The present invention relates to a method of providing piles comprising concrete or its equivalent, either plain or reinforced, and which may be used in various ways as a part of sub-foundations of structures on land, along shores and in, across or beneath water ways.

Among the principal objects of this invention are the production and placing of piles with sureness, exactness and ease, and to enable such to be done expeditiously; and to enable such piles to be placed upon or incorporated in bed rock or hard-pan, regardless of its depth from the surface and the number and character of the intervening strata.

It has been common practice in foundation work, where compressible soils exist, to use wooden piles either driven with a hammer or by a water-jet, where the compressible soil is not more than 40 feet deep and overlies a bed of rock; gravel, sand or clay. But owing to the limited length of suitable timber for piles, if the hard stratum is over substantially 40 feet below the surface of the compressible soil dependence must be placed upon the unreliable friction between the wooden pile and the surrounding soil, it being practically impossible to find timber long enough to reach the hard stratum. Furthermore, in some sections timber is not readily available or cannot be easily transported. Due to their liability to rot, wooden piles must be cut off at the low water level and hence cannot be incorporated in the foundations above the said water level.

Piles of concrete have been provided by driving forms to the desired depth and either permitting the forms to remain after the concrete has been poured, or withdrawing the form after it has been filled with concrete but before the cement has become permanently set. Such piles of concrete have also been molded to the required shape and after the concrete has set sufficiently, driven by hammer, a water jet, or a combination of both methods in much the same manner as wooden piles are driven. The driving of these piles, whether of wood or concrete, is dangerous to adjoining buildings due to the vibration or jar tending to weaken the neighboring walls and foundations.

It is another object of the present invention therefore to provide a method whereby piles may be produced in place without subjecting the soil to excessive vibrations such as would be likely to cause settlement, cracking or crumbling of adjacent foundations and to support the compressible soils during the placing of the piles in such a manner as to avoid destruction or damage to adjoining structures.

The driving of piles or pile forms also causes a readjustment of the particles of clay and sand into a jelly, which action is also brought about by water jets, thus greatly diminishing the resisting properties of the material adjacent the pile.

A still further object of the invention is to provide a method whereby certain steps in the method are the excavation of soil, clay, sand, gravel, rock, etc., for the reception of the material from which the pile is formed, such excavation taking place without material readjustment of the particles adjacent the hole, resulting in the natural formation remaining in condition to aid in maintaining the lateral stability of the pile.

Wooden piles and forms for concrete piles are usually pointed or so shaped at their lower ends as to facilitate driving. When such strike a boulder, root or similar obstruction they will inevitably glance off and hence fail to "line-up" with other piles.

The present invention has for another object the provision of a method whereby such obstructions are cut into and partially removed so that the various piles may all be disposed with their axes in substantially parallel relation.

A further object of the present invention is to provide a method of producing piles in place, in closely spaced or contiguous relation,—something which is deemed undesirable where piles are driven, due to the danger that they may force each other up from their solid bed on the bearing stratum.

A still further object of the invention is to provide a method by which piles of much greater magnitude than those of wood or cement, now in common use, may be placed. In both girth and length, these piles may exceed piles which are driven or sunk by the well-known methods. This, in contradistinction to the pneumatic caisson, is accomplished with ease, expeditiously, and mainly without the dangers to life incident to the use of air locks and the working of men in confined spaces and in air at greater than atmospheric pressure. The method is practical in the many instances where pneumatic
caissons may be used but which are used without the great saving in time and money incident to my present method; and in many instances where it would be practical to use either hammer or water jet driven piles, or pneumatic caissons, my present method may be resorted to, and thus permit of the erection of structure on sites heretofore deemed undesirable or impractical because of the attendant problems.

In carrying out the present method use may be made of the principle embodied in rotary drill apparatus which has proven successful in the drilling of oil wells, in which connection reference may be had to United States Patents 1,360,328 and 1,379,483 and 1,451,794, granted November 30, 1920, May 24, 1921, and April 17, 1923, respectively on the inventions of John C. Stokes. Such apparatus comprises a hollow drill stem for imparting a rotary movement to a collapsible bit, which bit, in its working position is supported by a drill collar or holder in such a manner that the bit may cut a hole substantially twice the diameter of the drill stem, and yet be withdrawn and replaced through the stem when such is desired. In using such principle in one of the steps in the method, the apparatus may be made on a larger scale than that now in use for oil well drilling, and as an example, say a pipe or drill stem 36 inches in diameter would be capable of operating a bit of a size to produce a hole 72 inches in diameter or of less diameter ranging down to say 48 inches.

