March 29, 1949. J. H. THORNLEY 2,465,557

PILE AND METHOD OF MAKING THE SAME

Filed Oct. 22, 1945

Fig. 1.

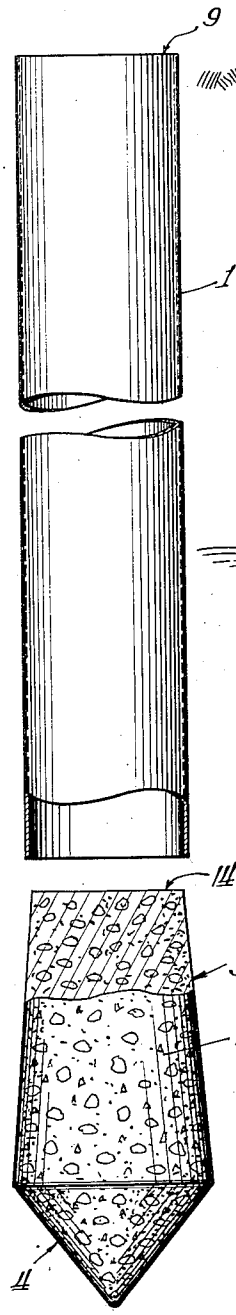


Fig. 2.

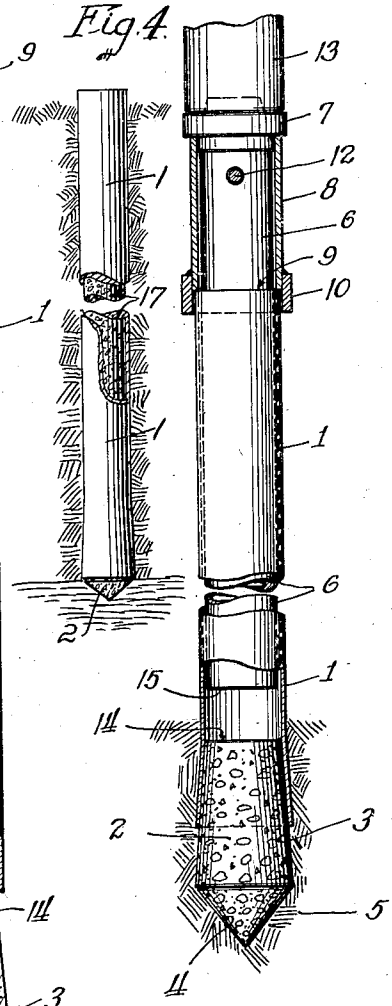


Fig. 3.

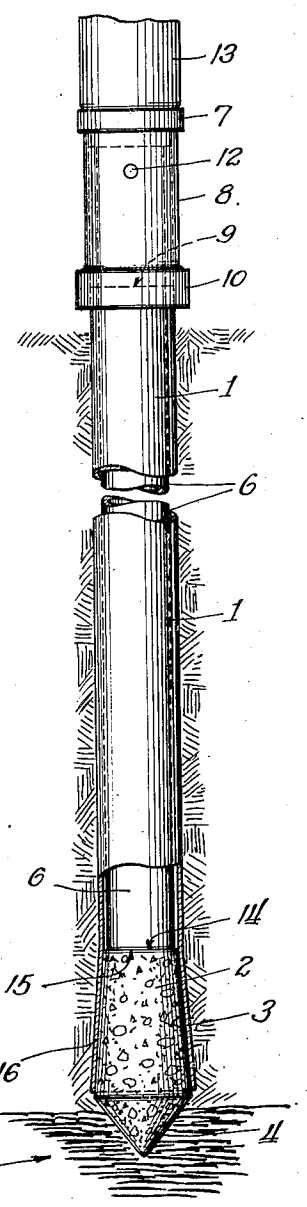


Fig. 4.

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PILE AND METHOD OF MAKING THE SAME

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10 Claims. (Cl. 61—57)

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My invention relates to pile construction and method, and more particularly to the provision of a suitable means and method for placing light weight pipe in the ground to form a pile. The pipe it is to be understood is to be filled with concrete to complete the formation of the pile.

