

[54] **PILING**
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[22] Filed: **Mar. 17, 1972**
[21] Appl. No.: **235,790**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 97,997, Dec. 14, 1970.
[52] U.S. Cl. **61/53, 61/53.5, 61/53.52, 61/53.6, 61/56, 61/56.5, 52/170**
[51] Int. Cl. **E02d 5/30, E02d 5/48, E08d 5/50**
[58] Field of Search..... **61/53, 53.5, 53.52, 61/56, 56.5, 53.70, 53.72; 52/170, 297**

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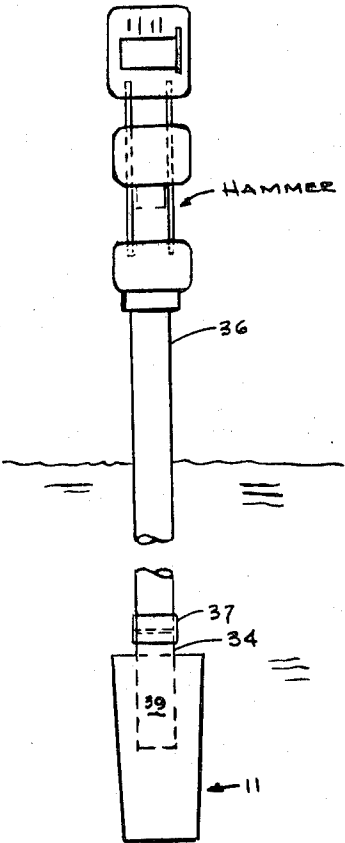
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Primary Examiner—Jacob Shapiro
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[57] **ABSTRACT**

A concrete pile fitted with a special slightly tapered concrete tip of larger area. The tip has a central stub with an open socket for receiving concrete poured in after the pile is in place.

