Jan. 20, 1970 H. SCHNABEL, JR 3,490,242

METHOD AND STRUCTURE FOR REINFORCING AN EARTHEN EXCAVATION

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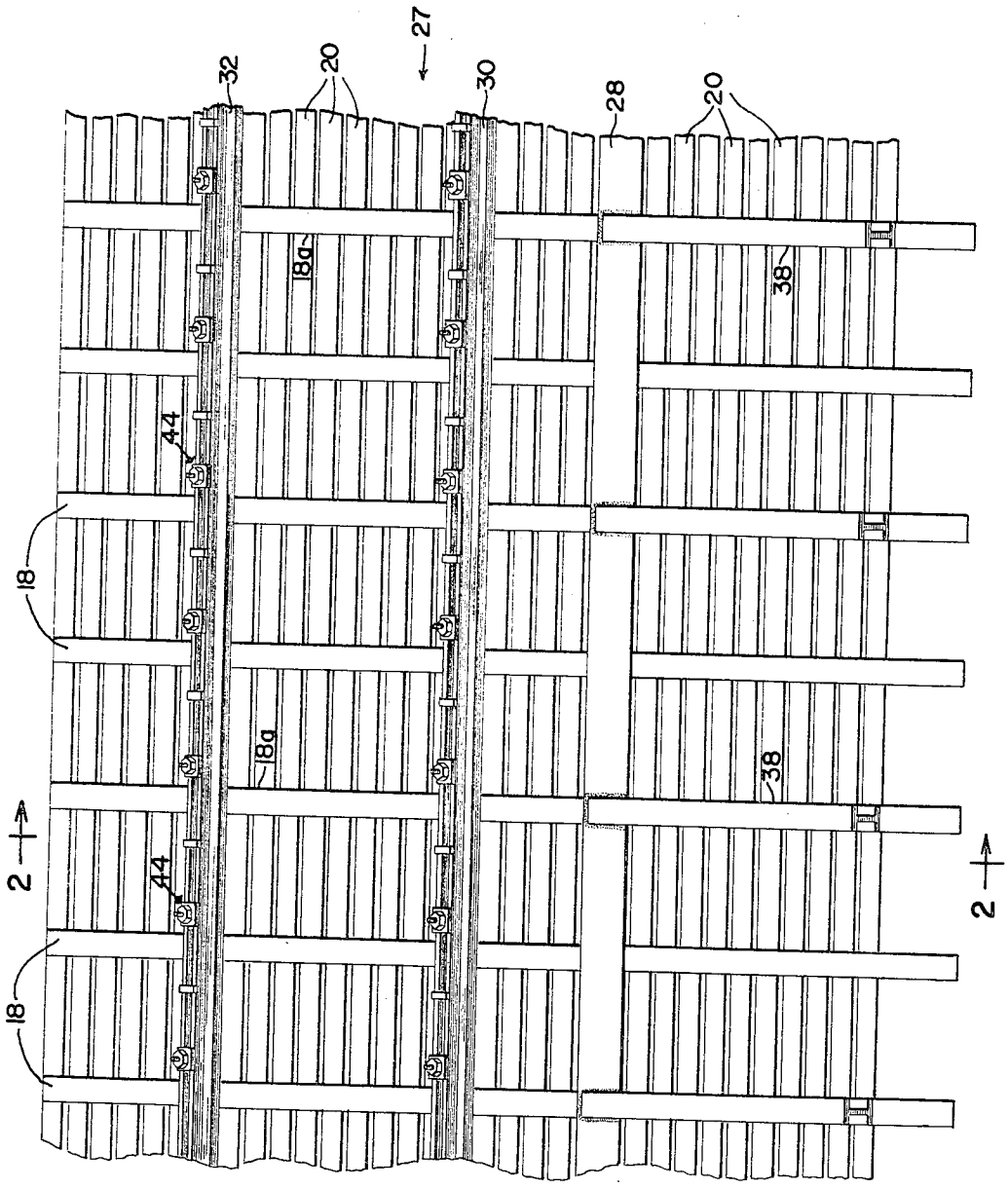


