Jan. 4, 1966 R. E. WHITE 3,226,933

SHEETING WALL SYSTEM AND METHOD OF CONSTRUCTING SAME

Filed March 20, 1961 5 Sheets-Sheet 1

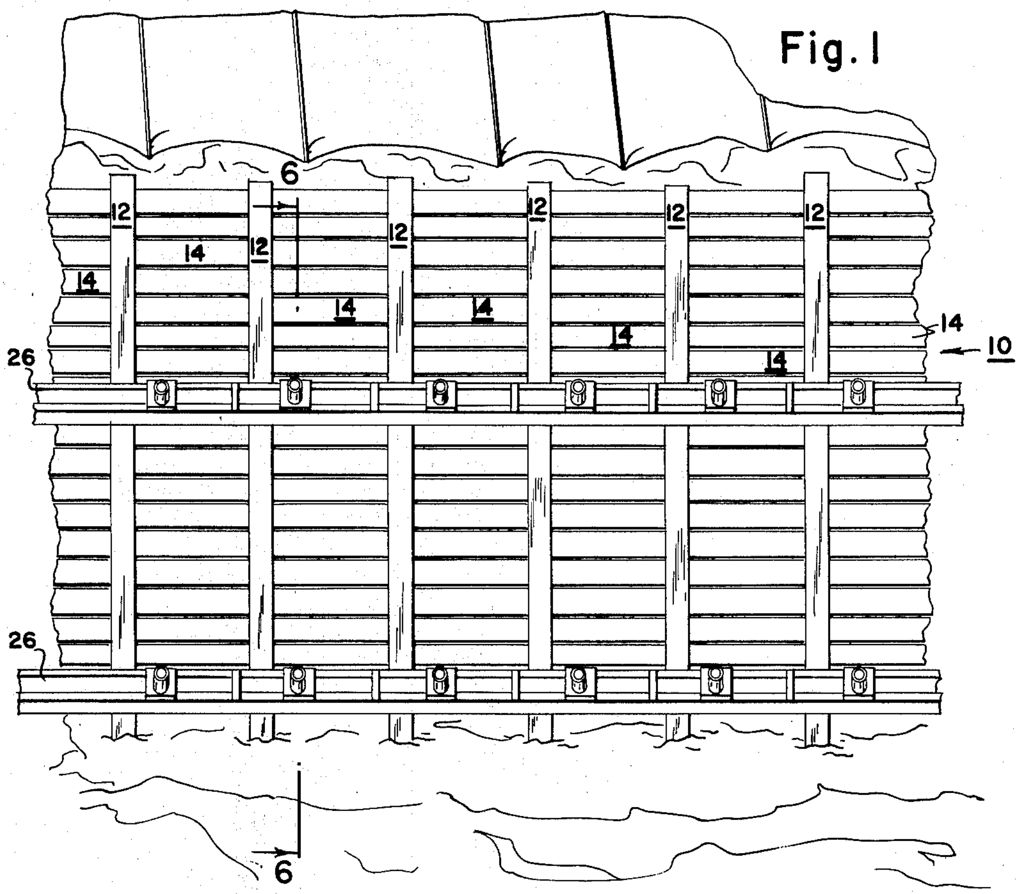

Fig. 1

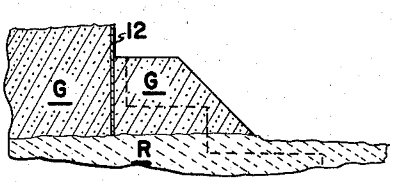

Fig. 2