Thus the same apparatus may be adapted for use in providing piles of different diameters,—those best adapted to support the load in the most economical manner and with the proper factor of safety.

Other objects and advantages of the invention will appear in the following detailed description, taken in connection with the accompanying drawings, forming a part of this specification, and in which drawings:

Fig. 1 is a view partly in vertical section and partly in elevation showing an initial step in the method, a rotary drill and casing penetrating the various strata encountered in the placing of the pile.

Fig. 2 is a similar view showing the drill as having reached and penetrated bed rock.

Fig. 3 is a similar view, showing the drill bit removed, and reinforcement and a conductor for concrete in place, the drill stem and conductor serving as a guide, for the reinforcement.

Fig. 4 is a similar view showing the drill stem removed and the conductor being lifted, depositing the concrete in the cavity.

Fig. 5 is a cross sectional view on the line 5—5 of Figure 3.

Figs. 6, 7, 8 and 9 are views similar to Figs. 1, 2, 3 and 4, respectively, showing a modified method.

Fig. 10 is a similar view of the modification, showing the casing being removed simultaneously with the conductor for the concrete.

Fig. 11 is a view in vertical section through the base of the pile produced by this modified method.

In the drawings, where like characters designate similar or corresponding formations or parts, the letter A designates compressible soil in or between which may occur various strata such as gravel, sand, clay, rock, etc., a more dense stratum being designated by B; and C bed rock the distance of which, beneath the surface of the soil varies in different localities and which in some instances is so far beneath the surface that it is impractical to drive piles by use of the hammer or water jet and under which conditions, pneumatic caissons have been resorted to or the project abandoned when bedrock could not be located within a reasonable distance. D designates suitable drilling apparatus, capable of producing a cavity D; F a hollow casing which may follow the drill as it penetrates the soil and various strata; G a suitable conductor for concrete; H and J suitable reinforcement which may be provided; and K concrete or other suitable material disposed in the cavity made by the drill D.

The drill D may comprise a hollow drill stem 12, a collapsible bit 13 and a drill collar or holder 14, all of which may be caused to rotate and descend in unison, the bit 13 being removable through the drill stem 12 in a manner well known in the art relating to well drilling apparatus and in which connection reference may be had for an example to the aforesaid U. S. Patents 1,360,328 and 1,379,483. In practice water or mud is introduced into the upper portion of the drill stem 12 is forced downwardly and outwardly about the bit 13 and is forced up through the cavity E from which it is conveyed to a suitable pit from which it is again pumped or circulated and reused. During its course of travel, the mud carries with it the material dislodged by the drill and also such material as is dislodged by the hollow casing when such is used, the cavity E being, at all times, open to the atmosphere in contradistinction to what takes place where pneumatic caissons are used and where the dislodged material is removed from the cavity as by means of buckets through airlocks.

The hollow casing F, in the example shown in Figures 1 to 5 inclusive is cylindrical in shape, preferably made of concrete, reinforced, when necessary, and provided at its lower portion with a metallic cutter 15, the cutting edge 16 being preferably at the outer periphery of the casing, and the cutter beveling inwardly and upwardly from the
cutting edge 16, as indicated at 17. It is preferred to make the casing F of a diameter slightly greater than the diameter of the cavity formed by the drill D so that the casing will disrupt or sever parts of the soil and strata encountered by the casing as it descends, thus enlarging the cavity formed by the drill. The discharged material will be caught up by the flowing mud reinforcement and removed from the cavity as is the material dislodged by the drill bit. The hollow casing F may be made in sections, joined together in any approved manner, or it may be molded directly above the cavity in axial alignment with the drill stem.

After the cavity has been drilled to the extent desired, such as until the bit 13 penetrates bed rock, as shown in Figure 2 of the drawings, and the cutter 15 of the hollow casing, bites into the bed rock, due to the superimposed weight, the collapsible bit 13 may be removed, the drill stem 12 lowered so as to rest upon the bed rock, and the conductor G lowered within the drill stem, as shown in Figure 3 of the drawings. The conductor G is in the form of a pipe, of a diameter relatively less than the diameter of the drill stem, so as to provide a space 18 between the conductor and drill stem, similar to space 19 between the drill stem and casing F.

