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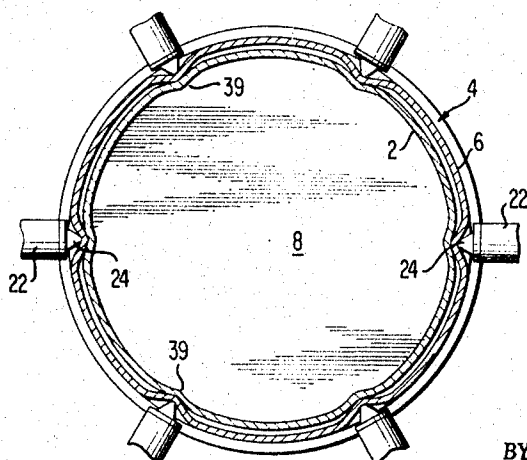
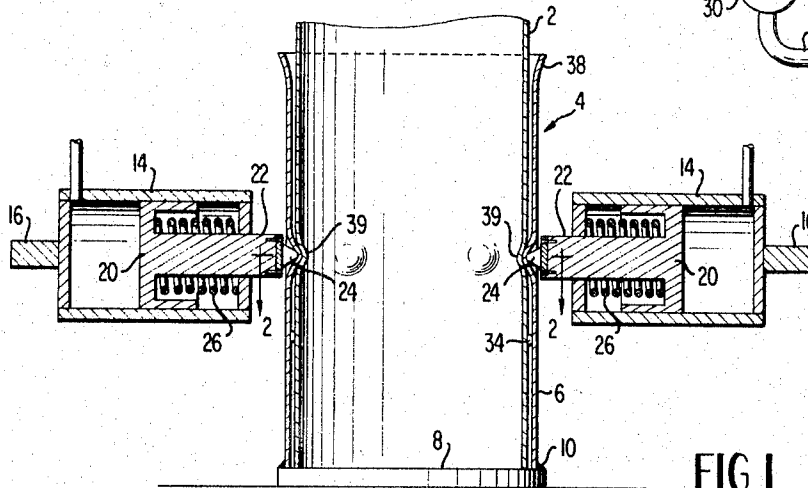
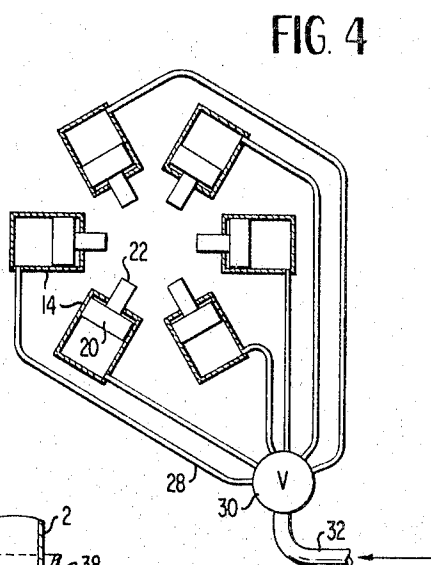
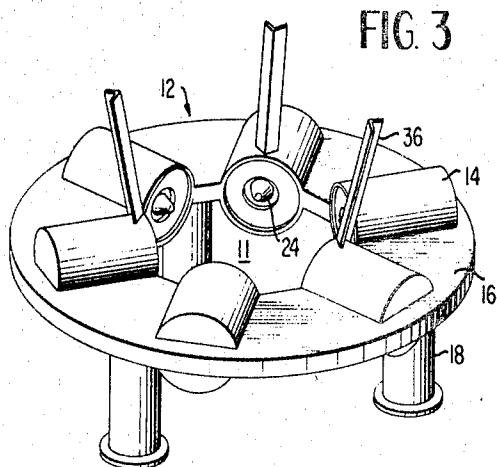
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3,453,831