FIG. 1

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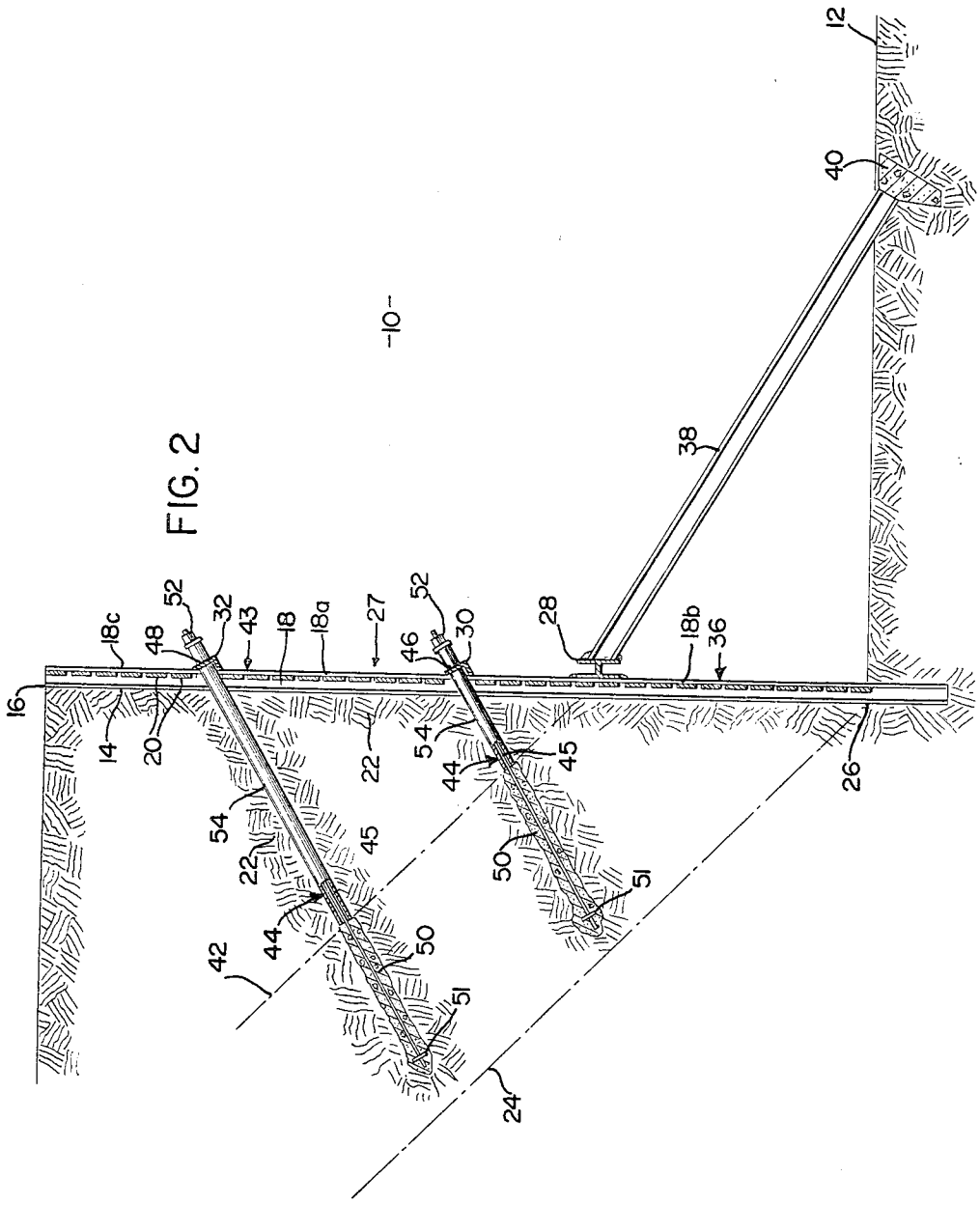
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FIG. 2



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METHOD AND STRUCTURE FOR REINFORCING AN EARTHEN EXCAVATION

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ABSTRACT OF THE DISCLOSURE

An upright face of an earthen excavation is reinforced by supporting the lower portion only of a sheeting wall covering the face with external rakers to produce a theoretical plane of earth slippage substantially higher than such theoretical slippage plane would be if the wall had no external support. The upper portion of the wall is shored by installing internal tie-backs between the upper portion of the wall and anchors located in the earth largely between the higher slippage plane and the lower slippage plane.

BACKGROUND OF THE INVENTION

The instant invention relates to earth excavating and more particularly to reinforcing the side faces of excavations to support the surrounding earth. In particular, the invention is applicable to excavations made incident to construction of building foundations and the like.

When such excavations are made, their side walls must be reinforced to preclude the surrounding earth from shearing off along sloping planes of rupture (planes of earth slippage) and falling into the excavation. In this respect it is to be recognized that such shearing (or slippage) if allowed to occur, would at least increase the amount of earth removal required and could result in collapse of adjoining streets, alleys, or the like.

