United States Patent

Fuller

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[54] **METHOD FOR FORMING EXPANDED BASE PILES FOR UPLIFT LOADS**

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[52] **U.S. Cl.**.....**61/53.6,** 61/53.62

[51] **Int. Cl.**.....**E02d 5/44**

[58] **Field of Search**.....61/50, 53.6, 53.62, 53.64; 61/53.66, 53.7

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Assistant Examiner—David H. Corbin
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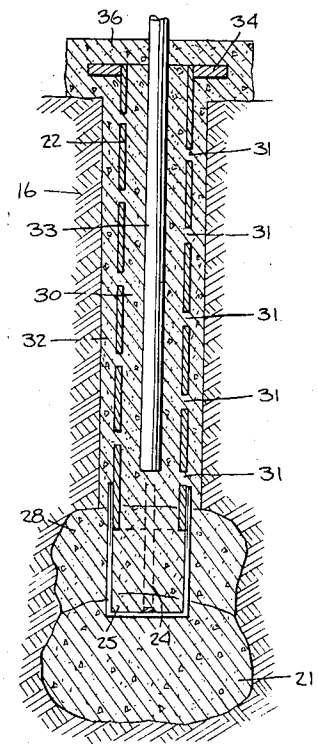
[57] **ABSTRACT**

This invention relates to a method for forming an expanded base pile capable of sustaining compression and uplift loads characterized by an elongated tensile element intimately connected to an expanded base and connected to a structure at the top, thereby to transfer the uplift load from the structure to the pile.

17 Claims, 20 Drawing Figures



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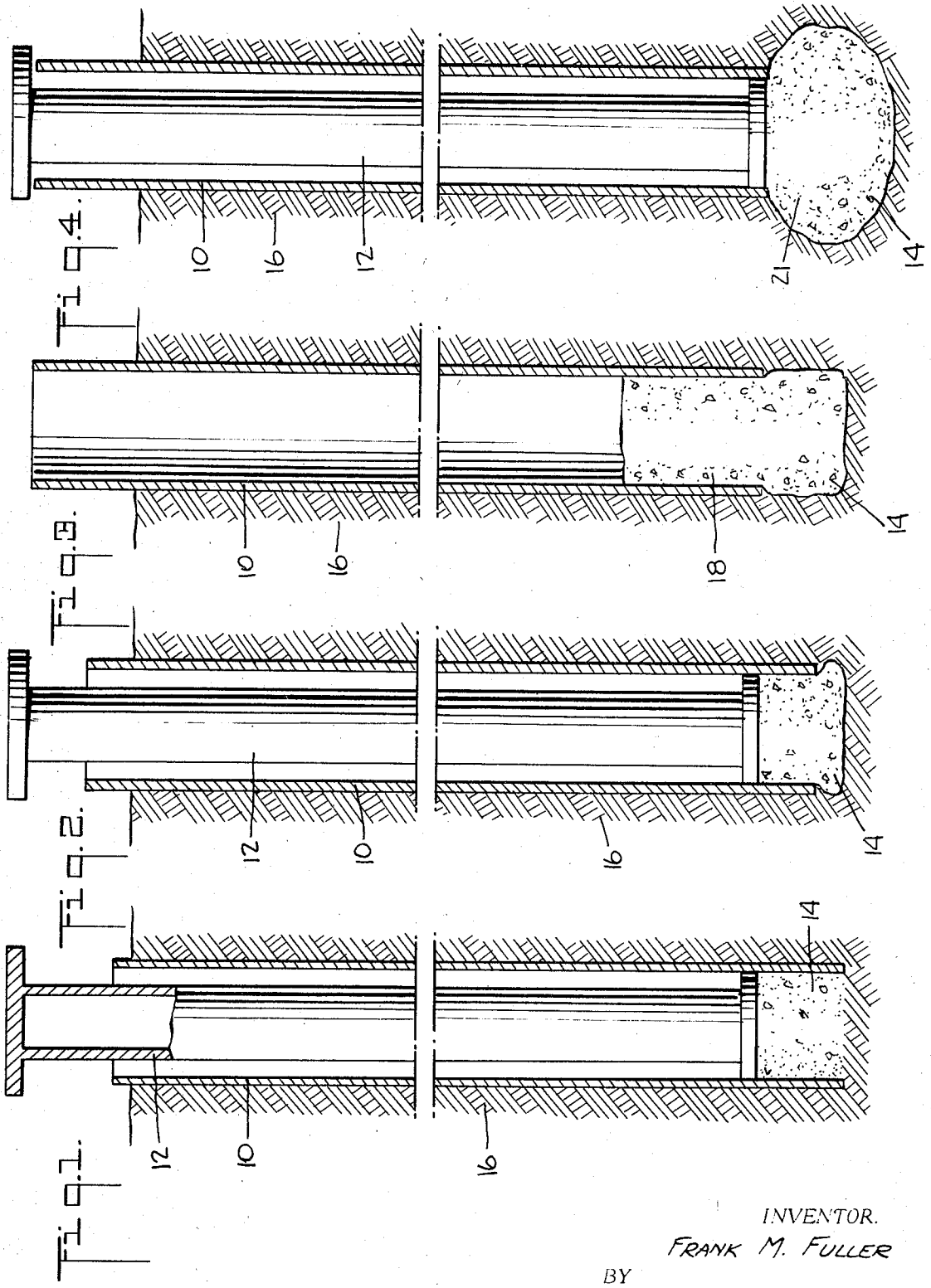

Fig. 4.

