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PILE DRIVING APPARATUS AND METHOD

Filed Jan. 31, 1963

2 Sheets-Sheet 1

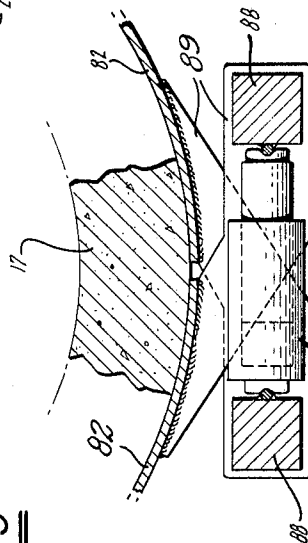
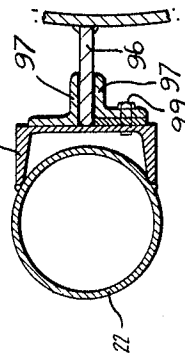
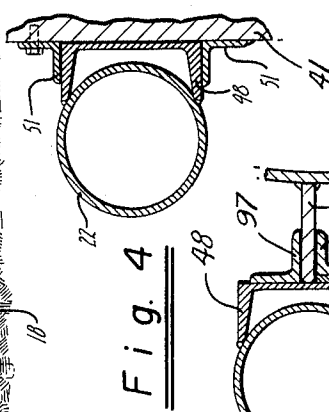
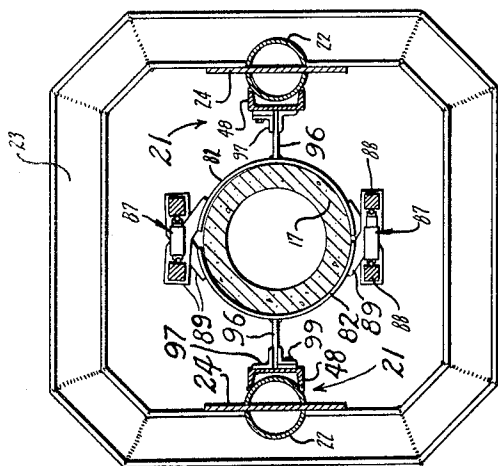
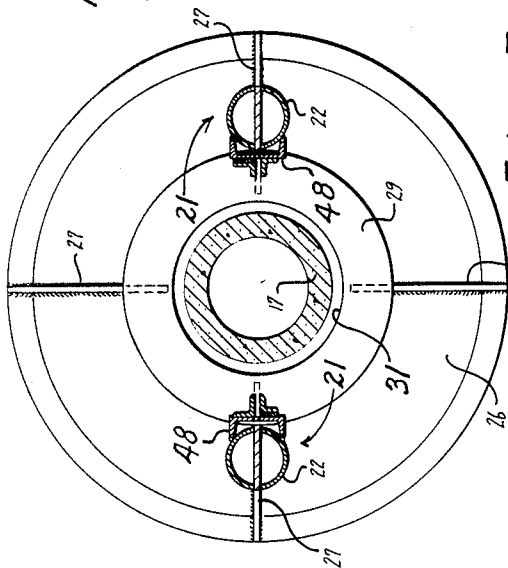
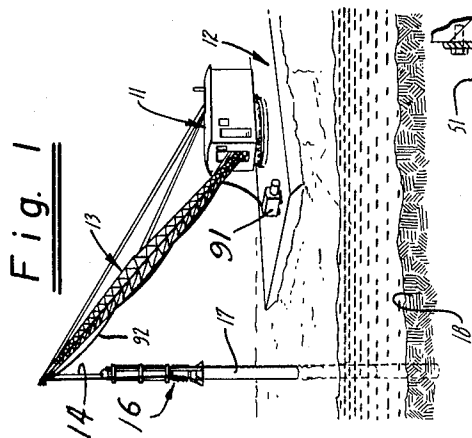


