Nov. 17, 1970 L. MÜLLER 3,540,225

CONSTRUCTION PILE AND A METHOD OF PRODUCING SAME IN SITU

Original Filed Nov. 9, 1966 5 Sheets-Sheet 1

Fig. 1a

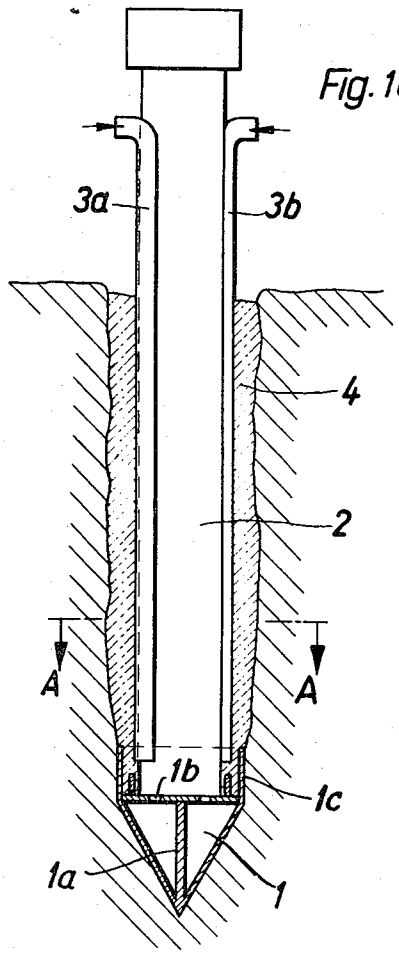


Fig. 1b

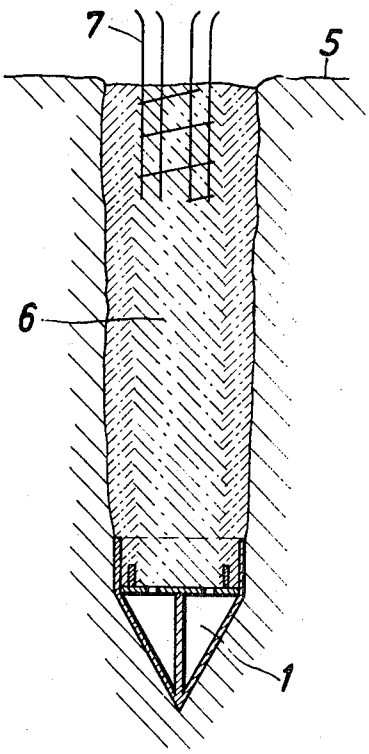
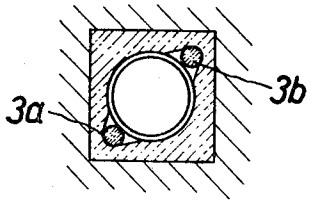


Fig. 1c
(A-A)