Fig. 3.

Fig. 2.

Fig. 1.

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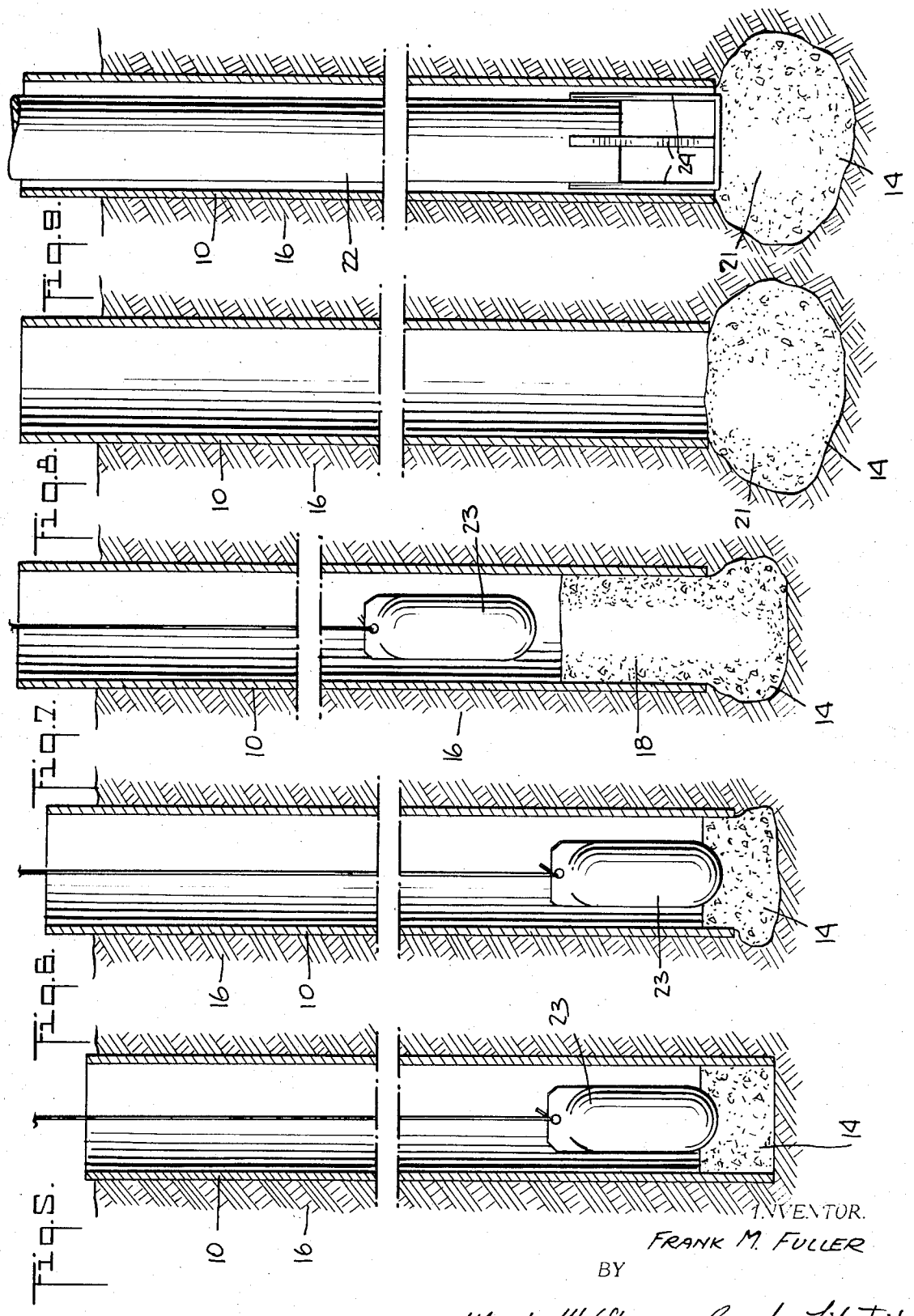

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Fig. 13.

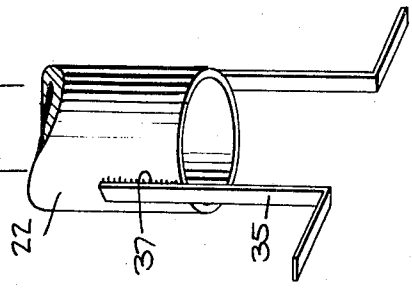


Fig. 14.

