July 14, 1953 W. P. KINNEMAN ET AL 2,645,090

REINFORCING OF CONCRETE PILES

Filed Feb. 6, 1951 2 Sheets-Sheet 1

Fig. 1. Fig. 3.

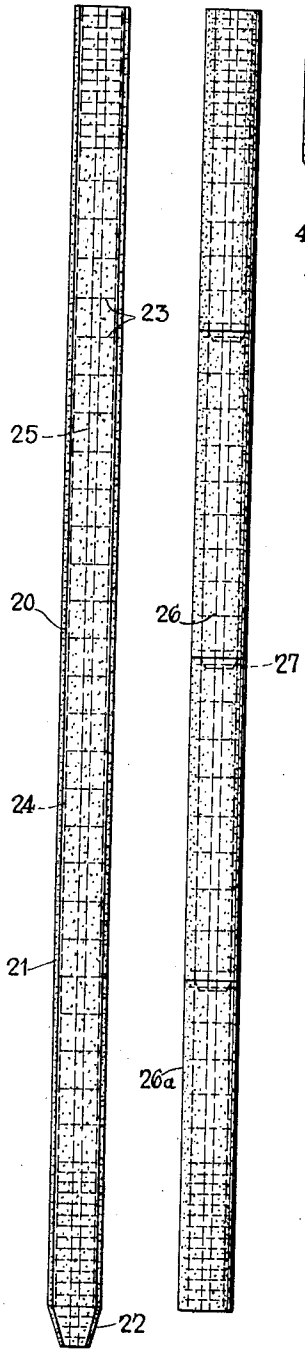


Fig. 5.

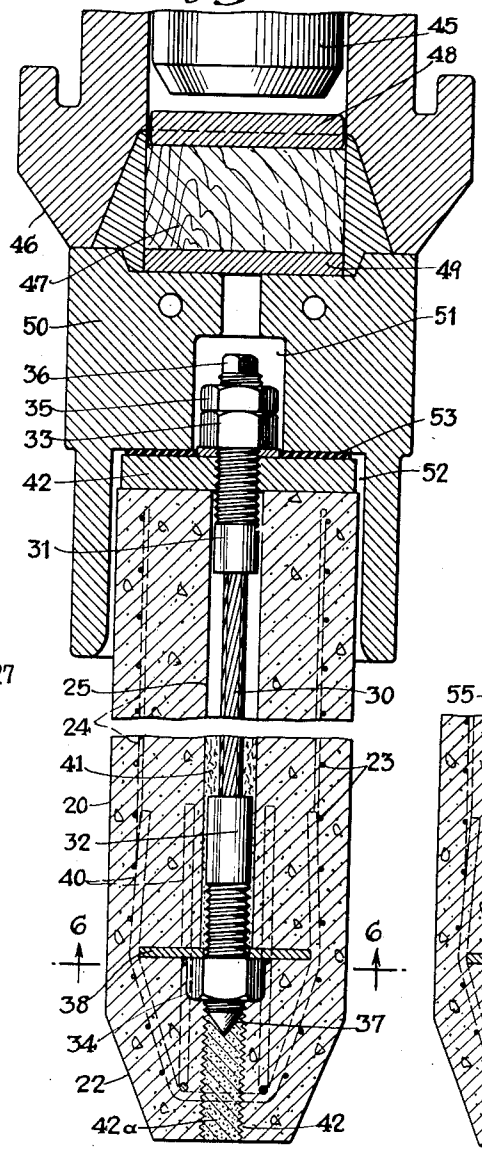


Fig. 8.

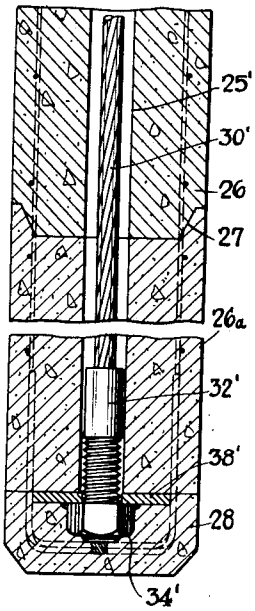


Fig. 7.