Fig. 7

Fig. 5

Fig. 4

Fig. 8

Fig. 6

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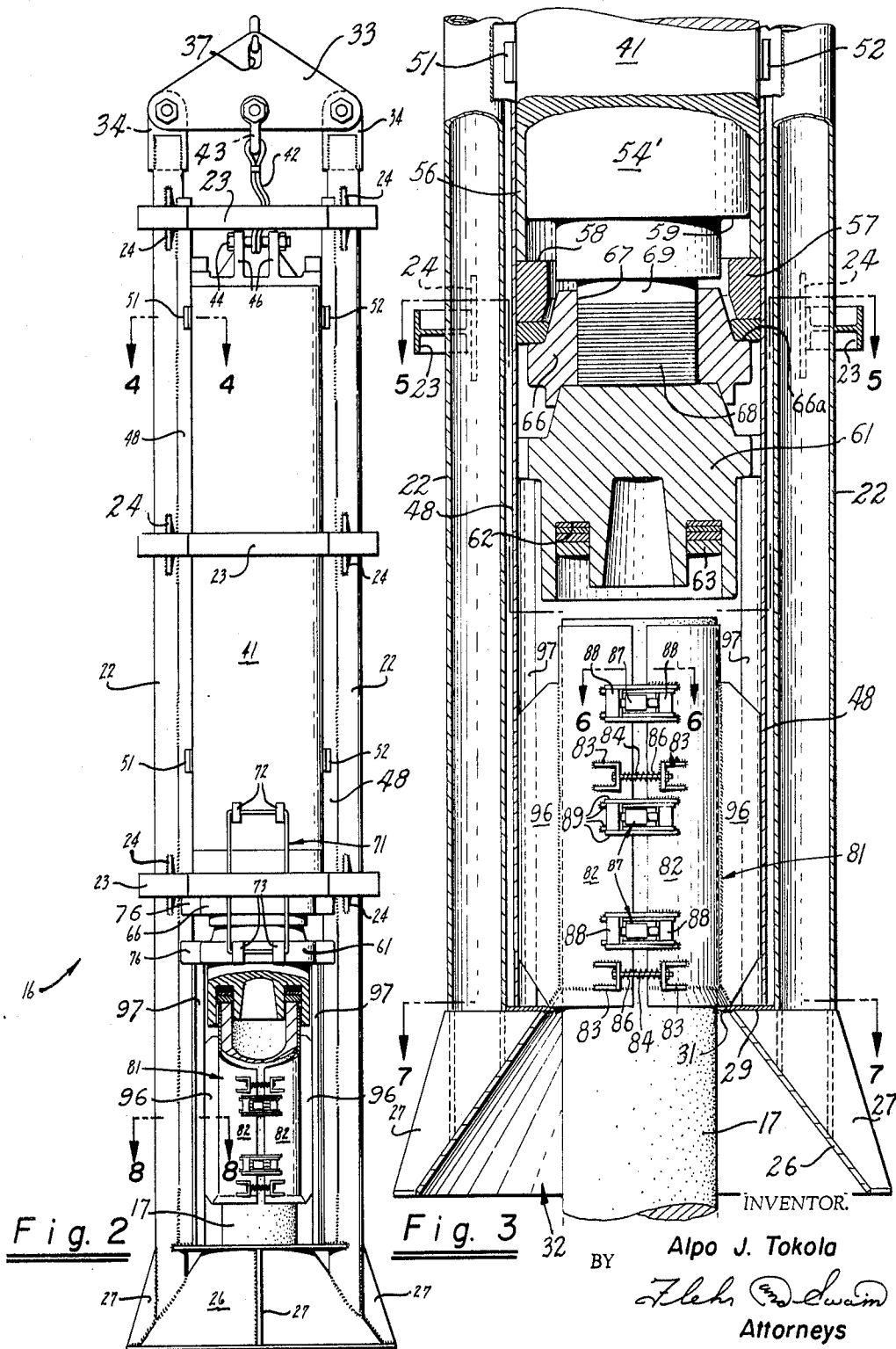
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2 Sheets-Sheet 2



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PILE DRIVING APPARATUS AND METHOD

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This invention relates to a pile driving apparatus and method, and more particularly to a pile driving apparatus having a unique pile hammer guide and pile clamp assembly.

In the driving of piles and particularly in the driving of prestressed concrete piles, considerable difficulty has been encountered. Many piles have been broken during driving to the required bearing or set and, in fact, many piles have been broken so badly as to prevent their being driven to the required bearing which necessitated pulling of the piles and replacement of the piles. Failures of several types have been encountered. One of the primary type of failure is shattering of the head of the pile. Other failures involved the spalling of concrete away from the reinforcement, and splitting and shattering of the pile. In view of these severe difficulties in driving such piles, there is a need for a new and improved pile driving apparatus and method.