In the example shown, the reinforcement H, disposed between the drill stem and casing comprises suitable uprights 20, to which are welded or otherwise secured spirally or circumferentially disposed rods or pieces 21. The uprights 20 have provided intermediate their ends suitable arcuate offsets 22 and 23, preferably at the joints, the former offsets to engage the interior of the casing F, and the offsets 23 to engage the exterior of the drill stem. These offsets are preferably radially disposed, and materially aid in guiding the reinforcement into place, and properly centering same within the cavity. The reinforcement J, disposed between the conductor G and the drill stem is similar to that designated H in that it comprises suitable uprights 24, circumferentially or spirally extending rods 25, and inwardly extending offsets 26, which are arcuate in shape and engage the exterior surface of the conductor G. The offsets 26 also aid in guiding the reinforcement downwardly into the cavity, and properly centering same therein.

After the reinforcements H and J have been properly disposed within the cavity, the drill stem 12 may be removed, as shown in Figure 4, and concrete K introduced into the bottom of the cavity through the conductor G, which latter is gradually removed and preferably vibrated as the cavity becomes filled, the vibration tending to compact the concrete, and force same into the interstices of the reinforcement. In Figure 4 of the drawings, the conductor G is shown as partially raised, and the concrete K flowing from the lower portion thereof, and embedding the reinforcements H and J.

The method set forth in connection with Figs. 1 to 5 inclusive is particularly well adapted to meet the requirements where flowing sand or quick sand is encountered which prevents the withdrawal of the casing. The hollow concrete casing, makes possible the provision of a pile of greater diameter than the cavity cut by the rotary drill, because of the weight of the casing rendering it susceptible of shearing off material from the strata encountered. This method also retards too rapid descent of the casing by the engagement of the casing with the material cut by the rotary drill but-closely adjacent to the cavity. In the event that the casing should engage strata which it can not penetrate by its own weight to that extent where portions are broken off and the casing follows the drill, the drill bit may be removed through the hollow drill stem and suitable bits substituted to under-ream the hard strata thus encountered, and permit the casing to sink therethrough, after which such drill bits are removed and those for producing the smaller cavity replaced.

The hollow casing F', as shown in Figures 6 to 11 inclusive, may be made of sheet material, suitably formed in cylindrical shape, and joined in sections, in any suitable manner. It is, however, made of an external diameter slightly less than the diameter of the cavity normally made by the rotary drill so that it descends freely, under control from above without severing material from the cavity as it follows the drill.

While the metallic casing may be left to remain in the cavity as described in connection with the method shown in Figures 1 to 5 inclusive, it is preferred to use the metallic casing, where the nature of the soil and strata is in a manner, self-sustaining, thus permitting the removal of the metal casing as the conductor G is being removed form the cavity, as shown in Figure 10.

In practice, a rotary rig, (not shown in the drawings) similar to those used in drilling oil wells, but modified to meet the requirements of new application, is used for the control and imparting of movement to the rotary drill, and the cavity started thereby, in the compressible soil at the place where the pile is to be disposed. As soon as the drill bit has penetrated the soil, to the desired extent, the hollow casing is permitted to sink, shoving off or enlarging the cavity, where a casing of an external diameter greater than the internal diameter of the cavity, formed by the rotary drill, is used. It is preferred that the drill bit penetrate the bed rock, as well as the lower portion of the casing, when the latter is to re-
main in the cavity. The removal of the bit and the settling of the drill stem on the bed rock may be expeditiously accomplished, as well as the insertion of the conductor G into the cavity. If no reinforcement is used in the cavity, the drill stem may be removed before entering the conductor G, but where such reinforcement is desirable, such may be disposed in the cavity, using the drill stem and conductor as a guide. 'The conductor G serves to hold the central reinforcement J centered, and the lower portion of the reinforcement is initially embedded in the concrete which aids in holding the reinforcement in place as the conductor is removed. Up and down motion, and circumferential motion may be imparted to the conductor G in any suitable manner so as to compact the concrete and force the same into the interstices of the reinforce-

ment.

In the majority of building or construction operations it will be found that the metallic casing may be removed as the cavity is being filled with concrete, resulting in a great saving in time and money because of the quick assemblage of the metallic casing and the re-use thereof in producing and placing a succession of piles. In some in-
stances no hollow casing will be necessary—where the formation is so self-sustaining that the walls of the cavity have no tendency to cave in and where any porosity may be overcome by the mud used with the rotary drill sealing any openings in the wall through which the cement might pass.