20 Claims, 11 Drawing Figures



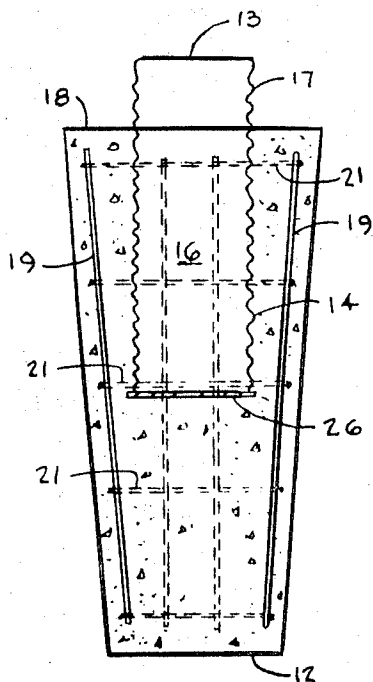


FIG. 1

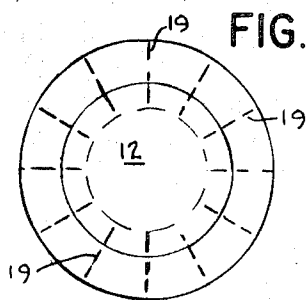


FIG. 2

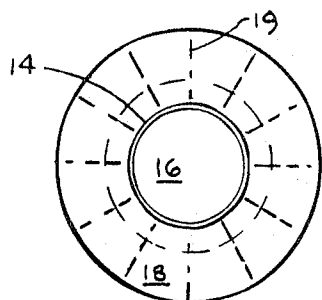


FIG. 3

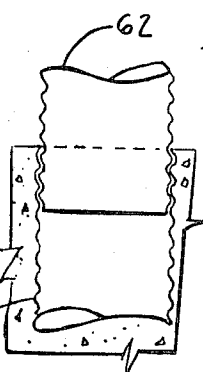


FIG. II

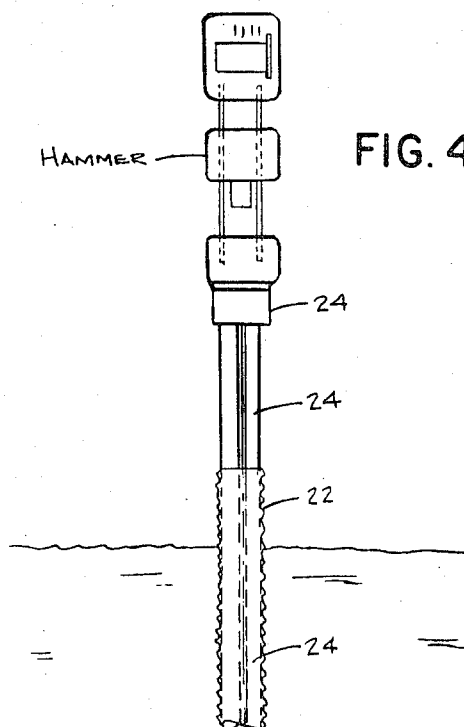
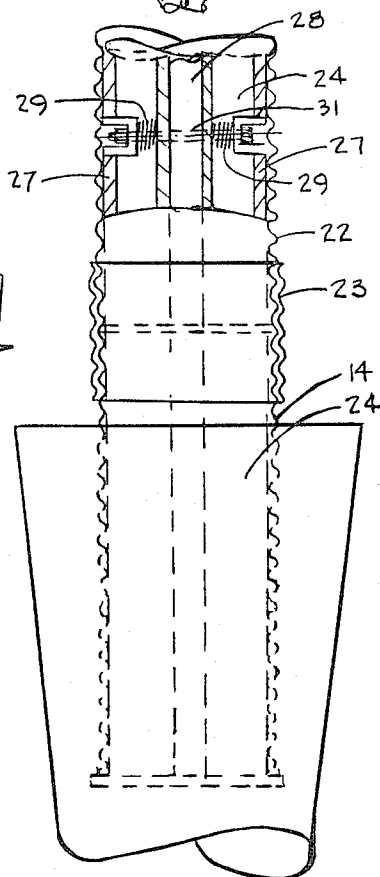


FIG. 4



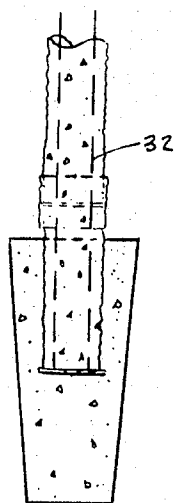


FIG. 5

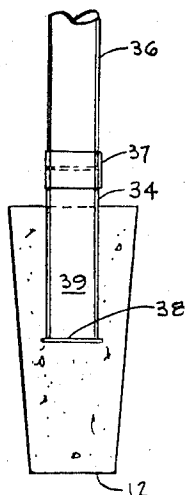


FIG. 6

FIG. 9

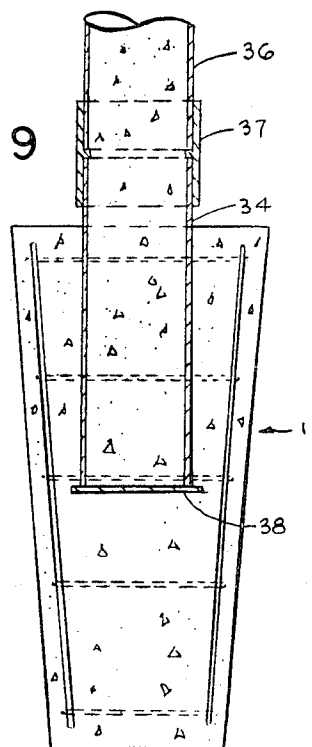
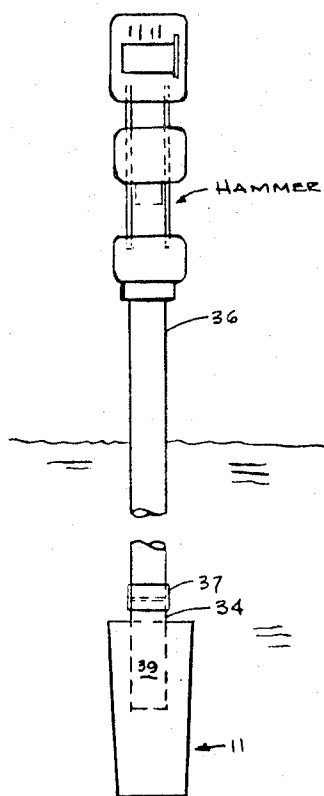