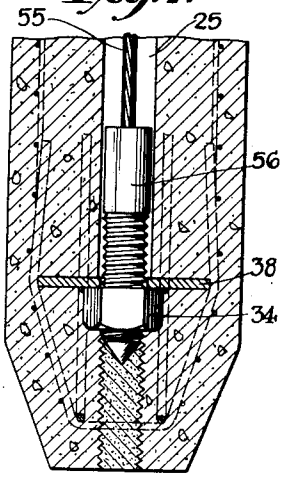


Fig. 6.

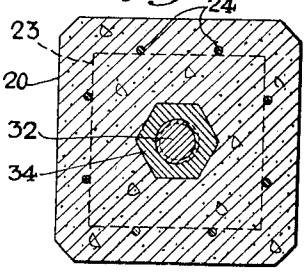
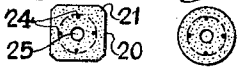


Fig. 2. Fig. 4.



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REINFORCING OF CONCRETE PILES

Filed Feb. 6, 1951

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Fig. 9.

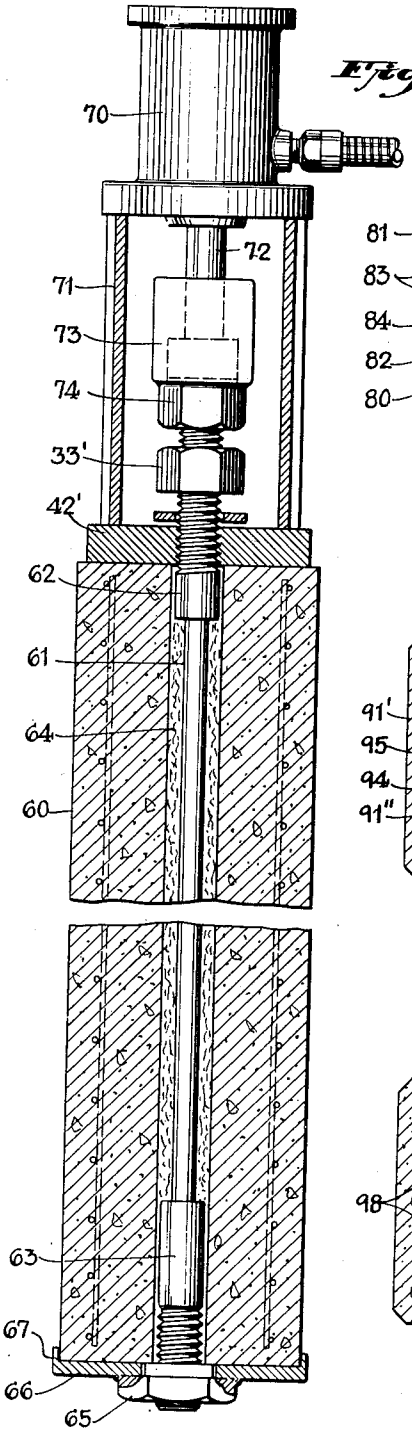


Fig. 10.

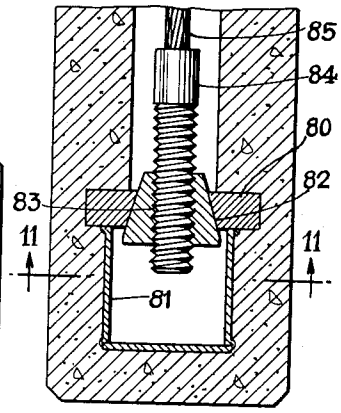


Fig. 11.

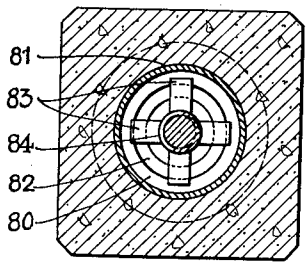


Fig. 12.

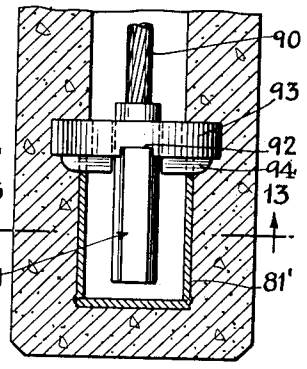


Fig. 13.