In general, it is an object of the present invention to provide a pile driving apparatus and method which overcomes the above named disadvantages and makes it possible to drive the piles without shattering or splitting the heads of the pile.

Another object of the invention is to provide an apparatus and method of the above character which strengthens the pile head against shattering, splitting and spalling.

Another object of the invention is to provide an apparatus and method of the above character in which the pile head is strengthened by applying lateral or circumferential compressive forces to the pile head.

Another object of the invention is to provide an apparatus of the above character in which a cushioning material is utilized and in which there is no tendency to drive the cushioning material down the hollow center of the pile.

Another object of the invention is to provide a pile driving apparatus of the above character in which the anvils strike the pile in a direction which is normal to the pile at all times.

Another object of the invention is to provide an apparatus of the above character in which the pile hammer and the anvils are accurately guided during the driving of the pile.

Another object of the invention is to provide an apparatus of the above character in which a follower is mounted on the pile and serves to continuously guide the hammer, the anvils and the ram driving the anvils.

Another object of the invention is to provide an apparatus of the above character which can be readily placed on the pile and readily removed from the pile.

Additional features and objects of the invention will appear from the following description in which the preferred embodiment is set forth in detail in conjunction with the accompanying drawings.

Referring to the drawings:

FIGURE 1 is a schematic illustration of a pile driving apparatus incorporating my invention.

FIGURE 2 is a side elevational view, with certain parts broken away, of the pile hammer guide and pile clamp assembly utilized in my pile driving apparatus and showing the apparatus in a pile driving position.

FIGURE 3 is an enlarged detail view, partially in cross-section, showing the position of the pile hammer

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guide and the pile clamp assembly during lowering of the assembly just prior to closing of the pile clamp.

FIGURE 4 is a cross-sectional view taken along the line 4-4 of FIGURE 2 and particularly shows the means provided in the follower for guiding the hammer.

FIGURE 5 is a cross-sectional view taken along the line 5-5 of FIGURE 3 and particularly shows the means for guiding the pile clamp and the means for opening and closing the pile clamp.

FIGURE 6 is an enlarged cross-sectional view of one of the hydraulic operators and associated structure shown in FIGURE 5.

FIGURE 7 is a cross-sectional view taken along the line 7-7 of FIGURE 3 and shows the construction of the cone-shaped guided member which forms a part of the follower.

FIGURE 8 is a cross-sectional view taken along the line 8-8 of FIGURE 2.

In general, my pile driving apparatus consists of a frame which serves as a follower. Means is provided for supporting the frame or follower in a generally vertical position. Means is carried adjacent the lower end of the frame and adapted to loosely fit over one end of a pile. A pile hammer is mounted in the frame and is provided with a ram which is movable vertically within the frame and adapted to strike the pile to drive the pile into the ground. Means is provided in the follower for guiding the hammer as it moves vertically in the frame. Clamping means is also provided in the frame and is adapted to engage the head of the pile. Means is also carried by the frame for guiding the clamping means within the frame and permits vertical movement of the frame with respect to the clamping means.

My pile driving apparatus, as shown in FIGURE 1, consists of a crane 11. The crane 11 can be of any suitable type such as a revolving crane mounted upon a floating barge 12. The crane is provided with a boom 13 which has a winch line 14 carried by the outer end of the same which can be raised and lowered by the crane controls. A pile hammer guide and pile clamp assembly 16 are secured to the end of the winch line 14 and are utilized for driving piles 17 to the desired load bearing capabilities into an underwater formation 18 as shown in FIGURE 1, or any other desired formation. The piles 17 can be of any suitable type. For example, they can be cylindrical prestressed concrete piles which are hollow, and having suitable dimensions such as an inside diameter of 15 inches and an outside diameter of 24 inches, and lengths ranging from 50 to 100 feet. The weight per foot can be approximately 290 lbs. Such piles can be constructed with a suitable number of prestressing strands to apply a compressive prestress of approximately 750 p.s.i. in the concrete extending longitudinally of the pile. If desired, spiral reinforcement can also be placed within the pile. Such piles can be readily manufactured to have a concrete strength of over 5000 p.s.i. within a suitable curing period as, for example, 28 days. In driving such piles, the piles can be driven to a suitable minimum bearing value such as 60 tons.

