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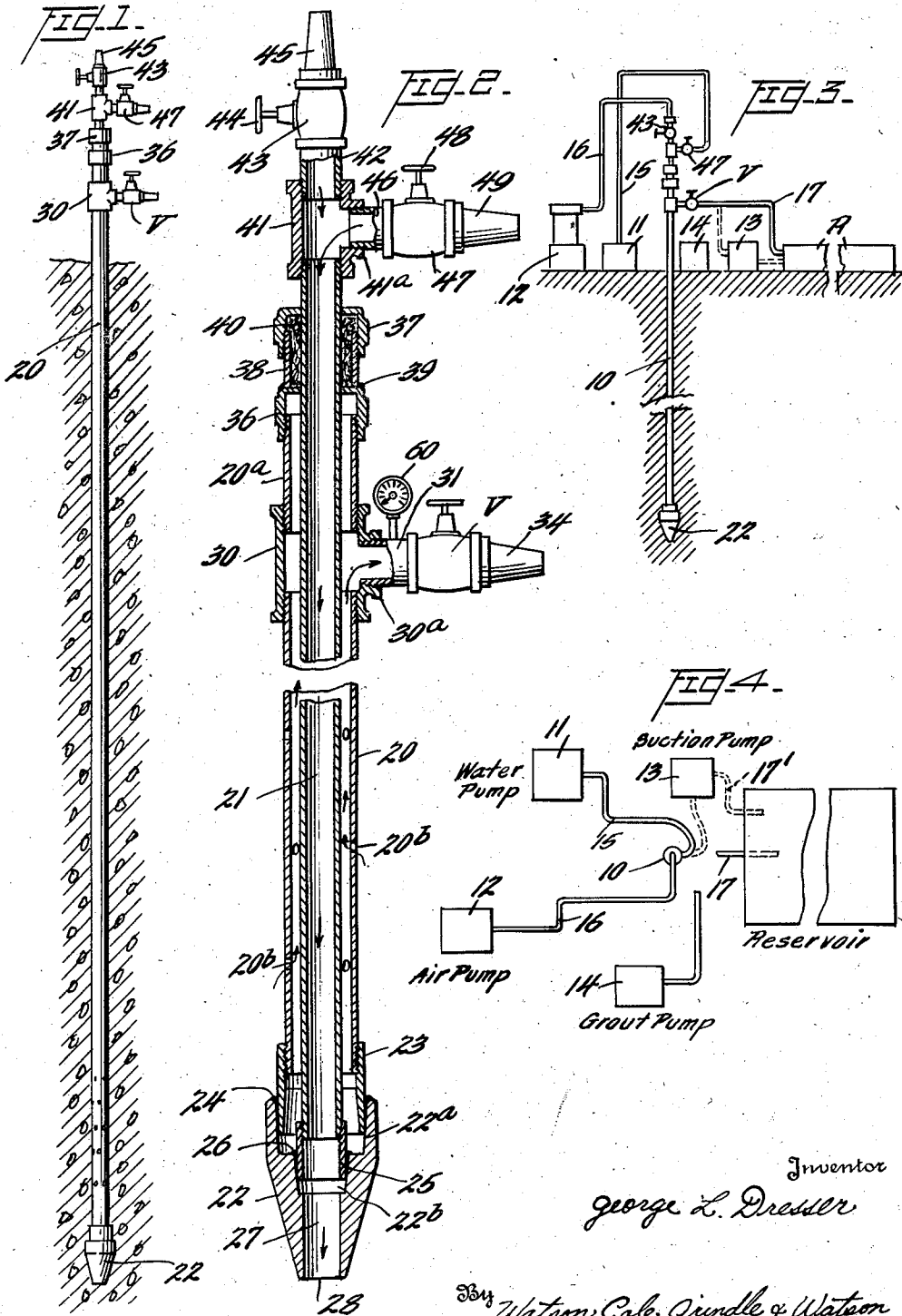
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METHOD OF AND APPARATUS FOR INTRODUCING GROUT INTO SUBSOIL