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CONSTRUCTION PILE AND A METHOD OF PRODUCING SAME IN SITU

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Fig. 2a

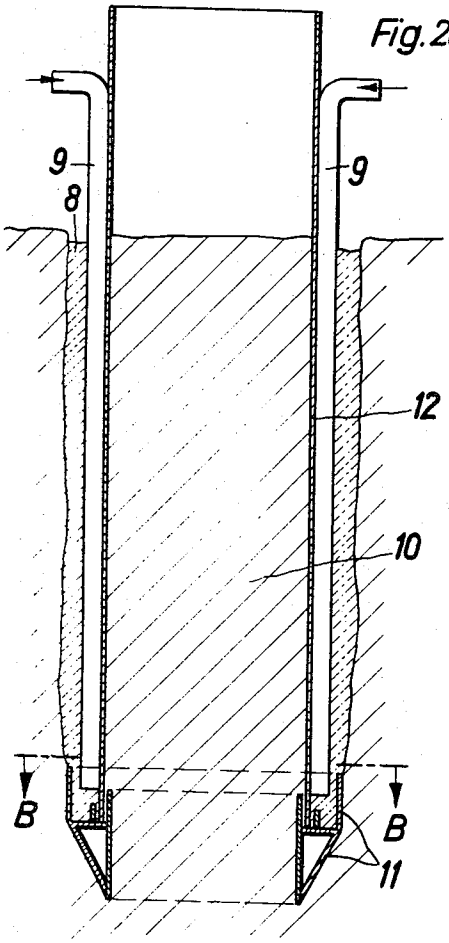
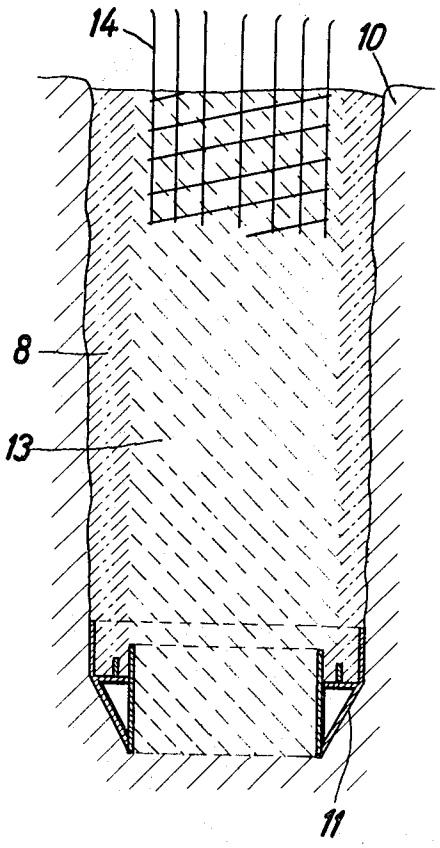


Fig. 2b



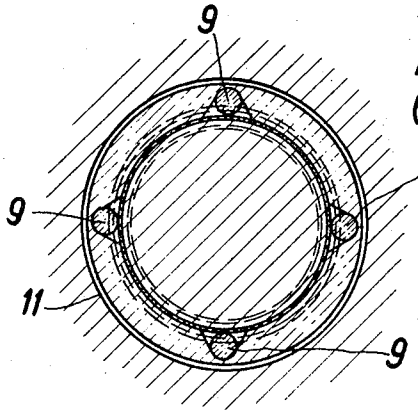


Fig. 2c
(B-B)

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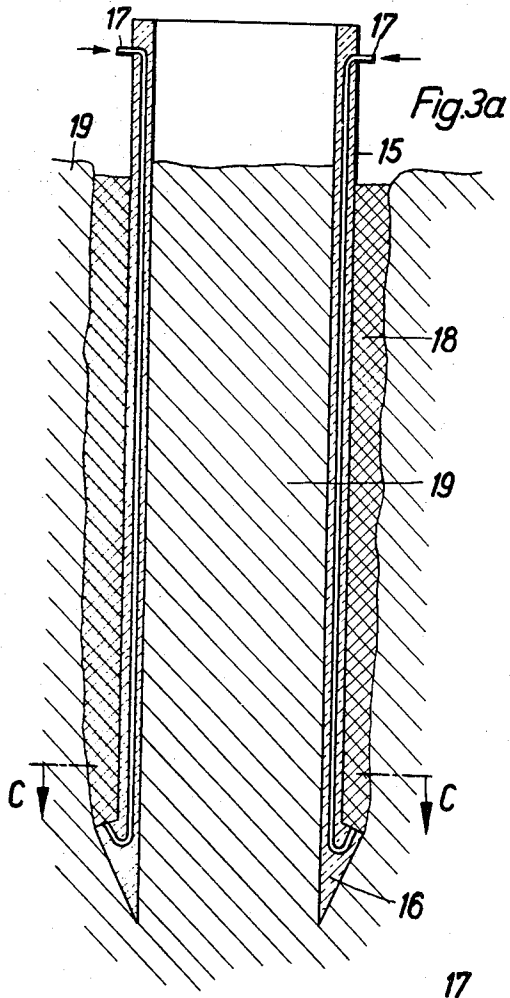

