

May 2, 1967

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3,316,722

PILE DRIVING MANDREL CONSTRUCTION AND METHOD

Filed Sept. 22, 1964

3 Sheets-Sheet 1

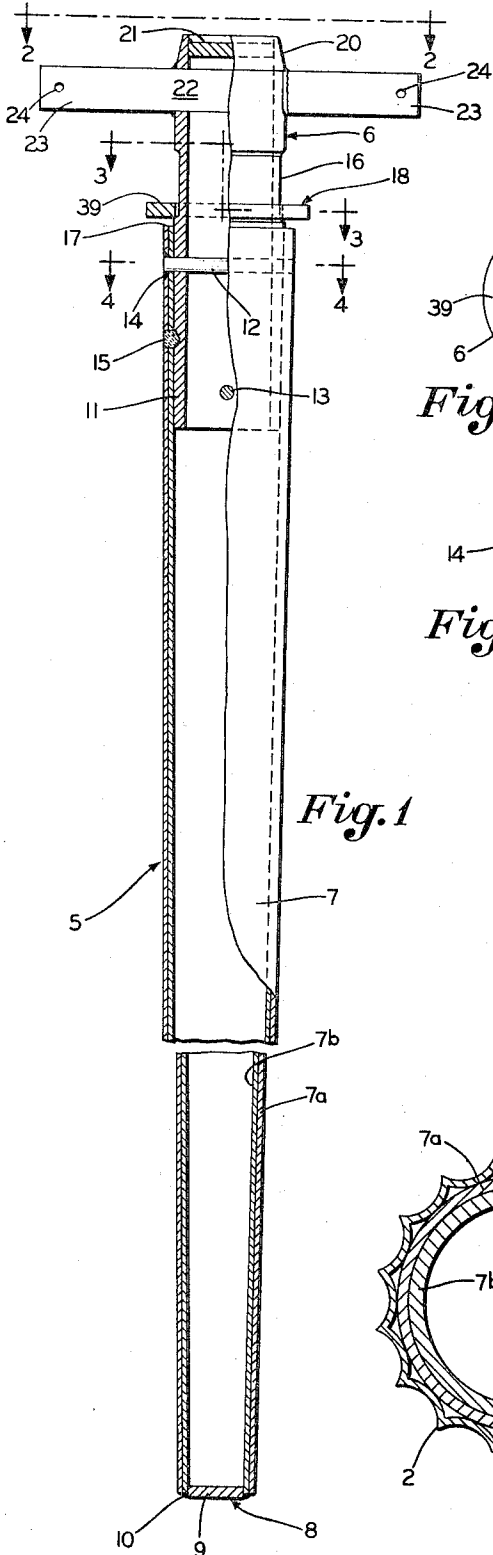


Fig. 1

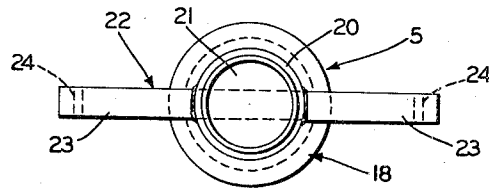


Fig. 2

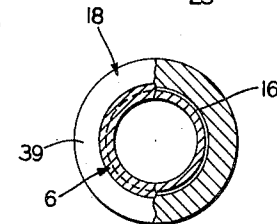


Fig. 3

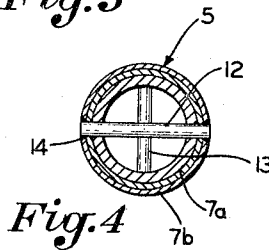


Fig. 4

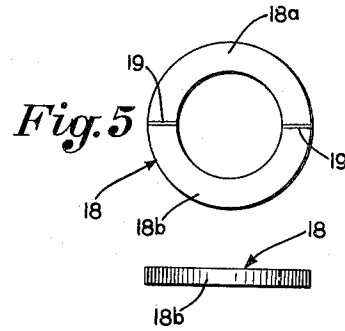


Fig. 5