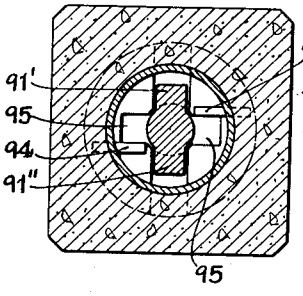


Fig. 14.

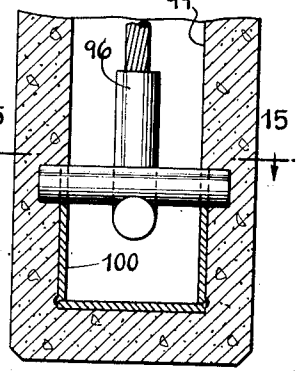
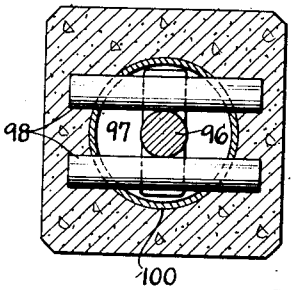


Fig. 15.



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Patented July 14, 1953

2,645,090

UNITED STATES PATENT OFFICE

2,645,090

REINFORCING OF CONCRETE PILES

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Application February 6, 1951, Serial No. 209,689

3 Claims. (Cl. 61—56)

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This invention relates to the reinforcing of concrete piles.

Piles formed of concrete are generally quite heavy and long and are thus subject to bending and possible cracking while being carried to the place where same are to be used and lifted into position for driving. Consequently it has been the practice to cast such piles with relatively heavy reinforcements permanently located therein in the form, for example, of large bars or rods which constitute a very important cost factor. When such piles are precast, especially if they are very long, the steel reinforcements therein will be subject to heavy compression forces due to the shrinkage of the concrete when it sets in adhering relation to the steel. Such compression may sometimes amount to as much as 12,000 lbs. per square inch of the cross-section of the steel. Consequently, before the steel can come under the tension forces for which it was designed, the concrete is frequently cracked or shattered, thereby permitting water and air to enter, which results in deterioration of the steel.

After a concrete pile is driven in place and is completely or largely embedded in the earth, it will not ordinarily be necessary for it to have great lateral strength, since it will be under compression from the earth from all sides, because of the displacement which results in driving it. Accordingly, permanent heavy reinforcement is not ordinarily required in such piles after they are driven in place, but before that time adequate steel reinforcement is required, not only to protect the pile against bending forces while it is being handled and put in place, but also to prevent the lower portions of the pile from cracking off as the result of the heavy blows which the upper end receives during driving, and which are transmitted down toward the lower point in such a way as to tend to cause cracking off of the lower portions. Thus the ordinary types of reinforcements heretofore generally used for this purpose not only involve waste of steel in that they are permanently installed although necessary only temporarily, but also they have to be so heavy that their initial cost is excessive, and such heavy ordinary reinforcements tend to defeat their intended purposes, because of the above mentioned shrinkage of the concrete and resulting compression of the steel and cracking of the concrete.

According to the present invention, the above difficulties are overcome by providing, preferably within a longitudinal central bore of the pile,

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a prestressing cable, or other high tensile strength member which is subjected to heavy tension before the pile is handled and put in place for driving, and such cable or member is so arranged that after the pile has been driven to the desired position in the earth, the cable or member may be easily and quickly removed in a condition suitable for repeated reuse.

Even though the pile, after being driven, is not expected normally to require any substantial longitudinal reinforcement, yet in order to protect the pile against any unexpected or accidental lateral forces, engineers may for safety reasons in some cases prefer to have at least some permanent longitudinal reinforcement remain in the piles, even though same does not need to have a strength comparable to the reinforcement required before driving is completed. To meet such conditions, according to the present invention, after the temporary heavy prestressing cable or member is removed, the arrangement is such that a substantially lighter weight cable or member may be inserted and put under tension, to remain permanently in the pile, thus reducing to a substantial degree the cost of the permanent reinforcement, while still permitting the temporary heavy reinforcement to be repeatedly reused in other piles.