Filed Feb. 25, 1944

2 Sheets-Sheet 1



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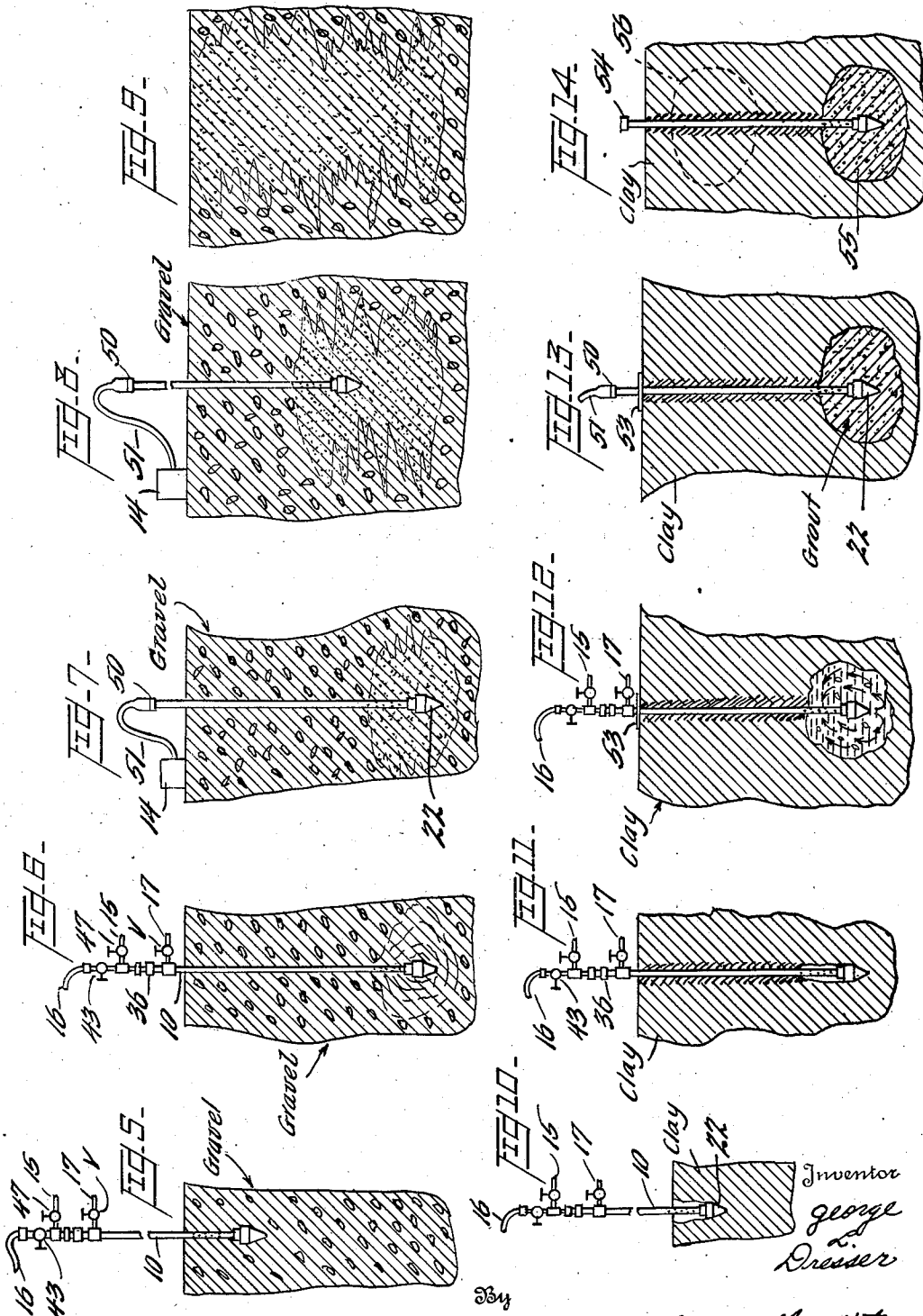
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## UNITED STATES PATENT OFFICE

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## METHOD OF AND APPARATUS FOR INTRODUCING GROUT INTO SUBSOIL

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16 Claims. (Cl. 61—36)

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The present invention relates to methods of and apparatus for introducing grout or the like into subsoil either for the purpose of increasing its bearing strength or to provide an anchoring mass for a pile.

More particularly stated the invention pertains to a novel method and apparatus by means of which grout, or other material of generally similar nature, which has the capacity to harden or solidify from a plastic condition, may be conveniently introduced into permeable subsoil of sandy or gravelly nature for the purpose of firmly supporting the lower end of a pile or for increasing the bearing strength of such soil, or a body of such material established at a desired distance below the surface of a bed of dense soil, such as clay, such body forming the anchoring means for a metallic pile or column the upper end of which may project above the surface of the ground. The method and means of the present invention are of such nature that an adequate foundation for any structure however massive, may be readily established at almost any site, even though soil conditions are most unfavorable. The invention is highly useful in establishing adequate foundations for new buildings and is likewise of great value in strengthening foundations of structures previously erected. While, in establishing the foundations for buildings to be newly erected it is quite possible to use conventional piling, in the event that the soil is of low bearing strength, it is not always possible to use conventional piling in the reinforcement of the weakened foundations of structures already erected, the weakened foundations of such structures being quite often unable to withstand the vibration or shock incident to the placement of piling by mechanical driving methods.