Fig. 6

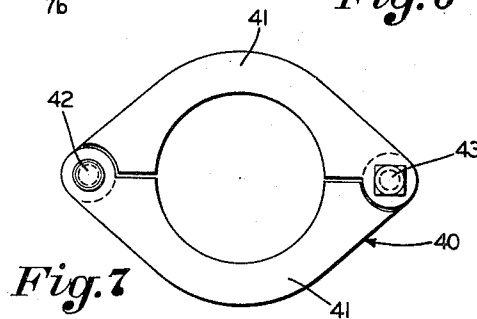


Fig. 7

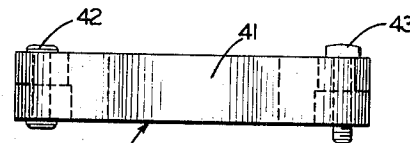


Fig. 8

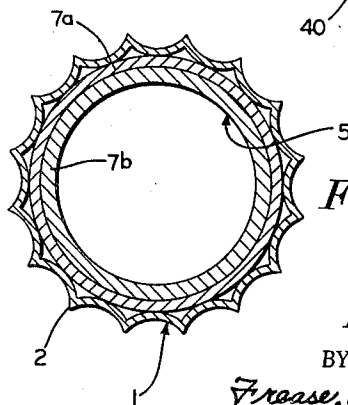


Fig. 14

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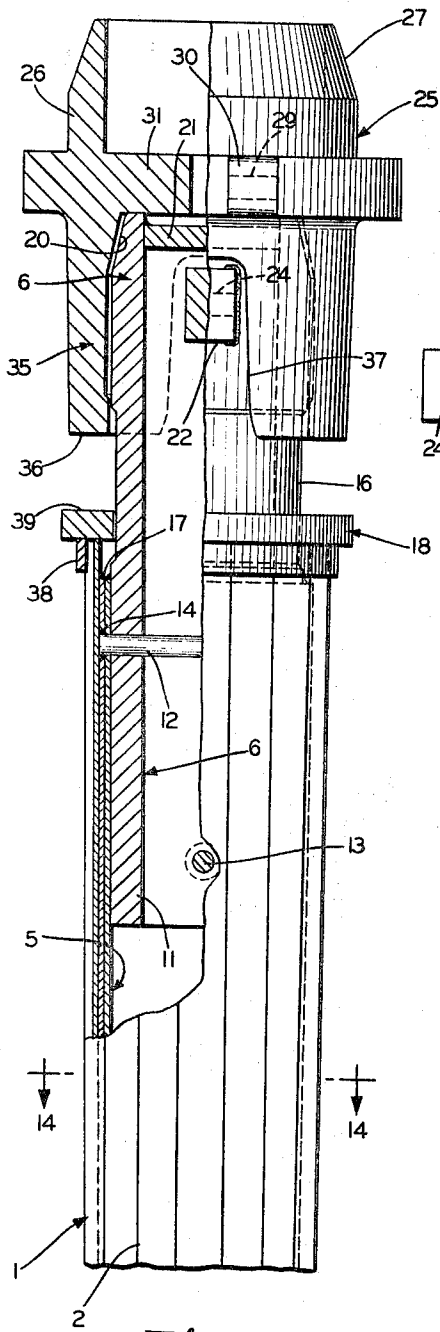


Fig. 9

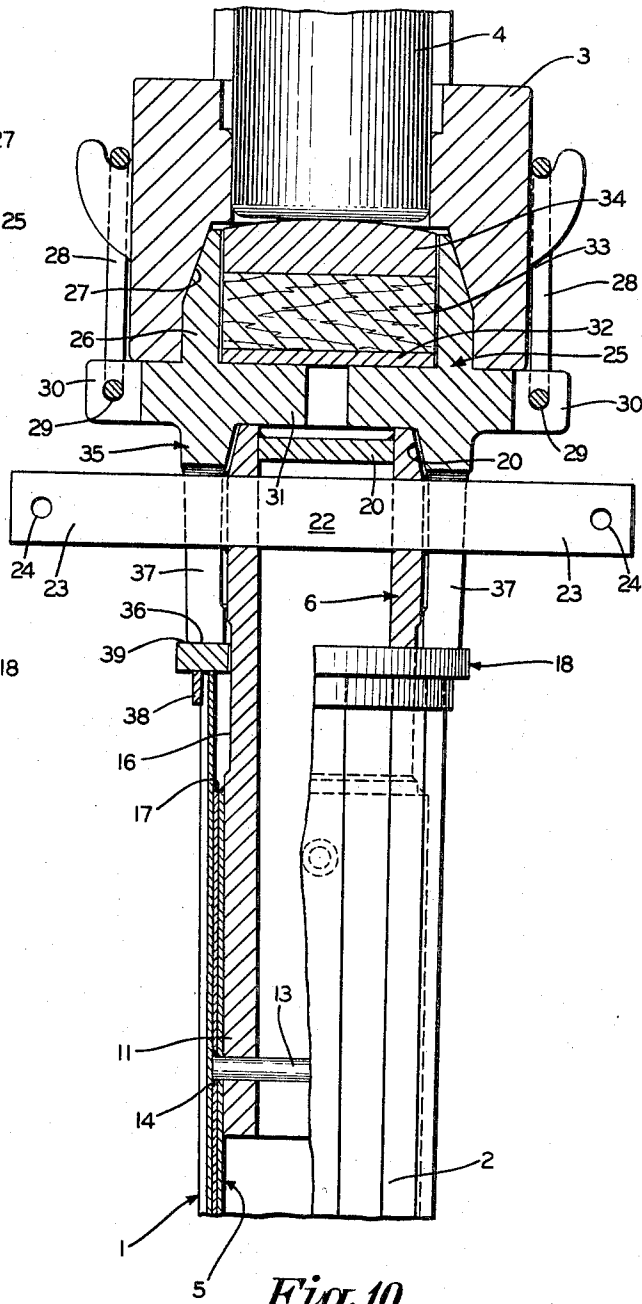


Fig. 10

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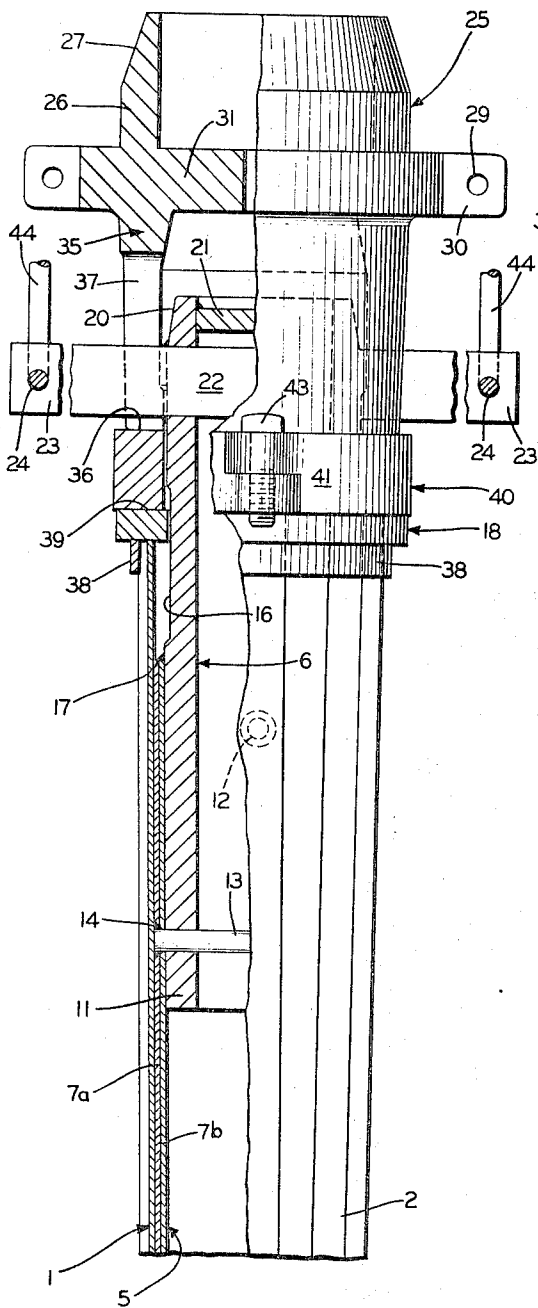