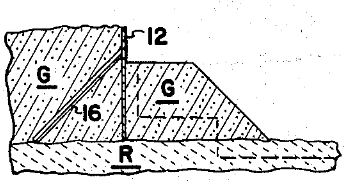

Fig. 3

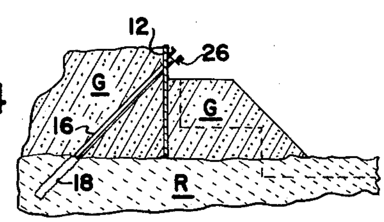

Fig. 4

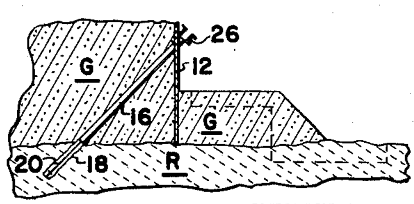

Fig. 5

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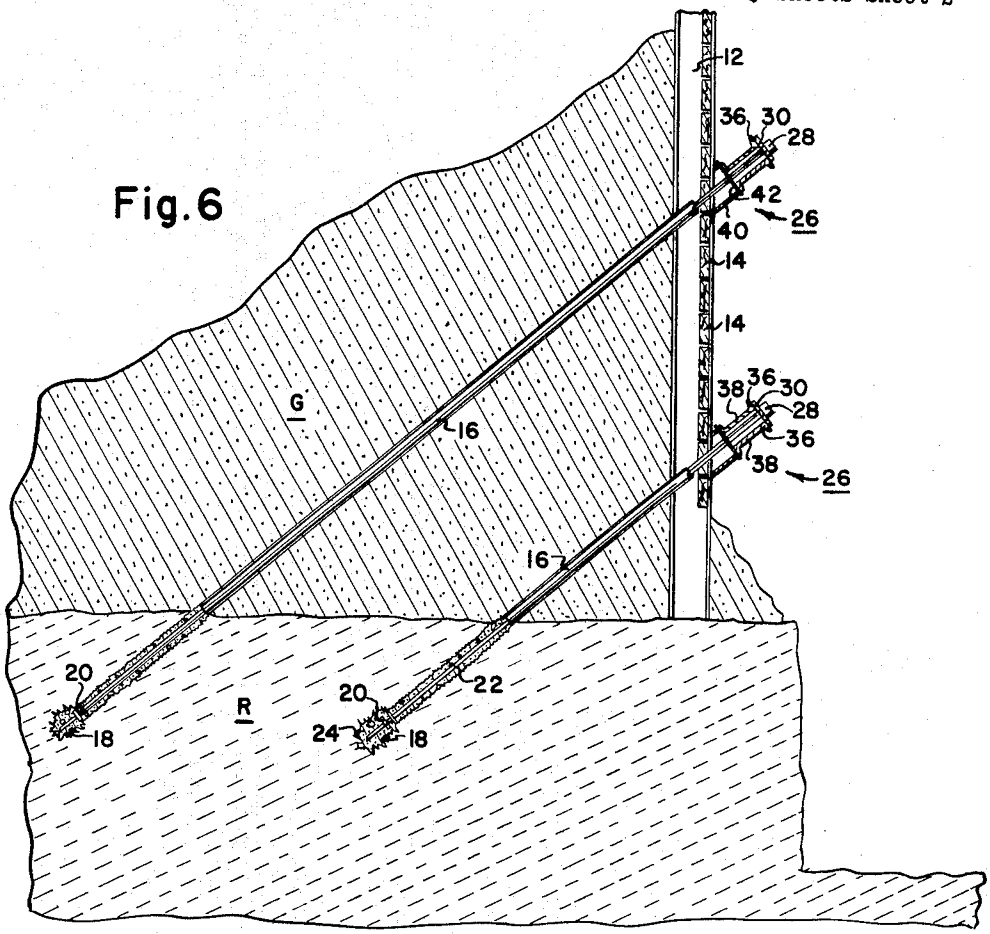
Fig. 6