In the event that a body of permeable subsoil is to be treated in order that its bearing strength may be increased this may be readily accomplished, in accordance with the present invention, by causing a jet or jets of a washing liquid such as water to be delivered into the body of permeable soil at a selected point below the surface and the washing effect of a flowing stream utilized to remove from the permeable body a substantial proportion of its lighter and weaker elements, leaving the denser and stronger elements such as stones behind, the wash water with its suspended waste matter being brought to the surface, by suction means if desired, and disposed of. The washing is continued until it is perceived, by inspecting the wash liquid which reaches the surface, that at least a substantial body of the permeable material

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below the surface has been cleared of its least desirable constituents. The flow of wash water may then be discontinued and grout under pressure introduced, the grout readily finding its way throughout the washed zone and surrounding and forming a matrix for the remaining and more substantial elements, the method involving as a matter of fact, the formation of a body of concrete in place, beneath the surface of the ground, by the preliminary washing of the aggregate and the introduction of the matrix or grout thereafter. When the grout hardens the zone into which it has been introduced becomes a solid mass of great bearing strength.

In accordance with the method a zone of permeable subsoil of any desired volume may be treated and a soil of limited bearing strength converted, in place, into a solid or body of great bearing strength, in a rapid, economical manner. By causing the washing operation to be carried out over a considerable area, measured horizontally, and by washing both deeply and toward the surface, a very large body of permeable soil may be treated and its bearing strength increased, the washing and grouting operation being carried out over as wide an area, and as deeply, as may be deemed necessary. The permeable soil beneath existing structures may be treated in this manner and the structures thus strengthened or, as has been previously stated, the grouting may be employed as a step preliminary to the erection of a new structure.

In dense, hard soil, which ordinarily provides adequate support for building structures, it is nevertheless frequently desirable to establish piles the upper ends of which project above the ground level, and which may constitute supporting or anchoring elements which may neither be withdrawn from the ground or forced downwardly by pressure. In accordance with the invention a body of grout or concrete may be readily established in subsoil of dense or clayey nature, to serve as a submerged anchor for a pile, or for any other purpose, all without the aid of vibration or shock creating instrumentalities. Hence if, for any reason, it is necessary to introduce a body of grout or concrete into the earth near an existing structure this may be readily accomplished without danger to such structure. In placing and anchoring a pile in dense soil a combined pile and jetting or earth penetrating device is introduced into the earth by the action of a jet of wash liquid under pressure which issues from the end of the device and a shaft being thus created as the device moves downwardly, the downward movement

being halted only after it has penetrated the desired distance. The washing action of the jet is, however, continued after its downward movement has ceased for the purpose of dislodging and bringing to the surface a body of the dense subsoil and thus creating at the bottom of the shaft a considerable cavity in the earth.

Suction means may be employed to withdraw the wash water from the earth and, in any event, the washing out action will be continued until it is estimated, by observing the character and extent of the solids withdrawn, that a cavity of desired size has been formed. The flow of wash water is then interrupted and grout forced downwardly through the jetting device, which also serves as a grout conduit, until the grout completely fills the cavity formed by the eroding action of the stream of wash water, a substantial body of artificial stone or the like resulting. The jetting or earth penetrating device is allowed to remain while the body of grout is hardening so that, when the grout has hardened, the jetting device is firmly bound and may not be moved. Its upper end may project above the ground and be employed as a stable point for the attachment of any structure to be secured against movement in any direction.

One apparatus is employed for carrying out either method and one form of this apparatus is illustrated, by way of example, in the accompanying drawings in which,

Figure 1 is a side view of the elongated element for sinking the necessary shaft, and transmitting wash water and grout into the subsoil;

Figure 2 is an axial section thru this element, partly broken away in order that the remainder may be shown on a larger scale;

Figure 3 is a diagrammatic view showing, in vertical section, a body of subsoil into which grout is to be introduced, together with the various essential pumps, etc. of the improved apparatus grouped together upon the surface;

Figure 4 is a top plan view of the apparatus shown in Figure 3;

Figures 5 to 9, inclusive, are of diagrammatic nature and successively indicate the various positions of the jetting or earth penetrating element of the wash liquid and grout-transmitting apparatus as used in the treatment of a body of permeable soil, such as gravel, to give it increased bearing strength;

Figures 10 to 14, inclusive, are also of diagrammatic nature and show, in sequence, the several steps involved in the establishment of a pile in a body of clayey soil.