It is known to dispose a steel or iron driving head or point on or against the lower end of a piece of heavy walled pipe and to drive the same down to the predetermined desired depth or to refusal. There are many situations, particularly in the case of medium length piles, calling for the driving of metal walled piles which, however, do not seem to justify the cost of pipe of a wall thickness great enough in itself to stand driving and the cost of the expensive driving head or point required in the known construction and method. One can accept the use of heavy walled pipe and an expensive driving head for a pile to be driven to great depth. It seems that there ought to be a way to avoid the necessity for the same gauge of pipe, and the expensive head when only a medium length of pile is involved. So far, no one has been able to do so successfully.

The aim of the present invention is to provide a construction and method for placing light weight pipe in the ground to form a pile—

(*a*) Without buckling due to bending of the pipe, such as tends to occur if the point strikes a boulder.

(*b*) Without crushing due to soil pressure.

(*c*) Without heave due to soil pressure which particularly affects piles tapered downwardly.

(*d*) To gain anchorage to reduce or prevent heave due to upward flow of soil on any known shape of driven pile.

(*e*) To provide means for safely redriving the pile in cases where bottom anchorage against heave is impossible, for example, where soft material extends all the way to rock or hard pan.

(*f*) To provide inexpensive but effective means for bottom closure of the pipe or shell, and

(*g*) To secure a "plow" action by the driving end of the pile to open a hole ahead of the pile, and so relieve the driving load of friction on the side walls of the light pipe.

It has been proposed to overcome buckling of thin walled pipe by bending through the expedient of longitudinal fluting, with or without tapering the shell. I have found that while the shell can thus be reenforced to resist buckling by bending the fluted pipe wall is subject to crushing by values of soil pressure which would do no harm to the same gauge shell without the flutes. To date, the only cure against failure due to bending and consequent buckling or against failure by collapse due to soil pressure has been the use of heavier shells.

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The pile and method of my invention solves the problem of buckling by bending of a light weight shell by taking the forces involving bending (and against collapsing pressures if such are encountered during driving) by a strongly constructed removable mandrel, as for example, a 10¾'' O. D. ½'' wall seamless tubing pipe, allowing no more than ⅛'' play all around between this mandrel and an 11'' I. D. ⅛'' wall permanent shell.

To avoid pressure heave and to gain anchorage, the taper of the shell, particularly at the lower end should be outwardly, i. e., larger diameter at the bottom or lower end than at the upper end. If the flare or outward taper could be concentrated at the bottom or very near the lower end of the pile, it would form an anchorgae in what would presumably be the best material penetrated, and would therefore resist heave due to upward flow of the soil.

It is difficult to conceive of a way to obtain such flare of the lower end of a shell supported by a close fitting mandrel, because the mandrel must be inserted and removed through the open top of the permanent shell. The pile of the present invention overcomes this difficulty by supporting the bottom 12'' or so of the pile shell, not by mandrel but by a precast tapered concrete plug, which constitutes the closure at the bottom of the pile shell.

The portion of the plug which will remain inside the pile shell is cast with a long gradual taper, so that it may act as a swedge to stretch or expand the bottom of the shell into a cone shape. The taper need not be uniform. For example, it may increase toward the bottom. The angle of taper is substantially below the critical angle so that the parts remain firmly fastened together.

In order to get the swedging action the plug is made of such dimensions that when jammed into the bottom of the shell into the top of which the driving mandrel has been inserted, there will be a space of 12'' or so between the bottom of the mandrel and the top of the concrete plug, when the driving head at the top of the mandrel bears against the top of the shell. The space between the mandrel and the top of the plug may be more or less, depending upon the taper of the plug, i. e., less for a greater taper and more for a smaller effective taper.