Conventionally, the reinforcement of such excavations has been accomplished by first inserting a plurality of steel soldier piles into the earth around the periphery of the area to be excavated. During excavation, horizontal lagging is installed between the piles. Generally, the piles and lagging must be further braced, which has commonly been accomplished by attaching horizontally extending wales between the piles and installing a plurality of angularly disposed rakers between the bottom of the excavation and each wale. Manifestly, such rakers must be installed prior to removal of all of the earth from the excavation and trenches are dug for this purpose. Thereafter, the rakers while providing the required support, interfere with both the process of excavating and the construction following excavation.

More recently, the problem has been attacked by the use of prestressed tie-backs behind the sheeting wall. Such tie-backs have been effective in reducing the costs of the excavating process itself, by eliminating the use of rakers in the excavation. However, the cost of the tie-backs installation usually exceeds the cost of equivalent rakers by an amount greater than the saving in excavation and subsequent construction costs. Furthermore, tie-backs frequently are not usable where the foundations of buildings on adjoining land are near the property line. In such cases there is insufficient room for the tie-backs which have been required to be anchored behind a theoretical slippage plane which intersects the sheeting wall at the bottom of the excavation and extends angularly upwardly therefrom through the earth behind the wall.

SUMMARY OF THE INVENTION

It is a primary object of this invention to provide an excavation reinforcement method and structure wherein advantages of prior art methods are gained while the disadvantages of such methods are eliminated or minimized.

An important object of the invention is to provide a method and structure for reinforcing an earthen excavation which finds wide application and reduces the cost of such an excavation.

Briefly, the invention contemplates a method of shoring a sheeting wall which reinforces an upright earthen face adjacent an excavation and the resulting structure. The upper portion of the sheeting wall is internally supported by a plurality of tie-backs. Each tie-back includes an anchor disposed in the earth placed behind the wall, and a tendon extending angularly downwardly into the earth behind the wall connecting the upper portion of the wall to the anchor. The tie-backs are installed by emplacing the anchors in the earth and then connecting the tendons between the anchors and the upper portion of the sheeting wall. The lower portion of the sheeting wall is externally braced by a plurality of rakers placed between the bottom of the excavation and spaced locations along the lower portion of the wall. These raker connections to the wall are placed above the bottom of the excavation. The rakers extend angularly downwardly from the sheeting wall into the excavation, and have sufficient compressive strength to raise the vertical plane of earth slippage from its normal location along a first plane intersecting the sheeting wall at the bottom of the excavation to a second plane intersecting the sheeting wall at or near the raker connections to the wall. Each of the anchors are emplaced with at least a major portion thereof positioned between the first nad second planes described above.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention having been generally described a specific embodiment will be discussed in detail with reference to the accompanying drawings in which:

FIGURE 1 is a fragmentary front elevational view of a vertical excavation face reinforced in accordance with this invention; and

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

DESCRIPTION OF THE PREFERRED EMBODIMENT

An earthen excavation which has been constructed and reinforced by the method and structure of this invention is broadly designated in the drawing by the numeral **10** (FIGURE 2). Excavation **10** presents a substantially horizontal subgrade surface or bottom **12** and a substantially upright face **14** which extends upwardly from bottom **12** to a line **16** at grade level which defines the upper peripheral boundary of excavation **10**. Although only a single face **14** is illustrated in the drawings, the peripheral boundary of the excavation will generally be defined by a plurality of upright faces. While the invention will be described with reference to the single face **14**, manifestly, each face of the excavation may be reinforced in accordance with the invention. In the description, the terms "earthen" or "earth," are used herein in their broad sense and are intended to include rock strata, soil or clay, and all other ground formations.

Basically, the excavation face **14** is supported (or reinforced) by a plurality of side-by-side, horizontally spaced, upright steel soldier piles **18** which may take the form of H-beams. The piles **18** are conventional and include flanges **18***a* for holding a plurality of wooden lagging members **20** in place against face **14**. The members **20** may be short sections disposed behind the outer flanges **18***a*. Alternatively, the members **20** may be longer sec-

tions extending outside of the side flanges and connected thereto by studs. The lagging **20** supported by the piles **18** prevent slippage of the earth **22** from behind face **14** into the excavation **10** in the conventional manner.