The pile hammer guide and the pile clamp assembly 16 used in my pile driving apparatus is shown in detail in FIGURES 1-7 and consists of a follower 21 comprising a pair of pipe frame members 22 which are fastened together in spaced parallel relationship by three vertically spaced parallel, substantially rectangular frame members 23. The rectangular frame members 23 are formed of a suitable material such as I-beams which have been cut and fabricated into the desired configuration. The rectangular frame members 23 are secured to the vertical pipe frame members 22 in a suitable manner such as by the use of plates 24 which extend through slots provided

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in the pipe frame members 22 and which are affixed to the pipe frame members and the rectangular frame members by suitable means such as welding.

Means is provided on the lower end of the follower and loosely fits over the top of the pile and serves to guide the follower on the pile and consists of a truncated substantially cone-shaped member 26 which is secured to the lowermost extremities of the pipe frame members 22 by suitable means such as welding. Reinforcing gussets 27 are secured to the sides of the cone-shaped member 26 and to the lower extremities of the pipe frame members 22.

A collar 29 is secured to the top of the cone-shaped member 26 and has the outer margins thereof secured to the pipe frame members 22 as shown particularly in FIGURES 3 and 7. The collar 29 is provided with an opening 31 which is the same size as the opening in the upper portion of the cone-shaped member 26. The size of this opening is such that it is only slightly larger than the outside diameter of the piles which are being driven. The cone-shaped member 26 is flared outwardly and downwardly from the opening 31 in the collar 29 to provide an opening 32 which is substantially larger than the outside diameter of the pile 17 so that the lower end of the follower 21 can be readily lowered onto the top or head of the pile as hereinafter described.

A triangularly shaped lifting plate 33 is secured to the upper ends of the pipe frame members 22 in a suitable manner such as by means of caps 34 which are mounted on the upper ends of the pipe frame members 22 by suitable means such as welding and by bolts 36 which secure the plate to the caps. The lifting plate 33 is provided with a hole 37 through which the hook or other suitable member connected to the winch line 14 can be connected.

A hammer 41 of a suitable type such as an S-14 McKiernan-Terry single acting hammer is mounted in the follower 21 between the pipe frame members 22 and within the rectangular frame members 23. The hammer 41 is supported within the follower 21 by a suitable flexible elongate member such as a flexible cable 42 which has one end secured to a clevis 43 fastened to the lifting plate 33. The other end of the cable 42 is secured to a bolt 44 which extends through a pair of ears 46 provided on the upper portion of the hammer as shown particularly in FIGURE 2.

Means is provided within the follower for guiding a hammer for movement longitudinally or vertically in the follower and consists of a pair of channel members 48 which are affixed to the surfaces of the pipe frame members 22 facing each other by suitable means such as welding. The channel members 48 extend substantially the entire length of the pipe frame members 22 and extend upwardly from the collar 29 parallel to the pipe frame members 22. Angle members 51 and 52 are affixed on opposite sides of the hammer 41 by suitable means such as welding and engage opposite sides of the channel members 48 as shown particularly in FIGURE 4 so that the hammer 41 is guided for vertical movement within the follower 21.

The hammer 41 is provided with a ram 54 which is periodically raised and then dropped in a vertical direction within the hammer and within the follower 21. The hammer also includes a casing 56 in which the ram travels. A retaining member 57 is secured to the lower end of the casing 56 and is provided with an annular shoulder 58 which is adapted to be engaged by an annular shoulder 59 provided on the ram 54. In this manner, the member 57 prevents the ram 54 from dropping out of the hammer when the hammer is raised as hereinafter described.

Anvil means is also provided within the follower below the hammer and consists of a double cup anvil 61 which has an annular recess 62 that is adapted to receive the upper end of the pile and in which there is also mounted cushioning material 63. The cushioning material can be

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of any suitable thickness such as 6 to 8 inches and can be formed of different types of materials such as 3 inches of Douglas fir, two inches of plywood, 1 inch of micarta and 2 inches of plywood, and in that order from the bottom to the top. An anvil block 66 is mounted on the double cup anvil 61 and is provided with a large cylindrical hole 67 which is adapted to receive additional cushioning material 68. The cushioning material 68 can be of any suitable type such as a eucalyptus block or a block formed from phenolic laminate with a heavy canvas base, alternated with aluminum discs for heat dissipation produced by Raymond International, Inc. A plate 69 is mounted within the hole 67 above the cushioning material 68 and is adapted to receive the blows of the ram 54.