If driving is now continued by striking upon the head, the resistance of the plug to penetra-

tion will cause the driven shell to slide down over the plug until the bottom of the mandrel bears upon the top of the plug, after which no further movement as between the plug and the shell can take place. In order to slide down over the tapered precast plug, the bottom section of the shell will have to expand thus producing the "flare" at the bottom which is desired.

Furthermore, since this plug is driven into the shell much as a cork might be introduced into a bottle, except that in this case the bottle neck expands instead of the cork contracting, the frictional hold between the plug and the shell is extremely high and it is almost impossible to draw the plug out again.

In experiments during the past few years it has been proven that tremendous increase in crushing strength of concrete can be obtained by the use of prestressed circumferential reinforcing. This is the condition under which the concrete of the plug will now be acting, and it will therefore be capable of resisting unusualy high impact or compressive forces.

In (*e*) above it was pointed out that means should be provided to permit of the redriving of shells in those cases where, owing to poor material overlying impenetrable bottom bearing stratum, the pile might be lifted even though it be provided with an outwardly flared bottom.

Obviously, in this type of pile redriving may be carried out by reintroducing the mandrel into the shell and again driving it. In such case, due to the tightly jammed plug there will be a triple action, first, the shoulder of the drive head on the mandrel will contact the top of the shell and force it down by a compressive action. If this action only took place, it would possibly cause crushing of the top of the comparatively thin walled shell. But a secondary action takes place, the mandrel contacting the top of the plug directly takes any upward force or resistance to downward movement which may occur from the soil resistance below the point; and, thirdly, as the highly jammed plug is driven down by the mandrel, it will tend to pull the shell down after it, thus relieving the compression in the shell.

The concrete plug forms an inexpensive but perfect bottom closure for the pipe. The cast steel pile points generally used for closure plugs in the bottom of driven pipes are very expensive, and constitutes a substantial part of the cost of the pile where the pile is short.

The flare plug, protected as it is by the sheath of steel on the outside, forms a perfect plow to open a hole through obstruction action in advance of the shell.

The only force which needs to be applied as direct compression at the top of the shell is that required to overcome such friction as may result from the quick return of the soil against the shell after it has been forced back by the larger diameter plug.

Even this compressive force is reduced by the tension created in the shell by the downward drag of the directly mandrel driven plug, as soon as it has become thoroughly jammed into the bottom of the shell.

In the accompanying drawings, I have illustrated a specific embodiment of my invention.

Figure 1 is a side elevation showing the light gauge shell and the tapered precast concrete plug which form the parts of the pile that are to be driven.

Figure 2 shows the driving mandrel and hammer with the driving operation carried to the point of partial insertion of the plug into the bottom of the shell;

Figure 3 shows the parts in the position that they occupy when the pile is driven to the desired depth or to refusal; and

Figure 4 is a view, on reduced scale, showing the pile driven to the desired depth and filled with concrete.

In Figure 1 the light gauge shell 1 of a suitable length is provided with a precast concrete plug 2 having an upwardly tapered portion 3 adapted to be inserted in the lower end of the pipe 1 and a conical point portion 4 for penetrating the soil. The plug 3 may have a cylindrical guide portion at its upper end to facilitate piloting the plug 2 in the lower end of the tube 1. Also the conical surface 3, instead of being composed of straight lines, may be composed of curved lines. For example, the flare may be more rapid as the diameter increases. The plug may be provided with steel reenforcement if desired. One advantage is that it need not be reenforced as the hoop strength of the lower end of the pipe 1 serves to act as a reenforcement.

In a specific example of my invention, the shell 1 may be a ⅛" wall pipe of 11" inside diameter. The tapered part of the plug 2 may be 18" long, with the top diameter 11" or slightly less, and the maximum diameter 12½". In that example, the included angle is 1" per foot, that is, the cone has a four degrees and 46 minutes included angle. Obviously, the tapered portion may be of greater or less length, and as above pointed out, may comprise a reduced or a cylindrical pilot portion at the top to facilitate its insertion into the lower end of the shell 1. The length of the shell 1 may be any suitable dimension for reaching from the surface to the supporting stratum. It is particularly adaptable to a short or a medium length pile, the limit of length being attained only when the side friction or lateral pressure becomes too great for the force which must be applied endwise upon the wall, or if the crushing stress should be too great for the given wall thickness.