Without reinforcement, the earth **22** behind face **14** would tend to shear along a theoretical plane of slippage **24** and fall into excavation **10**. The theoretical plane of slippage **24** extends along the angle of repose of the earth material and its location can be determined approximately for any particular site by well-known methods taking into account such criteria as type of material, loading, moisture control, and the like. The plane **24** extends upwardly through earth **22** from the line of juncture **26** between the bottom surface **12** of the excavation and upright face **14**. The piles **18** along with the lagging members **20** present a sheeting wall **27** which is substantially coextensive with and bears against face **14**. However, wall **27** alone does not provide adequate support against horizontal forces and therefore must be further supported against such forces.

The piles **18** are interconnected by a plurality of elongated, vertically spaced wales **28**, **30**, and **32** which extend horizontally of face **14**, outside of piles **18**. The wales **28**, **30**, and **32** may be constructed of steel or the like and are preferably attached to piles **18** by welding.

The lower wale **28** may be an H-beam and is disposed against the lower portion **36** of wall **27**. As shown, the wale **28** is at a point about one third of the distance from the bottom of the excavation to the top of the wall, but the height of the wale **28** may vary. Normally, however, the wale would be located in the lower third of the wall. A generally horizontal row of elongated, side-by-side, horizontally spaced, angularly disposed rakers **38** are positioned to extend between surface **12** and wale **28**. Each raker **38** may be welded to wale **28** and each is anchored to surface **12** by a footing **40** which may be concrete. The rakers **38** have sufficient compressive strength to provide support for the lower portions **18***b* of piles **18** against vertical displacement and thereby provide external support for lower portion **36** of wall **27**. The compressive strength of the rakers must be sufficient to raise the theoretical plane of slippage to the plane **42** which extends upwardly through the earth from a position at or near the connection between wale **28** and wall **27**.

As shown in FIG. 2, the upper portions **18***c* of piles **18**, and therefore the upper portion **43** of wall **27**, are internally supported by a plurality of elongated, side-by-side, horizontally spaced, angularly disposed tie-back elements **44** interconnected respectively with each of the upper wales **30** and **32**. It is to be appreciated that the number of wales such as **30** and **32**, which are necessary for supporting a given wall depends on the dimensions of the wall itself, its loading and other factors. Thus, although in the preferred embodiment two wales are shown, the invention broadly contemplates usage of only a single wale or more than two to which tie-backs are connected. Moreover, if a tie-back is used near each soldier pile, the wale or wales may be discontinuous.

Wales **30** and **32** present angularly disposed bearing faces **46** and **48** respectively. The tie-back elements **44** each include a tendon **45** extending inwardly and downwardly through earth **22** from faces **46** and **48** to positions beneath and behind plane **42** where each tendon **45** is embedded in an anchor **50** of concrete or the like. A connector **52** is provided to attach each tendon respectively to the appropriate bearing face **46** or **48**. Further, each tendon extends through a corresponding hollow pipe **54** which terminates adjacent slippage plane **42** as illustrated, although the use of such a hollow pipe is not essential. Desirably the tendons **45** are placed in substantial tension when they are installed.

In the illustrated structure, each anchor **50** is elongated and extends from a position near plane **42** toward plane **24** in general alignment with the corresponding

tendon **50**. Each anchor **50** includes a transverse flange **51** on the corresponding tendon **45** for rigidly interconnecting the anchor **50** and the tendon **45**. It will be appreciated that although anchors **50** are shown as being disposed entirely above plane **24**, the same might, under some circumstances, extend beyond plane **24**. Further other forms of anchors may be used. For example an enlarged opening may be formed at the end of each tendon and simply filled with concrete. The important factor is that the anchors **50** have at least a major portion thereof positioned between plane **24** and plane **42**. Thus, at least a major proportion of the internal support for wall **27** is provided by connection of the tie-backs to the earth between planes **24** and **42**. This earth would not support such connections unless the plane of earth slippage was raised from **24** to **42** by the external rakers **38** according to this invention. Usually the anchors **50** and tendons **45** are positioned in a pair of vertically spaced mutually parallel planes.

In the practice of the method of the present invention, the line **16** is laid out at the periphery of the excavation **10** which is yet to be dug. The piles **18** are then driven into the ground at appropriate intervals along line **16**. Excavation is begun within the confines of line **16** and as upper portions of piles **18** are exposed, lagging members **20** are installed. When the level of wale **32** is reached, the same is connected to piles **18** and a row of tie-backs **44** is installed. Likewise, when the level of wale **30** is reached, the same is connected to piles **18** and another row of tie-backs **44** is installed. Thereafter, when the level of wale **28** is reached, wale **28** is installed as is a horizontal row of rakers **38**. Appropriate trenches are dug to facilitate the latter while piles **18** are still supported by earth yet to be excavated. Thereafter the excavating is completed down to the surface **12**.