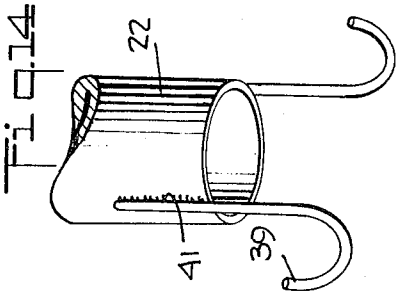
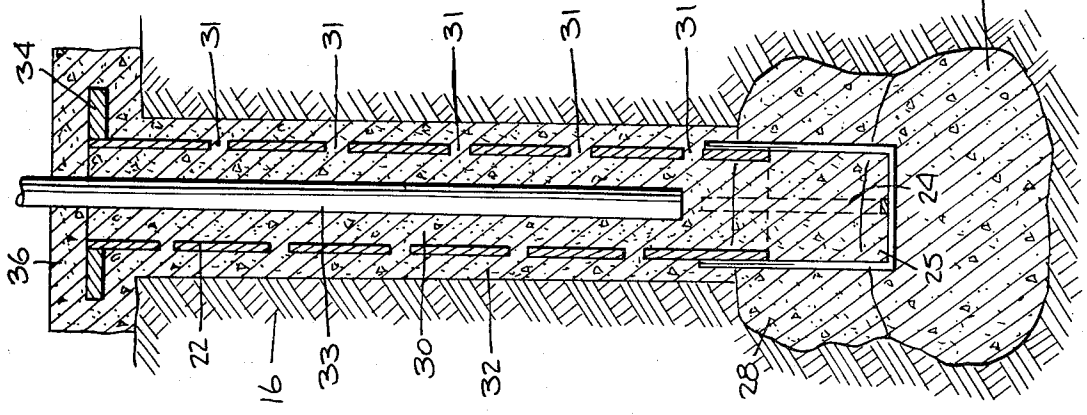


Fig. 12



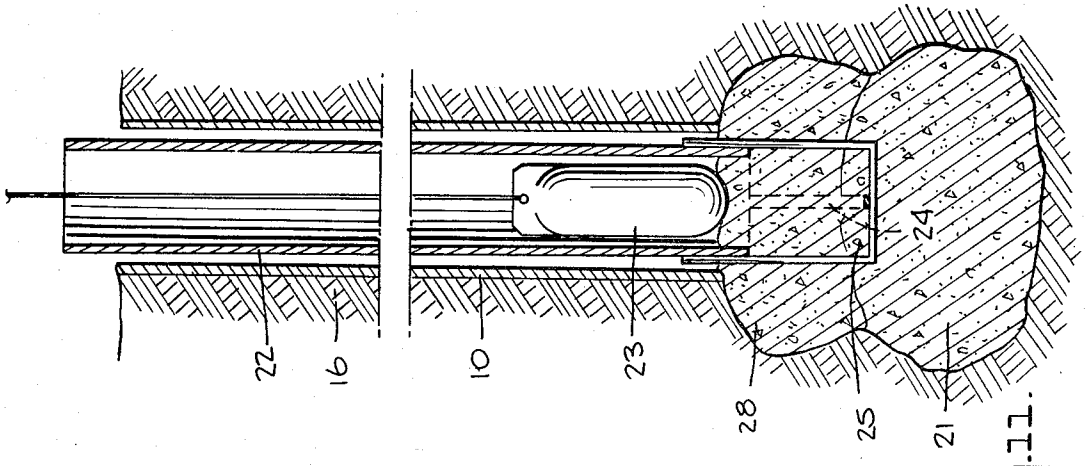


Fig. 11.

Fig. 10.

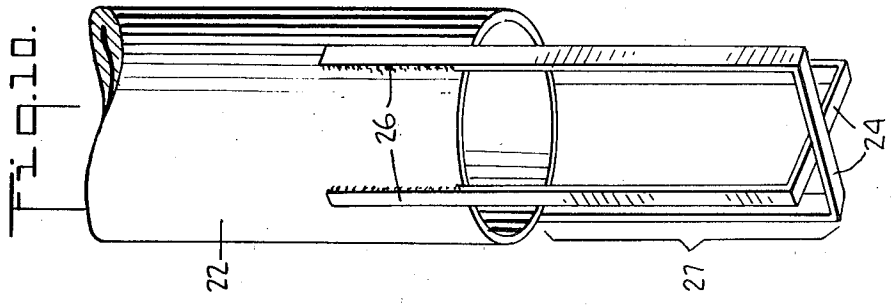


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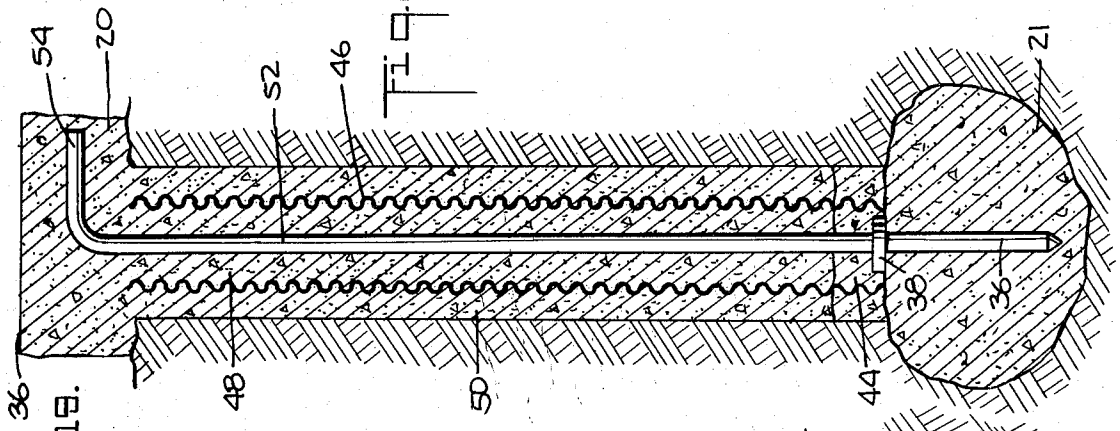
Fig. 20.