The operation of jamming the plug 2 into the open end of the tube 1 may be partly performed before driving occurs, but preferably the plug 2 is placed on the ground in position where the pile is to be driven, and the shell 1 is brought over the top of the plug 2 with the driving mandrel 6 disposed inside the shell 1. The driving mandrel 6 is connected to a driving head 7 which carries also a heavy driving sleeve 8 outside the same, the lower end of the sleeve 8 bearing upon the top end 9 of the shell 1, the top of the shell being surrounded by a restraining collar 10 which is secured as by welding to the said sleeve 8. The sleeve 8 may in turn be secured as by welding to the driving head 7, and the mandrel may be secured to a stub of the driving head 7, as by means of the cross pin 12. The driving head 7 is shaped to be engageable by a hammer 13 or other force applying means which forces the mandrel 6 and the sleeve 8 against the resistance of the pile. The initial driving of the plug 2 and shell 1 into the soil 5 is effected by the resistance of the plug 2 to entry into the lower end of the sleeve 1. The shell 1 is so related in length for driving to the resistance of entry of the plug 2 that before the pile has penetrated to the desired depth or stratum the plug 2 will have been forced into the lower end of the shell 1 until the top surface 14 of the plug is contacted by the bottom surface 15 of the mandrel. That is to say, the initial driving is entirely through the shell 1 until the

plug 2 has been forced far enough into the lower end of the shell to expand the same and provide a firm bond by frictional grip between the two, and this is determined by movement of the plug 2 into the lower end of the shell to the point where the plug engages the bottom of the mandrel. Thereupon the driving proceeds with limited pressure applied to the shell and the remainder of the pressure applied through the mandrel to the plug. The limitation of force applied to the shell is the frictional resistance which the shell has relative to the plug. Under the blows of the hammer, the shell 1 may have passed down on the taper of the plug to the point where substantially all of the force applied is through the mandrel and the plug 2. In that case, the plug tends to drag the shell along with it by pulling down upon the lower end thereof. When the pile has been driven to a firm stratum, such as indicated in Figure 3, the lower end of the shell now has an upward taper which tends to anchor the pile against heave by movement of the soil upward. In other words, the enlargement at the lower end of the pile serves as an anchorage. During the driving stage, the enlarged portion 16 containing the plug 2, creates a substantial easing of the friction on the side walls, since the enlarged lower end tends to produce a larger hole than the main shaft of the pile, and hence until the soil closes against the side walls, the progress downward is substantially easier.

After the pile is driven to refusal or to the desired depth, the mandrel 6 is readily withdrawn, since it is of a uniform diameter, consisting, in the specific illustration given by way of example of a piece of ½" wall pipe, 10¾" outside diameter, thereby providing a clearance all around of ⅛". The driving sleeve 8 may likewise be a piece of seamless tubing of ½" wall pipe of 11" inside diameter.

After the mandrel is withdrawn, other piles may be driven likewise in the same region, and when all of the piles have been driven into final position, they may be filled with concrete so that each shell 1 may have a concrete core 17, as shown in Fig. 4.

In the event that it is desired to redrive any particular pile which, in spite of the favorable construction, is heaved upward by upward movement of the soil, the mandrel may be reinserted and the pile redriven to the desired position. The redriving may be done by the same driving tool 6—7—8, applying the major part of the force through the mandrel 6 to the plug 2 and the minor part to the top of the shell 1 by means of the driving sleeve 8. It may in some cases be done by driving only upon the plug 2.

The concrete plug presents exceptional strength in the present circumstances, since it is pre-stressed by the entire hoop strength of the expanded portion 16 of the lower end of the shell. It is thereby enabled to sustain very heavy pressures, and no fear need be entertained of its failure upon being driven to refusal or in carrying the load afterward. The present invention provides a simple and inexpensive solution of a problem which heretofore has had no adequate solution.