METHOD OF FORMING AND DRIVING THIN WALL PIPE PILE AND BOOT

Filed Jan. 25, 1968

Sheet 1 of 2



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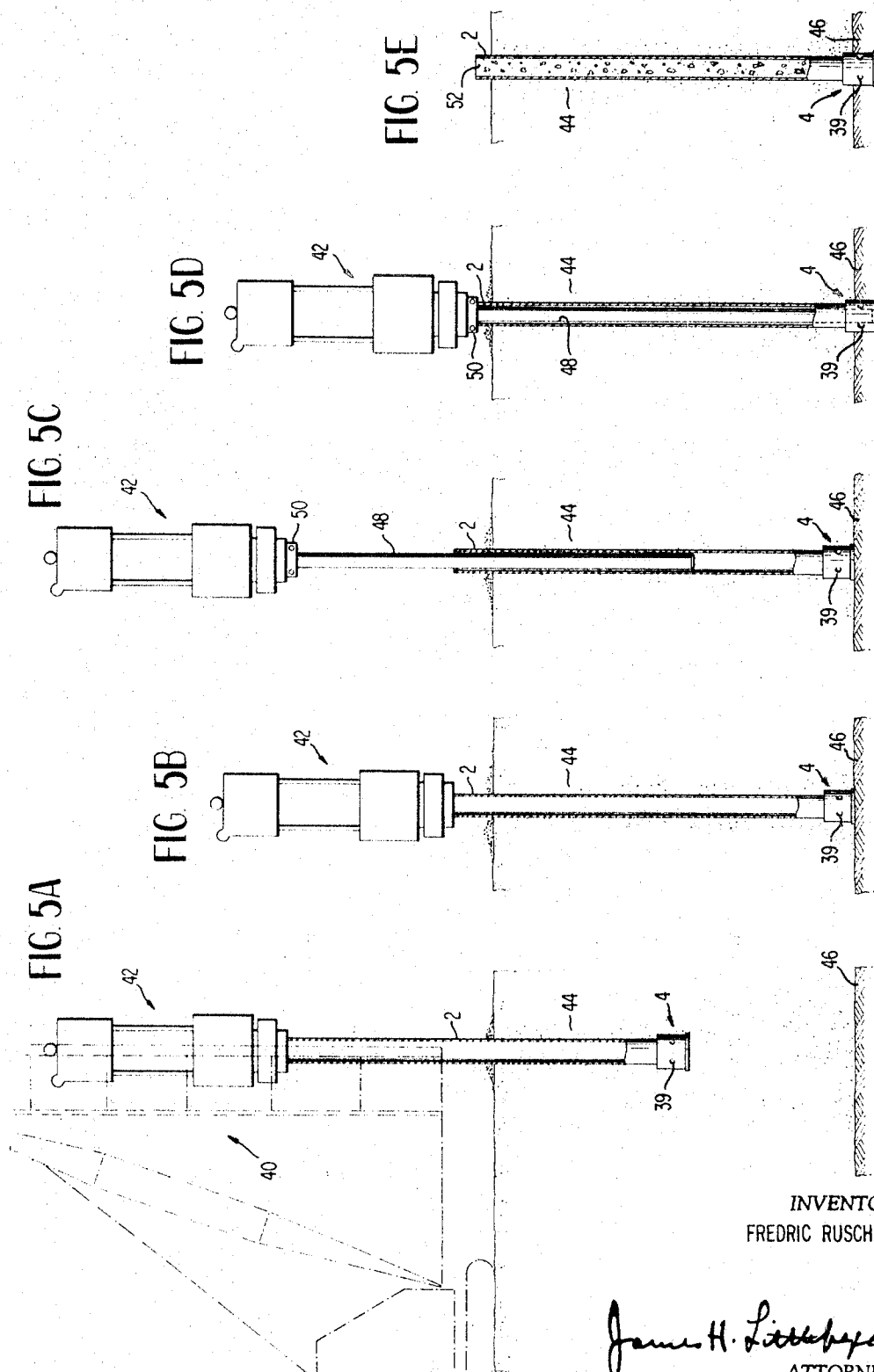
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Sheet 2 of 2