It has heretofore been proposed to apply tensioned wires or other members longitudinally at spaced positions around the outside of piles during the driving thereof and to thereafter remove such wires or members, but so far as we are aware, such methods have not proven satisfactory in practice, either because of the excessive labor cost for manipulating the numerous parts involved, or the wires could not be reused for the same purpose because their lower ends, after the pile is driven, have to be pulled free by breaking or overstretching same, or for various other reasons. All such difficulties are avoided with the present invention.

Other and more specific objects, features and advantages of the invention hereof will appear from the detailed description given below, taken in connection with the accompanying drawings, which form a part of this specification and illustrate by way of example preferred examples of the invention.

In the drawings:

Figs. 1 and 3 are elevational views respectively of an integral pile and of a pile of sectional type with which the invention may be used;

Figs. 2 and 4 respectively are top views of the piles of Figs. 1 and 3;

Fig. 5 is a vertical sectional view of a pile embodying the invention and also of driving means therefor;

Fig. 6 is a horizontal sectional view taken substantially along line 6—6 of Fig. 5;

Fig. 7 is a vertical sectional view of a portion of the pile of Fig. 5, but showing a smaller permanent prestressing cable therein which has been substituted for the heavier temporary prestressing cable indicated in Fig. 5;

Fig. 8 is a vertical sectional view of another embodiment of the invention as applied to a sectional pile;

Fig. 9 is a vertical sectional view of a pile according to the invention, showing hydraulic jack apparatus being used to apply tension to the prestressing member.

Figs. 10, 12 and 14 are vertical sectional views of the lower portions of alternative embodiments of the invention;

Figs. 11, 13 and 15 are horizontal sectional views taken along lines 11—11, 13—13 and 15—15 of Figs. 10, 12 and 14 respectively.

Referring now to the drawings in further detail, there is shown in Fig. 1 a one-piece concrete pile 20 of substantially square cross-section, except for the beveled corners 21 and the pointed lower end portion 22. Such pile is preferably cast with numerous relatively lightweight horizontally positioned reinforcing hoops as at 23 therein, same being located, as indicated, in more closely spaced relation near the upper and lower ends of the pile where there is greater danger of breakage during driving. Also, a plurality of longitudinal relatively lightweight reinforcements as at 24 may be embedded in the concrete as cast, and the pile as cast has a central bore 25 extending, in the form shown, from top to bottom.

In Figs. 3 and 4 another form of pile with which the invention also may be used is shown, this being similar to that of Figs. 1 and 2, except that instead of same being cast in one integral piece, it is formed of a succession of sections as at 26, 26a etc., each section being of circular cross-section and being provided at its ends with male and female interengaging portions as indicated at 27 (Figs. 3 and 8). Also, the pile in this form, instead of having a point at its lower end, may alternatively be equipped with a lower end portion such as indicated at 28 in Fig. 8.

Fig. 5 shows a pile such as of Fig. 1 in vertical section and as containing a high tensile strength prestressing cable 30 in the bore 25, this figure also showing the manner in which driving apparatus may be used in connection with such pile. The upper and lower ends of cable 30 are provided with connection fittings as at 31, 32 swaged thereon in a well known way, these fittings being externally threaded to receive nuts as at 33, 34, the upper end preferably also having a lock nut 35. The upper end 36 of fitting 31 is also preferably made square or otherwise suitably shaped to permit ready turning thereof as hereinafter described, whereas the lower end of fitting 32 is preferably formed with a point as at 37.

The pile 20 within a region near the lower end, as shown in Fig. 5, is formed with a plate-like member 38 cast therein, through which the fitting 32 extends and against the undersurface of which nut 34 bears when the cable 30 is under tension. The lower end portion of the pile may also contain suitable additional reinforcing members as at 40 in the region surrounding the member 38.