Fig. 11

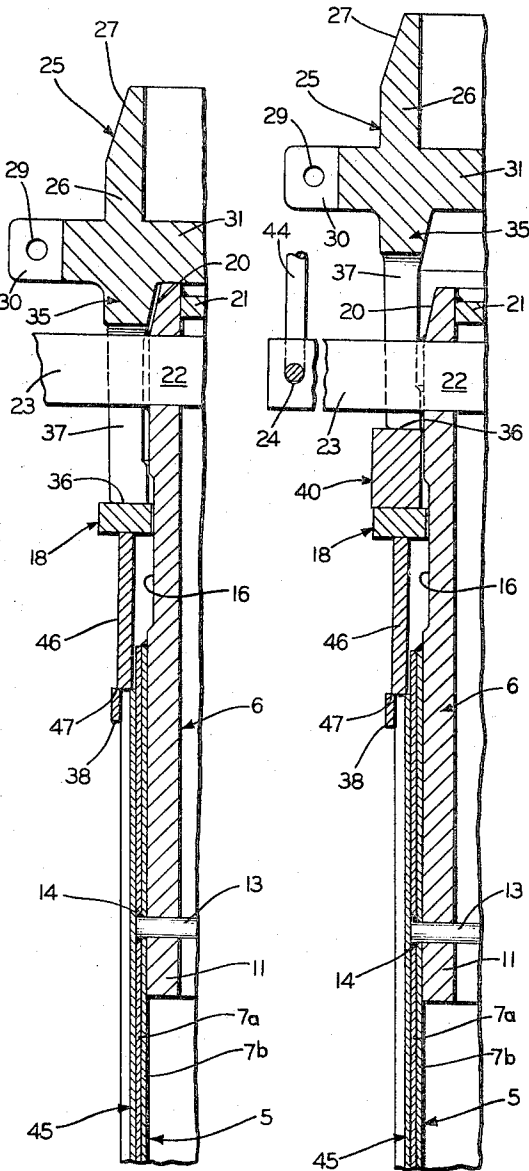


Fig. 12

Fig. 13

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PILE DRIVING MANDREL CONSTRUCTION AND METHOD

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Filed Sept. 22, 1964, Ser. No. 398,291
11 Claims. (Cl. 61—53.7)

The invention relates to piles and more particularly to the driving and forming of piles in which a preferably tapered, tubular metal shell is driven into the ground with a tapered, substantially rigid, driving mandrel or core, after which the mandrel is extracted from the shell and the latter is filled with suitable bearing material, preferably concrete, to form the pile; and the present invention constitutes improvements on the inventions set forth in Orr and Riemenschneider Patent No. 2,036,355.

The driving of tapered tubular metal pile shells into the ground with tapered mandrels heretofore has involved many problems. Sometimes a collapsible mandrel construction has been used to permit extraction of the mandrel from the shell. Collapsible mandrels have a high initial cost, involve many parts which may wear or be injured, and are frequently out of service for repairs. Thus, collapsible mandrels are extremely expensive to install, maintain and operate; and high mandrel costs are multiplied where it is necessary to provide a series of mandrels for driving pile shells of different diameters, tapers and lengths.

Some difficulties encountered with collapsible mandrels have been avoided by using a substantially rigid tapered mandrel to drive a tapered fluted shell but difficulties have been encountered in extracting the mandrel from the shell after driving the shell. Such a rigid mandrel in use transmits the driving forces from mandrel to shell through frictional contact between the mandrel and the shell flutes throughout their entire length and also through engagement of the lower end of the mandrel with the shell nose, which in effect tends to pull the shell into the ground through its nose.

However, such arrangement for transmitting driving forces from mandrel to shell can result in tearing or splitting of the shell or in tearing out the shell nose particularly where very thin sheet metal shell walls are used or where the tapered mandrel telescopically penetrates the tapered shell to a greater degree than intended. In prior arrangements, except for bottom end engagement of the mandrel with the shell nose, there have been no provisions for avoiding the tendency at least for continued penetration of the shell by the mandrel with each driving blow.

These difficulties among others have prevented desired economies from being obtained in the erection of piling. That is to say, either high collapsible mandrel costs, or high shell costs have been involved. In the latter instance, thicker metal shell walls then are otherwise necessary to act as concrete forms once the shell has been driven and the driving mandrel extracted, have been required in order to resist shell splitting or tearing or nose tear-out.

One of the fundamental objects of the invention is to control the relative amount of penetration of a rigid tapered mandrel into a relatively thin walled tapered tubular sheet metal pile shell during the mandrel driving of the shell into the ground for assuring (1) that the shell

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will not burst or split, (2) that the mandrel will not punch out the nose at the bottom end of the shell, and (3) that the mandrel may be extracted easily from the shell when the shell has been driven.