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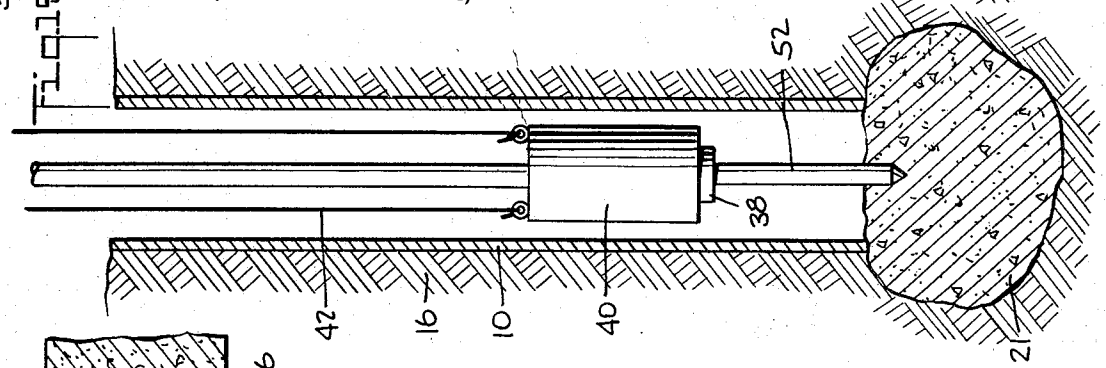

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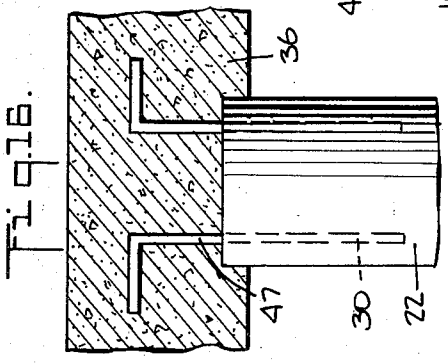

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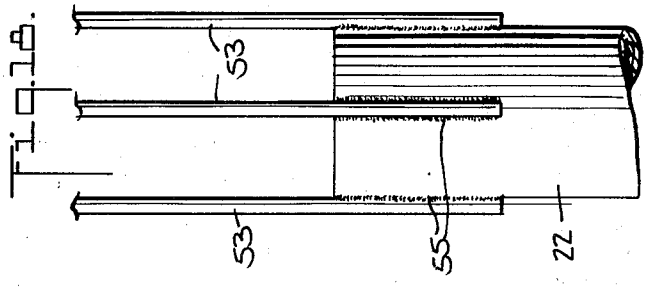

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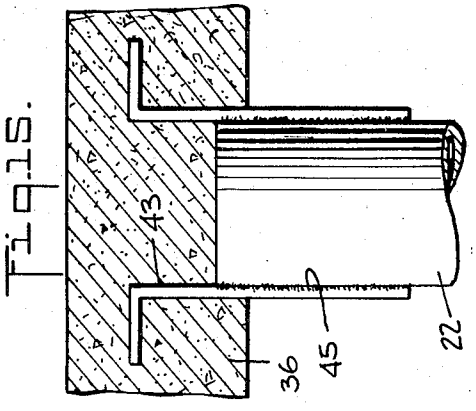
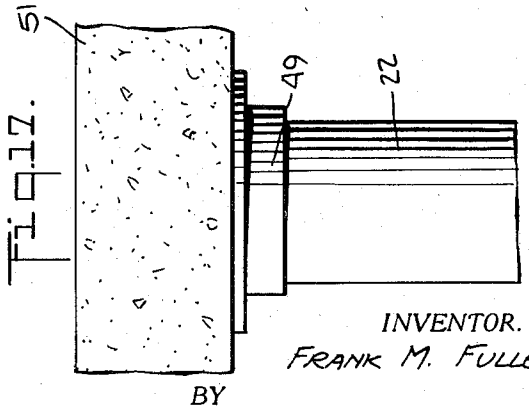


Fig. 17.



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METHOD FOR FORMING EXPANDED BASE PILES FOR UPLIFT LOADS

This invention relates to new and improved expanded base piles and more particularly to such piles which are capable of sustaining compression and uplift loads. The invention also relates to methods for forming such piles. The present invention is particularly adapted, among other possible applications, for use in tower structures, tank foundation flotation or earthpusher loads, for example.

It has been found that both compression and uplift load capacities of concrete piles can often be increased by enlarging their lower ends. For purposes of sustaining uplift loads, prior art pile arrangements were formed by hammering a cage, in the form of reinforcing rods, into a preplaced expanded base to make a connection therewith and then filling in and around the cage with concrete. Difficulties were encountered with such prior art techniques due to bending and deformation of the cage and due to the tendency to form an inadequate connection with the base, and hence the base did not effectively contribute to the uplift resistance of the pile.