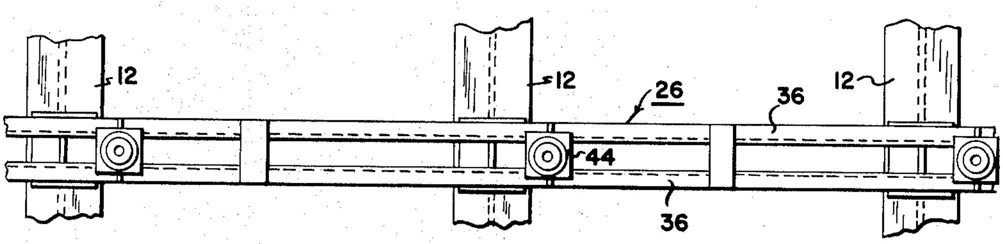


Fig. 7

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SHEETING WALL SYSTEM AND METHOD OF CONSTRUCTING SAME

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Fig. 12

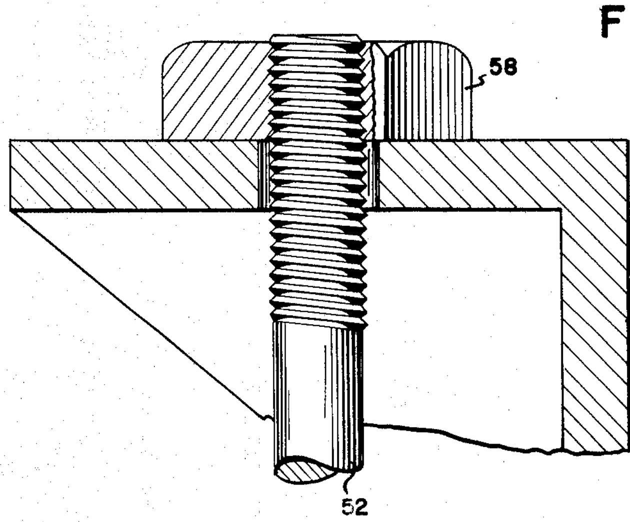
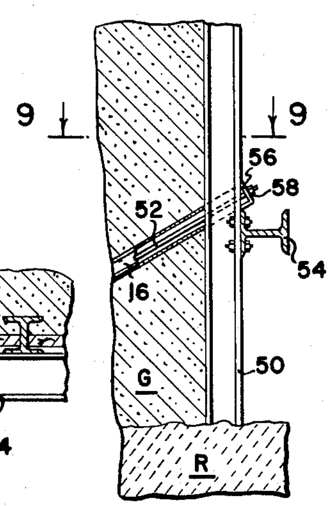


Fig. 8



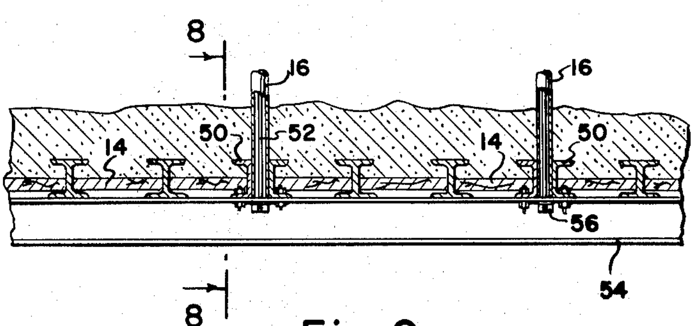


Fig. 9

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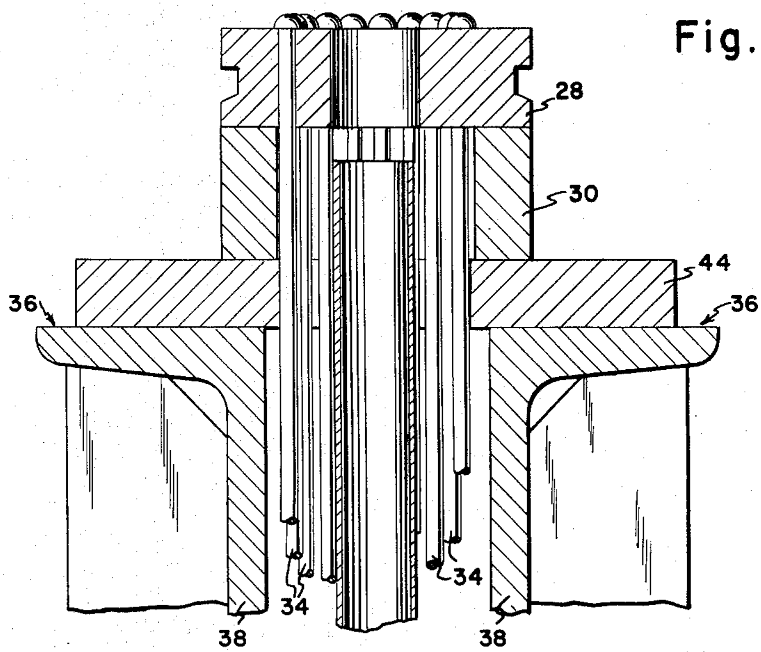

