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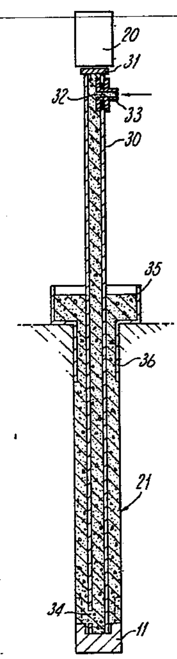
(54) **Piles.**

(57) The method involves driving into the ground a mandrel (1) carrying a pile shoe (2) and pumping a cementitious mixture (4) into the hole through the interior of the mandrel (1) as it is being driven into the ground. The cementitious mixture (4) leaves the interior of the mandrel (1) and enters the annular gap between the mandrel (1) and the earth surface via one or more holes (34) located at or close to its lower end and generally just above the pile shoe (2). The mixture (4) is maintained at a positive pressure relative to its surroundings, and is allowed to set after the mandrel (1) has reached the desired depth and has been withdrawn leaving the shoe (2) behind. The driving rig need not have the bulk required to exert the massive pulling forces required in conventional piling systems where a temporary casing which has been driven tightly into the soil is withdrawn prior to completion of the pile.



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PILES.

The invention relates to piles, and more particularly is concerned with piles which are of the driven cast-in-place type.

In conventional piling systems of the driven cast-in-place type, the stages of production are:

[1] a driving rig is set up at the desired pile position;

[2] a casing or tube [often fitted with an expandible base shoe to prevent entry of soil into the tube] is driven into the ground, the diameter of the tube being the same as that of the pile being formed;

[3] a steel reinforcing cage is placed inside the tube;

[4] concrete is poured into the interior of the tube, usually to ground level or slightly above; and

[5] the tube is then withdrawn from the ground, and the driving rig moves on to the next pile position. With current techniques, the time taken to complete these five operations for a single pile is on average around 45 to 50 minutes. The driving rig is also a robust and expensive piece of equipment, since the pulling force required to extract the tube in step [5] is often of the order of 100 to 150 tonnes. The masts of the machines have to be designed to carry this load and some means of transferring this force to the ground must also be provided.

In one prior art piling system, generally termed the "Interpile", a tubular, perforated mandrel carrying at its lower end a detachable pile shoe is driven into the ground. The dimensions of the pile shoe exceed those of the mandrel so that there is an annular gap between the outer surface of the mandrel and the earth wall[s] created by the driving of the pile shoe. A fluid concrete mix is poured into a hopper which surrounds the mandrel as the mandrel is driven into the ground. The gravity-fed concrete flows downwards, moving with the pile-shoe, and enters the interior of the mandrel via a large number of holes. Once the pile shoe and mandrel have reached the desired depth, they are left in place and the concrete is allowed to set. A similar method is described in U.S. Patent No. 779,881 issued January 10th, 1905. Systems of this type are not ideal for the construction of deep piles. Although in theory the hydrostatic pressure at the base of a fluid column will always exceed that at higher levels, in practice this does not always apply to a column of concrete which is to form the pile. For example, if there is significent bleeding of the concrete at the top of the pile, or if a band of concrete in this area sets against the surrounding earth and thus becomes separated from the remainder of the column [known as the "hang-up" effect], then the area in question will not contribute, or will not contribute in full, to the hydrostatic pressure acting on the concrete at the base of the pile. The normal frictional forces between concrete and the surrounding earth [which always exist when the concrete moves downwardly to follow the motion of the pile shoe] also contribute to the "hang-up" effect. The reduction of hydrostatic pressure at the base of the pile is accompanied by a proportional reduction in the concrete lateral pressure at the base of the pile, and it may thus become possible for soil to move inwards to fill any void being formed above the pile shoe. In this way the pile section is reduced to a value below that corresponding to the size of the pile shoe. In other words the pile may "neck", and this is highly undesirable. The tendency of the pile shoe to displace earth sideways and upwards also increases the lateral concrete pressure necessary to support the pile at its base.

An object of the present invention is to provide a method of forming piles which makes it possible to reduce the time required to form a pile, to reduce the mass of the machinery involved in producing the pile, and to reduce the possibility of the pile necking.

According to the present invention, there is provided a method of forming a pile in the ground, which comprises:

[a] driving into the ground a tubular mandrel carrying at its lower end a pile shoe the dimensions of which measured in a plane perpendicular to the direction of driving exceed the corresponding dimensions of the mandrel, the mandrel having at its upper end means for introducing a fluid cementitious mixture into the interior of the mandrel and having at or close to its lower end one or more holes whereby fluid cementitious mixture can flow outwardly into the space surrounding the lower part of the tubular mandrel;

[b] pumping a cementitious mixture through the interior of the tubular mandrel from the top to the bottom thereof and thence into the hole around the mandrel as the mandrel is being driven into the ground so as to maintain the cementitious mixture at a positive pressure relative to its surroundings; and

[c] when the mandrel has reached the desired depth, leaving the pile shoe in place, withdrawing the mandrel and allowing the cementitious mixture to set.