Fig.3a

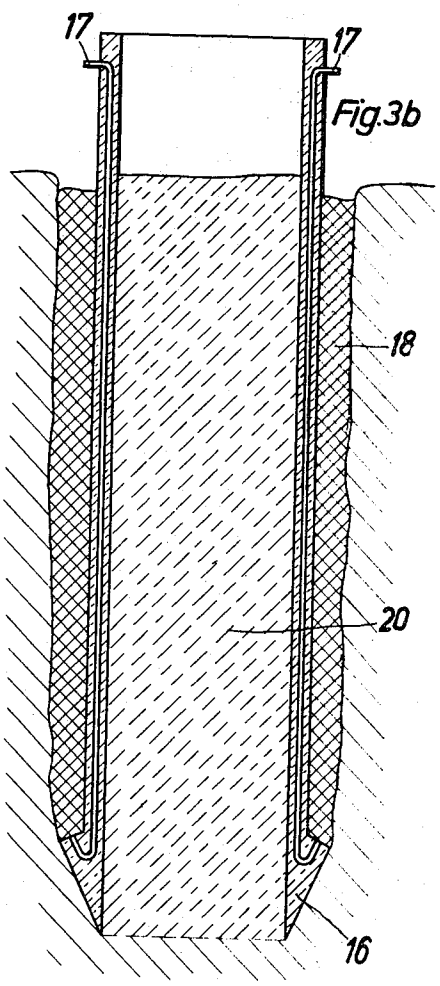

Fig.3b

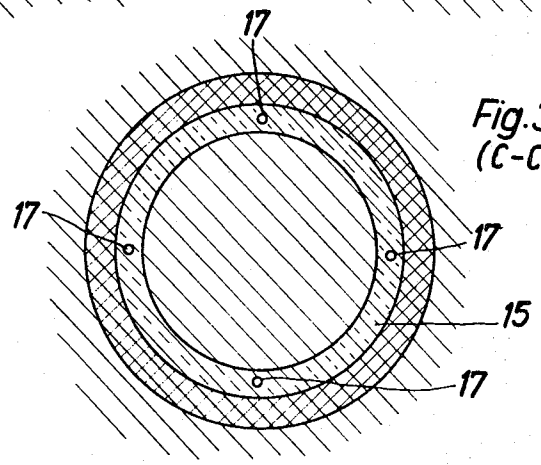

Fig.3c
(C-C)

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CONSTRUCTION PILE AND A METHOD OF PRODUCING SAME IN SITU

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Fig. 4a

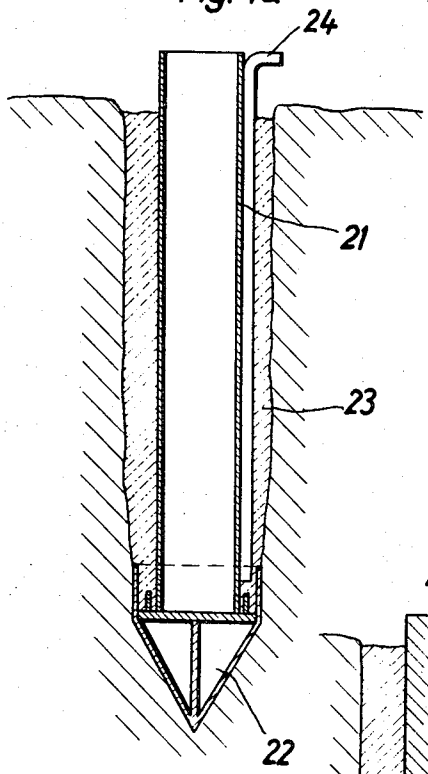
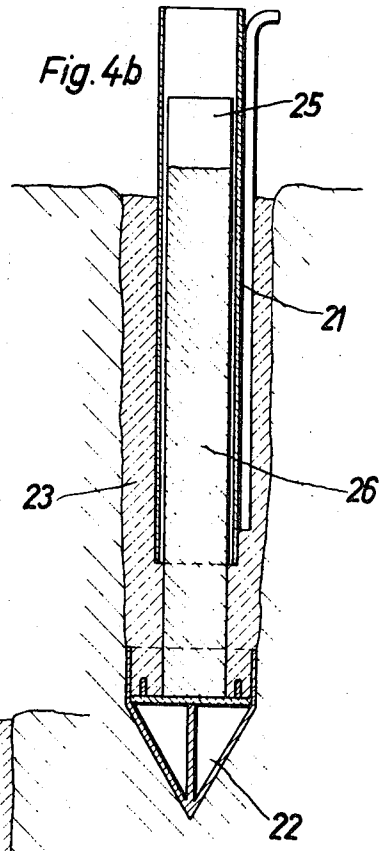