A further object of the invention is simultaneously to engage a pile driving hammer driving head with both the top of a rigid tapered driving mandrel and the top of a thin walled tapered tubular driven sheet metal pile shell within which the mandrel is telescoped, as soon as a predetermined penetration of the shell by the mandrel has occurred; so that the hammer blow driving forces are divided and simultaneously transmitted from the driving head to the shell not only directly at the top end of the shell, but also through frictional engagement between engaged telescoped tapered surfaces of the mandrel and shell, thereby to avoid shell bursting, splitting or nose puncturing, to enable ready extraction of the mandrel from the shell, and to enable very thin gauge sheet metal shells to be driven.

Also, it is an object of the present invention to provide mandrel components and cooperative mandrel and shell engaging and driving means which enable the amount of penetration of the shell by the mandrel to be controlled, and divide the transmission of driving forces from driving means to shell, between telescoped mandrel to shell frictional driving engagement and direct shell top driving; the cooperative relationship of the shell, mandrel and components of the mandrel and shell engaging and driving means permitting ready extraction of the mandrel from the shell after the latter has been driven.

Finally, it is an object of the present invention to provide a new pile driving mandrel construction for driving tapered thin walled tubular pile shells, eliminating difficulties heretofore encountered in the art; eliminating complicated and costly collapsible mandrel structures and maintenance and repair problems heretofore involved; achieving the indicated objects in a combined, simple effective and inexpensive manner; and solving problems and satisfying needs existing in the art.

These and other objects and advantages, apparent to those skilled in the art from the following description and claims, may be obtained, the stated results achieved, and the described difficulties overcome, by the apparatus, combinations, parts, elements, subcombinations, arrangements, relationships, constructions and methods which comprise the present invention, the nature of which are set forth in the following general statements, a preferred embodiment of which—illustrative of the best mode in which applicants have contemplated applying the principles—is set forth in the following description and shown in the drawings, and which are particularly and distinctly pointed out and set forth in the appended claims forming part hereof.

The nature of the improved pile driving mandrel construction of the present invention may be stated in general terms as including a substantially rigid longitudinally continuous mandrel having a head portion at its upper end and being tapered downwardly inwardly from said head portion to its lower end adapted to be telescopically inserted within and in frictional surface engagement throughout the entire length of the tapered portion of the mandrel member with inner surface portions of a tapered preferably longitudinally ribbed, corrugated, or fluted sheet metal shell to be driven; a floating driving ring surrounding and mounted on the mandrel head portion for movement axially of said head portion, means

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limiting axial movement of said floating ring on said head portion; extractor bar means projecting laterally of and mounted on the mandrel head portion above said floating ring; mandrel and shell engaging and driving cap means including upper preferably cushioned anvil means adapted to receive the blows of a pile driving hammer, means for lashing the cap means to the hammer, and a downwardly opening cup-shaped sleeve on the cap means having annular lower end surface means adapted to be telescoped over and engaged with the mandrel head portion, said sleeve being formed with cutout means straddling the laterally projecting extractor bar means when the sleeve is telescoped over and the cap means is engaged with the mandrel head portion, the annular sleeve surface means engaging the floating driving ring when the latter is adjacent its upper limit of movement on the mandrel head portion and when the cap means is in driving engagement with the mandrel head portion; and removable extractor convertor ring means adapted to be inserted between the annular sleeve surface means and the floating ring with the sleeve partially telescoped over and the cap means spaced from engagement with the mandrel head portion for imparting driving force to the upper end of a shell while pulling on the extractor bar means to upwardly extract the mandrel from such shell after the shell has been driven.

The nature of the improved method of driving a thin walled tapered tubular sheet metal pile shell into the ground may be stated in general terms as including the steps of telescoping a downwardly inwardly tapered portion of a substantially rigid longitudinally continuous mandrel having a head at one end and a nose at the other end into a tapered preferably longitudinally ribbed, corrugated, or fluted sheet metal pile shell also having a head at one end and a nose at the other end; driving the mandrel relatively into the shell to penetrate the shell and frictionally wedge engage the mandrel with and slightly radially expand the shell substantially throughout its length and to establish frictional driving contact between the mandrel and shell ribs throughout the telescoped portions of the mandrel and shell; controlling the penetration of the mandrel in the shell to a predetermined amount to prevent shell bursting and shell-mandrel nose engagement; then after the mandrel has penetrated the shell said predetermined amount simultaneously driving the mandrel and shell heads until the shell is in place in the ground; then freeing the mandrel head of driving engagement while maintaining driving engagement with the shell head; and then driving against the shell head while pulling on the mandrel to extract the mandrel from the driven shell.

By way of example, an embodiment of the improved mandrel construction and pile shell driving procedure is shown in the accompanying drawings forming part hereof in which:

FIGURE 1 is a side view of the improved mandrel construction with parts broken away and in section;

FIG. 2 is a top view of the mandrel looking in the direction of the arrows 2—2, FIG. 1;

FIG. 3 is a sectional view taken on the line 3—3, FIG. 1;

FIG. 4 is a sectional view taken on the line 4—4, FIG. 1;

FIG. 5 is a plan view of the floating driving ring component of the mandrel shown in FIG. 1;

FIG. 6 is a side view of the floating ring of FIG. 5;

FIG. 7 is a plan view of an extractor convertor ring;

FIG. 8 is a side elevation of the extractor convertor ring shown in FIG. 7;

FIG. 9 is an enlarged fragmentary view with parts broken away and in section of an upper end of a pile shell to be driven with the improved mandrel telescopically entered in the shell at the beginning of a driving operation;

FIG. 10 is a side view of the parts in FIG. 9 with parts broken away and in section illustrating the mandrel and shell during driving after a predetermined penetration of

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the shell has occurred with the mandrel and shell heads simultaneously engaged by the driving head to transmit driving forces directly to the top end of the shell and also to the shell through frictional engagement between telescoped surfaces of the mandrel and shell;

FIG. 11 is a view similar to FIG. 10 but showing the extractor convertor ring in place after the shell has been driven at the beginning of an operation for extracting the mandrel from the shell;

FIG. 12 is a fragmentary view similar to FIG. 10 showing how the improved construction can be adapted for driving an undersize pile shell;

FIG. 13 is a view similar to FIG. 11 illustrating the manner in which the mandrel may be extracted when an undersize pile shell has been driven as illustrated in FIG. 12; and

FIG. 14 is a sectional view through a mandrel and pile shell taken on the line 14—14, FIG. 9.

