

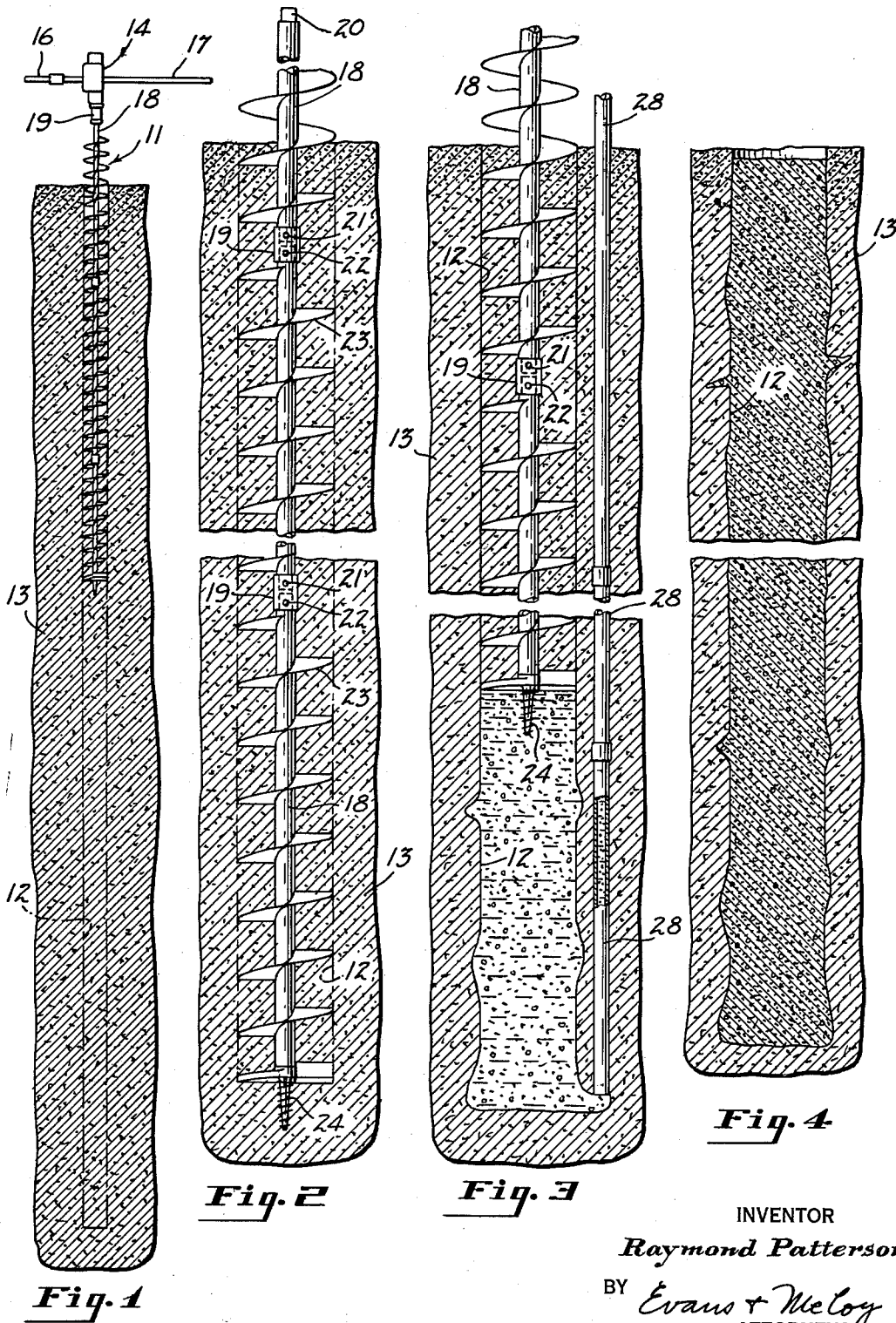
Jan. 3, 1956

R. PATTERSON
METHOD FOR FORMING PILES

2,729,067

Filed Sept. 18, 1951

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

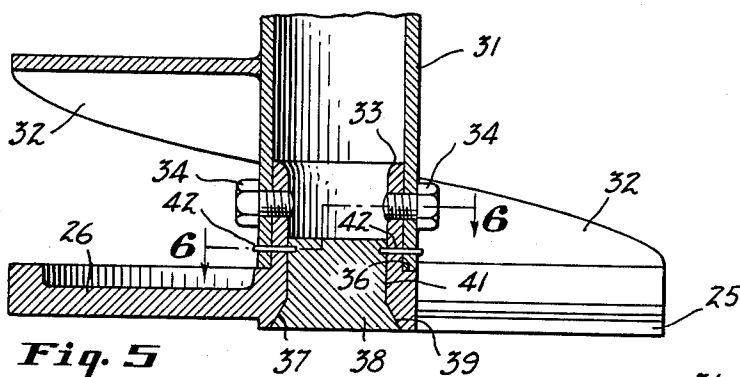


Fig. 5

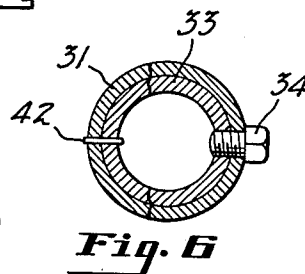


Fig. 6

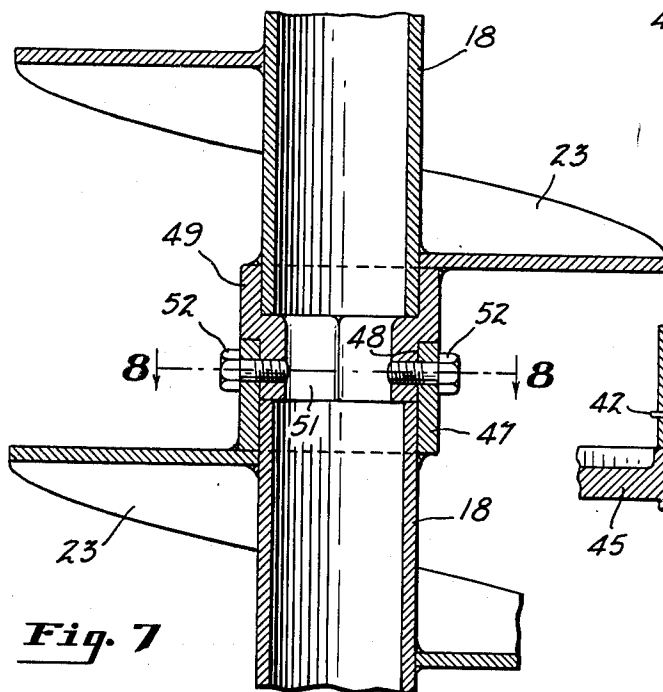


Fig. 7

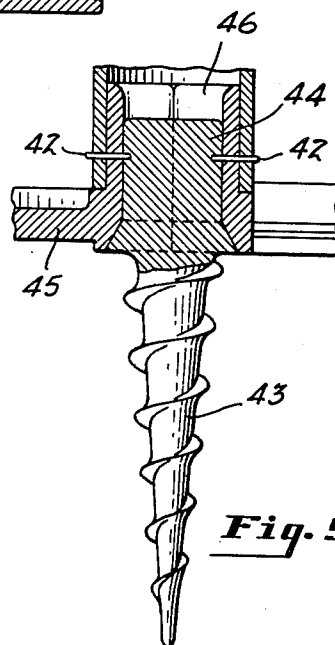


Fig. 9

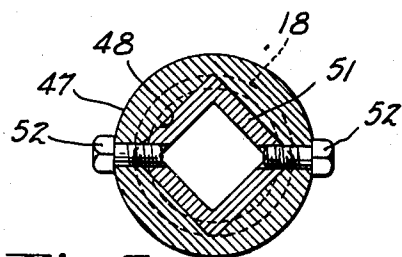


Fig. 8

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2,729,067

METHOD FOR FORMING PILES

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Application September 18, 1951, Serial No. 247,151

12 Claims. (Cl. 61—57)

This invention relates to the forming of concrete piles in the earth and particularly to simplified and improved methods and apparatus for forming concrete piles in all kinds of earth formations, other than solid rock formations.

Numerous methods and types of apparatus have been employed heretofore for forming or constructing concrete piles in the earth. The methods and apparatus employed have varied greatly according to the particular conditions under which the work must be performed, the character of the earth formations to be penetrated, and the type and magnitude of the loads to be supported or forces to be resisted. All of such methods and apparatus, however, have been subject in varying degrees to limitations restricting their use to certain types of working conditions, earth formations, and load resisting requirements.

Many of the methods have required the use of expensive and massive equipment. Most of them have required considerable headroom above the ground surface where the work is performed, and have required the difficult and tedious sinking of some kind of permanent or temporary casing. Few of the prior techniques have provided satisfactory frictional resistance to sinking of the finished piles under load when no adequate subterranean rock formations are available to provide vertical support. Moreover, many of the prior methods have been so expensive to employ or so slow in operation as to preclude their economical use on many proposed projects.