The apparatus includes the elongated earth penetrating device illustrated in Figures 1 and 2, by means of which wash water and grout may be introduced into the subsoil, together with suitable means such as indicated in Figures 3 and 4 for providing a supply of water under pressure, air under pressure, and grout under pressure, together with a suction pump. A settling basin or reservoir for the reception of wash liquid which issues from the earth after having been utilized for soil washing or excavating purposes is also preferably utilized. In Figures 3 and 4 the elongated earth penetrating element is indicated at 10, a water pump by means of which water under pressures up to 300 pounds per square inch can be supplied, is indicated at 11, a compressor for air is indicated at 12, a suction pump at 13, a grout pump at 14, and a reservoir for receiving wash water and washed out solids at R. Suitable flexible conduits connecting the water and air

pumps 11 and 12 respectively to the elongated element 10, are indicated at 15 and 16, and a conduit for leading wash water with its suspended solid matter from the element 10 to the reservoir R is indicated at 17. Where a suction pump is employed the conduit 17 is caused to terminate at the intake port of pump 13, as indicated in dotted lines in Figure 4, and a further offtake conduit 17' leading from the suction pump to the reservoir R is employed if necessary.

The details of the element for penetrating the soil may most readily be perceived in Figure 2 of the drawings. It comprises essentially a tubular casing 20 which may be relatively long in the event that deep soil penetration is desired or relatively short when shallow penetration only is necessary. Disposed within and coaxial with the casing 20 is a pipe or conduit 21. The lower end of the casing 20 is connected to a cast steel tip 22 and the lower end of the pipe or conduit 21 is likewise connected to this tip. The lower end of the casing is received within the upper end of a sleeve 23 which sleeve is in the nature of a short standard coupling, the lower end of this coupling projecting into a downwardly tapering recess 22<sup>a</sup>, formed in the rear end of the tip 22, in which position it is permanently secured as by a weld 24. Due to the fact that the recess 22<sup>a</sup> tapers downwardly, as stated, there will be no difficulty in assembly despite minor variations in coupling diameter. The inner face of the sleeve 23, at the upper end thereof, is interiorly threaded and this thread receives a corresponding thread formed upon the outer surface of the lower end of the casing 20. The inner pipe or conduit 21 likewise projects, at its lower end, into the upper end of a sleeve or standard coupling member 25, the conduit and sleeve having interengaging threads. The lower end of sleeve or coupling 25 projects into a tapered cylindrical recess 22<sup>b</sup> formed in the base of tip 22, the diameter of this recess being substantially less than that of the recess 22<sup>a</sup> which receives sleeve 23, sleeve 25 being likewise permanently attached to the tip by means of the weld 25. A central channel through the tip 22 is indicated at 27 this central channel terminating in a port 28 formed in an earth-engaging outer surface of the tip, at the smaller end or point thereof. Preferably this earth-engaging outer surface is frusto-conical as shown and the tip may advantageously be fabricated of cast steel. The wash liquid to be used in sinking the earth-penetrating element, or to be introduced into the body of earth to be excavated or washed, passes downwardly through pipe 21 and issues as a jet from port 28.

It will be observed that the casing 20 has a short upper section 20<sup>a</sup> which is connected to the lower section by means of a T-member 30 having a laterally extending branch 30<sup>a</sup>. Liquid issuing from branch 30<sup>a</sup> of the T-member passes thru a nipple 31 and then thru the casing of a valve V. The valve V may be of any suitable type provided that it may be adjusted to interrupt or permit, as desired, flow of liquid from the casing 20 to the offtake tube 34, to which tube the inlet end of a flexible hose or conduit, such as indicated at 17 in Figures 3 and 4, may be attached.

The inner duct or conduit 21 projects upwardly beyond the upper end of the upper portion 20<sup>a</sup> of the casing and this projecting portion is encircled by annular flanged caps 36 and 37. The downturned flange of the cap 36 has threaded engagement with the upper end of the casing 20<sup>a</sup> and the downturned flange of the cap 37 has

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threaded engagement with the outer surface of the upper end of a tube or sleeve 38 welded, as at 39, to the upper surface of cap 36. In the narrow space of annular cross section defined by the caps 36 and 37 and the tubular member or sleeve 38 there is contained a body 40 of packing material. This packing material prevents, when placed under pressure by suitably adjusting the position of cap 37, leakage from the casing 20 upwardly past cap 36 around the outside of the pipe or conduit 21. The upper end of pipe 21 projects into the lower end of a T-member 41 and, into the upper end of this T-member, there projects a nipple 42 to which is connected a valve casing 43. The movements of the valve within the casing are controlled by handwheel 44. A tapered nipple 45 is connected to the upper end of the valve body and to this nipple may be connected the end of a flexible hose for the transmission, from a suitable source of supply, of a compressed gas such as compressed air.