The pile may be either cast before the cable 30 is put in place, or if preferred, the cable 30 and its fittings may be initially surrounded with cardboard or other suitable filler material at 41, and the concrete then cast around the same, while the filler prevents the cable and its fittings from adhering to the concrete. If the concrete is cast before the cable and its connections are put in place, then the bore 25 may be formed therein in any well-known way, as by casting the concrete about a mandrel covered with flexible rubber or other material to permit the mandrel to be withdrawn without adhering to the concrete in the bore. In this event, the lower end of the bore, as at 42, is preferably cast with an internally threaded formation within which the fitting 32 may readily be threaded in position, after which the space at 42a may be filled with grout.

Whether the cable assembly is put in place during the casting of the concrete, or into the bore 25 afterwards, it should be substantially freely removable upwardly from the bore upon unthreading fitting 32 from nut 34. As initially installed, the cable, although secured at its lower end, will be substantially free of tension. But after the concrete has set and become sufficiently hard and strong, then the cable is subjected to heavy tension by force applied to the upper fitting 31 and reacting against a top end plate 42, which in turn reacts against the pile to subject the concrete endwise to heavy compression. This may be accomplished by hydraulic jack means such as described hereinafter in connection with Fig. 9. After a tension for example of from about 125,000 to 150,000 lbs. per square inch of wire cross-section of the cable has been applied thereto, and the nuts 33, 35 secured in place, the pile will then be ready to be moved about, lifted and handled, as required to put it in place for driving and for driving to the desired position in the earth, all without danger of cracking the concrete. The above tension limits are given as examples on the assumption that the wire of the cable has an ultimate tensile strength for example of about 200,000 lbs. per square inch. That is, substantially all parts of the concrete will be maintained uniformly under heavy endwise compression, rather than incurring the danger of being cracked apart by reason of any tension forces therein.

To drive the pile, a pile driving hammer may be used having for example a ram 45, a base portion 46 containing a wood cap block 47 and steel facing plates as at 48, 49 for the wood. As shown, a suitable follower member 50 is interposed under the hammer, such follower having a cavity as at 51 for receiving the nuts 33, 35 and fitting 31; also a larger cavity 52 for receiving the upper end of the pile and the plate 42. A rubber plate 53, if desired, may be interposed between the follower and the steel plate 42. With this arrangement the pile may be driven into the earth in substantially the same way as in the case of prior known forms of piles, but heavier blows of the hammer may be used to secure more rapid driving than heretofore generally possible with precast concrete piles.

After the pile is driven in place and the hammer and follower parts removed, the nuts 35, 33 may be loosened to release the tension in the cable 30, if the cable is to be removed for reuse. If difficulty is had in loosening the nuts, the hydraulic jack apparatus hereinafter described may first be screwed on to the upper end of the fitting 31, to raise same sufficiently to release the pressure on the nuts to permit them readily to be turned. After the cable tension is released, the assembly comprising the cable

30 and its fittings 31, 32 may be twisted by applying turning force to the upper end 36, sufficient to unscrew the fitting 32 from the lower nut 34, thereby permitting the cable assembly to be lifted out of the bore 25 so that it and the plate 42 may be reused for other piles.

The form shown in Fig. 8 is similar to that of Fig. 5, except that the cable 30' is positioned in a sectional type pile, such as of Fig. 3, and the apertured plate 38' within the bottom of the pile is here applied first to the bottom end of a pile section 26a and then covered by the pile tip portion 28 which is formed with a recess suitable for receiving the nut 34'.

After the piles, such as of Figs. 5 and 8, are driven in place and the cables and accompanying fittings are removed in the manner above described, then in the event (for safety reasons or to protect the pile against unexpected lateral forces) it should be desired to reinsert another but smaller and less expensive prestressing cable or member, this may be done as shown for example in Fig. 7 where a smaller prestressing cable 55 is inserted in the bore 25, such cable having a pointed lower end fitting 56 which may be threaded into the nut 34 on dropping the cable with the fitting on its lower end into contact with the plate 38 and then turning the cable by twisting its upper end.