Means is provided for supporting the anvils 61 and 66 on the hammer 41 and consists of slings 71 of a suitable material such as wire rope which are provided on opposite sides of the hammer 41 and which extend through a pair of ears 72 provided on opposite sides of the hammer and through a pair of ears 73 provided on opposite sides of the anvil 61.

The anvil 61 is also provided with means in the form of abutments 76 which engage opposite sides of the guide channel members 48 to guide the anvils during vertical movement within the follower 21.

The pile hammer and pile clamp assembly also include a pile clamp 81 which consists of a pair of elongate semi-cylindrical sleeve members 82 which are disposed within the lower portion of the follower 21. Means is provided for fastening the two sleeve sections into a unitary assembly and consists of vertically spaced brackets 83 secured to the side margins of the sleeve sections and which are loosely interconnected by bolts 84. Means is provided for yieldably urging the sections into an open position and consists of compression springs 86 mounted on the bolts 84 between the brackets 83. Means is provided for moving the sleeve sections 82 in a closed position to clamp the pile head and consists of vertically spaced hydraulic actuators 87 mounted between a pair of blocks 88. The blocks 88 are secured to brackets 89 which extend in opposite directions and overlap each other and are secured to opposite sleeve sections 82 as shown particularly in FIGURE 6.

Means is provided for supplying a fluid to the actuator 87 and consists of a hydraulic pump 91 which is mounted on the barge 12 and which is connected to the actuators by hydraulic lines 92 and control mechanisms (not shown). As shown particularly in FIGURE 5, the actuators are provided on opposite sides of the sleeve sections 82 and are normally connected to the pump 91 so that they are all actuated and released at the same time.

Means is provided for guiding the pile clamp 81 within the follower 21 so that relative movement can occur between the follower and the pile clamp and consists of a pair of radially and vertically extending fins 96 which are secured to the sleeve sections 82 by suitable means such as welding and which travel between pairs of spaced angles 97 secured to the channel members 48 by suitable means such as screws 99. It will be noted that the fins 96 extend over the collar 29 so that the pile clamp 81 cannot drop through the hole 31 in the collar. It also will be noted that, as shown in FIGURE 3, when the pile clamp 81 is in open position, it has a diameter which is slightly greater than the diameter of the hole 31 in the collar which also ensures that the pile clamp cannot pass through the hole 31.

Operation and use of my pile driving apparatus in performing my method may now be briefly described as follows. Let it be assumed that a pile such as pile 17 has been set and that it is desired to drive the pile to a certain bearing. The pile hammer, guide and pile clamp assembly is then lifted by the crane 11 and the boom 13 of the crane is manipulated to a position so that the pile hammer, guide and pile clamp assembly 16 generally

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overlies the upper end of the pile 17. The assembly 16 is then lowered so that the cone-shaped member 26 comes into engagement with the pile head. Continued lowering of the assembly 16 causes the assembly to be guided over the top of the pile head and through the opening 31 in the collar 29. Then, assuming that the pile clamp 81 is in an open position as shown in FIGURE 2, the entire assembly is lowered so that the pile passes upwardly into the pile clamp and until approximately one inch of the pile head extends above the pile clamp 81. Downward movement of the assembly is then arrested and control valves (not shown) are actuated in the assembly 91 to cause hydraulic fluid to flow into the hydraulic actuators 87 and to firmly clamp the pile clamp to the pile head against the force of the springs 86.

The size and number of the hydraulic actuators or jacks 87 is chosen so that the desired circumferential compressive forces are placed on the pile by the pile clamp. In the embodiment shown in the drawings, three pairs of hydraulic jacks have been provided of a suitable capacity such as ten tons each.

After the pile clamp has been secured to the pile head, the follower 21 is lowered so that the anvil 61 is lowered over the top of the pile head and so that the pile enters the annular recess 62 and is engaged by the cushioning material 63. Continued lowering of the follower causes the shoulder 66a of the anvil block 66 to engage the member 57 and also causes the plate 69 to engage the ram 54 to raise the ram within the hammer. Continued lowering of the follower causes the lower extremity of the follower to move away from the pile clamp 81 and also causes slack to occur in the cable 42.