Because the mandrel is smaller in size than the pile and is surrounded by unset [i.e. fluid] cementitious material, the forces required to extract it at completion of driving a pile are small compared with the pulling forces which are required in conventional cast-in-place driven piling systems to withdraw the temporary casings which have been driven tightly into the soil.

One or more holes are provided at or close to the base of the mandrel, generally just above the pile shoe. A cementitious mixture under pressure is supplied to the interior of the mandrel and passes downwardly under pressure to the hole[s] at the base of the mandrel and thence into the hole around he mandrel. The supply of cementitious mixture in this way ensures that the hole around the mandrel is filled with fluid cementitious mixture as the hole is being generated. The supply of concrete under pressure to the base of the mandrel also means that it enters the pile section just above the shoe position, and accordingly the frictional forces which in conventional piles oppose the downward flow of concrete into the pile do not occur. Advantageously, an open ended concrete reservoir which may be constructed, for example, of steel, is provided at the ground surface and is arranged so that the mandrel passes therethrough as the pile is being formed. If desired, the concrete reservoir can be closed at its upper surface to function as a pressure box.

The mandrel can be of square, circular or any other desired cross-section. The mandrel may be solid or tubular and conveniently is formed of steel or other high-strength material. The mandrel may be formed by the co-operation of a plurality of unit lengths joined together, e.g. with flush joints. The driving of the mandrel can be effected through a driving hammer which can be diesel- or hydraulically- driven or can be gravity-acting.

Where a pressure box is present, this can include a gland which, in use abuts the mandrel, and an air release valve. Downward pressure may be applied to maintain the position of the pressure box, e.g. through the weight of the driving rig for the mandrel.

The pile shoe [also known as a driving shoe] may be flat or pointed at its driving end, and may be formed of steel or concrete. The driving shoe may be circular, square or any other shape as viewed in a plane perpendicular to the direction of driving. Furthermore, an extension sleeve may be attached to the upper end of the driving shoe to prevent displacement of soil around the driving shoe into the intended pile section.

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It is possible to ensure that adequate pressures can be maintained in the cementitious mix [e.g. concrete] at all times during construction of the pile, thereby to preserve the shape of the pile and to give intimate bonding of the pile to the surrounding ground material.

In all embodiments of the invention, the driving of the mandrel into the ground and the supply of cementitious material [e.g. concrete] to form the pile are concurrent. Also, the need for a temporary casing or tube is obviated so that the high extraction forces normally involved with driven cast-in-place piles are avoided. This means in turn that the pile driving machine or rig can be of simpler construction since its mast need not withstand the normally large forces involved in extracting the casing.

The invention will now be described with reference to the accompanying drawings, in which:

FIGURE 1 illustrates the frictional forces acting during the construction of certain prior types of pile; and

FIGURE 2 illustrates an embodiment of this invention.

Referring now to Figure 1, a prior art arrangement involves a tubular mandrel 1 equipped at its lower end with a pile shoe 2. A fluid concrete mix is supplied under gravity to a hopper 3 located at the ground surface. As the mandrel 1 is driven downwardly [by means not shown], the fluid concrete mix 4 also travels downwardly in the direction of arrow 5. This results in frictional forces indicated by arrows 6; these forces oppose the downward flow of concrete, so that the longer and narrower the pile becomes then the less will be the vertical concrete pressure towards the base of the pile. Thus the concrete lateral pressure will also reduce in proportion, and the pile may neck.

Referring now to Figure 2, a concrete pile is formed by a method in accordance with this invention using a tubular mandrel 30 of unitary construction and formed of high-strength steel. The mandrel carries at its lower end a steel driving shoe 11 which, like the mandrel 30, is circular in cross-section. The driving shoe 11 has a flat base 12. As can be seen from the drawing, the dimensions of the driving shoe exceed those of the mandrel 30 so that an annular space is formed around the mandrel as the assembly is driven downwardly into the ground. The upper end of mandrel 30 is closed by a pressure-resisting plate 31. Just below this plate there is an aperture 32 in the side wall of the mandrel which aperture carries a shock-absorbing pipe connection 33 which receives a pipe for the supply of a fluid concrete mix under pressure. One or more holes 34 are provided in the lower part of the mandrel 30 adjacent to driving shoe 11. A reservior 35 the walls of which are formed of steel is positioned at ground surface level. A tubular extension 36 extends downwardly from the concrete reservoir for a few feet into the hole which is formed as the mandrel 30 is driven into the ground. The driving rig for the mandrel [not shown] carries a hydraulic mechanism for driving hammer 20.