Similar numerals refer to similar parts throughout the various figures of the drawings.

A tapered tubular pile shell generally is indicated at 1 and preferably is formed of light gauge sheet or strip metal such as 11-gauge strip steel. When the pile shell is driven into the ground, it may be filled with concrete to form a pile such as shown in said Patent No. 2,036,355. The shell 1 preferably is provided with a closed lower end or nose, not shown. Shell 1 preferably also is provided with longitudinally continuous outturned flutes 2 which not only reinforce or stiffen shell 1 but serve other purposes to be described. Shell 1 may have any desired length and because of its taper, it readily penetrates the ground and may, therefore, readily be driven to desired depth. For example, shell 1 may be 30 feet in length and may have a 12-inch top and an 8-inch bottom diameter, although these dimensions are given only for example.

Pile shell 1 may be driven by usual pile driving equipment, not shown, which may include a hammer and head guide 3 supported in the usual manner on the driving equipment and a reciprocable hammer plunger 4.

The improved mandrel construction preferably includes a substantially rigid, longitudinally continuous, mandrel member generally indicated at 5 in FIG. 1, having a head portion generally indicated at 6 at its upper end, and being tapered downwardly inwardly at 7 from the head portion 6 to the lower end or nose 8 of the mandrel which may be closed by a nose cap 9.

Tapered portion 7 of the mandrel 5 may be formed in any desired manner but preferably may comprise a plurality of plies such as plies 7a and 7b, of tapered tubular sheet metal members telescoped within one another to which the bottom nose cap 9 may be welded at 10, as shown.

The upper ends of the tapered tubular sheet metal mandrel ply members 7a and 7b telescopically receive the lower end portion 11 of the mandrel head portion 6 with a tight wedge fit. Spaced lateral pins 12 and 13 welded to the tapered tubular members 7a and 7b at 14 preferably tie tapered portion 7 of the mandrel to the lower end 11 of mandrel head portion 6. Members 6 and 7 may be secured together further by a series of plug welds, one such plug weld being illustrated at 15 in FIG. 1.

Mandrel head portion 6 is formed with an annular recess 16 above the upper end 17 of the tapered tubular portion 7 of the mandrel. A floating drive ring generally indicated at 18 is mounted on head portion 6 around said recess 16 and is movable axially of the head portion 6 up and down recess 16. Recess 16 limits axial movement of ring 18, floating ring 18 being illustrated in FIG. 1 at its bottom limit of movement. Referring to FIGS. 5 and 6, floating ring 18 preferably is formed from two semi-circular pieces 18a and 18b, which are placed in encircling relation around recess 16 of mandrel head portion 6 and then are welded together as indicated at 19 in FIG. 5 to maintain ring 18 assembled to and mounted on mandrel head portion 6 in floating relation thereto.

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The upper end of mandrel head portion 6 preferably is tapered slightly upwardly inwardly at 20 and may be closed by a welded-in head cap 21.

The upper end of mandrel head portion 6 preferably is provided with an extractor bar 22 extending through member 6 and having laterally projecting ends 23 preferably formed with openings 24. Extractor bar 22 is located below head cap 21 and above recess 16 and the floating drive ring 18 surrounding recess 16.

A mandrel and shell engaging and driving cap generally indicated at 25 forms one of the components of the improved mandrel construction. Cap 25 preferably includes an upwardly extending cup-shaped sleeve 26 tapered at its upper end as indicated at 27. Cap 25 may be lashed to hammer guide 3 as shown in FIG. 10 by cables 28 which extend through openings 29 formed in ears 30 projecting from cap 25 in the region of the cap member partition wall 31. A knockout plate 32, a cushion member 33, and an anvil 34 preferably are contained in a usual manner within the recess formed by cap sleeve 26 as shown in FIG. 10 so that the blows of a hammer 4 are imparted to cap 25 through members 34, 33, and 32.

The driving cap 25 also is formed with a downwardly opening cup-shaped sleeve 35 having an annular lower end surface 36. Sleeve 35 is adapted to be telescoped over and engaged with the mandrel head portion 6, the cavity formed by sleeve 35 preferably conforming in contour to the contour of the upper end of mandrel head portion 6 as illustrated in FIGS. 9 and 10.

Sleeve 35 is formed with downwardly opening cutouts 37 which straddle the laterally projecting extractor bar ends 23 when sleeve 35 is telescoped over mandrel head portion 6 with the cap partition wall 31 engaged on the top end of mandrel head portion 6 as shown in FIGS. 9 and 10.

Cap member 25 when telescoped over and in driving engagement with head portion 6 of mandrel 5 as shown in FIG. 9, has the end surface 36 of sleeve 35 spaced above floating ring 18 when the latter is at or adjacent its lower limit of floating movement along recess 16 is generally indicated in FIGS. 1 and 9.

Several operational steps in the use of the improved mandrel construction are illustrated in FIGS. 9, 10 and 11. When a shell 1 is to be driven, a mandrel 5 is telescoped into the top open end of the shell 1 (FIG. 9), driving cap 25 is lashed to the hammer guide 3 (FIG. 10), driving head sleeve 35 is telescoped over the upper end of head portion 6 (FIGS. 9 and 10) of the mandrel in shell 1, the entire assembly is suspended above the desired driving location, and shell 1 is ready to be driven. The parts, elements, and components at this time have the relative positions shown in FIG. 9 wherein the floating driving ring 18 rests on the top end of shell 1 which may be reinforced at its upper open end or head with a reinforcing collar 38.