Fig.10

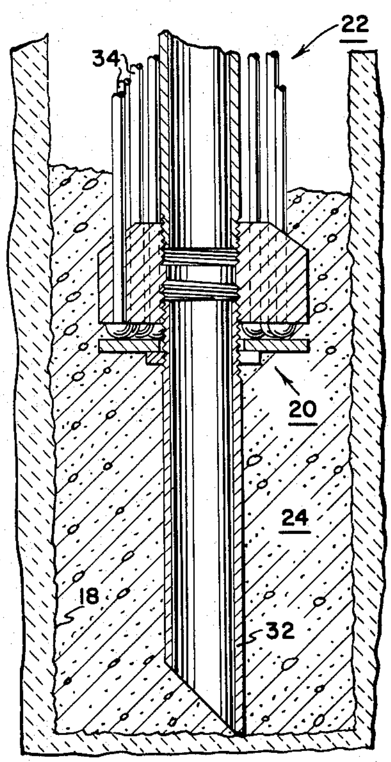

Fig. 11

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SHEETING WALL SYSTEM AND METHOD OF CONSTRUCTING SAME

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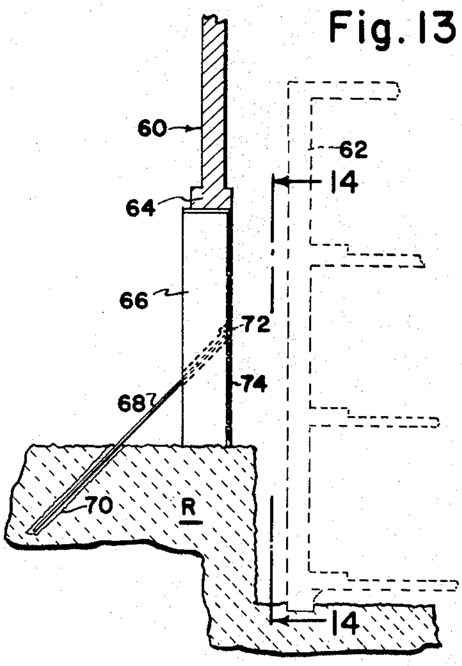
Fig. 13



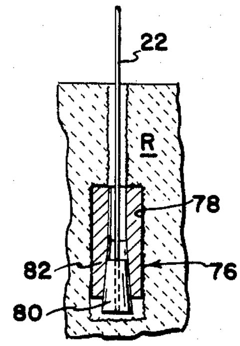


Fig. 15a

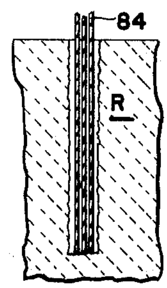
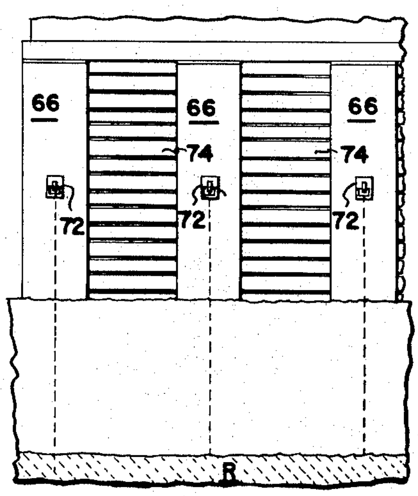


Fig. 14

Fig. 15b



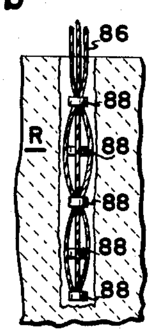


Fig. 15c

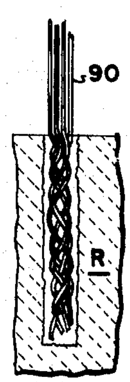


Fig. 15d

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3,226,933
SHEETING WALL SYSTEM AND METHOD OF CONSTRUCTING SAME

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Filed Mar. 20, 1961, Ser. No. 96,980
7 Claims. (Cl. 61—39)

This invention relates to a sheeting wall system and to a method of forming such a wall, and particularly to a wall system for use in retaining the banks of excavated areas.