FIG. 7

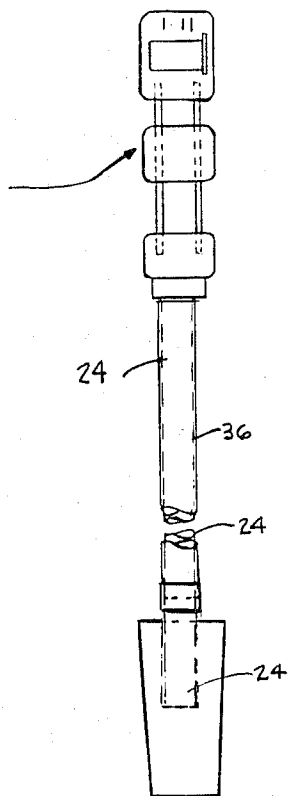
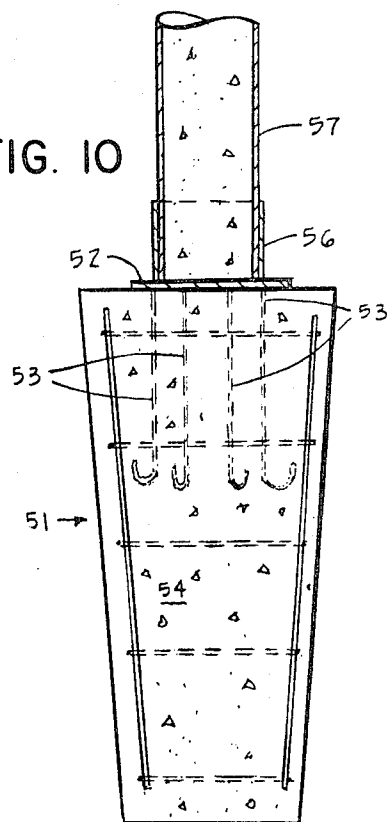


FIG. 8

FIG. 10



PILING

This application is a continuation-in-part of my U.S. Pat. application Ser. No. 97,997 filed Dec. 14, 1970, whose entire disclosure is incorporated herein by reference.

This invention relates to piling.

In present commercial practice, when bedrock is at a reasonable depth, high-capacity H pile steel sections, or open end or closed end pipe can be driven economically to capacities in excess of 100 tons. Compact sands and stiff clays will generally support H pile, steel pipe, mandrel-driven shell type piles, or pre-cast concrete pipe piles for capacities in excess of 50 tons and these piles are economical when the lengths are moderate.

However, there are situations where the soil conditions will not conveniently accommodate these specific piling types. For example along, and near, the sandy ocean beaches there are often great depths of relatively loose cohesionless materials. Here conventional piles must penetrate considerable distances to develop acceptable capacities by friction forces between the pile surface and the soil. In another situation, a thin layer of the relatively loose cohesionless material (usually situated underneath a non-bearing layer of silt, clay or fill or mixtures thereof) overlays a deep stratum of soil of very low bearing capacity such as soft clay. Here, when the pile is driven through the layer of loose material it must then be driven through the deep clayey layer to an acceptable bearing layer below the clay.

The piles of this invention are particularly suitable for use in supporting heavy loads on land in which the bearing soil is comparatively loose and granular, and not capable of sustaining high unit loads (e.g. soil of "N" value less than 30, say about five to 10) which soil may be situated below a relatively thick layer of soil unsuitable for bearing such as a fill or soft clay. In such cases it has been proposed to use a Franki type of pile, in which a mushroom base of concrete is pushed out at the bottom of the pile after the pile has been driven down to the bearing layer. Such piles are described at, for instance, pages 250-251 of the book "Pile Foundations Theory-Design-Practice" by Robert D. Chellis, published 1951 by McGraw-Hill, which also discusses a great many other types of piles known to the art. As pointed out by Chellis the Franki piles "are of particular advantage where a bearing stratum, of limited thickness only, can be reached within economical depths." While such Franki piles have, in many cases, large capacities (e.g. 120 tons per pile), their installation is quite complicated and very expensive; special costly equipment is needed and conventional automated pile-driving techniques cannot ordinarily be used. In addition the character of any individual driven pile is not readily predictable; I believe that this may be due, for instance, to eccentricities in the shape of the mushroom base of concrete that is rammed out of the bottom of the pile, and other factors.