Fig. 4b



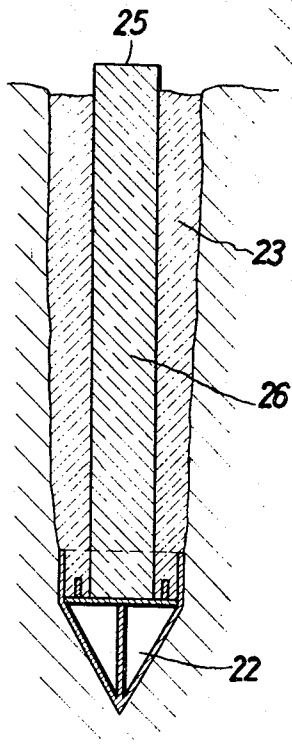


Fig. 4c

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CONSTRUCTION PILE AND A METHOD OF PRODUCING SAME IN SITU

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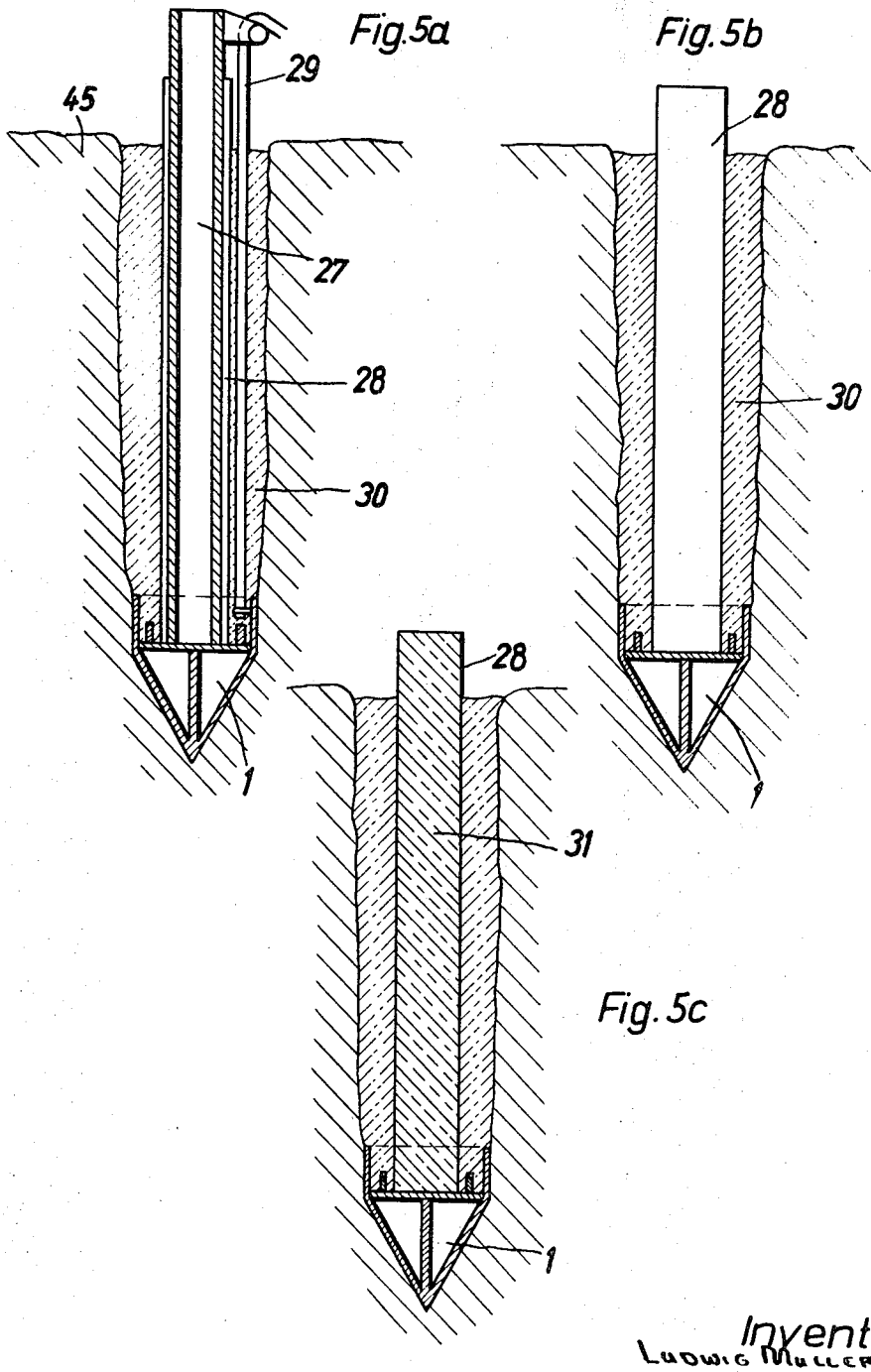