Driving blows from hammer 4 through cap 25 drive mandrel head portion 6 engaged by cap 25 downward into and relative to shell 1 so that tapered portion 7 of mandrel 5 penetrates shell 1. Penetrating movement of mandrel 5 establishes frictional wedge engagement between the tapered outer surface of mandrel outer ply 7a and the ribs formed by shell flutes 2 throughout the telescoped portions of the tapered mandrel 5 and shell 1. This frictional wedge engagement between mandrel 5 and shell 1 slightly radially expands 1 throughout its entire length.

In accordance with the invention, the amount of axial wedge penetration of shell 1 by mandrel 5 and the amount of radial expansion of shell 1 is controlled such as to prevent shell bursting. Furthermore, the tapered portion 7 of mandrel 5 is shorter in length than shell 1 so that at no time does nose 8 of mandrel 5 engage a similar nose of the shell. The controlled mandrel-shell penetration is predetermined to an amount preferably not greater than the axial dimension of mandrel head re-

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cess 16, or in other words not greater than the distance that floating driving ring 18 can move on mandrel head portion 6.

As indicated in FIG. 9, the mandrel 5 normally is telescoped to the position shown relative to the upper end 38 of shell 1 before driving blows are applied or wedging occurs. The showing of FIG. 9, however, is typical since variations in tapered rib formations, wear, etc., can slightly alter the relative positions shown. From this position the predetermined amount of shell penetration by the mandrel that subsequently can occur during initial driving may be measured in FIG. 9 as the axial distance between top face 39 of floating ring 18 and the lower end surface 36 of cap sleeve 35.

With the parts in the position of FIG. 9, operation of hammer 4 drives mandrel 5 downward in shell 1 to penetrate the shell the predetermined or controlled amount or distance until the relative positions of the parts shown in FIG. 10 are established, wherein cap wall 31 is in driving engagement with the head of the mandrel, and sleeve end surface 36 is in driving engagement with the floating ring 18. Direct driving engagement between cap 25 and head 38 of shell 1 thus is established, and the controlled predetermined penetration of shell 1 by mandrel 5 is achieved.

Under these conditions, shell 1 has not been subjected to sufficient bursting force to burst or split the shell, and the mandrel nose 8 has not contacted and, therefore, has not punched out the nose of the shell. However, sufficient frictional contact between telescoped engaged tapered surfaces of mandrel 5 and shell 1 has been established that the hammer blow forces are transmitted by driving cap 25 not only directly to the head of shell 1 but also are transmitted through contact of cap 25 with the mandrel, then through the mandrel, and finally through frictionally engaged surface contact between the mandrel and shell, to the shell substantially throughout the length of the shell.

Driving of shell 1 continues in this manner by operation of hammer 4 until shell 1 has reached the desired driven position in the ground. At this time, driving head 25 is raised free of driving engagement with the upper end of mandrel 5 to a position somewhat as illustrated in FIG. 11. Then an extractor convertor ring generally indicated at 40 is inserted between end surface 36 of cap sleeve 35 and top surface 39 of floating driving ring 18 to maintain cap wall 31 spaced from the top end of mandrel head portion 6.

Ring 40, as shown in FIGS. 7 and 8, preferably is composed of similar half-sections 41 hinged together at 42 and adapted to be held in ring-like relation by a bolt 43. The extractor convertor ring 40 thus is removable and insertable when desired. Conditions may arise where another extractor ring thickness may be required. Thus, any mandrel construction may include as a part of its related component equipment several rings 40 of different thicknesses.

After extractor ring 40 has been inserted as shown in FIG. 11, an upward pull may be exerted on the ends of extractor bar 22 by cables 44 suspended from a winch on the driving equipment. Cables 44 may be connected to extractor bar 22 at all times to suspend the mandrel 5 but only are subjected to lifting force during mandrel extracting or lifting operations.

Hammer 4 then is operated to drive cap 25 (FIG. 11) against extraction ring 40 while the upward pull through cables 44 is exerted on mandrel 5. In this manner the frictional engagement between the mandrel 5 and shell 1 is loosened or disengaged and mandrel 5 may be extracted or lifted from shell 1 leaving shell 1 in the ground to serve as a form in which concrete may be poured if desired to provide the final pile structure.

In the example given of a 30-foot pile shell 1, the mandrel plies 7a and 7b may be say 29 feet in length and the mandrel nose 8 may have an outside diameter

of about $6\frac{3}{4}$ inches with the upper end 17 of mandrel ply 7a having an outside diameter of say $10\frac{3}{4}$ inches.

Thus, as shown in FIGS. 9 and 10 normally the effective length of the outer tapered surface of the mandrel in contact with the shell, is shorter than the length of the shell; the top end 17 of the mandrel plies being below head 38 of shell 1 in each of FIGS. 9 and 10, and there being no nose contact between mandrel and shell in either condition.

Situations can arise wherein the pile shell 1 furnished or to be driven is undersize, that is the shell 1 may be shorter in length than normally intended to be driven by a particular mandrel 5. This condition is illustrated in FIGS. 12 and 13 wherein an undersize shell 45 may be driven by the same mandrel 5 illustrated in the other views by inserting a split sleeve filler 46 between the upper end 47 of shell 45 and the floating mandrel driving ring 18.