In the construction of large buildings and other such structures, it is generally necessary to excavate to a substantial depth to permit large foundations and/or the below ground level portion of the building or structure to be constructed. When excavations are made in normal types of earth such as sand, clay, gravel or combinations of these (as is usually the case), the banks of the excavated area tend to shear off along sloping planes of rupture, the exact angle of slope being dependent upon the nature and composition of the excavated material.

Engineers have attempted to prevent the shearing off of the excavated banks in many ways. The usual means employed heretofore has been to provide sheeting walls which are shored up by angularly or horizontally directed braces placed within the excavated area, and which will be referred to as internal bracings since they are located within the excavated area. Such internally braced walls have many disadvantages and shortcomings. Not the least of these is the interference of the braces with the various phases of construction work in the excavated area.

Among the phases of construction work which are interfered with are: excavation, form work, concreting, placing of reinforcing steel, waterproofing, placing of mechanical equipment and conduits, and like operations. Also, the use of large prefabricated panel sections and similar modular systems cannot be economically used where internal braces deprive the builder of complete and unhindered access to maneuver within the excavated area.

The internal braces of the prior art are exposed to certain hazards which are very real and which create safety hazards and hindrances. Internal braces are often knocked out or damaged by careless operation of construction equipment or other phases of construction work such as blasting. If a brace is knocked out or damaged, a section of the sheeting wall may collapse or, at least, bulge out and create a hazardous condition. In order to avoid damaging the braces, equipment must be moved with great caution and extra safeguards must be maintained; and blasting must be even more carefully controlled than normally required. Thus, in order to reduce the inherent safety problems of the internal braces, economy in some of the construction operations must be sacrificed.

In contrast with prior art internally braced systems where the braces are in compression, the present invention utilizes high tensile strength tie-backs or tendons which are post-tensioned for supporting the sheeting wall. Since most braces are made of steel and it has a greater tensile than compressive strength less material is required for tendons than is required for braces.

The post-tensioning of the tie-backs or tendons compresses the overburden and places substantial passive pressure on the sliding or shearing surface or plane of the earth overburden held back by the wall. Normally the wedge of earth between the sliding plane and the wall would tend to slide into the excavation. The pressure induced by the post-tensioning mobilizes the shearing

resistance of the earth along the shear plane and, thus, the present invention is more effective than internal bracing in preventing the start of possible movement of the overburden.

Accordingly, it is an object of the present invention to provide a sheeting wall system which is economical to install and practical to use in actual construction operations.

In the drawings:

FIGURE 1 is a front view of a portion of a sheeting wall in accordance with the present invention;

FIGURE 2 is a schematic view of the first stage in the construction of the wall;

FIGURE 3 is a schematic view of the second stage in the construction of the wall;

FIGURE 4 is a schematic view of the third stage in the construction of the wall;

FIGURE 5 is a schematic view of the fourth stage in the construction of the wall;

FIGURE 6 is a sectional view of the wall of FIGURE 1 along lines **6—6**;

FIGURE 7 is an enlarged fragmentary front view of the wale and soldier beam arrangement of the wall shown in FIGURE 1 looking downwardly at a 45° angle;

FIGURE 8 is a fragmentary side view of a portion of the wall showing another embodiment of the soldier beam, wale and anchor head arrangement;

FIGURE 9 is a sectional view of the embodiment of FIGURE 8 along lines **9—9**;

FIGURE 10 is a sectional view of an embodiment of an anchor head for holding a tie-back which is comprised of several wires of high tensile strength;

FIGURE 11 is a sectional view of a rock anchor for the tie-backs of FIGURE 10;

FIGURE 12 is a sectional view of an embodiment of an anchor head for holding a tie-back which is comprised of a solid high tensile strength rod;

FIGURE 13 is a sectional view of an underpinning wall with a tie-back construction;

FIGURE 14 is a view of the wall of FIGURE 13 along lines **14—14** of FIGURE 13;

FIGURE 15*a* is a sectional view of a rock socket with a mechanical type of anchor therein;

FIGURE 15*b* is a view similar to FIGURE 15*a* with a grouted anchor;

FIGURE 15*c* is a view similar to FIGURE 15*a* with another type of grouted anchor; and

FIGURE 15*d* is a view similar to FIGURE 15*a* with still another type of grouted anchor.