Fig. 5c

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CONSTRUCTION PILE AND A METHOD OF PRODUCING SAME IN SITU

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Original application Nov. 9, 1966, Ser. No. 593,139. Divided and this application Jan. 19, 1968, Ser. No. 721,901

Int. Cl. E02d 5/30, 5/60, 5/77

U.S. Cl. 61—53.52 5 Claims

ABSTRACT OF THE DISCLOSURE

A device for forming a construction pile in situ comprises an open-ended tubular shaft adapted for driving into the ground. The shaft has a hollow foot from the base of which a peripheral flange protrudes upwardly to define an annular space between the flange and the shaft. Hardening material is fed into the space defined by the foot when the shaft is driven by means of a pipe extending parallel to the shaft into the space defined by the flange.

This application is a divisional application divided out of my co-pending application 593,139 filed Nov. 9, 1966 and now abandoned.

The present invention relates to a construction pile to be driven into the ground and anchored therein, and particularly to a construction pile to be produced in situ.

As is known, piles of the general kind above referred to can be produced in situ by driving a tubular shaft with a loosely attached pile foot into the ground. The shaft is then withdrawn and while being withdrawn is filled with concrete so that the filled-in concrete, which is tamped or compressed if necessary, is pressed against the surrounding soil strata. The surface friction of such pile and thus the anchoring thereof is comparatively low since the concrete does not key itself into the surrounding soil even if the concrete is pressed down or tamped. Such failure of the concrete to key itself into the soil is primarily due to the fact that the concrete filled into the shaft is in a piece or granular form rather than in a flowable condition. In this connection, it should be pointed out that the term "granular" is not intended to indicate a specific size of the individual pieces of the concrete but merely to indicate that the concrete is not in flowable form.

Accordingly, the calculation of the load capacity of a pile of this kind must be based upon a low value of the friction between the wall of the pile and the surrounding soil.

It is an object of the present invention to provide a novel and improved construction pile of the general kind above referred to which when produced in situ is strongly keyed to the surrounding soil so that the load capacity of such pile is correspondingly increased by the high friction value between the soil and the wall of the pile.

According to the invention the aforepointed out object, feature and advantage and other objects, features and advantages which will be pointed out hereinafter are obtained by providing a pile which when formed in situ has an outer layer formed by an initially flowable but hardened material and an inner core. This core can be produced by several different means and processes as will be more fully explained hereinafter. It is merely necessary that the core is capable of transmitting load and in particular pressure forces to the surrounding soil.

The outer layer being made of initially flowable and subsequently hardened material keys itself to the surrounding soil while it is still in flowable condition so that a high friction factor between the outer pile layer and

the surrounding soil is automatically obtained. As previously pointed out, such high friction factor is highly desirable when the load capacity of the pile is calculated.

The outer layer of the pile can be formed of flowable cementitious material or plastic and the core may be formed of a filler capable of being fed by dumping for instance, sand or a hardening mass in granulated or piece form such as concrete.

The core may also be in the form of a prefabricated column of steel or concrete. This column may be for instance in the form of a tube filled with a filler such as sand or a hardening mass.

Accordingly, a pile according to the invention comprises at least two layers which have a consistency different from each other at the time they are used to produce a pile in situ. The outer layer serves to key the pile to the surrounding soil and the core serves to transmit the load to the soil.

According to one exemplification of the invention a suitable method of producing a pile resides in driving a preferably tubular shaft into the ground and forming an annular cavity about the shaft while the same is being driven into the ground. The cavity surrounding the shaft is then filled with a suitable hardening material in flowable condition so that the material can penetrate into the pores or interstices of the soil. The flowable mass is preferably subjected to pressure while being fed into the cavity to increase the keying action of the mass. After the flowable mass is sufficiently hardened, the tubular shaft is gradually withdrawn and simultaneously or thereafter the space vacated by drawing of the shaft is filled with a filler to form the core. Finally, if necessary, the narrow annular space vacated by drawing of the shaft may also be filled with a flowable hardening mass so that the core is strongly joined to the surrounding outer layer. The tubular shaft can of course also be filled with core material while being driven.