As will be noted from Fig. 7, the cable 55 preferably has wires helically wound in a direction such that the turns will tend to become more tightly wrapped as the cable is twisted in a direction to screw the fitting 56 into the nut 34, thus to enable the fitting readily to be screwed into place by turning the upper end of the cable without tending to unwrap the wires of the cable. On the other hand, in Fig. 5, where the cable is to be twisted to disconnect its lower end fitting, the wires are helically wound in the opposite direction as compared with cable 55, so that cable 30 may be twisted in a direction to screw the fitting 32 out of nut 34 without unwrapping the cable wires. The substitute cable 55 preferably has a swaged fitting at its upper end similar to that at 31 in Fig. 5 and adapted to be secured in the same way to permit permanent heavy tensioning of cable 55 to the same degree for example as above mentioned for cable 30. If desired, the space in the bore 25 surrounding cable 55 may be filled with grout after the cable is highly tensioned therein, such grout being introduced through a suitable aperture which may be provided through the wall of the pile near its upper end, or the grout may be introduced at the upper end of bore 25 just before cable 55 is finally tensioned, provided the tensioning is accomplished before the grout sets.

With the form of the invention shown in Fig. 9, the pile 60 is cast about a rod 61 having end fittings 62, 63 swaged thereon. Suitable cardboard or other filler means as at 64 surrounds the rod and fittings during the casting operation, to prevent the concrete from adhering to the metal. The rod 61 is preferably formed of high tensile strength alloy steel inasmuch as it is to be subjected to tension of a magnitude approaching the degree of tension of the cable 30 and for the same purpose. Here the lower fitting 63 is secured in place in a manner similar to that of Fig. 8, except that the lower nut 65 rests against a plate 66 positioned on the bottom end of the pile and having a peripheral flange 67 for holding the plate against transverse displacement during driving of the pile or when the heavy reinforcement 61 is being replaced by a similar lighter and less expensive reinforcement.

In order to tension the prestressing members, as shown in Fig. 9 a hydraulic jack as at 70 is provided, mounted on suitable stool or spacer means 71, which in turn rests upon plate 42'. The jack plunger 72 has rotatably secured thereon in any suitable way a member 73 terminating in a nut portion 74, adapted for threaded engagement with the upper end of the upper threaded swaged fitting 62. Thus to tension the member 61 and similarly in tensioning cables such as shown in Figs. 5, 7 and 8, the jack is first placed and attached as shown in Fig. 9, and then the plunger 72 is raised until the desired degree of tension is applied to the prestressing member. Then a nut as at 33' is screwed down tight against a top plate such as at 42', whereupon the jack and its stool may be removed and the nut 33' may be supplemented by a lock nut, such as 35 in Fig. 5. Similarly, in case the nut 33' is to be loosened to release the tension in the prestressing member upon removal of the latter, then the jack may be applied, as shown, to first tension the prestressing member to a slightly greater degree than maintained by the nut 33', whereupon this nut may be readily loosened without breaking same or the threads therein. Then the jack may be operated completely to release the tension.

In case the prestressing member 61 of Fig. 9 is to be replaced by a lighter and less expensive prestressing member after the pile is in position, then the nut 65 at the bottom end should be suitably retained in position as by welding same on the lower surface of the plate 66, whereby the aperture in the nut will be in proper position to facilitate threading in of the swaged fitting on the substitute prestressing member.

In Figs. 10–15 various alternative connections for securing the lower end of the prestressing member or cable are shown. For example, in Fig. 10 the pile is cast with a plate 80 within its lower end, having on its underside, secured thereto as by welding, a chamber 81. The plate 80 has a conical aperture 82 therein, the walls of which are adapted to engage a plurality of wedges 83, each of which has thread formations on its surface facing the threads on swaged fitting 84. To release this connecting means by manipulating the upper end of the prestressing cable 85, it is merely necessary to release the tension on the cable and allow the cable to drop a sufficient distance to permit the wedges 83 to fall into the receptacle 81, whereupon the cable assembly is free to be removed. The fitting 84 might also be released by turning the upper end of the cable.