Among the other piles which are in present commercial use in the loose soil conditions are the Raymond piles described on pages 233-235 of the Chellis book and the Monotube composite tapered pile which typically has a fluted heavy gauge shell which tapers down at its base. Where the loose granular soil layer is of limited thickness such piles tend to penetrate through that layer without attaining high capacities and must then be driven to considerable depths; even then the capaci-

ties do not approach those attainable using the piles of the present invention.

In accordance with one aspect of this invention there is provided a much less expensive pile, which can be installed economically with conventional automated techniques and which has high load bearing capacity in the soil conditions described above. Although the rated load bearing capacity of my new pile may be below that of a properly installed Franki pile, it is much higher than that of other conventional piles. The economy of installation makes it practical to overcome this lower bearing capacity by driving more of my new piles, so that the total cost for properly supporting a given building or other structure will be considerably lower when my new piles are used than when Franki piles are employed. The construction of my new pile is such that it can be driven rapidly, accurately, and easily, with good rigidity and stability of direction, by conventional automated pile driving hammers at high impact frequencies (e.g. 50 to 120 blows per minute using conventional hammers such as described at pages 70-72 of the Chellis book, the pile driving energy usually being in the range of about 15,000 - 36,000 foot pounds per blow).

Certain preferred forms of the invention are illustrated in the accompanying drawings in which

FIG. 1 is a cross-sectional view, to scale, of one preferred type of pile tip in accordance with this invention.

FIG. 2 is a bottom view of the pile tip of FIG. 1.

FIG. 3 is a top view of the pile tip of FIG. 1.

FIG. 4 is a side view, also in cross-section, showing the pile tip of FIG. 1 connected to the stem of the pile and showing the pile being driven into the ground with a removable mandrel housed in a socket in the pile tip.

FIG. 5 is a side view, also in cross section, of a portion of the tip and the lower portion of the pile stem after concrete has been poured into the stem.

FIG. 6 is a cross-sectional view, to scale, of another form of pile tip in accordance with this invention, showing the pile tip connected to the tubular stem of the pile.

FIG. 7 illustrates schematically one way of driving the pile shown in FIG. 6.

FIG. 8 illustrates schematically another way of driving the pile shown in FIG. 6.

FIG. 9 is a side view, in cross section, of a portion of the tip of FIG. 6 and the lower portion of the pile stem after concrete has been poured into the stem.

FIG. 10 is a side view of the invention using a pile tip without a socket.

FIG. 11 is a view of an arrangement employing a tip having a sleeve which does not project above the top thereof.

Turning now to FIG. 1 the tip 11 is of reinforced concrete of symmetrically tapered frusto-conical construction with its base 12 being substantially flat (and in a plane substantially perpendicular to the axis 13 of the tip). The taper is gradual; in FIG. 1 it is about one-half inch per foot. The concrete tip is formed by casting in place around a relatively short length or stub of threaded (corrugated) steel shell 14 of conventional type leaving a substantially cylindrical center open socket 16 in the upper part of the concrete of the tip, and with a portion 17 of the stub projecting above the substantially flat top surface 18 of the concrete tip.

In FIG. 1 the reinforcement of the concrete is constituted by a series of equally spaced axially oriented reinforcing bars 19 disposed around the socket 16 and ex-

tending below the level of the base of the socket, the bars 19 being tied together by transverse reinforcing rods or bars 21 secured to bars 19 as by suitable means, e.g. wires ties around the bars. Instead of, or in addition to, reinforcing rods, the concrete may contain pieces of sheet metal distributed therethrough.

In use, the tip 11 is connected to the stem 22 (FIG. 4) of the pile by a suitable connection, such as a threaded adapter 23, also of conventional shell construction, engaging both the projecting portion of the stub 14 and said stem. A mandrel 24 is disposed within the socket 16 (resting on a steel plate or boot which forms the base 26 of the socket; this plate preferably has a larger diameter than that of the stub and is put in place before the concrete of the tip is cast) for receiving the blow of the pile-driving hammer and transmitting its downward force to the concrete tip. The particular conventional mandrel shown in FIG. 4 extends the whole length of the stem. In FIG. 4 the upper portion is shown on a reduced scale and part of the lower portion is broken away to show details of the mandrel.