The tubular shaft can also be surrounded by an outer sleeve while being driven. The aforementioned annular cavity is then formed about the outer sleeve. This cavity is filled with a flowable hardening material capable of keying itself to the surrounding soil strata whereupon the tubular shaft is withdrawn and a filler is fed into the sleeve which remains in the ground, either simultaneously with the withdrawal of the tubular shaft or upon completion of such withdrawal.

Another suitable method according to the invention resides in driving a tubular shaft into the ground while simultaneously forming an annular cavity about the tubular shaft. This cavity is filled with a flowable hardening mass and thereupon a pre-fabricated column is inserted into the tubular shaft. Finally, the shaft is withdrawn and the now vacant annular space between the column and the outer layer is filled simultaneously with the withdrawal of the shaft or thereafter.

The pre-fabricated column may be a tube made of steel or concrete and filled with a filler such as a hardening mass or sand.

Arrangements using a column which either encompasses the shaft or is disposed within the shaft, have the advantage that it is not necessary to dimension the column so that it is capable of sustaining the driving forces but merely so that it is capable of sustaining the static forces of the load upon the soil. Moreover, the same tubular shaft can be used for several constructions of piles in situ since it is re-covered after each use.

Obviously, a tubular shaft can also be driven into the soil while forming an annular cavity about the shaft which is thereupon filled with a flowable hardening mass to form the aforementioned outer layer. The tubular shaft is left in the ground and filled with a suitable filler so

that the shaft itself constitutes the core or column of the pile.

As stated before, the cavity surrounding the tubular shaft is filled with flowable cementitious material or a hardening plastic mass. The use of a hardening plastic mass has the advantage that a pile having an outer layer made of hardened plastic can be safely used in aggressive water such as salt water. As is evident, the plastic layer protects the inner core and the tubular shaft against corrosion and other chemical attack.

The tubular shaft itself may be a steel tube, or a tube made of concrete or plastic.

The cavity formed about the tubular shaft can be filled with a flowable hardening mass while the shaft is being driven into the ground.

A suitable device for carrying out the method of the invention is for instance a tubular shaft which has at its lower end a foot the peripheral outline of which is wider than the maximal peripheral outline of the shaft. The foot preferably ends in a wedge shaped portion to facilitate driving of the shaft. The foot may be fixedly or releasably secured to the shaft. A pile foot suitable for the purpose of the invention is shown for instance in prior Pats. 3,040,810, 3,054,268, 3,137,140 and 3,152,450 of the applicant herein.

The pile foot may also be in the form of a collar fixedly or releasably secured to one end of the shaft and leaving said end uncovered. The outer wall of the collar is preferably inwardly tapered to form a wedge facilitating the driving of the shaft with the foot attached thereto. A foot fixedly secured to the shaft is preferably used when the tubular shaft is left in the ground.

When a tubular shaft with a foot or collar leaving uncovered the leading end of the shaft is driven into the ground, soil will naturally penetrate into the shaft and fill the same more or less. Upon completion of the driving operation, such soil can be removed by suitable means well known for the purpose if it be desired to fill the shaft with a material other than soil.

One or several feed pipes may be lengthwise attached to the shaft to feed suitable flowable material into the cavity surrounding the shaft upon or during completion of the driving operation.

It is also suitable and within the concept of the invention to provide a tubular shaft which has lengthwise spaced openings in its wall, preferably extending down to the pile foot or collar. The flowable material used for filling the cavity surrounding the shaft is then filled into the shaft itself and flows out through the openings into the cavity. A tubular shaft of this kind is preferably a centrifugally cast shaft. Obviously, the tubular shaft and the core can be formed of several lengthwise aligned sections. The use of a sectionalized tubular shaft or core has the advantage that the driving equipment can be designed for a correspondingly lower load.

In the accompanying drawing several preferred embodiments of the invention are shown by way of illustration and not by way of limitation.