Because of the various shortcomings of prior methods and apparatus, many projects have had to be abandoned as economically unfeasible, or structures have had to be specially designed at great expense to compensate for the shortcomings of the pile supports that could be provided by known techniques.

The general object of the present invention is to provide improved methods and apparatus for constructing piles in earth formations, which methods and apparatus are applicable under conditions that preclude the use of many types of prior methods and apparatus, are cheaper and faster to employ, and produce superior results.

More specific objects of the invention are to provide methods and apparatus for constructing concrete piles in loose and unstable earth formations without the use of any kind of casing, with a minimum of headroom above ground, and with the use of only small and relatively inexpensive equipment.

Another object of the invention is to provide methods and apparatus for constructing piles in earth formations without the need for applying vertical forces for driving apparatus or objects into the earth, or for withdrawing them from the earth in the course of the work.

Another object of the invention is to provide methods and apparatus for constructing piles in loose and unstable earth formations that lack adequate bedrock support while obtaining greater resistance to sinking of the piles under vertical loads.

Another object of the invention is to produce in loose or porous earth formations concrete piles having later-

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ally extended monolithic projections that fill existing voids in the earth formations around the piles along substantially the full vertical height of the piles.

A further object of the invention is to provide methods and apparatus for constructing piles in loose and unstable earth formations in such a manner that the loose earth masses around the piles are compacted laterally away from the piles, thus providing bulbous, monolithic projections on the piles that extend laterally into such masses to give vertical support to the piles while stabilizing the surrounding earth masses.

Still another object of the invention is to construct piles in the earth that are particularly effective when constructed adjacent each other to form more or less continuous walls of concrete extending around or along unstable earth masses.

Still another object of the invention is to accomplish the foregoing objectives without the necessity for leaving expensive equipment in the earth as a part of the finished pile structures.

A characteristic feature of the invention by which the foregoing objects are accomplished involves the use of an auger-type drill that is sunk into the earth to define the location and depth of the cavity in which a pile is to be constructed and the minimum lateral dimensions of the pile. The auger action of the drill permits it to be sunk to the desired depth without removing the earth from the cavity, the auger blade and the cylindrical mass of earth through which it passes acting together as a plug filling the space to be subsequently occupied by the pile. A hydraulic cement grout is then pumped into the earth below the lower end of the drill, either through a grout pipe jetted to substantially the same depth closely adjacent the drill or through the drill shaft itself. The grout is pumped with sufficient pressure to cause it to slowly raise the drill and the earth penetrated by the drill vertically out of the earth mass as the grout fills the cavity originally defined by the drill, and the pumping of the grout is continued until it has filled the cavity substantially to the ground level, or to any lower level at which the top of the pile is to be located.

The combined weight of the drill and the earth retained thereby keeps the grout under pressure throughout the pile casting operation and insures complete filling of the originally defined cylindrical cavity with a dense concrete having a minimum of voids. In addition, the grout pressure maintained in the cavity in this manner acts outwardly in all directions and compacts surrounding loose, sandy strata away from the pile with the formation of bulbous, laterally extending, monolithic projections on the pile body. This interlocks the pile with the firmer strata, greatly increasing the resistance of the pile to sinking under vertical loads, and gives the pile greater lateral support against tilting due to eccentric loads by densifying the surrounding loose strata. The grout also flows outwardly in all directions into all cracks, crevices, and interstices of the surrounding earth formations, whether they are loose and unstable or relatively rigid and stable, thus forming a multiplicity of smaller, lateral, monolithic projections of the pile body that give still further vertical and lateral support to the pile and that solidify and stabilize the entire surrounding earth mass.

According to preferred practice, particularly when working with limited head room above ground, the auger-type drill is made up of short sections, four feet or so in length, that are assembled one by one in end-to-end relation as the auger is sunk into the earth and that are disassembled in the reverse order as the drill is forced out of the earth again by the pressure of the grout introduced therebelow. The earth removed with each auger section may be knocked loose, and hauled away if desired, as the drill sections emerge from the ground. In

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this case, in order to maintain the grout under pressure and prevent it from being forced back out of the cavity by the weight of the earth-loaded drill string, it is most convenient to introduce the grout into the pile cavity through a separate pipe that is jetted or otherwise sunk into the earth beside the drill, as mentioned above. Alternately, of course, the hollow shaft of each drill section may be provided with any suitable type of check valve to prevent the reverse flow of grout therethrough.