As the pile is driven, the tip penetrates through the non-bearing soil, until it reaches the bearing soil. Continued driving forces it into the latter, generally until the resistance to the driving force indicates that there is adequate load bearing capacity (e.g. using standard pile-driving formulas which relate load-bearing capacity to driving resistance and/or using actual static load tests in which the pile is loaded with twice the load it is expected to carry and the movement of the pile under such loading is measured, a movement of about one inch or less in this test generally being an indication that the pile will be satisfactory to carry the expected load).

The mandrel 24 may be of conventional construction. For instance it may be of the type having a pair of almost hemicylindrical halves 27 which, in use, are pressed apart against the internal walls of the shell (in this case, including the section of shell lining the socket 16). To this end there is an inflatable element 28 to which air (or other fluid) is admitted under pressure so as to expand the element 28 against the inwardly facing walls of the mandrel halves 27. When the mandrel is to be removed from the socket, the pressure in the inflatable element is reduced and the mandrel halves move together, away from the walls of the shell, under the influence of springs 29 mounted on rods 31 which pass through the mandrel halves; one end of each spring engages a wall of a mandrel half 27 while the other end is held at the outer end of its rod.

Another conventional type of mandrel which may be used is simply a heavy pipe extending through the stem and into the socket and resting on the base of the socket. For instance when the stem and socket each have an internal diameter of 13 inches, the mandrel may be a 12-3/4 inch outside diameter heavy-walled pipe which is driven by the hammer and transmits the driving force to the base 26 of the socket.

After removal of the mandrel, the shell (including the stub and the main stem of the pile) is filled with concrete. As shown in FIG. 5 the concrete fills the socket, making for an excellent connection between tip and stem so that they behave more as an integral unit even in response to tension forces. If desired, reinforcement, such as reinforcing rods 32, may be placed so as to extend from the cavity up into the stem before the concrete is poured.

In the tip illustrated in FIGS. 6 to 9 the stub 34 is a short piece of pipe, e.g. straight-sided steel pipe having a diameter of about 8 to 14, or even 18, inches and having a wall thickness of about 0.17 to 0.4 inch or more; the tubular material conventionally used for pipe piles may be used. It is adapted to be joined to the stem 36 of a pipe pile by a connector, such as an internally tapered sleeve 37 whose internal diameter is about the same as the external diameter of the stub and stem, there being a drive fit between the sleeve 37 and the top of the stub and between the sleeve and the bottom of the stem; this connection may be formed by welding if desired. To assist in anchoring the stub in the concrete of the tip the stub of FIG. 6 may have welded to its base a flat transverse plate 38 of larger area than the cross-sectional area of the stub. This plate (e.g. of 1/2 inch thick steel) may be welded to the stub before the concrete of the tip is cast. The pile may be driven by pile-driving hammer blows at the top of the stem (FIG. 7) or, particularly when a thin-walled stem is used (which stem may even be of corrugated construction), it may be driven by such blows applied to an internal mandrel 24 (FIG. 8) in the socket 39 formed inside the stub 34. The plate 38 also helps to distribute the vertical pile driving forces more uniformly through the concrete tip. When the concrete is poured into the stem 36 it fills the socket 39, as shown in FIG. 9; here again reinforcement may be placed so as to extend from the cavity up into the stem.

The particular tips shown in the drawing are designed for use with a stem having a diameter of about 12 inches (for the embodiment of FIG. 6) or 14 inches (for the embodiment of FIG. 1). The base 12 of the tip has a diameter of about 24 inches, which is considerably larger than that of the stem. The maximum diameter of the tip, at the top, is about 30 inches and the axial height of the tip, measured from its base to the level at which its diameter attains its maximum, is about 60 inches, so that its taper is about three-fifths inch per foot.