In the drawing:

FIG. 1*a* is a sectional elevational view of a tubular pile shaft with a loose foot;

FIG. 1*b* is a sectional view of the finished pile after withdrawal of the shaft, the foot being left in the ground;

FIG. 1*c* is a section taken on line A—A of FIG. 1*a*;

FIG. 2*a* is a sectional elevational view of a modification of a tubular shaft with a loose foot;

FIG. 2*b* shows the completed pile, the foot being left in the ground;

FIG. 2*c* is a section taken on line B—B of FIG. 2*a*;

FIG. 3*a* is an elevational sectional view of a tubular shaft with a foot in the form of a tapered collar fixedly secured to the shaft or integral therewith;

FIG. 3*b* is an elevational sectional view of the completed pile;

FIG. 3*c* is a section taken on line C—C of FIG. 3*a*;

FIG. 4*a* is an elevational sectional view of a further modification of a tubular shaft with a loose foot;

FIG. 4*b* is an elevational sectional view showing an intermediate stage of forming the pile in situ;

FIG. 4*c* is an elevational sectional view of the completed pile;

FIG. 5*a* is an elevational sectional view of a tubular shaft with a loose foot and an outer sleeve encompassing the shaft;

FIG. 5*b* is an elevational sectional view showing the outer sleeve after withdrawal of the tubular shaft; and

FIG. 5*c* is an elevational sectional view of the completed pile.

Referring first to FIGS. 1*a*, 1*b* and 1*c* more in detail, these fiigures show a tubular shaft **2** supporting at its leading end a hollow foot **1** which has preferably a rectangular cross-section and the maximal peripheral outline of which is larger than the peripheral outline of shaft **2**. A peripheral flange **1***c* extends upwardly from the base wall of the shaft. The foot is reinforced by a vertical strut **1***a* and has openings **1***b* in its base wall to permit ingress of the hardening material into the foot as will be more fully described hereinafter. Shaft **2** together with foot **1** are driven by suitable and conventional pile driving means into selected load carrying soil strata. Foot **1** due to its enlarged peripheral outline forms about shaft **2** an annular cavity when and while the shaft is being driven. This cavity is filled with a flowable hardening mass such as a cementitious material as the driving of the shaft progresses. The cementitious material may be fed into the cavity, preferably under pressure, through feed pipes **3***a* and **3***b*. As is evident, the cementitious material gradually forms a jacket **4** about shaft **2** increasing upwardly from the bottom of the hole.

Pipes **3***a* and **3***b* may extend down to the foot, or they may terminate a selected level of shaft **2**. They can be fixedly or exchangeably mounted on the shaft. Shaft **2** is withdrawn after the desired driving depth is reached and the cementitious material has sufficiently hardened.

The interior of the shaft **2** is filled with a suitable filler material such as concrete to form a core **6** of the pile. The concrete may be fed into shaft **2** after completion of the driving operation or during withdrawal of the shaft.

The annular space vacated by shaft **2** when the same is withdrawn, is also immediately filled with cementitious material preferably under pressure. Due to the filling of the annular space vacated by withdrawal of shaft **2**, core **6** and the outer layer formed by jacket **4** are safely and strongly joined to each other.

The aforedescribed method of producing a pile in situ has the advantage that flowable hardening material such as cementitious material fed into the cavity formed about shaft **2** will penetrate into the pores or interstices of the surrounding soil strata **5** thereby strongly keying the jacket formed in the cavity to the surrounding soil. As is evident, the jacket increases the frictional force by which the finished pile is anchored in the ground.

According to FIGS. 2, 2*b* and 2*c*, a tubular shaft **12** has at its leading end a collar **11**. The collar leaves uncovered the respective end of shaft **12** and has an inwardly tapered outer wall. The resulting wedge shape facilitates driving of the foot and the shaft. The peripheral outline of the collar is again larger than the peripheral outline of the shaft to form an annular cavity **8** about the shaft as the same is being driven.

Lengthwise pipes **9** serve to feed cementitious material into cavity **8**.

As is evident, shaft **12** will be filled with soil **10** during the driving operation. The soil may be removed by suitable means well known for the purpose so that the shaft can be filled with a suitable filler such as concrete or sand to form a core **13**.

Obviously, a reinforcement such as a wire grid **14** may be inserted into the cylindrical space vacated when shaft **12** is withdrawn after jacket **8** has sufficiently set. The foot is left in the ground.