The present invention involves a novel combination of features combined in such a way as to afford a very efficient solution to the difficulties encountered with the prior art, as will become apparent as the description proceeds.

The present invention, in one form thereof, involves a method of forming an expanded base pile capable of sustaining compression and uplift loads comprising the steps of forcing concrete down into the bottom of a preformed hole in the earth with sufficient force so as to produce an expanded base and thereafter placing an elongated tensile element into contact with the expanded base, said element having laterally and longitudinally extending spaced projections near the expanded base. The next steps in the method include, pouring concrete into the opening to extend up and form a column, and then expanding the column laterally in the region of the base to form a secondary expanded base. According to the invention, an additional step is included which comprises transferring the uplift load from the structure to the pile. In one form short dowels are connected to the top of the elongated tensile element which usually consists of a steel pipe. In another form of the invention a single pile is used under a load element and no pile cap per se is formed. Various means may be employed to make a positive connection between the pile and the structure such as welding the dowels to the pipe, inserting reinforcing steel dowels in the concrete used to fill the pipe and thus transferring tension loads through the bond, welding the main longitudinal steel for the reinforced concrete building columns directly to the pipe pile, welding a collar around the top of the pipe to which building columns of structural steel could be bolted or welded or embedding the collar itself in the concrete to form a part of the structure, such as the floor of a tank, for example.

In another form, the invention involves a method of forming an expanded base pile capable of sustaining compression and uplift loads comprising the steps of forcing concrete down into the bottom of a preformed hole in the earth with sufficient force to produce an expanded base, thence placing an elongated rod-like tensile element into contact with said expanded base, and driving the lower end of said rod-like tensile element into said base so that it extends up from the base in the hole to the top of the pile. In one form the method includes the additional steps of placing a small amount of normal slump concrete on top of the base, inserting a shell down into the hole to bear in this freshly placed concrete and on the expanded base, and thereafter filling the shell with concrete.

In still another form, there is provided a new and improved expanded base pile for sustaining compression and uplift loads including an enlarged bulbous base under the surface of the earth, a concrete column extending up from the base and a tensile element embedded in the base and extending up the column. The tensile element has a laterally and longitudinally extending portion in intimate contact with the base to provide uplift load restraint. In addition, the tensile element is intimately connected to a structure at the top of the pile, thereby to transfer the uplift load from the structure to the pile.

According to my invention, in another form thereof, an expanded base pile includes a second bulbous base overlying the first bulbous base and a concrete column extending up from said bases and a tensile element embedded at least in the second base and extending up the column. The first bulbous base serves primarily to develop high load bearing capacity in compression and the second bulbous base serves primarily to provide the necessary uplift resistance.

There has thus been outlined rather broadly the more important features of the invention in order that the detailed description thereof that follows may be better understood, and in order that the present contribution to the art may be better appreciated. There are, of course, additional features of the invention that will be described more fully hereinafter. Those skilled in the art will appreciate that the conception on which this disclosure is based may readily be utilized as the basis for the designing of other structures for carrying out the several purposes of the invention. It is important, therefore, that this disclosure be regarded as including such equivalent constructions as do not depart from the spirit and scope of the invention.

Several embodiments of the invention have been chosen for purposes of illustration and description, and are shown in the accompanying drawings, forming a part of the specification, wherein:

FIG. **1** is a vertical sectional view through a drive tube and mandrel disposed in a hole driven in the earth according to a first step of one embodiment of the present invention;

FIG. **2** is a view similar to FIG. **1**, but showing the mandrel forcing a plug from the lower end of the drive tube;

FIG. **3** is a view similar to FIG. **2**, but showing a charge of concrete inserted in the hole;

FIG. **4** is a view similar to FIG. **3**, but showing a mandrel inserted inside said drive tube for forcing the concrete to form an expanded base;

FIG. **5** is a vertical, sectional view through a drive tube having a dry concrete plug in the bottom end thereof and an internal drop weight therein, according to another form of the present invention;

FIG. **6** is a view similar to FIG. **5**, but showing the plug being forced from the lower end of the drive tube;

FIG. 7 is a view similar to FIG. 6, but showing a charge of concrete inserted in the hole;

FIG. 8 is a view similar to FIG. 7, but showing the charge of concrete formed into an expanded base;

FIG. 9 is a view similar to FIG. 8 and FIG. 4, but showing the arrangement after forming the base, and with a pipe, having strap means at the lower end thereof, inserted in the drive tube;

FIG. 10 is an enlarged, perspective view showing details of U-shaped straps attached to the lower end of the pipe;

FIG. 11 is a view similar to FIG. 9, but showing an internal drop weight forcing a charge of concrete out to form a second expanded base overlying the first expanded base;

FIG. 12 is a view similar to FIG. 11, but showing the drive tube withdrawn and the pipe filled with concrete, and a structure connected to the pipe at the top thereof;

FIGS. 13 and 14 are enlarged, perspective views showing two additional anchorage systems for the bottom of the pipe in the base;

FIGS. 15, 16, 17 and 18 are enlarged, perspective views showing three additional anchorage systems for connecting a structure to the top of the pipe;

FIG. 19 is a vertical, sectional view similar to FIG. 9, but showing a rod-like tensile element being driven into the expanded base by slip weight means according to another embodiment of the invention, and

FIG. 20 is a vertical, sectional view similar to FIG. 19, but showing the tensile element driven into the base, a shell inserted, the drive tube removed, the shell filled with concrete.