The method of construction of the present invention may best be understood by referring to the drawings. In FIGURE 1, a complete sheeting wall **10** is shown which has been constructed without the necessity of internal braces.

To construct the sheeting wall **10** of FIGURE 1, a series of soldier beams **12** are driven into the ground along the desired line of the sheeting wall. The soldier beams **12** usually are wide flange or bearing pile steel piling members having a cross-sectional area such as shown in FIGURE **9**, but other suitable construction materials such as wood or concrete may also be used. The pilings may be placed by driving, drilling or boring, and in the case of concrete by pouring.

It is to be understood that the present invention is not limited to sheeting walls of the type wherein wood sheeting is used as the covering material. It is also contemplated that interlocking sheet steel piling may be used as a combination piling and sheeting material. In addition, the present invention is also applicable to the underpinning of adjacent structures during excavation operations.

Since the present invention is preferably used where there is a rock layer R not too far below ground level, the soldier beams 12 are first driven to refusal and if the rocker layer R which underlies the earth overburden G is close to the surface, the beams will become seated thereon. As shown in FIGURE 2, with the soldier beams 12 in place, the overburden G is excavated to an elevation where a safe berm of earth still remains outside the line of soldier beams 12. If necessary, sheeting pieces 14 may be advantageously placed horizontally joined to adjacent soldier beams 12 at this time to insure that the unexcavated overburden holds during further operations.

With the soldier beams 12 in place and the overburden sheeted, a series of casings or pipes 16 are then driven into the overburden G, each casing 16 being oriented at an angle of about 45° with the horizontal. The casings are placed by any conventional means such as jetting, drilling, etc., until the driving end of the casing becomes seated on the rock layer R.

With the casings 16 seated on the rock layer, rock sockets 18 are drilled in the layer R, each socket being substantially in line and extensive from the end of the casing 16. These sockets may be drilled by any suitable means, such as percussion, rotary or diamond drills which are well known in the art.

With the sockets 18 prepared anchors 20 are then placed therein with high strength tendons 22 attached thereto. Grout 24 is next introduced into the rock sockets and the anchors 20 are fixed in place. The grout 24 is permitted sufficient time to set and harden, about three days or longer, before any considerabel load is put on the tendons 22. To insure proper anchorage, a test load substantially greater than the final load is first placed on the tendons before final post-tensioning. For example, where a load of 133,000 pounds is to be finally placed on a tendon 22, an initial load of 200,000 pounds is first applied for about ten minutes before the load is reduced to 133,000.

If desired mechanical anchors such as cone type wedges may be used in place of the grouted anchors. Such mechanical anchors are usually more expensive than the grouted type and in some cases they may take longer to place.

Horizontally mounted on the soldier beams 12 and along the line of intersection between the casings 16 and the solder beams 12 is a wale 26 on which is placed anchor heads 28 for holding each tendon 22. When the final desired load is placed on the tendons 22, the head 28 becomes spaced from the wale 26 due to the elongation of the tendons by the applied load. This spacing of the head from the wale is maintained by means of spacer plates 30 so that the final applied load is constant.

Further excavation and sheeting between the soldier beams 12 may now continue. As shown in FIGURE 1, if the depth of the excation is very great additional lines of tie-backs may be provided at lower elevations if required.

The sheeting wall structure which is obtained by the method of the present invention may be best understood by a reference to FIGURES 1 and 6–11 and the particular structure illustrated therein. The wall comprises a frame of vertically aligned soldier beams 12 driven to refusal and at least one row of wales 26 directed substantially horizontally and connected to the soldier beams 12, a series of tendons 22 in the form of tie-backs anchored beyond the line of beams 12 and maintained under a high tensile load, and sheeting 14 horizontally positioned and affixed to the frame of soldier beams 12 and wales.

The tie-backs or tendons 22 of the illustrated structure offer no interference with work operations being conducted in the excavated area. This is particularly advantageous in a case where a building or a similar structure is to be built on a limited plot of land in a crowded city or industrial area. If the building is to abut against existing structures care must be taken to insure that such structures are not disturbed by the excavation.