The employment of an auger-type drill in accordance with the invention has still other advantages. Because it is propelled in a downward direction by its spiral blade and by its own weight when rotated, no vertical forces need be applied to sink it into the earth. This dispenses with the need for massive pile driving equipment, reduces the head room required by such equipment, and eliminates the vibration that is inherent in the operation of such equipment and is often damaging in its effects on surrounding structures and formations. Also, since the auger cuts its way into the earth without any material compacting action against the cavity walls, there is no tendency to so densify the earth immediately adjacent the cavity as to seal it against penetration by the grout. Thus, maximum freedom of the grout to penetrate cracks, crevices, and interstices of the surrounding formations for great distances is insured, with the benefits explained above.

While I prefer to use an auger type drill made up of short sections, each of which carries an auger blade running spirally about the shaft thereof for substantially its full length, as hereinafter described, the invention is not to be construed as limited to the use of such a drill except as the claims may so require. Satisfactory results may be obtained if the drill has an auger type cutting blade at its lower end that makes at least one full convolution about the shaft and is, therefore, capable of providing ample support for the cylindrical mass of earth penetrated thereby over the entire transverse cross section of the pile cavity to raise the earth out of the cavity in accordance with the invention.

The foregoing and still further objects, advantages, and features of the invention will be better understood, or will become apparent, from the following detailed description of preferred apparatus and methods for carrying out the invention, and from the accompanying drawing in which:

Figure 1 is a vertical section through an earth mass in which a pile is to be constructed during an early stage in the construction of the pile, with the drilling apparatus employed shown partially sunk into the earth mass;

Fig. 2 is a fragmentary vertical section on an enlarged scale showing, in more detail, a portion of the apparatus of Fig. 1, sunk into the earth mass to the full depth of the pile;

Fig. 3 is a similar sectional view showing additional apparatus employed at a later stage in the construction of a pile and showing the lower portion of the pile cavity filled with concrete and the drilling apparatus partially removed.

Fig. 4 is a similar vertical sectional view through the finished pile;

Fig. 5 is a vertical sectional view through the lower end of a modified form of auger-type drill for use in accordance with the invention;

Fig. 6 is a fragmentary horizontal section showing details of the apparatus of Fig. 5, the section being taken as indicated by the line 6—6 of Fig. 5;

Fig. 7 is a vertical sectional view through another portion of the apparatus of Fig. 5, showing how a series of auger sections may be secured together in end to end relation;

Fig. 8 is a horizontal section through the apparatus of Fig. 7, the section being taken as indicated by the line 8—8 of Fig. 7; and

Fig. 9 is a fragmentary vertical section through the

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lower end of still another modified form of auger-type drill adapted for use in accordance with the invention.

Referring first to Fig. 1, an auger-type drill, generally designated 11, is shown sunk into the earth to a portion of the depth of a pile cavity 12 (shown in phantom outline) to be drilled in an earth mass 13. The drill 11, being of the auger type, requires only to be rotated to cut its way into earth masses other than more or less solid rock, and it may conveniently be rotated by any suitable motor 14 coupled thereto and having handle bars 16 and 17, or the like, attached thereto for manually holding the motor itself against rotation. With larger equipment and deeper pile cavities to be drilled, the motor may be more securely held by any convenient structure (not shown). The motor shaft is preferably coupled to the drill shaft 18 by a simple sliding fit permitting quick coupling and uncoupling by merely lowering and raising the motor, as by means of a sleeve 19 on the lower end of the motor shaft having a square or other non-circular bore and a complementary shaped end 20 on the upper end of the drill shaft closely embraced by the sleeve 19.

The drill 11 is preferably comprised of a plurality of relatively short lengths, as stated above, each length having a sleeve, like the sleeve 19, mounted on one end of its shaft and a complementary shaped, square or other non-circular opposite end 20 to be embraced by the socket of the adjoining drill section with a close sliding fit. Each sleeve 19 may be either permanently or removably secured to the shaft 18 of one drill section as by a suitable pin 21, and adjoining drill sections are preferably secured together by means of a tapered pin 22 so as to permit rapid assembly and disassembly of the drill string. The drill sections may all be identical and of conventional design, with an auger blade 23 spiralling about the central shaft 18 from end to end thereof. Alternately, if desired, the lowermost drill section may have the lower end of its shaft equipped with a lead screw 24, preferably removable for replacement, and a special cutter blade 25 and supporting structure 26 therefor (Fig. 5), the special cutter blade being removable for sharpening or replacement. Since the detailed construction of the drill may be conventional for carrying out the invention as illustrated in Figs. 1 to 4, a minimum of such details is shown for the sake of simplicity.