After the pile hammer guide and pile clamping assembly has been moved to the position shown in FIGURE 1, driving of the pile can be undertaken by applying steam to the hammer 41 in a manner well known to those skilled in the art to cause raising of the ram 74 and then release of the ram to permit the ram to fall and strike the plate 69 which strikes the cushioning material 68 to apply forces to the anvil 61 and to the pile head through the cushioning material 63.

Repeated blows are applied to the pile in this manner as, for example, 2 to 600 blows may be required to drive the pile to the required set even with the McKiernan-Terry single acting hammer described above which causes the application of over 35,000 ft. lbs. of energy per blow with the ram having a weight of 14,000 lbs.

With the use of such a pile hammer guide and pile clamp assembly, it was found that piles of the type described above could be driven to the required set without shattering, splitting or spalling of the piles. It is believed that this is primarily due to the fact that the follower 21 and its associated guide means with the associated pile clamp causes the anvils to strike the pile in a direction which is always normal to the pile. This helps to ensure that the blows are distributed evenly along the upper head of the pile. By keeping the pile and the hammer in line with my pile hammer guide and pile clamp assembly, whipping of the pile under impact is prevented. The pile clamp 81 serves to confine the pile head to prevent shattering, splitting or spalling of the pile. Also, in addition to actually confining the top of the pile, it is believed that the pile clamp places the pile head under circumferential compressive forces which strengthens the concrete pile laterally in much the same manner as the pile is strengthened longitudinally by prestressing as hereinabove described.

The use of the double cup anvil makes it possible to utilize a cushioning which is in contact with the pile but in which there is no tendency to drive the cushioning material down the center of the pile and thereby placing outward pressure on the pile wall. By utilization of a special cushioning material 68 within the cylindrical recess 67, it is possible to obtain a cushion block stiffness which

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is substantially constant and does not increase as the pile is driven.

As the pile is being driven, the hammer 41 will follow the anvils downwardly as the pile moves downwardly. During driving, it is necessary for the operator of the crane to observe the cable 42 and to progressively lower the follower 21 so that there is slack at all times in the cable 42 to ensure that the anvils are continuously in engagement with the pile head.

After the pile has been driven to the required set, the pile clamp can be readily released by releasing the hydraulic pressure from the actuators. As soon as this is done, the springs 86 will force the semi-cylindrical sleeve sections apart to free the pile head. Thereafter, the entire pile hammer guide and pile clamp assembly can be raised by the crane which first lifts the hammer 41, then causes the hammer to lift the anvils 61 and 66 and then raises the pile clamp 81 as the collar engages the lower portion of the pile clamp so that the entire assembly can be readily lifted off of the pile. The assembly can then be placed on the next pile which has been positioned to drive it to the required set as hereinbefore described.

The pile hammer guide and pile clamp assembly is constructed in such a manner that it can be readily disassembled. The pile clamp 81 can be removed merely by removing the bolts 98 and releasing one of the angles 97. It can then be slipped sideways out of the follower 21. After the pile clamp has been removed, it is easy to obtain access to the anvils 61 and 66 and the hammer 41.

It is apparent from the foregoing that I have provided a new and improved pile driving apparatus and method which particularly facilitates the driving of certain types of piles as, for example, prestressed concrete piles. The pile driving apparatus is such that the axes of the pile, the ram and the hammer are always concentric so that the surfaces of the anvil will be parallel to the top surface of the pile. The pile driving apparatus is constructed in such a manner that it can be readily used and maintained.

I claim:

1. In a pile driving apparatus, a follower, the lower extremity of the follower having means adapted to loosely encompass the outer perimeter of the pile, a pile hammer, means mounting the pile hammer in the follower for guiding the pile hammer for vertical movement within the follower, the pile hammer having a ram movable vertically within the follower and anvil means mounted within the follower below the ram movable into engagement with the top of the pile, said anvil means comprising an anvil having an annular recess therein adapted to receive the top of the pile and cushioning material disposed in the recess and adapted to engage the top of the pile.

2. Apparatus as in claim 1 wherein the anvil means includes an additional anvil mounted on the first named anvil, the additional anvil having cushioning means mounted therein and engaging the first named anvil.