The lateral branch 41<sup>a</sup> of the T-member 41 is connected by means of a nipple 46 to the outlet end of a valve body 47 which valve body is likewise provided with a valve the movements of which are controlled by a handwheel 48 and with an inlet nipple 49 which may be connected by means of a flexible hose to a suitable source of wash liquid under pressure. As shown in Figures 3 and 4 the nipple 45 is connected to the air hose 16, the nipple 49 to the hose 15 leading from the water pump 11 and the nipple 34 to the discharge conduit or hose 17.

The lower end of the casing 20 has formed therein a plurality of relatively small apertures or ports 20<sup>b</sup> which are provided to permit wash liquid which has been discharged through the port 28, and has moved upwardly, to re-enter the element 10, carrying with it the lighter and smaller particles of the soil which is being subjected to the washing operation. The water thus entering the casing 20 from without passes upwardly, with its contained suspended matter, and outwardly through the nipple 31, valve V, nipple 34 and offtake conduit 17 to a point where it may be wasted or collected in a pond or settling basin such as that indicated diagrammatically at R. The wash water entering the soil penetrating element, of course, passes through valve body 47 and downwardly through pipe 21. During the washing operation the valve controlling the flow of compressed air into pipe 21 will normally be in closed position. If at any time, however, it is desired to project a stream of air under pressure into the subsoil the valve within casing 47 will be closed and that within valve casing 43 opened. Hence the element 10 may be employed either to project a stream of wash water into a body of soil, or a current of compressed air or, in some cases, both wash water and compressed air, for purposes hereafter to be made more clear.

Two preferred methods of use of the apparatus as so far described may be most readily perceived from an inspection of Figures 5 to 14, inclusive. Where it is desired to increase the load bearing strength of a body of permeable soil the apparatus is moved into position and the soil penetrating element 10 disposed vertically just above the zone or body which is to be strengthened with grout, the apparatus being shown in this initial position in Figure 3. Handle 48 is then manipulated to open the associated valve and permit the inflow of water under pressure into the inner duct 21. The jet of water will be projected from the tip 22, through fluid discharge port 28, against

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the surface of the ground. Due to the eroding effect of the water jet the soil immediately below the cast steel tip 22 will be displaced and the element 10 will begin to settle into the ground, during this preliminary stage the wash water simply passing upwardly around the outer surface of the tip 22 and flowing away over the surface of the ground. The action of the jet is continued and the downward movement of the element 10 likewise continues, the downward movement being aided somewhat by pressure from above if necessary.

After the element 10 has sunk part way toward its final position, to such extent that the apertures 20<sup>b</sup> in the casing 20 are beneath the ground level, the wash water will either wholly or in part pass through these ports or apertures into the interior of the casing, together with substantial amounts of suspended matter, and then pass upwardly through the casing until it reaches the level of the T-member 30, then through the body of valve V and into the offtake conduit 17. If desired the suction pump 13 may be connected to the offtake conduit 17 so that there is a positive lift applied to the column of outflowing wash water. The action may be continued until the element 10 has penetrated into the permeable soil to the desired extent, for instance to the position diagrammatically illustrated in Figure 6. The flow of wash water may be continued after full penetration has been obtained, however, in order that further washing of the permeable body of earth around the lower end of element 10 may be effected, preferably at reduced pressure. If desired, the flow of water may be discontinued and air under pressure allowed to flow to the discharge port 28 of the tip and thence into the surrounding soil, to further prepare the soil for the grout which is to follow, or air and water allowed to flow together to and out of port 28.