In use, concrete is supplied under pressure through pipe connection 33 and passes downwardly through mandrel 30 to aperture 34. The supply of concrete occurs simultaneously with the driving of the mandrel 30 downwards by action of driving hammer 20. The concrete is at a pressure sufficient to maintain the column of fluid concrete at a positive pressure relative to the earth wall 21. The reservoir 35 is of a height sufficient to support the head of concrete which is generated owing to the pressurised concrete supply. Because in this embodiment the concrete is supplied under pressure to the mandrel and enters the pile section just above the driving shoe 11, the frictional forces shown at 6 in Figure 1 which normally oppose the downward flow of concrete into a pile do not apply. In fact, the direction of motion of concrete within the pile can be the reverse of that encountered with conventional gravity feed systems: in these circumstances, the wall friction is also reversed and the pressure of concrete at the base of the pile is enhanced during the driving of the pile. Also, the "hang-up" effect is of no consequence because concrete is always supplied at the right place to fill up the void created by downward motion of the pile shoe. If very high concrete supply pressures are used, the reservoir 35 may be modified so as to resemble a pressure box.

Once the mandrel 30 has reached the desired pile depth, it is withdrawn leaving the pile shoe in place. The driving rig is then removed and the concrete mixture is left to set. During removal of the mandrel, the concrete mixture can be maintained under positive pressure so as to ensure that the mixture moves into the void created as the mandrel is lifted ; in this way the concrete mixture is caused to permeate the whole volume of the pile.

Construction of piles in accordance with the present invention is especially advantageous in soft clays, water-bearing soils and other poor ground. In these conditions, pore water pressures can be high and soil shear strength low during the driving of piles. In gravity-fed systems which do not use a temporary casing, these conditions are particularly favourable for soil to re-enter the pile section and to displace any fluid concrete which is still present. By operating in accordance with the invention, this ingress of soil is prevented and thus stronger and deeper piles can be constructed.

It should be noted that, in practising the present invention, the cross-sectional shape of the pile can be round, square, elongate or any other desired shape. Where the pile section is elongate, the mandrel may be twinned.

After the first pile has been completed and the concrete has hardened to a reasonable degree, the continuity and general cross-sectional area of the pile can be tested if desired; in this way the concrete pressure used in the construction of subsequent piles can be adjusted to give the desired structure of full cross-sectional area.

CLAIMS.

1. A method of forming a pile in the ground, which comprises:

[a] driving into the ground a tubular mandrel carrying at its lower end a pile shoe the dimensions of which measured in a plane perpendicular to the direction of driving exceed the corresponding dimensions of the mandrel, the mandrel having at its upper end means for introducing a fluid cementitious mixture into the interior of the mandrel and having at or close to its lower end one or more holes whereby fluid cementitious mixture can flow outwardly into the space surrounding the lower part of the tubular mandrel;

[b] pumping a cementitious mixture through the interior of the tubular mandrel from the top to the bottom thereof and thence into the hole around the mandrel as the mandrel is being driven into the ground so as to maintain the cementitious mixture at a positive pressure relative to its surroundings; and

[c] when the mandrel has reached the desired depth, leaving the pile shoe in place, withdrawing the mandrel and allowing the cementitious mixture to set.

2. A method according to claim 1, wherein after the first pile of a series has been completed and the cementitious mixture thereof has hardened, the continuity and cross-sectional area of the pile are tested and the supply pressure of the cementitious mixture used in the construction of subsequent piles is adjusted, if necessary, in order to give the desired pile structure.

3. A method according to claim 1 or 2, wherein the cementitous mixture is caused to permeate the whole volume of the pile during removal of the mandrel.

4. A method according to claim 3, wherein the cementitious mixture is maintained at a positive pressure relative to its surroundings during removal of the mandrel.

5. A method of forming a pile in the ground, substantially as hereinbefore described with reference to Figure 2 of the accompanying drawings.

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Fig.1.