The drill 11 is screwed into the earth while connecting section after section thereof in end-to-end relation as required to keep the upper end of the drill above the surface where it may be driven by the motor 14 as the lower end of the drill moves downwardly. Where feasible, the drill is sunk until solid rock is encountered. Otherwise, the depth to which the drill is sunk is determined largely by the load resisting requirements of the finished pile and the character of the earth formations penetrated, which effect the load resisting capacity of the finished pile, as explained above.

When the drill has been sunk to the depth required to define the general dimensions and location of a pile cavity to be formed, the drill is left in place with the earth bounded by the defined limits of the pile cavity retained between successive convolutions of the drill blade. The drill and the earth so retained thereby thus together constitute, in effect, a plug that completely fills the cavity to be formed.

At this point, a grout feeding pipe, preferably comprised of a plurality of sections 28 connected together as shown (Fig. 3), is driven into the earth closely adjacent the drill 11 by hammering or jetting. When this pipe is driven by hammering, it is desirable to temporarily close the lower end thereof with a suitable, loosely fitting cap or plug (not shown) to prevent soil and gravel from entering and packing in the pipe. Either water or intrusion materials may be pumped through the grout feeding pipe to hydraulically dig the hole for the pipe in accordance with known practices. The grout feeding pipe may also be assembled section by section as it is

projected downwardly, particularly when required by limited head room above ground.

The grout feeding pipe may be inserted from any desired point around the drill so long as it is directed to bring the lower end of the pipe into close proximity with the lower end of the drill, preferably at or slightly below the depth to which the drill has been sunk. A source (not shown) of a suitable, fluid grout is then connected through a suitable pump (not shown) to the upper end of the grout feeding pipe, and grout is pumped under relatively high pressure through the pipe and into the earth adjacent the lower end of the drill, from whence it will flow in any direction through existing cracks, crevices, and interstices of the surrounding formations, sooner or later penetrating the region immediately below the drill. As the voids in this general region become filled with grout and the grout is forced farther and farther outwardly in one or more directions, the resistance to its flow increases, and the pressure in the immediate vicinity of the lower ends of the drill and grout pipe increases, eventually developing sufficient force against the lower end of the earth-loaded drill to raise it slowly as the pumping of grout is continued. The previously defined pile cavity is thus filled with grout from the bottom upwardly under high pressure maintained by the earth-loaded drill as the drill rises. The pressure at any depth is, of course, roughly proportional to the weight of the earth-loaded drill and the frictional forces resisting its rise, plus the weight of any grout above that depth, per unit area of the drill bottom. The drill sections may be disconnected one by one as they emerge above the ground level, and the earth carried thereby may be removed, thus gradually reducing the back pressure on the grout and effecting a gradually decreasing pressure gradient in the grout filled cavity from the bottom toward the top. This avoids any danger of shooting large quantities of grout upwardly out of the cavity around the drill.

By reason of the grout pressure within the pile cavity, the grout is forced into cracks, crevices, and interstices of the surrounding earth formations in all directions along the major part of the length of the pile from the bottom end thereof. This solidifies and rigidifies porous surrounding masses, particularly below the pile and round the lower portions of the pile, giving greater lateral and vertical support to the pile and increasing the load carrying capacity of the surrounding earth. The monolithic character of all the grout supplied, both within and beyond the boundaries of the pile cavity itself, forms, in effect, an enlarged pile base and interlocks the pile with the surrounding earth formations along the length of the pile, thus further increasing the resistance to vertically applied loads, particularly when the pile does not rest on bedrock. In addition, loose porous masses adjoining the pile cavity are compacted and compressed away from the cavity so as to form bulbous enlargements of the cavity here and there along its originally defined boundary. This compacting action and the consequent filling of the enlargements so formed also contributes substantially to both the vertical and lateral support of the pile.

Depending largely upon the depth to which the drill has been sunk, the grout pressures may range from as low as 25 or 30 lbs./sq. in. to as high as 400 or more lbs./sq. in. When working in earth formations of average density, the pressure required to lift the earth-loaded drill string is about 2 lbs./sq. in. per linear foot of the drill string. In the majority of cases, according to my experience, pumping pressures in the range from about 30 lbs./sq. in. to 120 lbs./sq. in. will suffice, and pressures as high as 400 lbs./sq. in. will be required only for building piles of unusually great depth.

Though pressures of the order of 30 to 120 lbs./sq. in. are relatively low, they are highly efficient in compacting and densifying the lower strata where the major portion of the vertical load is normally applied. Because the

grout is fed with only minor friction losses directly to the bottom of the pile cavity, it is applied with substantially the full pumping pressure precisely where it is needed the most. Driving forces applied downwardly on masses of preplaced aggregate, and grout pressures applied by pumping grout downwardly through a mass of preplaced aggregate, are, by contrast, largely dissipated by frictional losses, etc., and only relatively small forces and pressures are actually applied at the bottom of the pile and are relatively ineffective for accomplishing the above described results.