In the embodiment of the invention illustrated in FIGS. 1–5, the method of forming an expanded base pile capable of sustaining compression and uplift loads comprises the steps of driving a mandrel 12 and a drive tube 10, FIG. 1, having a dry concrete plug 14 at the bottom thereof, which serves to close the lower end of the tube, down into the earth 16 into the bearing stratum, and then as seen in FIG. 2, driving the plug from the bottom of the tube while raising the tube from the hole, and thereafter placing a charge of zero slump concrete 18, FIG. 3, in the bottom of the drive tube 10. As seen in FIG. 4, the mandrel 12 serves to drive or force the concrete 18 downwardly and outwardly to form a first expanded base 21 having a cross section greater than that of the hole or drive tube. This first or initial base is formed under very high driving energies to develop a pile with a high compression load bearing capacity.

In the form of the invention illustrated in FIGS. 5–12, the method of forming an expanded base pile capable of sustaining compression and uplift loads comprises the steps of driving a drive tube 10, FIG. 5, having a dry concrete plug 14 at the bottom thereof, which serves to close the lower end of the tube, down into the bearing stratum of the earth 16 by means of an internal drop weight 23, provided for the purpose. The next step, as seen in FIG. 6, is driving the plug from the bottom of the tube 10 while raising the tube from the hole, and thereafter placing a charge of zero slump concrete 18, FIG. 7, in the bottom of the drive tube 10. The charge of concrete 18 is driven downwardly and outwardly, from its position as seen in FIG. 7 to its position as seen in FIG. 8, to form a first expanded base 21 having a cross section greater than that of the hole or drive tube, by means of the internal drop weight 23. As pointed out hereinbefore, this first or initial base is formed under very high driving energy to develop a pile with a high compression load bearing capacity.

After forming the expanded base, by either the method illustrated in FIGS. 1–4 or by the method illustrated in FIGS. 5–8, the next step, as seen in FIG. 9, is lowering an elongated pipe 22 into the drive tube 10. As best seen in FIG. 10, the pipe 22 has steel strap means which, as illustrated, comprise a pair of U-shaped steel straps 24 welded to the bottom end thereof, as at 26. It should be noted that one U-shaped steel strap could suffice and that the distance 27 which the straps project below the end of the pipe varies depending upon the uplift loads to be resisted and upon other considerations. This distance could range from a few inches to several feet, for example. These straps are driven partially into the initial base 21 as at 25, FIG. 11, to form a bond between the concrete of the first and second base. Then a charge of concrete is placed in the pipe 22 and is based out as by means of the internal drop weight 23 into or on top of the initial base 21 to form a second base 28 (FIG. 11) having full anchorage with the base 21. At this point, as can be seen, the base extends at or above the pipe bottom and is of greater cross section than that of the pipe 22. It will be appreciated that the initial base 21 is formed under very high driving energy to develop a pipe with high compression load bearing capacity and the second base 18 is rammed out with less energy but still sufficient energy to form an expanded secondary base to develop the uplift capacity. The magnitude of the required capacity in uplift is generally much less than that required in compression. The size of the bases depends on many factors such as the soil conditions, for example. Accordingly, it will be appreciated that the two bases have different functions. The use of a pipe 22 for the tension element is particularly advantageous because, as seen in FIG, 11, the drop weight 23 operates inside thereof and the pipe provides a smooth, continuous and unobstructed guide for the heavy drop weight. In addition, it should be noted that the concrete used in forming the secondary base 28 is not of zero slump, but should contain enough moisture so that it can be forced out around the straps 24 and compacted or rammed into the soil to form the second expanded base as the drive tube is being withdrawn. As seen in FIG. 12, the drive tube 10 is thereafter withdrawn and the pipe 22 is filled with concrete 30. The space 32 around the pipe 22 may be filled with any suitable material depending upon such factors as the soil conditions, for example. For some soils this space may be filled in by the soil itself, as the drive tube is withdrawn. In some cases the space may be filled with sand, other soil, or gravel, for example. In the form of the invention illustrated in FIG. 12, the pipe 10 is provided with ports or openings 31 staggered along its length and around its circumference so that when the concrete is poured into the pipe it flows out the ports and fills any voids between the ground and the pipe. An internal vibrating rod 33 serves to assist the movement of this concrete out of the ports. This process assists in establishing lateral support to the pile shaft. However, sufficient and continuous cross sectional area of steel is left in the pipe 22 to resist the

necessary tensile stresses which is the primary purpose of the pipe.

Still referring to FIG. **12**, the next step is welding short dowels **34** to the top of the pipe to provide a connection transferring the uplift loads from a structure **36** to the pile. It will be appreciated that the pipe **22** serves a dual purpose. It acts as a tensile member, thereby replacing the reinforcing bars used by prior art installations, and at the same time provides a steel encasement for the shaft concrete, to protect the concrete from detrimental ground pressures and movement, thereby replacing the shell used by prior art installations. The use of the pipe to replace both the shell and the reinforcing bars saves material in addition to installation costs.