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METHOD OF FORMING AND DRIVING THIN WALL PIPE PILE AND BOOT

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6 Claims

ABSTRACT OF THE DISCLOSURE

A driving boot is fitted over the lower end of a thin wall pipe pile and mechanically joined thereto by dimpling the walls of the boot and pipe pile inwardly at angularly spaced points so as to retain the over-all cylindricity of the pile. Thereafter, the pile, with the boot thereon, is driven into the ground until a hard pan or rock bearing strata is reached. Thereafter, if not before, a mandrel is inserted and the pile is driven either entirely by hammer blows applied to the mandrel only, or by hammer blows applied to the mandrel and to the top of the pile. If desired, a close-fitting mandrel is inserted into the pile so as to flatten the dimples outwardly and thus return the lower end of the pile to columnar shape.

Prior art

Mackay 914,437, Heck 1,703,037, Booth et al. 2,650,119, Caudill 2,979,912, Reverman 3,068,563, Mount 3,326,006, and Taylor 3,333,319.

Objects

Heretofore, thin wall pipe has been used successfully only for low and medium capacity piles because they could not be seated firmly enough in a hard pan or rock layer to serve as high capacity piles. When attempts were made to drive such a pile without a boot plate, not only was the lower end of the pile destroyed by the highly resistant strata, but also the elastic shortening of the pile under the action of a suitable size hammer kept the full force of the hammer blows from reaching the tip of the pile.

Boot plates were tried, usually without success, for thin wall piles with high capacity loading. Ordinarily, when the boot plate reaches a resistant strata, such as hard pan or rock, no special connection is needed to keep it on the pile tip, because the pile may move only an inch or less per hammer blow. However, when sinking the pile through soft earth or into a pre-drilled hole, before its tip reaches a highly resistant strata, it is necessary to fasten the boot plate to the pile because of what may be termed a "pool ball" effect. An unfastened boot plate, when the top of the pile is hit with a hammer, acts like the last one of a row of pool balls when the first one is hit, and the boot plate advances off the end of the pile. Hence, the obvious answer was to weld on the boot plate.

Even with a welded-on boot plate, the pile cannot be driven through hard pan or seated in bed rock by driving only on the top of the pile, because if the springy reaction of the pipe absorbs so much of the energy of the hammer blow, and if a large enough hammer is used to overcome this, then the pile begins to form a series of accordion pleats and collapses. Hence, it was attempted to drive the pile by inserting a mandrel which engages the boot plate, and which may have a driving collar which engages the top of the pile. However, with this arrangement, when the boot plate reached a highly resistant strata, either the weld broke and/or the bottom end of the pile ruptured, the boot plate was driven off the bottom of the pile, and these were unacceptable results.

The reasons for this are as follows: Assuming, first, that the pile is driven by a mandrel which engages the boot plate and which also has a driving collar which engages the top of the pile, then the mandrel, being of much greater cross-section than the pile (it may be solid) does not undergo appreciable elastic shortening when hit, and the pile does. The distance through the pile between the top of the pile and the driven face of the boot plate becomes less than distance through the mandrel between the collar and the driven face of the boot plate. If the boot plate is connected to the mandrel by rigid joint, such as a weld, the tremendous stresses imposed across the weld breaks it or, if the weld does not break, the material of the pile adjacent the weld ruptures. If the pile is driven by a mandrel on the boot plate alone, then the boot plate must pull the pile down, and the inertia of the pile, plus the resistance of the earth around it, also set up intolerable stresses across the weld or in the vicinity of the weld. In either case, the bottom of the pile ruptures and/or the boot plate is driven off.

The exact mechanics of the failure are too complex for rigid analysis. The tremendous accelerations involved, the instantaneous stress reversals, and the instantaneous dynamic shearing resistances involved in a rigid connection between a driving boot and a pipe pile exceed the allowable working stresses of the weld and/or the pipe, and failure takes place during the repetitive loading cycles.