Thus, the benefits of constructing a pile in this manner are numerous, both as regards the strength and density of the solidified concrete of which the pile itself is made and the imperviousness, rigidity, and general stability of the surrounding earth for considerable distances from the pile body. Because of these effects, a plurality of such piles formed side by side are most effective as retaining walls around unstable earth masses and as barriers to the seepage of water.

As explained above, the grout pumped into the earth below the lower end of the drill may be conveyed to that region through the shaft of the drill itself, rather than through a separate pipe sunk into the earth beside the drill. This, of course, requires a drill having a hollow shaft that is open at its lower end for discharge of the grout pumped therethrough. During the sinking of such a drill, the lower end of the shaft may be closed to prevent the forcing of earth into the hollow shaft and thereby plugging it so as to impede the flow of grout therethrough. This may be accomplished with any of a number of closure arrangements, one simple form of which is illustrated in Fig. 5.

Referring to Fig. 5, there is shown a hollow drill shaft 31 having an auger blade 32 mounted thereon. The special cutter blade 25, removably mounted in the supporting structure 26 thereof, is shown attached to the lower end of the drill shaft by means of a hollow sleeve 33 and a plurality of bolts or pins 34. The blade supporting structure 26 is shaped to provide a shoulder 36 that bears against the lower end of the hollow drill shaft 31 and a conical seat 37 for a plug 38 having a correspondingly tapered shoulder 39 and a cylindrical portion 41 that projects into the cylindrical interior of the sleeve 33. Abutment of the tapered periphery 39 of the plug 38 with the correspondingly tapered shoulder 37 of the sleeve 33 prevents the plug from being forced into the drill shaft 31 as the drill is sunk into the earth.

The plug may be restrained from falling out of the blade supporting structure 26 in any desired manner that will permit it to be easily ejected by the application of pressure to the upper end of the plug by the grout to be pumped through the drill shaft. A pair of shear pins 42 of soft metal, such as lead, may be inserted for this purpose through aligned apertures drilled through the walls of the hollow drill shaft 31 and sleeve 33 and into the cylindrical portion 41 of the plug 38. These pins are easily sheared off by pressure exerted against the inner end of the plug 38.

In the event it is desired to employ a lead screw on the lower end of the lower drill section, this may be accomplished by securing a lead screw 43 to a modified plug 44 in any desired manner, as by welding. Rotation of the lead screw 43 and the plug 44 in a blade supporting structure 45 may be prevented by providing a square or other non-circular bore 46 through the sleeve portion of the blade supporting structure 45 and making the plug 44 of corresponding cross-sectional configuration, as shown in Fig. 9. In other respects, the plug, the blade supporting structure, and the drill sleeve assembly may be the same as the assembly shown in Figs. 5 and 6.

Adjoining sections of the drill string may be connected together so as to permit the application of a driving torque from one section of the drill string to the next by welding a sleeve 47, having a square or other non-circular internal

socket 48, on one end of each section of the drill string, and a sleeve 49 on the opposite end of each section, the sleeve 49 having a hollow projection 51 of complementary, square or non-circular, exterior shape to be received with a close sliding fit in the socket 48 of the sleeve 47 on an adjoining drill section. Each pair of interfitting sleeves 47 and 49 may be locked together by means of bolts or pins 52.

When employing drill sections with a hollow shaft for conveying the grout into the earth below the drill string, it is not convenient to disassemble the drill string section by section as it is ejected from the earth by the grout pumped into the pile cavity unless special provision is made for disconnecting the grout supply line and blocking the reverse flow of grout through the drill string while each drill section is being removed. Accordingly, the introduction of grout through the drill string is preferably employed only in forming relatively shallow piles requiring the use of a relatively short drill string, or in situations where there is sufficient head room above ground to permit the entire drill string to be removed without disassembling it as section after section emerges from the pile cavity.

In other respects, operation of the pile forming process is substantially the same whether the grout is introduced into the earth through a separate grout conduit sunk adjacent the drill or is introduced into the shaft through the drill itself.