As stated previously the present invention is also applicable to underpinning adjacent structures during excavation operations. As shown in FIGURES 13 and 14 an existing structure 60 is adjacent to a building 62 which is to extend below the elevation of the structure 60. Beneath the bottom of the footings 64 of the existinng structure 60 a series of underpinning piers 66 are placed. These piers 66 rest on the rock layer R in much the same manner as the soldier beams 12.

The piers 66 are held in place during construction of the building 62 by means of a series of tendons 68. Each tendon 68 is anchored in a rock socket 70 by a suitable anchor and also connected to an anchor head 72 mounted on the pier 66. Each tendon 68 is elongated and post-tensioned as described previously.

If desired, sheeting 74 is provided between the piers 66 to hold back the overburden beneath the existing structure 60; or a continuous underpinning wall may be providing eliminating the necessity of sheeting between the piers.

With the present invention the bank driven tie-backs or tendons leave the excavated area substantially clear and no unnecessary loss of building space need occur.

The tie-backs or tendons 22 may be composed of a number of high tensile strength wires or a single high tensile strength rod. When a number of wires are to be used the tie-back may be of the type shown in FIGURES 10 and 11.

Referring to FIGURES 10 and 11, after the soldier beams 12 are driven, the casing 16 is in place and the rock socket 18 is drilled, a grout pipe 32 with an anchor 20 mounted near the end thereof is placed in the casing. Attached to the anchor 20 is a series of high tensile strength wires 34. The grout pipe 32 is extended to the bottom of the rock socket 18 and the anchor 20 and wires 34 are carried along with it. For convenience in installation, the grout pipe 32 may be in lengths of twenty feet, each length being connected to the preceding one as required.

Water is flushed through the pipe 32, which has an angularly cut end or any other suitable construction which permits ease in placing the grout, until the water runs from the top of the casing 16 in a clear condition free of dirt. The supply of water is then shut off and the water in the casing and socket is allowed to settle and seek its own level. In some cases the use of water may not be necessary and it will be sufficient to use high pressure air which may be blown into the socket.

Grout 24 is then pumped through the grout pipe 32 and into the rock socket 18. The amount of grout 24 used for each tie-back should be sufficient to fill the rock socket 18, the grout pipe 32 and about 3 to 7 feet of the casing 16 above the rock socket 18. By placing at least this amount of grout in the socket 18, pipe 32 and casing 16, the anchor 20 is firmly and securely held in place.

The grout is allowed to set until the desired minimum strength is obtained before the wires 34, which had been drawn taut before grouting, are post-tensioned. The post-tensioning is accomplished by jacking the wires 34 against the wale 26. As shown in FIGURES 6, 7 and 10, the wale 26 is comprised of a pair of steel channel members 36 spaced back to back to permit the wires 34 and the grout pipe 32 to be inserted between them. The channels 36 are advantageously positioned so that the webs 38 are parallel to the line on which the casings 16 are driven and may serve as a guide when the casings are inserted. The wales 26 may be of any desired shape, such as I-beams, wide flange members, built up sections, angles, channels and such; and they may be at an angle or horizontally directed.

In order to maintain the channels 36 in proper position, a short bracket 40 together with a top bearing plate 42 is welded to each soldier beam 12. The channels 36 are set on the plates 42 and held in place by tack welding the flange of each channel 36 to the plates.

In jacking the wires **34** the anchor head **28** is drawn away from the wale **26** until a load in excess of the final post-tension load is achieved. As discussed previously, this excess load is held for about ten minutes and then the load is reduced to the desired amount. At this time the anchor head **28** will be spaced from the wale since elongation of the wires **34** takes place during the loading operation. In order to maintain the elongation (and the accompanying developed load on the wires **34**) spacer plates **30** are inserted between the anchor head **28** and the wale **26**. A spreader plate **44** may also advantageously be placed between the spacer **30** and the wale **26** so that the load is distributed over a greater portion of the channels **36**.

In FIGURES 8, 9 and 12, another embodiment of the tie-back, wale and soldier beam construction is shown. As shown therein, every third soldier beam **50** is a master beam comprised of two heavy channels spaced apart a short amount, sufficient to permit the casing **16** and the solid tendon **52** to be inserted therethrough. The remaining soldier beams **12** are similar to those described previously.