The split sleeve filler 46 may be a hinged sleeve similar in construction to the extractor ring 40 illustrated in FIGS. 7 and 8. Sleeve 46 in effect forms a driving extension for the end of shell 45 to extend the effective (undersize) length of shell 45 and locate in effect its upper end or head above the upper end 17 of the mandrel plies 7a and 7b at a position for simultaneous shell head and mandrel-shell frictional driving engagement, as illustrated in FIG. 12. The positions of the parts in FIG. 12 with an undersized shell 45 and an extension sleeve 46 correspond to the positions of the parts shown in FIG. 10.

After shell 45 has been driven, driving cap 25 may be lifted and an extractor ring 40 inserted to extract the mandrel from shell 45 as shown in FIG. 13, in a manner similar to that described in connection with FIG. 11.

Ideally, in the use of the improved mandrel construction a fluted pile shell will be driven with a mandrel circular in cross section as generally illustrated in FIG. 14. This particular arrangement is desirable for several reasons. First, with a fluted shell wall and a reinforcing collar 38, a wide upper edge or head is provided on the shell on which driving forces can be applied directly to the top of the shell after predetermined penetration by a mandrel. This wide upper fluted edge construction is quite stiff and when supported internally by the tapered mandrel provides maximum resistance to crushing by the force of the hammer blows.

Second, with a mandrel circular in cross section and a shell of fluted cross section as shown in FIG. 14, the frictional contact between mandrel and shell established by the predetermined mandrel penetration of the shell comprises a series of line contacts between the surface of the mandrel and the bases of the flutes. This distributes the frictional contact for transmission of driving forces from mandrel to shell at spaced intervals and throughout the length of the mandrel. At the same time a minimum of frictional surface engagement is present to be overcome during extraction, and extraction of the mandrel is easier to perform at the proper time. Obviously, a similar frictional surface contact arrangement can be obtained if it is desired to drive a round tapered shell by using a tapered fluted mandrel.

Furthermore, the attainment of the desirable advantages is not predicated on the particular form of flutes shown in FIG. 14 since other longitudinal rib, flute, or corrugation formations can be used instead.

Thus, in accordance with the invention, a floating driving ring is provided at the top of a tapered mandrel, the mandrel is entered into a tapered pile shell and driven through an engaged driving head until the driving head simultaneously engages both the top of the mandrel and the top of the shell through the floating driving ring. At this time the driving proceeds with blows at the top of the entire assembly, while preventing any tendency of the mandrel to further enter the pile shell and cause splitting or bursting or nose punchout. Finally, the controlled amount of mandrel penetration of the shell being driven always assures that the mandrel can be extracted.

Accordingly, the present invention provides an improved pile driving mandrel construction and method which is simple, practical, and low in cost; which solves problems that have existed for years in the driving of tapered tubular sheet metal pile shells; which avoids difficulties encountered in the use of collapsible mandrels for driving tapered tubular sheet metal pile shells; which avoids shell bursting; splitting and nose punchout difficulties that have been encountered in prior attempts to satisfactorily drive relatively thin gauge tapered tubular sheet metal pile shells with substantially rigid tapered mandrels; which enables lighter gauge tapered sheet metal pile shells to be driven with longitudinally rigid tapered mandrels than heretofore practical; and which eliminates other difficulties heretofore encountered in the art, achieves the stated objects, accomplishes the many new functions and results described, and generally solves problems which have existed in the art.

In the foregoing description, certain terms have been used for brevity, clearness and understanding but no unnecessary limitations are to be implied therefrom beyond the requirements of the prior art, because such terms are used for descriptive purposes and are intended to be broadly construed.

Thus, the terms "rigid" or "substantially rigid" used herein distinguish from "collapsible" or "longitudinally sectional" mandrels and are intended to describe mandrels having sufficient rigidity and strength to be driven into the ground or removed therefrom without failure under normal conditions; and the terms "ribbed," "corrugated," or "fluted" are used herein more or less synonymously to refer to tapered structures with which spaced line contacts are established when telescoped into and engaged with relation to other tapered members circular in cross section.

Moreover, the description and illustration of the invention is by way of example and the scope of the invention is not limited to the exact structures shown or the lengths, diameters and metal thicknesses described for example, because of the sizes of the various parts and components may be varied to provide other structural embodiments without departing from the fundamental principles of the invention.

For example, although normally the tapered portion 7 of mandrel 5 may have the same taper as that of the shell 1 to be driven, as shown, nevertheless the mandrel taper may be slightly greater than that of the shell so that during controlled or predetermined penetration of the shell by the mandrel frictional wedge-contact therebetween is established progressively from top to bottom. This reduces resistance to penetration, since the line contacts between telescoped surfaces of mandrel and shell are permitted to increase in length from top to bottom during the initial driving stage. Such slight differences in mandrel and shell tapers has the further advantage of avoiding the necessity and expense of providing absolute matching tapers on mandrels and shells driven by such mandrels which, if required, could substantially increase material and pile driving costs.

Having now described the features, discoveries and principles of the invention, the construction, operation and use of preferred forms thereof, the preferred steps of the improved method, and the advantageous, new and useful results obtained thereby; the new and useful discoveries, principles, apparatus, combinations, parts, elements, subcombinations, arrangements, relationships, constructions, methods and steps and mechanical equivalents obvious to those skilled in the art are set forth in the appended claims.

We claim:

1. Pile shell driving mandrel construction, including a substantially rigid longitudinally continuous mandrel member having a head portion at the upper end of the member and a downwardly inwardly tapered shell-contacting portion extending downward from said head por-

tion to the lower end of the member, the mandrel head portion having a lower end, the tapered mandrel portion comprising tapered tubular sheet metal means having an upper end telescoped over the lower end of the head portion, means securing the telescoped upper end of the tapered tubular means and the lower end of the head portion together, there being an annular recess formed in the head portion above the upper end of the tapered tubular means, floating driving ring means mounted on the head portion around said recess for movement axially of the head portion, and the recess limiting axial movement of the ring means on the head portion.