The grout employed in accordance with the present invention should be of a highly fluid consistency with as low a viscosity as can practically be obtained while retaining the essential characteristics of high strength in the solidified concrete. A grout having these characteristics to an outstanding degree is described in United States Patent No. 2,434,302, granted January 13, 1948, to Louis S. Wertz. Such a grout consists essentially of water having dispersed therein a high strength hydraulic cement, such as Portland cement; fine sand in an amount up to about twice the amount of cement by weight; a finely divided gas producing material, such as aluminum powder, in an amount from about 0.005% to about 0.05% of the amount of cement by weight; a finely divided inorganic filler, such as fly ash, blast furnace slag, pozzolanas, and other finely divided, natural or artificial, siliceous materials, in an amount from about 1/2 to 2 or 3 times the amount of cement by weight; and a lubricating and/or suspending agent to increase flowability.

At least some of the finely divided inorganic filler preferably contains acidic colloidal silica to retard the gelation or setting of the cement.

The lubricating agent may be any of a wide variety of oleaginous materials, such as mineral oils, stearates, natural or sulfonated vegetable oils, and mixtures thereof. The amount of these lubricating agents required will vary somewhat with the type selected and the flowability desired, but will usually be between about 0.1% and 2.0% of the weight of the cement. Since these lubricants also act as set retardants and, in large amounts, tend to weaken the solidified concrete, their quantity should be less than 2% in most instances.

In addition to the above ingredients, the grout may contain a small amount of a cement dispersing agent, such as a lignin sulfonic acid residue, and other conventional additives. Also, as disclosed in the copending patent of Louis S. Wertz, Number 2,655,004 dated October 13, 1953, for Composition for and Method of Solidifying Porous Masses and Structures, a water-soluble cellulose ether, such as methylcellulose or sodium carboxymethylcellulose, may be employed to great advantage in very small amount as a substitute for all or most of the oleaginous types of lubricating agents. In amounts of about 0.005% to about 0.25% of the weight of the total solids in the grouts, these cellulose ethers lubricate the grouts without any noticeable increase in viscosity and without deleteriously affecting the strength of the set concrete. They

reduce the water gain and rate of water extraction of the grouts and are excellent suspending and lubricating agents.

From the foregoing description it will be appreciated that the invention accomplishes the various objectives and advantages described above in a simple manner admirably adapted for use under a wide variety of conditions. While specific examples of the method and of certain special apparatus for use in carrying out the method have been described in detail, it will also be appreciated that numerous modifications thereof may be employed by those skilled in the art while following the general principles of the invention and without departing from the scope thereof as defined in the appended claims.

Having described my invention, I claim:

1. A method of forming piles in the earth comprising sinking an auger-type drill into the earth to define the location and depth of a pile cavity without removing the earth therefrom, and forcing a fluid hydraulic cement grout into the earth below said drill with sufficient pressure and in sufficient quantity to raise said drill from said cavity and form the pile therein.

2. A method of forming piles in the earth comprising screwing an auger-type drill into the earth to define the location and depth of a pile cavity while retaining the earth in said location, and forcing a fluid hydraulic cement grout into the earth below said drill and into contact with the lower end thereof with sufficient pressure and in sufficient quantity to raise said drill and earth from the pile cavity and simultaneously to fill with grout both said cavity and voids in the earth communicating therewith.

3. A method of forming piles in the earth comprising sinking an auger-type drill into the earth to define the location and depth of a pile cavity without removing the earth therefrom, and forcing a fluid cementitious mixture into the earth below said drill with sufficient pressure and in sufficient quantity to exert an upward raising force on said drill, while restraining the drill from rotation in said cavity, to form the pile therein, said drill having a hollow shaft, and said mixture being fed into the earth below said drill through said hollow shaft.

4. A method of forming piles in the earth comprising screwing an auger-type drill into the earth to define the location and depth of a pile cavity while retaining the earth in said location, and forcing a fluid hydraulic cement grout into the earth below said drill and into contact with the lower end thereof with sufficient pressure and in sufficient quantity to exert an upward raising force on said drill and earth in the pile cavity, while restraining the drill from rotation, thereby filling with grout both said cavity and voids in the earth communicating therewith, said drill having a hollow shaft, and said grout being fed into the earth below said drill through said hollow shaft.

5. A method of forming piles in the earth comprising sinking an auger-type drill into the earth to define the location and depth of a pile cavity without removing the earth therefrom, sinking a pipe into the earth adjacent said location to a depth at least substantially as great as the depth of the lower end of said drill, and forcing a fluid hydraulic cement grout, through said pipe and into the earth below said drill with sufficient pressure and in sufficient quantity to raise said drill from said cavity and form the pile therein.