In general, tips of this invention may be used with stems of about 8 to 18 inch diameter. The tip is preferably circular in cross section (although other cross-sections adapted to give a substantially uniform load distribution around the pile, e.g. square cross section, may be employed) and its projected area (at its maximum diameter) is above twice, and preferably about 5 to 15 times, the cross-sectional area of the stem. Preferably the base of the tip has a diameter of at least 8 inches, although the use of pointed tips is also within the broader scope of this invention. Preferably the axial height of the tip is at least two feet and at least 1 foot greater than the depth of the socket but less than one-half, more usually less than one-third, of the overall height of the pile (including the stem). The taper is generally less than 3 inches per foot (and preferably less than 1 1/2 inches per foot) and above one-fourth inch per foot (but it is within the broader scope of the invention to use an untapered tip). The depth of the socket is generally within the range of 1/10 to 9/10 of the axial height of the tip, preferably at least three-tenths and less than seven-tenths of that height, more preferably about 0.4 to 0.6 times the height of the tip.

The use of the tip of this invention enables one to use shorter lengths of pile for a given load bearing capacity. Generally the overall length of the pile (including tip) will be in the range of about 10 to 50 feet or more.

The ground-engaging surfaces of the concrete tip may be smooth or textured (e.g. corrugated).

The "N" value, previously mentioned, is a conventional reference for soil compactness. It is the number of blows of a 140 lb. hammer, dropped from a height of 30 inches, required to advance a standard 2 inch diameter split spoon sampling tube a distance of 12 inches.

When the tip is driven through certain non-bearing soils, the soil does not flow back around the stem above the tip and there is an unfilled space around the stem. This space is preferably filled in, from the top, by dumping or otherwise placing material such as sand which may be applied dry or with water (e.g. it may be puddled or jetted in).

It is also within the broader scope of the invention to use a pile tip without a socket. For instance, as illustrated in FIG. 10 the tip 51 may have an upper plate 52, to which are welded downwardly extending reinforcing rods 53 (or other suitable anchoring means) around which the concrete 54 of the tip is cast, with the concrete being in contact with the lower face of the plate 52. A stub 56 (which may be a short length of pipe of the type used in the embodiment shown in FIG. 6) is welded to the top of the plate (either before or after the concrete of the tip is cast) to provide an attachment to the stem 57 of the pile. After driving the stem and stub are filled with concrete, as previously described.

While the tip of this invention is particularly suitable for use when attached to the longer stem of a pile, it is also within the broader scope of this invention to use the tip with a very short stem, or without any stem at all, as in situations in which piles or other driven elements have not been previously employed. For example, when the bearing soil (e.g. a fine to medium sand of "N" value about 8 to 10) is at, or very near, the surface and is not overlaid by other non-bearing strata of significant thickness, the tip itself (without a stem) may be driven directly into the surface, e.g. the tip illustrated in FIG. 1 may be driven some 6 feet into the soil by means of a conventional pile driving hammer operating on a mandrel within the socket of the tip. A spaced series of such driven tips (the axes of adjacent tips being spaced apart by a distance equal to say about 1½ times the largest diameter of the tip) can support a heavy building or other structure without the need for extensive excavation and without the need for large footings or mat foundations.

Instead of using a projecting stub for lining the socket of the concrete tip, one may employ a sleeve which does not project above the top of the concrete tip and which is adapted to be connected to the stem of the pile. In one suitable construction, illustrated in FIG. 11, this sleeve 61 is made of corrugated shell material of slightly larger diameter than the shell material of the pile stem 62 so that, after the tip has been fabricated and is ready for use, the stem can be attached to the tip by screwing it into the sleeve 61.

The present invention makes it possible for relatively large volumes of concrete, comparable to the volumes of extruded material in Franki piles, to be more economically put in place in deeper strata and with more uniform results. As with the Franki piles, the piles of the present invention give their results largely by the compaction of the soil of low bearing value and they attain very high load bearing capacity in relatively shallow strata. Typical examples of such conditions are as

follows: (a) 18 feet of miscellaneous fill and gray clayey organic silt overlying a 15 foot thick layer (of N value about 25) of fine silty sand (containing some medium gravel) overlying more than 50 feet of clay; (b) 15 feet of miscellaneous fill, peat and gray silt overlying a 10 foot thick layer of medium to fine loose sand (N value about 12) overlying another 50 feet of red brown silty fine sand; (c) 10 to 15 feet of fill overlying 1 to 4 feet of peat and an underlying layer of loose sand of N value 6 to 30.