The object now is to provide a joint which will both absorb some of the tremendous energy normally imparted to a boot by a pipe or shell pile when the latter is hit by a hammer, and which, particularly, also will "give" sufficiently to make up for the lesser length of the pile when the latter momentarily shortens more than does the pile. Starting with a driving boot, which may more properly be called an "overtboot" because it has a cylindrical wall telescoped over a substantial length of the cylindrical lower end of a thin wall pipe or shell pile (hereinafter called a "pipe pile"), it is intended now to provide mating dimples connecting the boot and pipe pile, wherein the metal of both of the boot and the pipe pile is forced inwardly at angularly spaced points so as to provide surface interlocks between the boot and pipe pile.

With the foregoing in mind, it is a further object that the dimples be so spaced around the peripheries of the boot and pipe pile, and of sufficient number so that the over-all cylindrical shape of the pile is maintained; and where it is desired to regain whatever columnar effect is lost by the dimples, it is intended now to provide for the flattening out of the dimples, once the pile has been driven to the point where the boot meets substantial resistance by forcing a close-fitting mandrel into the lower end of the pipe pile.

These and other objects will be apparent from the following specification and drawings, in which:

FIG. 1 is a vertical cross section through the lower end of a pipe pile with a driving boot installed thereon, showing the dimpling apparatus in action;

FIG. 2 is a fragmentary horizontal cross section along the line 2—2 of FIG. 1;

FIG. 3 is a perspective view of the dimpling apparatus;

FIG. 4 is a diagrammatic plan view of the dimpling apparatus and fluid circuit therefore; and

FIGS. 5A—5E are successive diagrammatic views showing the driving, dimple-flattening and completion of a typical thin wall pipe pile embodying the subject invention.

Referring first to FIGS. 1—4, there are shown (FIGS. 1 and 2) the cylindrical lower end of a thin wall pipe pile 2, which, for purposes of present consideration, may be assumed to be formed of steel having a diameter of perhaps 12.75 inches and a wall thickness of from about

0.125 inch to 0.215 inch. Telescoped over the lower end of pipe pile 2 is the overboot 4, consisting of a cylindrical side wall some $\frac{1}{8}$ inch to $\frac{1}{4}$ inch larger in inner diameter than the outer diameter of the pile, and preferably, in this example, about 18 inches long, and of about the same wall thickness as the pile. A bottom plate 8 is secured by a weld 19 across the lower end of the cylindrical wall 6.

FIGS. 1 and 2 show overboot 4 installed on the lower end of pipe pile 2. To accomplish this, overboot 4 is first set down into the open center 11 of a dimpling tool 12, which has six inwardly convergent fluid cylinders 14 secured in an annular plate 16, which plate is supported above the floor by legs 18. Within cylinder 14 are pistons 20 which have inwardly directed plungers 22 with points on their inner free ends. Springs 26 retract pistons 20 outwardly, and the latter are simultaneously forced inwardly by pressure fluid supplied via lines 28 (FIG. 4) stemming from a common control valve 30. A pressure fluid line 32 feeds pressure fluid into control valve 30 from a suitable source of pressure fluid, not shown.

After overboot 4 has been rested in dimpling tool 12, a gasket 34 is fitted around the lower end of pipe pile 2 and the latter is lowered into overboot 4. Guides 36 may be provided for directing the lower end of the pipe pile into the overboot, and the top of the overboot may be flaired at 38 for the same purpose. Then valve 30 is opened and the pressure fluid drives pistons 20 inwardly, thus creating the mating dimples 39 as shown in FIGS. 1 and 2, which constitute interlocking surface connections.

It is important that the dimples be angularly spaced at sufficient intervals so as to leave the cylindrical shape of the side wall of the pipe pile intact, so as to preserve its columnar form. The columnar strength of the pipe pile must be enough to keep it from collapsing under heavy driving. Likewise, it is important that the dimpling operation shall not bend the metal of the pile side wall therebetween; and it has been found that the simultaneous impressing of all the dimples does this. For a nominal twelve inch pile, six dimples have been found to be adequate to provide the necessary holding power, while still meeting the above requirements. For larger diameter piles, it is anticipated that more dimples would be used.