3. In a pile driving apparatus, a follower, means for supporting the follower in a generally vertical position, the follower including means on its lower extremity adapted to encircle the upper portion of the pile and to guide the lower extremity of the follower on the pile as the follower is lowered over the top of the pile, a pile hammer, flexible means secured to the follower and the hammer for suspending the hammer within the follower, means carried by the follower and engaging the hammer for mounting the hammer within the follower and for guiding the hammer for vertical movement within the follower, a pile hammer having a ram movable vertically within the follower, anvil means mounted in the follower between the ram and the upper end of the pile, the anvil means being adapted to engage the upper end of the pile and the ram being adapted to apply blows to the anvil means, a pile clamp comprised of a plurality

of sections mounted within the lower portion of the follower, said pile clamp having a configuration adapted to encompass the outer perimeter of the upper portion of the pile, means for moving the pile clamp between open and closed positions comprising means yieldably urging the sections apart and hydraulically operated clamps for moving the sections towards each other, said pile clamp in an open position permitting the pile clamp to be removed from the pile and in a closed position placing compressive forces on the upper portion of the pile in a direction lateral to the longitudinal axis of the pile, and means carried by the follower and the pile clamp for guiding the follower and permitting relative vertical movement between the follower and the pile clamp.

4. In a pile driving apparatus, a follower, means for supporting the follower in a generally vertical position, means carried adjacent the lower end of the follower for encompassing the upper end of the pile to guide the follower on the pile, a pile clamp comprising a pair of semi-cylindrical sections mounted on the lower portion of the follower, vertically spaced hydraulic actuators connecting the sections and serving to move the sections toward a closed position, said pile clamp in a closed position placing compressive forces on the pile in a direction lateral to the longitudinal axis of the pile when the pile clamp is closed and to release the pile when the pile clamp is open, means carried by the follower for guiding the pile clamp to permit relative movement between the pile clamp and the follower, and hammer means mounted within the follower for applying blows to the top of the pile while it is retained in the pile clamp.

5. In a pile driving apparatus, a frame, means for supporting the frame in a generally vertical position, means mounted on the lower end of the frame and adapted to loosely fit over the end of a pile for guiding the frame onto the pile, hammer means mounted in the frame and adapted to strike the pile to drive the pile into the ground, clamping means mounted within the frame and adapted to engage the pile circumferentially to axially confine the upper portion of the pile under circumferential compressive forces to thereby provide lateral support for the concrete pile, said clamping means also being formed so that the top surface of the pile is exposed whereby hammer means strikes the top surface of the pile, and means operatively connecting the frame and the clamping means for guiding the frame for vertical movement of the same with respect to the clamping means.

6. Apparatus as in claim 5 wherein said clamping means is movable between open and closed positions, together with means for yieldably urging the clamping means into an open position and means for moving the clamping means into a closed position against the forces of the yieldable means.

7. In a pile driving apparatus, a follower, means for supporting the follower in a generally vertical position, the follower including means on its lower extremity adapted to encircle the upper portion of the pile and to

guide the lower extremity of the follower on the pile as the follower is lowered over the top of the pile, a pile hammer mounted within the follower, flexible means secured to the follower and the hammer for suspending the hammer within the follower, means carried by the follower for guiding the hammer for vertical movement within the follower, the pile hammer having a ram movable vertically within the follower, anvil means mounted in the follower between the ram and the upper end of the pile, the anvil means being adapted to engage the upper end of the pile and the ram being adapted to apply blows to the anvil means, a pile clamp mounted within the lower portion of the follower, said pile clamp having a configuration adapted to encompass the outer perimeter of the upper portion of the pile and being movable between open and closed positions, said pile clamp in an open position permitting the pile clamp to be removed from the pile and in a closed position placing compressive forces on the upper portion of the pile in a direction lateral to the longitudinal axis of the pile, means for moving the pile clamp between open and closed positions, and means carried by the follower and the pile clamp for guiding the follower on the pile clamp and permitting relative vertical movement between the pile clamp and the follower.

8. In a pile driving apparatus, a follower, means for supporting the follower in a generally vertical position, means carried adjacent the lower end of the follower for encompassing the upper end of the pile to guide the follower on the pile, a pile clamp mounted on the lower portion of the follower, said pile clamp being movable between open and closed positions to place compressive forces on the pile in a direction lateral to the longitudinal axis of the pile when the pile clamp is closed and to release the pile when the pile clamp is open, means operatively connecting the follower to the pile clamp for guiding the follower and permitting relative vertical movement between the pile clamp and the follower, and hammer means mounted within the follower for applying blows to the pile while it is retained in the pile clamp.

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