Tie-backs such as **44** must be anchored behind and beneath the theoretical plane of slippage. Hence, but for the resistive action of rakers **38** and the resultant elevation of th theoretical plane of slippage (from **24** to **42**) the anchors **50** would have to be positioned entirely behind plane **24** at a resultant substantial increase in cost. Furthermore, the foundation of an adjacent structure might well prevent such positioning of the anchors. On the other hand, but for the use of tie-back elements **44**, additional rakers would have to be used to shore wales **30** and **32** externally of face **14**. Manifestly, such additional rakers would interfere with the process of excavation.

By use of the prior art methods, as the excavation proceeded, either extremely long rakers would be installed and further excavation would be impeded, or extremely long and expensive tie-backs would be installed. By use of th present invention, relatively short tie-backs are utilized, and excavation proceeds unimpeded. Likewise, further savings are made when the level of wale **30** is reached. Since tie-backs **44** support the upper portion **43** of wall **27**, only the lower portion **36** thereof need be reinforced by rakers and therefore, rakers **38** are relatively shot and present little obstruction to the remainder of the excavating. Hence, the present invention provides a method for reinforcing excavations which is adapted for substantially universal application and substantially decreases constructional costs.

What is claimed is:

1. A method of shoring a sheeting wall which reinforces an upright earthen face adjoining an excavation, said method comprising the steps of:

internally supporting an upper portion of said wall by emplacing anchors in the earth spaced behind the wall and connecting a tendon between said upper portion and each of said anchors, said tendons extending angularly downwardly into the earth behind said wall; and

externally supporting a lower portion of said wall by connecting rakers between the bottom of the excava-

tion and locations on said lower portion which are spaced apart and spaced above the bottom of the excavation, said rakers extending angularly downardly from said wall into the excavation and having sufficient compressive strength to raise the theoretical plane of earth slippage from its normal location along a first plane intersecting the sheeting wall at the bottom of the excavation to a second plane intersecting the sheeting wall near the raker connections to said wall, each of said anchors being emplaced with at least a major portion thereof positioned between said first and second planes.

2. A method according to claim **1** wherein the upper ends of said anchors are emplaced near said second plane.

3. A method according to claim **1** wherein said anchors are emplaced entirely above said first plane.

4. A method according to claim **1** wherein said rakers are connected to said wall along a generally horizontal row.

5. A method according to claim **4** wherein said rakers are connected to the lower one-third of said wall.

6. A method according to claim **4** wherein said tendons are connected to said wall along a generally horizontal row.

7. A method according to claim **6** wherein said anchors and tendons are emplaced in a plurality of vertically spaced generally parallel planes.

8. A structure reinforcing an upright earthen face adjoining an excavation, said structure comprising:

a sheeting wall bearing against said face;

a plurality of rakers connected between the bottom of the excavation and locations on a lower portion of said wall which are spaced apart and spaced above the bottom of said excavation, said rakers extending angularly downwardly from said wall into the excavation and having sufficient compressive strength to externally support said lower portion and raise the theoretical plane of earth slippage from its normal location along a first plane intersecting the sheeting wall at the bottom of the excavation to a second plane intersecting the wall near the raker connections to said wall; and

a plurality of tie-backs internally supporting an upper portion of said wall, each of said tie-backs including an anchor disposed in the earth spaced behind said wall with at least a major portion of the anchor positioned between said first and second planes and a tendon extending angularly downwardly into the earth behind said wall and connecting the upper portion of said wall to said anchor.

9. A structure according to claim **8** wherein said anchors are elongated and extend angulary downwardly from near said second plane in alignment with corresponding tendons.

10. A structure according to claim **8** wherein said anchors are disposed entirely above said first plane.

11. A structure according to claim **8** wherein said rakers are connected to said wall along a generally horizontal row.

12. A structure according to claim **11** wherein said rakers are connected to the lower one-third of said wall.

13. A structure according to claim **11** wherein said tendons are connected to said wall along a generally horizontal row.

14. A structure according to claim **13** wherein said anchors and tendons are disposed in a plurality of vertically spaced, substantially mutually parallel planes.

15. A structure according to claim **14** wherein said anchors are elongated and extend angulary downwardly from near said second plane in alignment with corresponding tendons.

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61—49, 50, 41