joins mandrel **31** and tube **35** for permitting relative axial movement therebetween and preventing relative rotation. Lower mandrel **34** is also provided with a central bore **37** communicating with laterally extending ports **38**. A thrust bearing **39** is connected to the top portion of mandrel **34** and the upper flange is rotatable relative to the mandrel. A plurality of blades **41** extend longitudinally between and are pivotally connected to flanges **33** and **40**. In their normal position blades **41** are bowed slightly outwardly. Each blade **41** is provided with an appropriate cutting edge **42**. The tool **30** is lowered into the hole **11** and with mandrel **34** engaging the bottom of the hole the tool is rotated by means of mandrel **31** which is connected to the drill string. A downward force is applied to the drill string, and therefore to mandrel **31**, during rotation thereby forcing the blades **41** to bow outwardly and engage the wall of the hole. The preferred operation is to draw a suction on the drill string during rotation whereby the cuttings by blades **41** are drawn through ports **38** between the blades and upwardly through bores **37** and **32** and the drill string. Continued rotation and application of downward force causes the tool **30** to ream the cavity **12** to the desired dimensions. The tool **30** is then removed and tension anchor assembly **10** installed as heretofore described. In this manner the desired shape of cavity **12** is created wherein the cavity is essentially concentric with the hole **11** and of the proper overall diameter to achieve the desired characteristics of the tension anchor.

The retaining wall system of FIGURES 4A, 4B and 4C is for retaining a bank of ground **50** during and after a portion **51** of the bank, outlined by phantom lines, is cut away to form a new level grade **52** or the like. If a retaining wall were not employed the bank **50** would have to be cut along a design slip plane **53** of a predetermined angle to prevent subsequent sliding of earth. Design slip plane **53** is at a particular angle to the horizontal and may be calculated by soil engineers or required by the appropriate building and construction codes. In the construction system of this invention a first stage of ground **54** is excavated at the top of where the retaining wall will be located and only to a vertical depth which is practical and permissable for avoiding complex shoring of the wall **55** of the excavation. Tension anchor assemblies **10**, diagrammatically illustrated in these figures, are then installed at the upper and lower limits of this first excavation in the manner heretofore described. These tension anchor assemblies **10** are positioned at a substantial angle to the verticle and extend to a depth beyond the designed slip plane **53**. The tension anchor assemblies **10** are spaced horizontally along the excavation at appropriate intervals for producing the desired retention forces. A retaining wall segment **56** of a height equal to the wall **55** of the excavation is then installed. The wall **56** is secured to the tension anchor assemblies **10** and the appropriate tension is applied to hold the wall in place. Wall **56** may be of any convenient type such as but not limited to prestressed concrete, precast concrete, cast-in-place concrete, masonry block, steel panels and the like. A second stage of earth **57** is then excavated immediately in front of wall **56** to the desired depth as heretofore described. Tension anchor assemblies **10** are then installed at horizontally spaced locations along the lower end of the excavated wall **58** and a retaining wall **59** is installed in the same manner heretofore described. The top of wall **59** is connected to the base of wall **56** by an appropriate structural member **60** for transmitting the outward load on the top of wall **59** to the tension anchor assemblies **10** extending from the base of wall **56**. Structural members **60** may be of any convenient form and may even include an impervious apron to prevent water from seeping down behind wall **59** from the area in front of wall **56**. This procedure of excavating in stages, installing tension anchor assemblies **10** at base of each excavation, installing retaining wall segments **61**, **62**, etc., and connecting the wall segments with structural members **60** is repeated until the desired new grade level **52** is reached. An appropriate footing **63** may be provided at the base of the lowermost retaining wall segment to prevent undesirable erosion and to support the vertical load developed by the wall segments and anchor assemblies. For clarity of illustration the retaining walls **56, 59, 61** and **62** have been illustrated as being laterally spaced a substantial distance whereas in actual practice such spacing may be reduced to the minimum necessary to adequately support the previously installed retaining wall segment during excavation therebelow.