Pipe pile 2, with overboot 4 thereof, is raised in a pile driving rig 40, and the pile is then driven into the ground by blows of the hammer 42. In the steps shown in FIGS. 5A-5E, it will be assumed that the pile is first driven down through soft earth 44 until overboot reaches a hard bearing strata 46. Alternatively, a hole may be wet-drilled through earth 44 if the latter is not suitable for easy driving.

During the easy stages of driving the "pool ball" effect tends to drive the dimpled overboot off the end of the pipe. The force tending to separate the overboot from the pipe is in the magnitude of 10,000 pounds.

The six dimpled connections between the overboot and the pipe can provide approximately 20,000 pounds of resisting force so there is a 2 to 1 safety factor against separation. This safety factor can be increased by increasing the number of dimples or by increasing the depth of the dimples or both.

According to the method illustrated in FIGS. 5A-5E, when overboot 4 reaches a hard bearing stratum 46, a close fitting mandrel 48 is inserted until its lower end reaches bottom plate 8 and mandrel collar 50 engages the top of pipe pile 2, whereupon hard driving ensues until the pipe is seated home. As mandrel 48 passes dimples 39, the latter are flattened outwardly so that the lower end of pipe pile 2 regains substantially its original columnar form. After the pile is seated home, mandrel 48 is withdrawn and the pipe pile is filled with concrete 52.

Alternatively, a not-so-close fitting mandrel may be inserted into the pipe pile before its booted lower end has reached the desired final hard bearing stratum, or in instances where the friction of the pile is to sustain it. In

this sort of driving, the lower end of the mandrel would tend to knock the boot off the pile. Here again, the "give and take" of the dimpled joint prevents the boot from being driven off the lower end of the pile.

For purposes of analysis, assume that hard driving is defined as that point where the pile point penetration rate is less than one inch per blow for a 24,000 foot pound hammer when driving a $12\frac{3}{4}$ " diameter pipe. From this point on through successfully hard driving the accelerations will vary from 100 G's to 400 G's.

However, at this stage of the driving it is not imperative that the dimpled connection be able to hold the overboot to the pipe, as by this time it is impossible for the overboot to escape any way. In other words, the farthest the overboot can advance past the bottom end of the pile is one inch, at which point its travel is arrested by the resistance of the soil. The pipe itself quickly catches up by the driving action of the mandrel on the top of the pipe. The system then comes into equilibrium and the whole process is again repeated the desired number of times.

During the entire process (assuming the rate of penetration is one inch to the blow) the overboot will always lap the pipe by at least 17 inches assuming that an 18 inch overboot is being used as illustrated.

In order to better understand some of the forces involved during the rapid decelerations which take place in pile driving, the following simple example is given.

Suppose the hammer in a particular case is a single acting hammer having an 8,000 pound ram with a free fall of three feet. Neglecting friction, this gives a kinetic hammer energy per blow of 24,000 foot pounds.

Now, if there be assumed an incompressible pile (approximated by a heavy mandrel) and the weight of the mandrel is neglected for purposes of simplicity only, the following facts can be assumed with good accuracy within the parameters established:

(1) If the driving resistance is at the rate of one foot of penetration per blow of the hammer then the resisting force at the foot or boot of the pile is 24,000 foot pounds divided by one-tenth inch equals 2,880,000 pounds.

(2) If the driving resistance is one inch of penetration per hammer below the resisting force at the boot of the pile is 24,000 foot pounds divided by one twelfth foot equals 288,000 pounds.

(3) If the driving resistance is one inch of penetration per ten blows of the hammer then the resisting force at the foot of the pile would be 24,000 foot pounds times 12 divided by one tenth inch equals 2,880,000 pounds.