The present invention also makes it possible to drive the pile accurately in the desired direction. One factor in this is the presence, during driving, of the rigid mandrel within the socket which helps to insure that the tip does not become deflected by localized variation in soil resistance, e.g. boulders, debris, uneven strata, etc. Any appreciable deflection tendency will cause a portion of the inner wall of the socket to press hard against the corresponding outer wall of the sturdy rigid mandrel which will resist such deflection.

The particular tip size can of course be adjusted in accordance with the desired load bearing capacity. Thus as between (a) a tip having a height of 34 inches, and diameters of 20 inches at its base, and 24 inches at the top on a 10-¾ inch diameter stem and (b) a tip having a height of 60 inches, and diameters of 23 inches at its base and 29 inches at the top, on a 12-¾ inch diameter stem, the load bearing capacity was higher for the larger tip but the small tip is more economical to fabricate and drive.

The piles of this invention are easily inspected and tested. Thus, if the tip should be seriously defective (e.g. cracked) this can be readily detected since driving characteristics of the pile will be as if there were no tip. The stem of the driven pile can be readily inspected by visual methods before the concrete is poured into it.

It is understood that the foregoing detailed description is given merely by way of illustration and that variations may be made therein without departing from the spirit of the invention. The "Abstract" given above is merely for the convenience of technical searchers and is not to be given any weight with respect to the scope of the invention.

I claim:

1. A method of producing a driven pile, which comprises attaching to a tubular stem a tip of reinforced concrete having a larger diameter than said stem and having a central cavity aligned with said stem and adapted to receive the lower end of a pile driving mandrel, the base of said central cavity being spaced above the base of said tip so that between said bases there is a mass of the concrete of said tip, placing a pile driving mandrel within said stem with the lower end of said mandrel within said cavity, driving said tip, to embed it in a bearing layer, by the action of a pile driving hammer on said mandrel whereby said mass of concrete between said bases receives and transmits the pile-driving forces, removing said mandrel and pouring concrete into said stem whereby the poured concrete enters said cavity and extends up into said stem forming a unitary body of hardened concrete joining said tip and stem.

2. A method as in claim 1, said tip being tapered to increase in diameter from the bottom upwards, the maximum horizontal cross-sectional area of the tip being about 5 to 15 times the cross-sectional area of the stem, the taper being less than about 3 inches per foot

and the axial height of said tip being at least about 2 feet.

3. A method as in claim 2 in which the depth of said cavity is 3/10 to 7/10 of the axial height of the tip, and in which said cavity is lined with thin corrugated tubular metal shell, said stem being of thin corrugated tubular metal shell whereby said poured concrete is surrounded by said corrugated metal shell within said cavity and within said stem.

4. A method as in claim 1 in which said tubular stem is a thin metal shell incapable of withstanding the pile driving blows needed to force said pile to its driven load carrying position and the tip having a cross-sectional area which is at least twice, and up to 15 times, the cross-sectional area of the stem.

5. A method as in claim 1 in which said pile is driven until the resistance to the driving force indicates that the desired load bearing capacity is attained, said bearing layer being loose granular soil having an N value of less than 30.

6. A method as in claim 4, in which said pile is driven until the resistance to the driving force indicates that the desired load bearing capacity is attained, said bearing layer being loose granular soil having an N value of less than 30, said tip being tapered to increase in diameter from the bottom upwards, the maximum horizontal cross-sectional area of the tip being about 5 to 15 times the cross-sectional area of the stem, the taper being less than about 3 inches per foot and the axial height of said tip being at least about 2 feet, the depth of said cavity being 3/10 to 7/10 of the axial height of the tip, said poured concrete is surrounded by said metal shell within said cavity and within said stem, the axial height of said tip being less than one-third of the overall height of said pile.

7. A method as in claim 4 in which said tip has a diameter of about 24 inches at its base, a diameter of about 30 inches at the top, an axial height of about 60 inches and a taper of about three-fifths inch per foot and said stem has a diameter of about 14 inches, and the depth of said socket is about 0.4 to 0.6 of the height of the tip, the ground-engaging surfaces of said tip being of smooth concrete, said tip having a circular cross-section.

8. Process as in claim 1 in which said hammer is driven at 50 to 120 blows per minute with a pile driving energy of above 15,000 foot pounds per blow.