The retaining wall system of FIGURES 5A, 5B and 5C is for retaining a bank of fill earth in an area **70** above the original ground line **71** to create a new grade level **72**. Without a retaining wall, generally located by phantom line **73**, the area **70** could only be filled to the design slip plane **74** and a large area of the new grade level **72** would be lost. As is conventional the original ground line **71** is benched as shown by phantom lines **75** for obtaining an optimum backfill and compaction. A wall segment **76**, of any of the convenient types heretofore described with respect to wall segment **56**, is constructed to a limited height. If the wall segment **76** and subsequent wall segments are to be of a preformed type rather than formed in place it is preferred that vertical columns, coinciding with phantom line **73** be set in concrete footings **77** before wall **76** is installed. The columns are longitudinally spaced at appropriate intervals for supporting the wall segments and of a total height equal to the proposed total wall height. A plurality of tension anchor assemblies **10** are installed at the base of wall segment **76** and extend at a substantial angle to the vertical into the area behind the retaining wall. Where the heretofore-described columns are employed the tension anchor assemblies **10** are preferably located at each column and connected thereto. The wall segments are then placed behind the columns. A first stage of earth **78** is then filled in and compacted behind wall segment **76** and to the height of wall segment **76**. Wall segment **76** is preferably of a height and adequate strength for permitting this backfill and compaction procedure without overturning the wall segment and without requiring bracing of or tie-backs to the top portion of this wall segment. Further, the wall segment need not be of sufficient strength independent of further anchoring to resist the overturning moment caused by the retained ground when the wall is finished to its complete height as would be required with conventional construction methods. Referring specifically to FIGURE 5B, a second series of horizontally spaced tension anchor assemblies **10** are then installed from the top of wall segment **76** and through the already compacted ground **78**. A second wall segment **79** of relatively the same height and structural characteristics as wall segment **76** is then installed on top of and connected to wall segment **76**. The second stage of earth **80** is then backfilled and compacted. This procedure of installing tension anchor assemblies **10** at the top of the last-placed wall segment, installing retaining wall segments **81**, **82**, etc., and backfilling and compacting ground areas **83**, **84**, etc. is repeated until the desired new grade **72** is reached. In this manner the area behind the retaining wall that is being backfilled and compacted is completely unobstructed by tie-backs or the like and therefore backfilling and compaction may be readily and efficiently completed. Each wall segment is tied back both top and bottom by tension anchor assemblies **10** for supporting the loads of subsequent backfilling and compaction of higher levels and for retaining the earth after the entire retaining wall and backfill has been completed. Thus, each wall segment may have the structural characteristics heretofore mentioned.

FIGURE 5D illustrates a modified form of the backfill type retaining wall system illustrated and described with respect to FIGURES 5A, 5B and 5C. In this system of FIGURE 5D it is again preferred, although not essential, that a plurality of horizontally spaced columns **90** be set in concrete **91** at the location of the base of the wall. A first wall segment **92**, again of any type and of limited height, is then installed behind the columns. A tension anchor assembly **10** may be installed at each column **90** at the base of wall segment **92**. The first stage of backfill and compaction to the top of wall segment **92** is completed and then a second series of tension anchor assemblies **10** may be installed along the top of that wall segment. A second series of columns **93** are then set in concrete **94** in the filled and compacted ground. A second wall segment **95** is then installed behind columns **93** and tension anchor assemblies **10** are installed from the top of wall segment **90**. This series of procedures is continued until the desired new grade **96** is reached. A structural member **97** may be employed between the top of each wall segment and the bottom of the next higher wall segment similar in purpose and construction to the heretofore-described structural member **60**, and therefore it is obvious that the anchor assemblies **10** may be installed at the base of each successive wall segment rather than at the top of each preceding wall segment. The successive wall segments have been illustrated as being spaced a relatively substantial distance for clarity of illustration, whereas in actual practice there generally will be a greater proportional difference between the height of a wall segment and its distance from each adjacent wall segment.

Referring more particularly to FIGURES 6A, 6B and 6C, a modified form of retaining wall system for retaining a cut bank is illustrated and in contrast to the system of FIGURES 4A, 4B and 4C the completed wall will be substantially vertical. A first stage excavation of ground **101** is made leaving an exposed wall **102** of a height having all of the characteristics of the heretofore described wall **55**. Tension anchor assemblies **10** are installed at the top and the base of exposed wall **102** and preferably extend in a more horizontal direction than any of the heretofore-described tension anchor assemblies **10**. The tension anchor assemblies **10** also preferably extend a depth beyond the design slip plane **103** drawn from a location that will be the base of the completed retaining wall. A wall segment **104** of any convenient type such as those described with respect to wall segment **56** is then installed against wall **102**. Means are provided for supporting some of the downward vertical load on wall segment **104** and these means may include a cantilever beam **105** connected at one end to the wall segment **104**, supported intermediate its ends by means **106**, and connected at its other end to the ground such as by a vertically extending tension anchor assembly **10**. The top and bottom of wall segment **104** are secured to the tension anchor assemblies **10**. A second stage excavation of ground **107** is then made to the desired depth and extends beneath wall segment **104**. Another series of horizontally spaced tension anchor assemblies **10** are installed at the base of this excavation and a second wall segment **108** is installed below wall segment **104**. In FIGURE 6B wall segment **108** is specifically illustrated as a preformed type wall which is moved into place, although it is to be understood that a cast-in-place type wall may be employed. It is preferred that means **109** be provided at the top and bottom of each preformed type wall segment for interlocking and connecting such wall segment with previously and subsequently installed wall segments. This procedure of excavating in stages, installing tension anchor assemblies **10** at the base of each excavation, and installing a wall segment **110**, **111**, etc. is repeated until the desired new grade level **112** is reached. An appropriate footing **113** may be provided at the base of the lowermost retaining wall segment to prevent undesirable erosion and to assist in supporting the entire wall in the vertical direction. The cantilever means attached to wall segment **104** may then be removed. It may be seen that it is preferred to place tension anchor assemblies **10** at an angle more closely approaching the horizontal so that there is no excessive downward force on the attached wall segment. In fact, under many conditions, it may be possible to develop a sufficient frictional force between the wall segment and the excavated wall to adequately support the wall segment while subsequently excavating therebelow thereby eliminating the necessity for any vertical support means such as the desired cantilever beam **105**.