After such washing has been completed T-member 30 and associated parts are removed from the upper end of the casing 20, the lower end of pipe 21 being unscrewed from the coupling member 25 and the pipe 21 with caps 36 and 37, and parts 38 and 20<sup>a</sup> lifted upwardly. A further cap, indicated diagrammatically at 50, is then affixed to the upper end of casing 20, this cap having connected thereto the end of a flexible duct or hose 51 leading to the delivery port of the grout pump diagrammatically indicated at 14. The pump is then operated to deliver grout under substantial pressure to the casing 20, the grout passing downwardly through the casing and outwardly through the discharge port 28 and through the ports 20<sup>b</sup> formed in the casing and which have previously been employed as water inlet ports. A substantial body of grout may thus be delivered into the zone immediately adjacent the lower end of the element 10. In some instances, when desired, the grout may be caused to penetrate considerable distances in all directions from the lower end of the element 10, finding its way through the spaces between the stones, gravel, sand and particles of soil.

When a sufficient amount of grout has been delivered in this manner the element 10 may be removed. If desired grout may be forced into the body of soil surrounding the lower end of element 10 at higher elevation, the element 10 being halted from time to time in its upward movement, one such more elevated grout delivery point being indicated in Figure 8. Figure 9 illustrates diagrammatically a body of earth into which

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grout has been forced from a point well below the surface all the way up to the surface so that this body has been transformed into a relatively deep body of concrete, in place, the aggregate having been present originally and having been washed, in place, to eliminate its more undesirable constituents and to make room for the grout which forms the matrix for the concrete. While this method is particularly useful where the subsoil contains many stones and rocks it is nevertheless useful even where the subsoil contains large quantities of vegetable matter. Washing operations may be conducted from points closely adjacent the surface to points far below the surface and grout injected under heavy pressure to fill the voids created and to force its way into and through the interstices of the earth. Any character of subsoil, however poor, can be given greatly increased bearing strength by the method of grout application which has just been described. If it is desired to establish a permanent pile instead of simply increasing the bearing strength of the porous soil, and it is frequently so desired, the pumping of grout may be halted when a sufficiently large anchoring body has been established, such for instance as indicated in Figure 7. The casing 20 and tip 22 are left in place, the pump disconnected, and a suitable cap placed upon the upper end of the casing, if desired.

Where the soil is dense and particularly where it is desired to establish one or more piles, a somewhat different procedure is followed, as diagrammatically indicated in Figures 10 to 14. The soil penetrating element 10 is connected up as before and it is sunk vertically downwardly by jetting, as before, being shown in Figure 10 to have penetrated the dense soil for a short distance and in Figure 11 to have penetrated the soil to the full extent desired. Naturally the element 10 may be caused to penetrate to any desired depth within the limits of the apparatus. Initially the jetting fluid, which is usually water under high pressure, escapes to the surface of the ground along the outer wall of the casing but later, as the element 10 descends, the earth encircling the upper portion of the element tends to "back-fill" and to closely engage the outer surface of the casing so that there is an increasing tendency for the wash water to enter the casing through the ports 20<sup>b</sup> provided for such entry, as the casing descends, and to pass upwardly through the casing and outwardly through the offtake to the reservoir or pond R. When the jetting element has descended as far as desired a holding clamp 53 of any suitable type is applied at the ground level to prevent its further downward movement, but the flow of wash water is continued, the action being such that a considerable cavity is gradually formed by washing, at the lower end of the earth penetrating element 10, as indicated in Figure 12.

By closely observing the wash water discharged into the pond or basin R and estimating or actually measuring the rate at which solids are being brought to the surface, the size of the cavity thus formed by washing during any period of time can be estimated, and the washing action may be halted after this cavity has become as large as thought to be necessary or desirable. Grout may then be forced downwardly as before, after removal of the inner pipe 21, and caused to fill the cavity which has been previously washed in the dense soil. A cavity thus filled with grout is shown in Figure 13. The casing 20 is allowed to remain in the position in which it is shown in this figure, after the grout has been introduced

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and while it is hardening. The grout hose 51 is then removed and a solid casing cap applied, such as indicated at 54. The casing is thus definitely anchored to a body of artificial stone 55 well below the surface. In Figure 14 there is indicated in dotted lines, at 56, an alternative position for the body of grout and it will be appreciated that the apparatus disclosed may be employed in establishing a grout body close to the surface as well as one well below the surface.

It not infrequently happens that the soil into which the grout is to be introduced is of such character that no cavity of adequate size, the walls of which are self-sustaining, can be established, thus making it essential to provide a means for and method of supporting such walls during the period of time following interruption of the flow of water under pressure and before the cavity has been filled with grout. It has been found that, in numerous instances, collapse of the walls of the cavity resulting in its complete elimination immediately follows stoppage of the water pump, unless the fluid pressure in the cavity is maintained by the use of other means.