In the foregoing description the term "casing" has been used to designate the portions "P" and "P'" of the apparatus, and this term is also used in claims which follow. It is to be understood, however, that the term is to be broadly construed as embracing what might be specifically termed a form, caisson, or mould.

By this method a continuous concrete pile, suitably reinforced if desired, and of considerable diameter, say seven feet, may be anchored securely in the underlying bed rock, and reaching to the surface, is ready to be joined to suitable sub-foundations, varying in shape and size to meet the require-
ment of the superstructure it is to support.

In reduction to practice I realize that the condition concurrent with the adoption of the method will necessarily vary, and I desire to emphasize the fact that various changes in the sequence of steps taken in the method may be resorted to, or steps omitted, when required or desirable without sacrificing the advantages of the method.

While I have herein referred to certain patents relating to rotary drills, it is to be distinctly understood that such are merely by way of example, and that the method may be carried out by the use of other apparatus than that herein disclosed and referred to without departing from the spirit or scope of the appended claims.

I claim:

1. A method of producing and placing piles which comprises, drilling a cavity in the soil and removing the dislodged material through the cavity; placing a hollow cylindric casing, open to the atmosphere and of slightly greater diameter than the cavity, thus formed, to follow in the cavity as the drilling and removal of the dislodged material progresses, and to disrupt or separate the strata encountered by the casing; placing reinforcement in the cavity when same has been drilled to the desired extent, and centering said reinforcement by engagement with the interior of the casing and filling the cavity with concrete embedding the reinforcement therein.

2. A method of producing and placing piles which comprises, drilling a cavity in the soil and removing the dislodged material through the cavity by aid of a hollow drill stem and removable bit; placing a hollow casing, open to the atmosphere, to follow in the cavity as the drilling and removal of the dislodged material progresses; removing the drill bit with the hollow drill stem remaining in the cavity; placing a hollow conductor for concrete within the hollow drill stem; placing reinforcement between the casing and the drill stem, and between the drill stem and the conductor, and centered thereby; removing the drill stem; and delivering concrete into the cavity through the lower end of said conductor embedding the reinforcement therein and removing the conductor from the cavity as it becomes filled with concrete.

3. A method of producing and placing piles which comprises, drilling a cavity in the soil and removing the dislodged material through the cavity by aid of a hollow drill stem and removable bit; placing a hollow casing, open to the atmosphere, to follow in the cavity as the drill and removal of the dislodged material progresses; removing the drill bit with the hollow drill stem remaining in the cavity; placing a hollow conductor for concrete within the hollow drill stem; placing reinforcement between the drill stem and conductor, and centered thereby; removing the drill stem; and delivering concrete into the cavity through the lower end of said conductor embedding the reinforcement therein and removing the conductor from the cavity as it becomes filled with concrete.

4. A method of producing and placing piles which comprises, drilling a cavity in the soil and removing the dislodged material through the cavity by aid of a hollow drill stem and removable bit; placing a
hollow casing, open to the atmosphere, to follow in the cavity as the drilling and removal of the dislodged material progresses; removing the drill bit with the hollow drill stem remaining in the cavity; placing a hollow conductor for concrete within the hollow drill stem; placing reinforcement between the casing and the drill stem and between the drill stem and conductor, and centered thereby; removing the drill stem; delivering concrete into the cavity through the lower end of said conductor embedding the reinforcement therein; and vibrating and gradually removing the conductor to compact the concrete and force same into interstices of the reinforcement.

5. A method of producing and placing piles which comprises forming a cavity in the soil, placing a hollow conductor in the cavity, introducing concrete into the cavity through the lower end of said conductor embedding the reinforcement therein, and vertically reciprocating, circumferentially moving and gradually removing the conductor to compact the concrete as it becomes placed.

6. A method of producing and placing piles which comprises drilling a cavity in the soil and removing the dislodged material through the cavity by the aid of a hollow drill stem and removable bit; placing a hollow casing, open to the atmosphere, to follow in the cavity as the drilling and removal of the dislodged material progresses; removing the drill bit with the hollow drill stem remaining in the cavity; placing a hollow conductor for concrete within the hollow drill stem; placing reinforcement between the casing and drill stem, and centered thereby; removing the drill stem; and delivering concrete into the cavity through the lower end of said conductor and embedding the reinforcements therein, and removing the conductor from the cavity as it becomes filled with concrete.

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