In this embodiment the solid tendon **52** is passed through a casing **16** and grouted in place as described previously. However, the wale construction and anchor head are different. The wale **54** is mounted by its flange directly to the flanges of the channels of the master beam **50**. Welded above the wale **54** and to the master beam **50** is an anchor bearing piece **56**. The bearing piece **56** is comprised of a built up angle section through which the solid tendon **52** extends. The upper end of the tendon **52**, in the illustrated embodiment, is threaded and a heavy duty nut **58** is placed thereon. In order to post-tension the tendon **52** the nut **58** is tightened against the bearing piece **56** to control means such as a torque wrench.

In the prior art where braces are used within the excavated area, the braces are in compression while the tendons of the present invention are in tension. Since higher design stresses are permitted with tension members than with compression members, the size of the tendons is reduced compared to a brace which carries the same equivalent load as the tendon. In addition, long braces must be supported by secondary bracing or the design load must be sharply reduced. Accordingly, the present invention not only aids the builder during construction, but it also assists the designer by allowing him greater latitude since the allowable stresses are greater.

Various types of anchors will occur to these skilled in the art. In FIGURES 15*a–d* four additional anchors are shown.

In FIGURE 15*a* a mechanical anchor **76** is illustrated which is comprised of a cone and wedge combination of the expansion type. In this embodiment the rock socket has an oversize lower section **78** which is carefully drilled. The anchor **76** is affixed to the tendon **22** and inserted into the lower section **78**. The anchor **76** is comprised of a cone **80** fitted into split wedges **82** which mate with the surface of the cone **80**. When tension is applied to the tendon **22**, the cone **80** spreads the wedges apart and presses them into tight locking engagement with the walls of the lower socket section **78**. The time to drill the section **78** and the cost of the cone and wedge combination have to be carefully considered before using this type of anchor in place of a grouted anchor.

Some additional grouted anchors are shown in FIGURES 15*b*, *c* and *d*. In FIGURE 15*b* a simple series of parallel strands **84** are shown.

In FIGURE 15*c* a series of wire tendons **86** are shown which are woven under and over a series of rings **88**. The open structure about the rings provides very high holding power when the rock socket is filled with grout.

In FIGURE 15*d* a series of wire tendons **90** are shown which have been twisted together to provide additional bond surface and added holding power.

In addition to these anchors others such as buttons and nut and washer combinations may also be used.

The tendons may also be of various kinds. Besides solid rods and wires, the tendons may be of strand, i.e. a series of wires twisted about a larger center wire, or of cable.

It is to be understood that the embodiments shown are illustrative of the present invention and are not to be a limitation thereof as other embodiments will occur to those skilled in the art which will be within the scope of the accompanying claims.

I claim:

1. A rock anchored wall structure and an undisturbed and in place overburden which overlies a rock layer said overburden substantially compressed by the structure, said structure comprising a retaining wall, anchors set in rock sockets in the rock layer beneath the undisturbed overburden, connecting means extending from the wall downwardly at an angle through the overburden to the rock layer post-tensioned tendons inserted through the connecting means and joined to the anchors and to the wall whereby the undisturbed overburden is compressed and maintained in place without any bracing of the wall on the side of the wall opposite the rock anchors.

2. A rock anchored wall structure an undisturbed and in place overburden which overlies a rock layer as defined in claim **1** wherein the connecting means is comprised of a casing member.

3. The method of constructing a sheeting wall structure for retaining undisturbed and in place an overburden which overlies a rock layer comprising erecting a wall framework including a series of upright pilings driven into the overburden along the line of the overburden to be retained, inserting casings downwardly into the overburden and at an angle with the pilings until said casings reach the rock layer, preparing rock sockets in the rock layer, said rock sockets set below the lower extent of the casings, inserting a tension member through each casing, anchoring said tension members in the rock sockets, tensioning the tenison members and affixing them to said framework.

4. The method of claim **3** wherein said tension members have anchors attached thereto and said anchors are fixed in the rock sockets by grouting.

5. The method of claim **3** wherein the casings are inserted at an angle of about 45°.

6. The method of claim **3** wherein the tenison members are initially temporarily tensioned to a load of two to three times the final desired load before being finally affixed to the framework.

7. The method of claim **3** wherein said upright pilings are interlocking sheet piles.

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