As seen in FIGS. **13** and **14**, two other means are illustrated for anchoring the pipe **22** to the base. As shown in FIG. **13**, two or more steel L-shaped elements **35** are welded to the bottom of the pipe **22**, as at **37**. As seen in FIG. **14** two or more steel hooked elements **39** are welded to the bottom of the pipe **22**, as at **41**.

Referring next to FIGS. **15**, **16**, **17** and **18**, there are illustrated four additional means for anchoring the system to the top of the pile. As seen in FIG. **15**, two or more hooked or L-shaped steel elements **43** have their upper ends embedded in the concrete of the structure **36** and their two lower ends are welded to the pipe **22**, as at **45**. As seen in FIG. **16**, two or more hooked or L-shaped elements **47** have their upper ends embedded in the concrete of the structure **36** and their lower ends embedded in the pile concrete **30**. In FIG. **17** a steel collar **49** is welded to the top of the pipe **22** and embedded in concrete or bolted to a column base plate **51**. As seen in FIG. **18**, a plurality of main column reinforcement bars **53** of a structure are welded to the pipe **22**, as at **55**. Accordingly, the embodiments of FIGS. **16**, **17** and **18** show means for connecting the top of the pile to a structure, thereby to transfer the uplift load from the structure to the pile.

In the embodiment of the invention illustrated in FIGS. **19** and **20**, an expanded base **21** is formed in the ground in the same manner as described hereinbefore in connection with FIGS. **1–4** or **5–9**. After forming the base **21**, the next step in this method includes driving the end of a rod-like tensile element **52** into the concrete base **21**. The rod is of sufficient size to take an uplift load, and it has a steel collar **38** welded thereto at a position located a short distance upwardly from the end thereof so that a slip weight **40** may be employed to drive the bar into the base **21**. Lifting lines **42** serve to lift the slip weight **40**, as required. It will be appreciated that this method of providing uplift resistance can be used either with a cased or with an uncased shaft. If a shell is to be used (to form a cased shaft) the next steps, FIG. **20**, comprise placing a small amount of normal slump concrete **44** on top of the base **21** and then inserting a shell **46** down into the hole to bear in the freshly placed concrete and on the expanded base, and thereafter filling the shell **46** with concrete **48**. Thereafter, the steps include withdrawing the drive tube **10** and filling the space around the shell **46** with any suitable material **50** depending upon the soil condition as discussed more fully hereinbefore with respect to space **32**, FIG. **12**. The upper end of the rod-like tensile element **36** is positively connected to the structure **36**, as hooking over the upper end portion **54** of the rod, and embedding it in the structure.

It will thus be seen that the present invention does indeed provide improved methods for forming an expanded base pile capable of sustaining uplift loads which are superior in simplicity, economy and efficiency as compared to prior art such methods.

Although certain particular embodiments of the invention are herein disclosed for purposes of explanation, various modifications thereof, after study of this specification, will be apparent to those skilled in the art to which the invention pertains.

What is claimed and desired to be secured by Letters Patent is:

1. A method of forming an expanded base pile capable of sustaining compression and uplift loads, said method comprising the steps of forming an opening down through the earth, forcing concrete down into the bottom of said opening under sufficient force to form a first expanded base having a cross-section greater than that of said opening, placing an elongated tensile element into contact with said first expanded base to extend up through said opening, said elongated tensile element being hollow and having laterally and longitudinally extending projections near said first expanded base, placing a secondary charge of concrete in the bottom of said tensile element and basing it out on top of said first expanded base to form a secondary expanded base having a cross-section greater than that of said tensile element, said basing being continued until full anchorage is achieved between the tensile element and the second base and pouring concrete to extend up as a column through said opening.

2. A method of forming an expanded base pile capable of sustaining compression and uplift loads, said method comprising the steps of driving a drive tube down into the earth into the bearing stratum to form an opening down through the earth, placing a primary charge of concrete in the bottom of the drive tube, forcing the concrete downwardly and outwardly to form a first expanded base, lowering an elongated tensile element into said drive tube to a position at least adjacent said first expanded base, said tensile element being hollow and having anchoring means on the bottom end thereof, placing a secondary charge of concrete in the bottom of the tensile element and basing it out on top of the first expanded base to form a second expanded base having a cross-section greater than that of said tensile element, said basing being continued until full anchorage is achieved between the tensile element and the second base, withdrawing the drive tube and filling the opening with concrete.

3. A method of forming an expanded base pile capable of sustaining compression and uplift loads according to claim **2** wherein said primary charge of concrete in the bottom of the drive tube is zero slump concrete and said secondary charge of concrete in the bottom of the tensile element is low slump concrete.

4. A method of forming an expanded base pile capable of sustaining compression and uplift loads according to claim **2** wherein said anchoring means comprises at least one U-shaped strap fixedly connected to the bottom end of the tensile element.

5. A method of forming an expanded base pile capable of sustaining compression and uplift loads accord-

ing to claim 2 wherein said anchoring means comprises at least two L-shaped elements fixedly connected to the bottom end of the tensile element.

6. A method of forming an expanded base pile capable of sustaining compression and uplift loads according to claim 2 wherein said anchoring means comprises at least two hooked elements fixedly connected to the bottom end of said tensile element.