2. Pile shell driving mandrel construction, including a substantially rigid longitudinally continuous mandrel member having a head and a tapered shell-contacting portion, mandrel and shell engaging and driving cap means releasably telescoped over and engaged with the mandrel head, the tapered mandrel portion being telescoped within a tapered tubular pile shell to be driven with the cap means spaced above the upper end of such shell, and floating ring means for establishing driving engagement between the cap means and the upper end of the shell after the mandrel has been driven into the shell to penetrate the shell a predetermined distance; said ring means comprising a ring surrounding the head above the tapered shell-contacting mandrel portion, means mounting the ring on the head for axial movement relative to the head above said tapered portion and below said cap means, and the ring being engaged by the cap means and engaging the upper end of the shell when said driving engagement is established.

3. The construction defined in claim 2 in which extractor bar means is mounted on the mandrel member above the tapered mandrel portion and below the head projecting laterally of the mandrel member, and in which removable extractor convertor ring means is inserted between the cap means and the ring with the ring engaging the upper end of the shell after the mandrel and shell have been driven into the ground to space the cap means from the mandrel head, whereby the mandrel may be extracted from the shell leaving the shell in the ground by pulling on the extractor bar means and by hammering the cap means.

4. Pile shell driving mandrel construction, including a substantially rigid longitudinally continuous mandrel member having a head and a tapered shell-contacting portion, floating driving ring means mounted for axial movement on the mandrel member above the tapered portion and below said head, mandrel and shell engaging and driving cap means, downwardly opening cup-shaped sleeve means on the cap means having annular lower end surface means, said cup-shaped sleeve means being releasably telescoped over and engaged with the mandrel head, and the tapered mandrel portion being telescoped within a tapered tubular pile shell to be driven with the floating driving ring means engaged with the upper end of such shell and spaced below the sleeve means lower end surface means; whereby pile driving hammer blows on the cap means initially drive the mandrel member to penetrate the shell until said sleeve means lower end surface means engages the floating driving ring means, and whereby said blows thereafter coincidentally drive the mandrel and shell into the ground by simultaneous driving engagement of the cap means with the head of the mandrel and through said floating ring means with the upper end of the shell.

5. The construction defined in claim 4 in which the mandrel member is formed with an annular recess having a lower annular edge located above the upper end of the tapered mandrel portion and having an upper annular edge located below the mandrel head; in which the floating driving ring means is mounted for axial movement on the mandrel member around said recess and between said recess lower and upper edges; in which the lower end surface means of the cap means is located below said upper recess edge when the cap sleeve means is en-

gaged with the mandrel head; and in which the upper end of a shell being driven by the mandrel when the latter is telescoped within the shell is spaced above the lower recess edge; whereby the spacing of the floating driving ring means engaged with the upper end of the shell below the lower end surface means of the cap means provides a predetermined amount of shell penetration by the mandrel before the mandrel and shell are coincidentally driven.

6. The construction defined in claim 4 in which extractor bar means is mounted on the mandrel member above the floating driving ring means and below the mandrel head projecting laterally of the mandrel member, and in which the cap sleeve means is formed with cutout means straddling the laterally projecting extractor bar means when the cap sleeve means is telescoped over and engaged with the mandrel head.

7. The construction defined in claim 4 in which extractor bar means is mounted on the mandrel member above the floating driving ring means and below the mandrel head projecting laterally of the mandrel member, and in which removable extractor convertor ring means is inserted between the floating driving ring means and the lower end surface means of the cap means after the mandrel and shell have been driven into the ground to space the cap means from the mandrel head, whereby the mandrel may be extracted from the shell leaving the shell in the ground by pulling on the extractor bar means while hammering the cap means.

8. The method of driving a thin walled tapered tubular sheet metal pile shell into the ground, including the steps of telescoping a downwardly inwardly tapered portion of a substantially rigid longitudinally continuous mandrel having a head at one end and a nose at the other end into a tapered tubular sheet metal pile shell also having a head at one end and a nose at the other end; driving the mandrel relatively into the shell to penetrate the shell and frictionally wedge-engage the mandrel with the shell substantially throughout its length and to establish frictional driving contact between the mandrel and shell throughout the telescoped portions of the mandrel and shell; controlling the penetration of the mandrel in the shell to a predetermined amount to prevent shell bursting and shell-mandrel nose engagement; then after said predetermined penetration simultaneously driving the mandrel and shell heads until the shell is in place in the ground.

9. The method as set forth in claim 8, including the further steps after the shell is in place in the ground of freeing the mandrel head of driving engagement while maintaining driving engagement with the shell head; and then driving the shell head while pulling on the mandrel to extract the mandrel from the driven shell.

10. Pile shell driving mandrel construction, including a substantially rigid longitudinally continuous mandrel member having a head provided with upper and lower ends and a tapered shell-contacting portion connected with the lower end of the head, floating shell-contacting driving ring means surrounding the head between the upper and lower ends of the head, and means mounting the ring means on the head for axial movement relative to the head above the tapered portion and below the upper end of the head.

11. Pile shell driving mandrel construction, including a substantially rigid longitudinally continuous mandrel member having a head portion provided with upper and lower ends at the upper end of the mandrel member and a downwardly inwardly tapered shell-contacting portion connected with and extending downward from the lower end of the head portion to the lower end of the mandrel member, floating driving ring means surrounding the head portion above the tapered portion, means mounting the ring means on the head portion for axial movement relative to the head portion above the tapered portion, means limiting relative axial movement of the ring means

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on the head portion, the ring means being adapted to engage the upper end of a tapered pile shell to be driven by the mandrel when the mandrel is telescoped into such shell, and the ring means being movable upward axially of the head portion by such shell as the mandrel is driven to penetrate the shell and to establish frictional driving engagement between tapered mandrel and shell surfaces.

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