Referring now to FIGURES 7A, 7B, 7C, 7D and 7E, a system is illustrated for shoring the walls of an excavation during the excavation and using the shoring means for completing a vertical retaining wall that may also be a structural wall such as in the basement of a building. A plurality of longitudinally spaced soldier beams **120** are installed along the desired line of the excavation and to a depth beyond the desired finished grade **121** of the excavation. The beams **120** may be driven into the ground or placed in drilled holes. A first stage of ground **122** is excavated including the area between the soldier beams **120** and to a small depth **123** behind the soldier beams. The depth of the excavation of ground **122** should be such that good workmanlike practice and building codes do not require shoring of the exposed wall **124**. Appropriate lagging **125** is then installed behind and extends between the soldier beams **120**. Lagging **125** may be of any convenient type depending for example on whether or not waterproofing of the final wall is required and in the drawings lagging **125** is illustrated as corrugated sheet steel. A tension anchor assembly **10** is then installed at the base of excavation **122** and secured to the soldier beam **120**. A second stage of excavation of ground **126** is then made to the heretofore-described desired depth. A second segment of lagging **127** is installed and a second series of tension anchor assemblies **10** are installed at the base of the excavation of ground **126**. This procedure of excavating to a limited depth in stages, installing lagging, and installing tension anchor assemblies is repeated till the desired finished grade **121** is reached. Thus, the entire excavation has been made without any shoring being positioned in the area of excavation to obstruct the excavation. Referring specifically to FIGURE 7D, appropriate bolts **128** may be installed on the soldier beams **120** for securing a form **129** at a location spaced from the lagging **125**, **127**, etc. A concrete wall **130** may then be cast in place between the form **129** and the lagging and surrounding the soldier beams **120**. A footing **131** may also be provided around the base of the soldier beams and the wall **130**.

Having fully described out invention, it is to be understood that we do not wish to be limited to the details herein set forth or to the details illustrated in the drawings since it will readily appear to those skilled in the art that numerous modifications and combinations may be made without departing from our invention which is of the full scope of the appended claim.

We claim:

In a method of constructing a relatively high wall for retaining filled ground, the steps of: boring a hole in the ground at the desired base of the wall at a substantial angle to the vertical in a direction beneath the ground to be retained by the wall, enlarging the diameter of a portion of the hole at a substantial depth, securing a tension member in the hole by filling the enlarged diameter portion of the hole with a hard setting material, erecting a wall segment of a height capable of retaining earth filled therebehind to such height and equal to only a portion of the total wall height, securing said wall segment to said tension member and applying tension to said member to securely locate said wall segment, placing fill earth behind the wall and compacting the earth to the level of the top of the wall segment, installing another tension member at the top of said wall segment by boring a hole in the filled ground at a substantial angle to the vertical and enlarging the diameter of a portion of the hole at a substantial depth and securing such tension member in the hole by filling enlarged diameter portion with a hard setting material,, securing the top of said wall segment to the latter said tension member and applying tension to the latter said member to securely locate said wall segment; and successively erecting additional wall segments at successive different vertical elevations to a desired total wall height, back-filling and compacting earth behind each successive wall segment, installing a tension member from the top of the previously installed wall segment subsequent to such back-filling and compacting and before erecting the next successive wall segment thereabove, and securing the base of each said successive wall segment to the top of next previously erected wall segment and tension member prior to erecting the next wall segment.

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CHARLES E. O'CONNELL, *Primary Examiner.*

JACOB L. NACKENOFF, *Examiner.*

JACOB SHAPIRO, *Assistant Examiner.*