7. A method of forming an expanded base pile capable of sustaining compression and uplift loads according to claim 2 further comprising the step of connecting anchoring means to the top of the tensile element to transfer the uplift load from a structure to the pile.

8. A method of forming an expanded base pile capable of sustaining compression and uplift loads according to claim 7 wherein said structure has a concrete portion adjacent the top of said tensile element, and wherein said anchoring means to the top of the tensile element comprises at least two L-shaped elements embedded in said concrete portion.

9. A method of forming an expanded base pile capable of sustaining compression and uplift loads according to claim 7 wherein said structure has a concrete portion adjacent the top of said tensile element, and wherein said anchoring means to the top of the tensile element comprises at least two hooked elements having their lower ends embedded in the pile concrete and their upper ends embedded in said concrete portion.

10. A method of forming an expanded base pile capable of sustaining compression and uplift loads according to claim 7 wherein said anchoring means comprises a collar fixedly connected to the top of said tensile element and connected to said structure.

11. A method of forming an expanded base pile capable of sustaining compression and uplift loads according to claim 7 wherein said anchoring means at the top of the tensile element comprises a plurality of main column reinforcement bars depending from said structure and fixedly connected to the upper end of said tensile element.

12. A method of forming an expanded base pile capable of sustaining compression and uplift loads according to claim 2 wherein said tensile element is driven partially into said first expanded base, before said second base is formed, to form a bond between said first and second bases.

13. A method of forming an expanded base pile capable of sustaining compression and uplift loads, said method comprising the steps of driving a drive tube down into the earth into the bearing stratum, placing a charge of zero slump concrete in the bottom of the drive tube, forcing the concrete downwardly and outwardly to form a first expanded base having a cross-section greater than that of the drive tube, lowering an elongated pipe into said drive tube to a position at least adjacent said first expanded base, said pipe having anchoring means on the bottom end thereof, placing a charge of low slump concrete in the pipe and basing it out into and on top of the first expanded base to form a second expanded base having a cross section greater than that of the pipe, said basing being continued until full anchorage is achieved between said pipe and the second base, withdrawing the drive tube and filling the pipe with concrete.

14. A method of forming an expanded base pile capable of sustaining compression and uplift loads according to claim 13 wherein said pipe has a plurality of ports staggered along its length and around its circumference, and further comprising the step of vibrating the concrete in said pipe to promote its flow outwardly through said ports.

15. A method of forming an expanded base pile capable of sustaining compression and uplift loads, said method comprising the steps of driving a mandrel in a drive tube having a dry concrete plug at the bottom thereof down into the earth to form a hole therein, driving the plug from the bottom of the tube while raising a portion of the tube from the hole, placing a charge of zero slump concrete in the bottom of the drive tube, forcing the concrete downwardly and outwardly to form a first expanded base having a cross-section greater than that of the hole and drive tube, said first expanded base being formed under high driving energy to develop a pile with a high compression load bearing capacity, lowering an elongated pipe into the drive tube to a position at least adjacent said first expanded base, said pipe having anchoring means on the bottom end thereof, forming a secondary expanded base by placing a charge of low slump concrete in the pipe and basing it out into and on top of the first expanded base until full anchorage is achieved between said pipe and said secondary base and until the second base has a cross-section greater than that of the pipe, withdrawing the drive tube and filling the pipe with concrete.

16. A method of forming an expanded base pile capable of sustaining compression and uplift loads, said method comprising the steps of driving a drive tube having a dry concrete plug at the bottom thereof down into the bearing stratum of the earth by means of an internal drop weight to form a hole extending down into the earth, driving the plug from the bottom of the tube while raising a portion of the tube from the hole, placing a charge of zero slump concrete in the bottom of the drive tube, driving said charge of concrete downwardly and outwardly to form a first expanded base having a cross section greater than that of the hole and drive tube by means of an internal drop weight, said first expanded base being formed under very high driving energy to develop a pile with a high compression load bearing capacity, lowering an elongated pipe into the drive tube into contact with said first expanded base, said pipe having anchoring means at the bottom end thereof, placing a charge of low slump concrete in the pipe and then basing it out into and on top of the first expanded base by means of an internal drop weight within said pipe to form a second expanded base having a cross-section greater than that of the pipe, said basing being continued until full anchorage is achieved between said pipe and second base, withdrawing the drive tube and filling the pipe with concrete.

17. A method of forming an expanded base pile capable of sustaining compression and uplift loads, said method comprising the steps of forming an opening down through the earth, forcing concrete down into the bottom of said opening under sufficient force to form a first expanded base having a cross-section greater than that of said opening, placing an elongated tensile element into contact with said first expanded base to extend up through said opening, placing a secondary

charge of concrete at the bottom of said tensile element and then basing it out into and on top of the first expanded base by means of an internal drop weight guided by said tensile element to form a secondary expanded base having a cross-section greater than that of said tensile element, said basing being continued until full anchorage is achieved between the tensile element and the second base, and pouring concrete to extend up as a column through said opening.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,685,302 Dated August 22, 1972

Inventor(s) Frank M. Fuller

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 3, line 35, for "5" read --4--;

Column 4, line 30, for "pipe" read --pile--;

Column 4, line 31, for "18" read --28--.

Signed and sealed this 9th day of January 1973.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents

FORM PO-1050 (10-69)

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