9. A method as in claim 1 in which said cavity extends down, from a level at which the horizontal cross-sectional area of said tip is substantially at its maximum, for a distance which is at least three-tenths of the axial height of the tip and less than seven-tenths of that height, said cavity being lined with a central tubular liner rigidly embedded in the concrete of said tip, said mandrel extending into and having its lower portion housed in said cavity to align said tip and stem during the driving of said pile, said liner and said stem being of corrugated tubular metal.

10. A method as in claim 9 in which said unitary body of hardened concrete is in contact with, and conforms to, the corrugations of said liner and said stem and said hammer is driven at 50 to 120 blows per minute with a pile driving energy of above 15,000 foot pounds per blow, and in which the pile is driven until the resistance to the driving force indicates that there is adequate load bearing capacity, said loose granular soil having an N value of less than 30.

11. A load-carrying pile in place in the ground, comprising a metal tube attached to a tip of pre-cast reinforced concrete having a substantially flat base and a central cavity aligned with said tube, said tube extending into said cavity, the base of said central cavity being spaced above the base of said tip so that between said bases there is a mass of the concrete of said tip of sufficient strength to receive and transmit the pile-driving forces needed to force said tip and tube to the fully driven load-carrying position, and a body of concrete, emplaced after said tip and tube have been forced to said position, filling said cavity and extending up into said tube above said tip, said body having a structure unstressed by said driving, said tip being tapered to increase in diameter from the bottom upwards, the maximum horizontal cross-sectional area of the tip being at least twice, and up to 15 times, the cross-sectional area of the tube, the taper being less than about 3 inches per foot and the axial height of said tip being at least about 2 feet, said pile extending through non-bearing soil to a bearing layer of loose, granular soil, said layer having an N value less than 30, said tip being embedded in said loose granular soil which has been compressed by the driving of said tip thereinto.

12. A pile as in claim 11 in which said tube is incapable of withstanding the pile driving blows needed to force said pile to its driven load-carrying position.

13. A pile as in claim 12 in which said tube is of corrugated metal shell.

14. A pile as in claim 11 in which the base of said tip has a diameter of at least 8 inches, and the depth of said cavity is at least three-tenths and less than seven-tenths of the axial height of said tip.

15. A pile as in claim 11 in which the axial height of said tip is less than one-third of the overall height of said pile.

16. A pile as in claim 12 in which the base of said tip has a diameter of at least 8 inches, and the depth of said cavity is at least three-tenths and less than seven-tenths of the axial height of said tip, and the axial height of said tip is less than one-third of the overall height of said pile.

17. A pile as in claim 16 in which said tip has a diameter of about 24 inches at its base, a diameter of about 30 inches at the top, an axial height of about 60 inches and a taper of about three-fifths inch per foot and said tube has a diameter of about 14 inches, and the depth of said socket is about 0.4 to 0.6 of the height of the tip, the ground-engaging surfaces of said tip being of smooth concrete, said tip having a circular cross-section.

18. A pile as in claim 11 in which said cavity has a depth of 3/10 to 7/10 of the axial height of said tip, the depth being measured downward from the level at which the horizontal cross section of the tip reaches its maximum.

19. A method of producing a driven pile, which comprises attaching to a tubular stem a tip of reinforced concrete having a larger diameter than said stem and having a central cavity aligned with said stem and adapted to receive the lower end of a pile driving member extending down through said stem, the base of said central cavity being spaced above the base of said tip so that between said bases there is a mass of the concrete of said tip, placing a pile driving member within said stem with the lower end of said member within said cavity, driving said tip, to embed it in a bearing layer,

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by the action of pile driving forces transmitted by said member whereby said mass of concrete between said bases receives and transmits the pile-driving forces, removing said member and pouring concrete into said stem whereby the poured concrete enters said cavity and extends up into said stem forming a unitary body of hardened concrete joining said tip and stem, said tip being tapered to increase in diameter from the bottom upwards, the taper being less than about 3 inches per

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foot and the axial height of said tip being at least about 2 feet.

20. Process as in claim 19, said cavity having a depth of at least three-tenths of the axial height of said tip, said depth being measured downward from the level at which the horizontal cross section of the tip is a maximum.

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