In actual practice I prefer to employ air under pressure as a medium for supporting the walls of the cavity after the flow of water under pressure has been cut off. To effect this desired result air under desired pressure from pump 12 is conducted to pipe 21 through conduit 16 and valve 43, simultaneously with or immediately after the closure of valve 47. Compressed air then issues from the aperture 28 in the tip and into the cavity, where it displaces the water, the water being forced through the perforations 20<sup>b</sup> into the casing 20 and escaping through valve V. After all of the water has been thus driven from the cavity and air under pressure begins to escape through offtake conduit 17 the valve V is closed. Pressure of the air is maintained sufficiently high to insure adequate support to the walls of the cavity.

The water conduit 15 is then disconnected from nipple 49 and a connection to the grout pump 14 established. Valve 43 may then be closed and valve 47 opened so that grout under pressure will be forced downwardly through pipe 21 and caused to be discharged into the cavity, the flow of grout under pressure being continued until the cavity has been filled. After this pipe 21, T-member 30, and all associated parts are removed from the casing 20. The cap 50 may then be attached to the top of casing 20 and grout caused to flow into the casing until it is completely filled. In this manner the walls of any cavity formed by washing may be fully supported until the cavity is completely filled and obviously the method may be employed even though the casing be removed after the introduction of the grout instead of being allowed to remain in the ground as a pile. The method just described has the further, and very substantial, advantage of avoiding the necessity of introducing grout directly into a body of water within a newly formed cavity, which is undesirable, and air under pressure may be utilized to free the cavity of water even where there is little danger of collapse of the walls of the cavity if unsupported.

By the use of suitably placed pressure gauges the air pressure existing in the cavity at any time may be ascertained and if necessary to do so to obviate the need to pump in grout against an excessive air pressure, the pressure may be reduced by allowing air to escape through valve V until the desired value is reached. Such a

gauge is diagrammatically shown in Figure 2, being indicated at 60.

The novel apparatus shown and described may be modified in various respects to render it more suitable for use when unusual soil conditions are met with, without departure from the invention, and the methods described may be likewise modified slightly when found necessary. Grout may be forced downwardly through the smaller inner pipe by connecting a grout supply conduit to the nipple 45 after having disconnected the compressed air hose from this nipple. When this is done the grout will issue from the discharge port in the tip of the soil penetrating element and more grout will be delivered into the zone below the tip than is the case when the outer casing is used as the grout conducting tube, after removal of the smaller pipe. When grouting with the aid of the inner pipe 21 is being effected valve V will remain open and offtake hose 17 disconnected so that the operator may readily perceive any outflow of grout which will, of course, indicate that no more grout can be forced into the earth at that point. The inner pipe may be left in place, if desired, after grouting has been completed, and the casing also filled with grout to form a stronger pile if piling is being placed, but in the usual case the inner pipe is removed before the grout hardens, and the casing suitably capped.

The earth penetrating element of the apparatus comprises not only a means for sinking a shaft in vibrationless manner, but a means for introducing and withdrawing wash water and air under pressure, a means for forcing grout into a previously prepared zone, and as the metallic shell of a permanent pile. It may be introduced into the earth at various angles so that it can be most conveniently employed in reaching subsoil zones in and around existing foundation structures.

Having described the invention, what is claimed as new and desired to be secured by Letters Patent, is:

1. Apparatus of the type described comprising an elongated casing having a tip fixed upon one end, said tip having a fluid discharge channel therein terminating in a fluid discharge port formed in a soil engaging outer surface, and said casing having fluid inlet ports formed in the wall thereof at points remote from the discharge port of the tip, and a pipe or conduit for leading fluid under pressure from a source of supply thru said casing to said channel.

2. Apparatus of the type described comprising an elongated casing having a tip fixed upon one end, said tip having a fluid discharge channel therein terminating in a fluid discharge port formed in a soil engaging outer surface, a pipe or conduit for leading fluid under pressure from a source of supply thru said casing to said channel, said casing having fluid inlet ports formed in the wall thereof at points remote from the tip, and means for establishing a sub atmospheric pressure in said casing.

3. Apparatus of the type described comprising in combination, an elongated casing having a tip fixed upon one end provided with a fluid discharge port in an outer surface, said casing having a series of fluid inlet ports formed in that portion thereof which is adjacent the tip said ports being remote from the fluid discharge port of the tip, the remainder being imperforate, and means for supplying fluid under pressure to said

tip, to be discharged from the fluid discharge port thereof.