The specific examples given and the stated dimensions relating thereto are given by way of example, and are not intended to be limiting, as will be apparent to those skilled in the art.

I claim:

1. Method of driving a pile which comprises disposing a tapered concrete plug on the ground

at the location where the pile is to be driven, disposing the open end of a relatively thin walled tubular shell over the plug, pressing the shell down to drive the plug into the ground, the resistance of the plug to driving causing the lower end of the shell to telescope over the tapered plug to a predetermined distance and thereupon simultaneously applying driving pressure to the shell and to the plug.

2. Method of driving a thin walled shell which comprises jamming a tapered precast concrete plug into the open lower end of the shell to expand the lower end of the shell, and forcing the plug and shell down into the ground by pressure applied in major amount or wholly directly to the concrete plug, and in minor amount or none at all to the top of the shell.

3. Method of driving a thin walled shell to refusal upon a firm subterranean stratum which comprises forcing a tapered precast concrete plug into the lower end of the shell to close and to expand the same, then applying limited force to the top of the shell, and applying the force of refusal to the concrete plug, said limited force being less than that which will distort the upper end of the shell.

4. The method of driving a pile, which method comprises disposing a tapered plug on the ground at the location where the pile is to be driven, disposing the open end of a relatively thin walled shell over the plug, pressing the shell down to drive the plug into the ground, the resistance of the plug to driving causing the lower end of the shell to telescope over the tapered plug, said telescoping being permitted for a predetermined distance, and then simultaneously applying driving pressure directly to both the shell and to the plug.

5. The method of driving a pile, which method comprises disposing a plug on the ground at the location where the pile is to be driven, said plug having a driving point adapted to enter the ground and a tapered portion, disposing the open end of a relatively thin walled shell over the tapered portion of the plug, pressing the shell down to drive the plug into the ground, the resistance of the plug to driving causing the lower end of the shell to be outwardly spread and to telescope over the tapered plug into tight frictional engagement, said telescoping action and spreading being permitted for a predetermined distance along said shell, and then simultaneously applying driving pressure directly to both the shell and to the plug, but primarily to the plug.

6. A prestressed plug for a pile comprising a precast body of concrete having an upwardly tapered shank with a substantially flat driving face at the top and having a downwardly convex working face for penetrating the soil, and a thin walled steel tube forced down over the said tapered shank to expand the tube and to put the shank under prestress of radial compression to reenforce the plug against driving impact applied to the said driving face, the taper of the plug being less than the critical angle whereby the parts are held together by friction between them.

7. A thin walled hollow pile having a prestressed driving plug, comprising a precast body of concrete having an upwardly tapered shank of substantially frusto-conical form with a substantially flat driving face at the top and having at the bottom a downwardly projecting convex driving face for penetrating the soil, and a thin walled steel tube of a length suitable to form a pile, having its lower end forced down

over said tapered shank to stretch the circumference of the tube wall and to put the shank under prestress of compression to reenforce the driving plug against impact applied to the driving face at the top of the plug inside the tube, the taper of the plug being small enough to cause the stressed parts to remain in permanent frictional engagement.

8. The pile of claim 7 wherein the tube is of insufficient wall thickness to withstand by itself the necessary force of driving the pile to seat.

9. A hollow thin walled pile having an enlarged lower end, comprising the combination of a thin walled steel tube and a tapered precast concrete plug forced into and held by friction in the lower end of the same to expand the said lower end and produce an enlargement of the diameter thereof, said plug being prestressed in radial compression by the grip of the tube to strengthen it against driving impact applied to it inside the tube.

10. A hollow pile comprising a thin walled steel tube, a tapered precast concrete plug forced into

and producing expansion of the lower end of the tube and prestressing of the plug in compression, whereby it is strengthened against the force of driving impact applied directly to the plug inside the tube, the taper of the plug being below the critical angle of friction between the plug and the tube wall, and the length of the portion of the plug engaged by the tube being greater than the maximum diameter of the plug.

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