According to FIGS. 3*a*, 3*b* and 3*c*, a tubular shaft **15** terminates at its leading end in a foot in the form of a generally wedge shaped collar **16**. The wall of shaft **15** includes one or preferably several lengthwise ducts **17** which terminate, upwardly turned, in collar **16** as it is clearly shown. The ducts serve to feed a flowable hardening mass such as cementitious material into an annular cavity **18** formed by the action of the collar during the driving operation as previously explained. The jacket formed by the hardening cementitious material about shaft **15** keys itself to the surrounding soil strata, especially when the cementitious material is fed under pressure.

Shaft **15** being open at its leading end, is filled with soil **19** during the driving operation. Upon completion of this operation the soil is removed by means suitable for the purpose and the cylindrical space now vacated within the shaft is filled with a suitable filler **20** which forms the core of the pile. As can best be seen in FIG. 3*b*, shaft **15** remains in the ground and thus becomes part of the core.

FIGS. 4*a*, 4*b* and 4*c* show a pile structure in which a tubular shaft **21** releasably mounting a foot **22** is driven into the ground. The foot again has a peripheral outline wider than the maximal peripheral outline of shaft **21** to form a cavity **23** surrounding shaft **21** when the same is driven into the ground. The cavity is filled with a cementitious material or other suitable hardening material by one or several feed pipes **24** mounted on the outside of the shaft to form the outer layer or jacket of the pile.

Upon completion of the driving of the shaft and filling of cavity **23**, a pre-fabricated column **25** is inserted into shaft **21**. Thereupon shaft **21** is withdrawn and the annular space formed between the jacket and column **26** is simultaneously or shortly thereafter filled with cementitious material to join column **25** to the jacket. Column **25** can be solid or be hollow. If hollow, it is filled with a suitable filler such as concrete or sand as is indicated in FIG. 4*b*.

According to FIGS. 5*a*, 5*b* and 5*c*, a tubular shaft **27** together with an outer sleeve **28** closely jacketing the shaft is driven into the ground by applying the driving force to the shaft. The enlarged head **1** at the leading end of shaft **27** and the sleeve **28** form a cavity **30** about sleeve **28**. This cavity is filled with cementitious material or other flowable material by means of a hose **29** detachably secured to the outside of shaft **27** and extended close to foot **1**.

Sleeve **28** may be fixedly secured to foot **1** or may loosely rest upon the same.

When the required driving depth is reached shaft **27** is withdrawn and the interior of sleeve **28** is filled with a suitable filler **31**. As is evident, the core is formed by the filler material in the sleeve **28**.

When a loose pile foot is used, the interior of the pile shaft or the sleeve is sealed at the pile foot against the cavity formed about the shaft or the sleeve.

Finally, it may be mentioned that in all the illustrated exemplifications of the invention the cavity formed by foot **1** during the driving operation may be filled by a hose extended from the top into the cavity as the same is being formed.

While the invention has been described in detail with respect to certain now preferred examples and embodiments of the invention, it will be understood by those skilled in the art, after understanding the invention, that various changes and modifications may be made without departing from the spirit and scope of the invention, and it is intended, therefore, to cover all such changes and modifications in the appended claims.

What is claimed is:

1. A device for forming a construction pile in situ, said device comprising:

an open-ended tubular shaft adapted to be driven into the ground by applying a driving force to the trailing end of the shaft;

a hollow foot of lengthwise tapered cross-section and of larger peripheral outline at its wide end than the tubular shaft, said foot having a base wall peripherally protruding from the shaft and said base wall having a peripheral upwardly extending flange, said base wall and said flange forming a cup-shaped receiver for the leading shaft end, said shaft end extending into said receiver spaced apart from the flange and abutting against the base wall; and

a feed pipe extending parallel to said shaft into the receiver defined by said base wall and flange.

2. The device according to claim **1** wherein said foot is a hollow closed body and has ingress openings in its base wall.

3. The device according to claim **1** wherein an open-ended sleeve encompasses said shaft closely fitting the same, said sleeve terminating within the receiver defined by said base wall and flange.

4. The device according to claim **3** wherein said feed pipe extends outside of the sleeve into the receiver defined by said base wall and flange.

5. The device according to claim **1** wherein the base wall of the foot has a central opening, the open leading end of the shaft being aligned with said opening.

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U.S. Cl. X.R.

61—53.62, 53.64, 53.66, 56.5