4. Apparatus of the type described comprising in combination, an elongated casing having a tip fixed upon one end provided with a fluid discharge port in an outer surface, said casing having a series of fluid inlet ports formed in that portion thereof which is adjacent the tip said ports being remote from the discharge port of the tip, the remainder being imperforate, means for supplying fluid under pressure to said tip to be discharged from the fluid discharge port thereof, and suction means for establishing a sub atmospheric pressure in said casing.

5. Apparatus of the type described comprising, in combination, an elongated casing having a tip fixed upon one end, said tip having a fluid discharge port formed in a soil engaging outer surface and the casing having apertures formed in the wall thereof remote from the discharge port of the tip, a conduit extending thru the casing to the tip for leading fluid under pressure to said discharge port, connections between said conduit and sources of liquid and gas under pressure, respectively, and means controlling the flow of liquid and gas into said conduit from the respective sources.

6. The method of subsurface reinforcement which comprises progressively forming an elongated substantially vertical shaft by directing a jet of fluid under pressure downwardly against the soil and advancing the same downwardly as the soil against which it is directed is displaced, halting the downward movement of the jet after a shaft of predetermined depth has been formed but maintaining the flow of wash liquid for a further period of time to form a cavity at the lower end of the shaft, and conducting to the surface of the ground the fluid so used for the displacement of soil, together with soil particles carried by said liquid, and thereafter introducing grout into said cavity.

7. The method of treating, in place, a body of porous or permeable subsoil to give it increased bearing strength which comprises, delivering into said body at a chosen distance below the surface a stream of wash fluid, under pressure to wash such subsoil and cause its lighter elements to be dislodged, conducting such wash fluid with such dislodged elements of subsoil to the surface of the ground, and, after such washing operation has been completed, forcing grout into the washed zone.

8. The method set forth in claim 7 in which suction is applied to remove from said body the wash liquid and its contained lighter elements.

9. The method of placing a body of artificial stone or the like below the surface of a body of dense soil which comprises, sinking a shaft thru said soil by means of a jet of fluid under pressure which is gradually lowered until a shaft of desired depth is formed, the fluid thus discharged, with soil suspended therein, being conducted to the surface, forming at the bottom of said shaft, by continued washing, a chamber for the reception of grout or the like, and thereafter interrupting the flow of wash water and forcing grout into said cavity.

10. The method set forth in claim 9 in which suction is applied to remove from said body of soil the wash liquid and lighter elements of the soil.

11. The method of placing a body of artificial stone or the like below the surface of a body of soil which comprises, forming a cavity in such soil body by discharging water under pressure into

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the same and conducting the discharged water and soil particles carried thereby to the surface of the ground, cutting off the inflow of wash water after formation of the cavity, introducing air under pressure to force the water from the cavity, and thereafter introducing grout or the like.

12. The method of placing a body of artificial stone or the like below the surface of a body of soil which comprises, forming a cavity in such soil by the use of a water jet, conducting the discharged water and soil particles carried thereby from the cavity as the washing proceeds, removing all water from the cavity, after its completion, by introducing air under pressure into the same, and thereafter introducing grout.

13. The method of placing a body of artificial stone or the like below the surface of a body of soil which comprises, forming a cavity in such soil by the use of a water jet, conducting the discharged water and soil particles carried thereby from the cavity as the washing proceeds, introducing air under pressure into the cavity after its formation to support the wall, thereof, and introducing grout while maintaining the pressure of the air against the walls of the cavity.

14. The method of treating in place a body of porous or permeable subsoil to give it increased bearing strength which comprises removing from such body the lighter and weaker elements thereof, and transferring such elements to the surface of the ground, by causing a current of water to

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flow downwardly to said body, and thereafter through said body and upwardly to the ground surface, the upflowing water carrying with it the said lighter and weaker elements of the soil, and introducing grout under pressure into the washed body of subsoil.

15. The method of increasing the bearing strength of a body of subsoil which comprises forming a shaft extending from the ground surface down to such body by means of a downwardly directed jet of fluid which is lowered as the soil is displaced until it has reached the desired elevation, continuously removing the displaced soil, as the jet descends, to the surface of the ground, maintaining the jet after its descent has been terminated until a substantial body of soil has been washed and the lighter and weaker elements thereof removed to the ground surface, and thereafter introducing grout under pressure into the washed body of subsoil to form a matrix for the washed material.

16. The method of forming a body of artificial stone or the like below the ground level which comprises forming a cavity by means of a jet of fluid, the displaced soil being floated to the ground level by the discharged and upwardly rising fluid, introducing air under pressure to support the otherwise unsupported walls of the cavity, and introducing grout into said cavity while maintaining the air pressure.

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