6. A method of forming piles in the earth comprising screwing an auger-type drill into the earth to define the location and depth of a pile cavity while retaining the earth in said location, sinking a pipe into the earth adjacent said location to a depth at least substantially as great as the depth of the lower end of said drill, and forcing a fluid hydraulic cement grout through said pipe and into the earth below said drill and into contact with the lower end thereof with sufficient pressure and in sufficient quantity to raise said drill and earth together out of the pile cavity and simultaneously to fill with grout both said

cavity and voids in the earth communicating therewith.

7. A method of forming piles in the earth comprising screwing an auger-type drill into the earth to define the location and depth of a pile cavity while retaining the earth in said location, said drill having a shaft composed of sections coupled together in end-to-end relation, forcing a fluid hydraulic cement grout into the earth below said drill and into contact with the lower end thereof with sufficient pressure and in sufficient quantity to raise said drill and earth from the pile cavity and simultaneously to fill with grout both said cavity and voids in the earth communicating therewith, and disconnecting and removing the drill shaft sections one-by-one as they emerge from the pile cavity to effect a stepwise reduction in the back pressure maintained on the grout by the drill and the earth raised therewith.

8. A method of forming piles in the earth comprising screwing an auger-type drill into the earth to define the location and depth of a pile cavity, said drill having an auger-type blade spiralling upwardly from the lower end thereof for a plurality of continuous convolutions to retain earth in said location between successive convolutions of the drill blade, said drill having a shaft composed of sections coupled together in end-to-end relation, sinking a pipe into the earth adjacent said location to a depth at least substantially as great as the depth of the lower end of said drill, forcing a fluid hydraulic cement grout through said pipe and into the earth below said drill and into contact with the lower end thereof with sufficient pressure and in sufficient quantity to raise said drill and the earth retained between successive convolutions of the drill blade and supported thereon from the pile cavity and simultaneously to fill with grout both said cavity and voids in the earth communicating therewith, and disconnecting and removing the drill sections one-by-one as they emerge from the pile cavity to effect a stepwise reduction in the back pressure maintained on the grout by the drill and the earth raised therewith.

9. A method of forming piles in the earth comprising screwing an auger-type drill into the earth to define the location and depth of a pile cavity while retaining the earth in said location between successive convolutions of the drill blade, said drill being composed of drill sections coupled together in end-to-end relation, driving a pipe into the earth in a direction to bring one end thereof closely adjacent the lower end of the drill, forcing a fluid hydraulic cement grout through said pipe and into the earth below said drill and into contact with the lower end thereof with sufficient pressure and in sufficient quantity to raise said drill and the earth retained between successive convolutions of the drill blade from the pile cavity and simultaneously to fill with grout both said cavity and voids in the earth communicating therewith, and disconnecting and removing the drill sections one-by-one as they emerge from the pile cavity to effect a stepwise reduction in the back pressure maintained on the grout by the drill and the earth raised therewith.

10. A method of forming piles in the earth comprising screwing an auger-type drill into the earth to define the location and depth of a pile cavity, said drill having an auger-type blade spiralling upwardly from the lower end thereof in a series of substantially continuous convolutions extending substantially the full depth of said cavity for retaining and supporting the earth in said location between successive convolutions of the drill blade, and forcing a fluid hydraulic cement grout into the earth below said drill and into contact with the lower end thereof with sufficient pressure and in sufficient quantity to raise said drill and the earth retained between successive convolutions of the drill blade from the pile cavity and simultaneously to fill with grout both said cavity and voids in the earth communicating therewith.

11. A method of forming piles in the earth comprising screwing an auger-type drill into the earth to define the location and depth of a pile cavity, said drill being composed of drill sections coupled together in end-to-end relation and each of said drill sections comprising a shaft having an auger-type blade spiralling about the shaft substantially from end to end thereof, whereby the earth in said location is retained between and supported by successive convolutions of the drill blade for substantially the entire depth of the cavity, forcing a fluid hydraulic cement grout into the earth below said drill and into contact with the lower end thereof with sufficient pressure and in sufficient quantity to raise said drill and the earth retained between successive convolutions of the drill blade from the pile cavity and simultaneously to fill with grout both said cavity and voids in the earth communicating therewith, and separating and removing the drill sections one by one as they emerge from the pile cavity to effect a stepwise reduction in the back pressure maintained on the grout by the drill and the earth raised therewith.

12. A method of forming piles in the earth comprising screwing an auger-type drill to sink it into the earth to define the location and depth of a pile cavity while retaining the earth in said location, forcing a fluid hydraulic cement grout under pressure into a space below said drill to exert a removing force on the drill while restrained against rotation in an unscrewing direction, the grout being supplied in sufficient quantity to fill the cavity created by the withdrawal of said drill and form a pile.

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