In case 3 of course the developed force would be less than this because in this range of penetration the elastic shortening of the mandrel and the pile become significant decelerative distances in themselves which reduce the force at the tip of the pile. Nevertheless it is apparent that the forces involved here are of considerable magnitude and that decelerative distances however small between the overboot and the pile itself are very important.

The above examples explain why a rigid connection between a boot plate and a pipe pile results in failure.

Overboot 4 can be lengthened out considerably to compensate for particular soil collapse pressure problems, and it can be thickened considerably to compensate for especially hard driving through hard pan layers. In any event, the joint between it and the pipe pile should be non-rigid while still providing a strong interlock between the members, and the metal deformation which provides the interlock should not weaken or destroy the columnar strength of the pipe pile.

Further advantage of the overboot is that it affords outside protection to the tip of the thin wall pipe, and during driving the direction of the opening at the top of the overboot is such that the soil material does not tend to drive into the opening and tear the metal, whereas with other boots and driving points the tendency is for them to be driven up into the pile and rupture it.

The invention is not limited to the specific structure and steps detailed and illustrated, but is intended to cover all substitutions, modifications and equivalents within the scope of the following claims.

I claim:

1. The method which comprises
first joining to the lower end of the pipe pile an over-
boot having a cylindrical side wall telescoped over
the lower end of the pipe pile by means of interlock-
ing surface distortion means which extend inwardly
of both the side walls of the overboot and pipe pile,
driving the pipe pile with the overboot thereon into the
ground until the overboot reaches a stratum of suffi-
cient resistance to retain it on the pipe pile,
and thereafter forcing outwardly the surface distortion
means in the pipe pile by means of a close-fitting
mandrel inserted downwardly into the pipe pile. 15
2. The method which comprises
telescoping over the lower end of a thin cylindrical wall
pipe pile an overboot having a cylindrical side wall, 20
impressing into the wide walls of the overboot and pipe
pile yieldable interlocking surface distortion means
which extend inwardly of both the side walls of the
overboot and the pipe pile,
driving the pipe pile with the overboot thereon into the 25
ground at least partially by the force of hammer
blows applied to the top of the pile until a bearing
stratum is reached,
and thereafter seating the pile home in the bearing
stratum partially by the force of hammer blows ap- 30
plied to the overboot by means of a mandrel inserted
into the pile until it engages the overboot and par-
tially by the force of hammer blows applied to the
wall of the pile.
3. The method recited in claim 2, wherein the inserted 35
mandrel fits closely against the inside of the pipe pile, in-
cluding the step of forcing outwardly the surface distor-
tion means in the pipe pile until the latter regains a sub-

stantially cylindrical shape as the latter approaches the overboot.

4. The method recited in claim 2, wherein said inter-
locking surface means are dimples disposed at angularly
spaced intervals around the side walls of the overboot and
pipe pile. 5
5. The method recited in claim 2, wherein the overboot
has a bottom plate joined to the lower end of the cylin-
drical side wall, and wherein the overboot is telescoped
over the lower end of the pipe pile until the lower end of
the pipe pile engages the bottom plate of the overboot.
6. The method which comprises
telescoping over the lower end of a thin cylindrical
wall pipe pile an overboot having a cylindrical side
wall and a bottom plate until the bottom plate sub-
stantially engages the lower end of the pipe pile,
simultaneously impressing into the side walls of the
overboot and pipe pile, from the outside in, a plural-
ity of interlocking dimples at angularly spaced inter-
vals,
driving the pipe pile with the overboot thereon into the
ground at least partially by the force of hammer
blows applied to the wall of the pile until a bearing
stratum is reached,
and thereafter seating the pile home in the bearing
stratum at least partially by the force of hammer
blows applied to the bottom plate by a mandrel ac-
commodated within the pipe pile.

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JACOB SHAPIRO, *Primary Examiner.*

U.S. Cl. X.R.

29—516; 61—53.7, 53.72