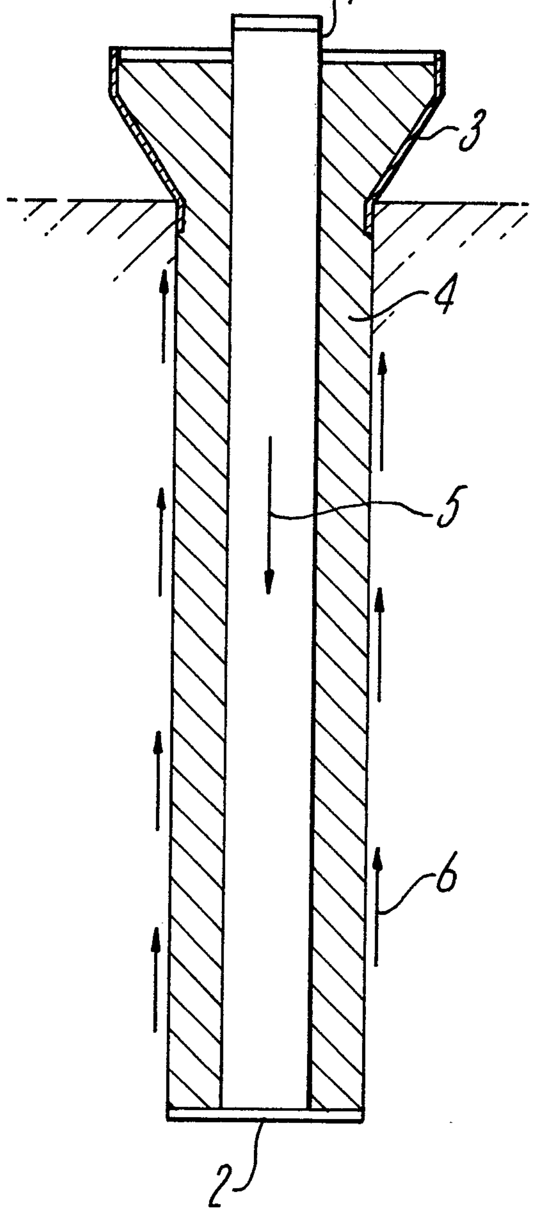
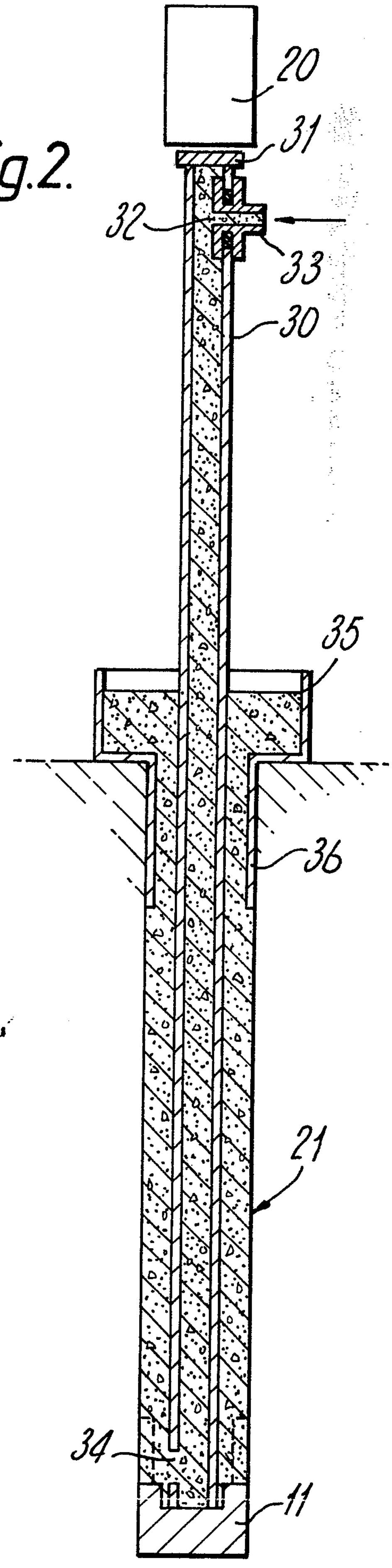


Fig.2.



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EUROPEAN SEARCH REPORT

Application number

EP 83 30 0003

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 3)
X	US-A-3 925 998 (LE CORGNE) * Column 4, lines 45-60; column 5, lines 63-68; column 6, lines 1-19,24-42; figures 1,3A-3E *	1,3,5	E 02 D 5/38

X	US-A-4 152 089 (STANNARD) * Column 2, lines 14-30,54-68; column 3, lines 1-24,50-55; column 4, lines 3-11,19-24,43-56; column 5, lines 1-5,15-32,42-58; figures 1-6 *	1-5	

Y	GB-A-1 603 425 (BICC) * Page 2, lines 7-27,52-65; figures 1-4 *	1,3,4, 5	
	---		TECHNICAL FIELDS SEARCHED (Int. Cl. 3)
Y	US-A-3 851 485 (STEDING) * Column 8, lines 40-47; figures 1,29 *	1,3,5	E 02 D

A	US-A-3 638 433 (SHERARD) * Column 11, lines 15-65; column 14, lines 59-74; column 15, lines 15-45; figures 1,1A,1B,5 *	1,3,4, 5	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	21-04-1983	RUYMBEKE L.G.M.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
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E : earlier patent document, but published on, or after the filing date
D : document cited in the application
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