With the embodiment shown in Figs. 12 and 13, a prestressing cable 90 is provided on its lower end with a swaged fitting 91. As shown in the cross sectional view (Fig. 13) of the fitting 91, its lower portion is formed with a pair of oppositely directed wing portions 91', 91'', which, when the cable is tensioned, are pulled up into engagement with grooves as at 92 in the underside of a plate 93. To disconnnect this arrangement by manipulating the upper end of the cable 90, the cable tension is first released and the cable lowered sufficiently so that the wing portions 91', 91'' are turned through an angle of 90° into engagement with suitable detents or stop means 94 formed on the underside of plate 93, whereupon the cable is lifted again and the fitting thereon is free to slide up with the wing portions passing through slots 95 in the plate 93. As in the case of Fig. 10, a

chamber 81' may be provided on the underside of plate 93.

In the form shown in Figs. 14 and 15, the lower end of the cable is provided with a swaged fitting 96 of inverted T shape, the cross portion of the T being adapted to be lowered through a space 97 provided between two heavy bars 98 cast in place in the concrete, whereupon the cable, upon being turned through a 90° angle, will turn the T shaped member to the position shown in Fig. 15, and thereafter upon tensioning the cable, the bars 98 act to hold the fitting against release until the tension is again released and the cable is turned through an angle such as to permit the cross portion of the T to pass up between the bars 98. The lower end of the central bore 99 of the pile in this case, may be closed and reinforced by metal chamber member 100.

With all of the above described embodiments of the invention, it will be noted that only a relatively small amount of reinforcement of permanent non-removable nature ordinarily needs to be used in the piles. This may take the form of wires such as indicated at 23, and 24, and which may be quite inexpensive and still protect the concrete against such small lateral forces as the pile may usually be subjected to after being driven in place. Also, these lightweight reinforcements are preferably of such small cross section that, upon setting and shrinking of the concrete, any compression established therein due to their adhesion to the concrete will be immaterial and insufficient to cause any danger of cracking the concrete.

On the other hand, all the above described embodiments of the invention provide for a temporary prestressing reinforcement in the form of a single high tensile strength cable or alloy steel rod, which is easy to insert and remove and yet when in place same acts in conjunction with lower and upper plate-like members, such as at 38 and 42, to subject the concrete of the pile substantially throughout its length to very high compression, thus enabling the piles, even if of great length, to be hoisted in any desired position by a derrick without danger of breaking the concrete, and also permitting the piles to be driven with unusually heavy blows without cracking off the lower portions. And since this heavy prestressing member is to be used only temporarily, and may be used in other piles over and over again, the expense involved in making same of extra strength is of little ultimate consequence. Also, since such a single axially positioned prestressing member applies heavy pressure centrally of the lower and upper plate-like members 38 and 42 etc., the compression developed thereby in the concrete is substantially uniform throughout the cross section of the pile. Since all of the prestressing is accomplished uniformly by a single cable or other member, the labor involved in installing and removing such member or in replacing same with a smaller cheaper member, is slight as compared with certain prior proposals of placing numerous prestressed members about the perimeter of the pile. The latter proposals also have the disadvantage that it would be substantially impossible in practice therewith to insure the above described uniformity of compression of the concrete, particularly during the process of applying or removing tension to members.

The location of the prestressing member entirely within a bore in the concrete in accordance with this invention, enables the external surfaces along the sides of the pile to be clamped or otherwise gripped as desired during handling and placing of the pile, without danger of injuring the prestressing member. Also, during the driving of the pile, the prestressing member, internally located in the pile, is well protected by the concrete against injury in case the sides of the pile should engage rocks or other obstructions. Further, the prestressing member will maintain its full tension even though in handling a heavy long pile there should be some tendency for it to bend. That is, the prestressing cable or rod will, upon any tendency of the pile to bend, come into engagement with the internal side walls of the bore and thereby be retained substantially along the arc of the bend rather than being permitted to retain a straight line position, which would tend to decrease its length under those conditions, with consequent reduction of the desired heavy tension just at the time when such tension is most needed to prevent further bending and cracking of the pile.

Although certain particular embodiments of the invention are herein disclosed for purposes of explanation, various further modifications thereof, after study of this specification, will be apparent to those skilled in the art to which the invention pertains. Reference should accordingly be had to the appended claims in determining the scope of the invention.

What is claimed and desired to be secured by Letters Patent is:

1. In the prestressing and driving of a concrete pile, the combination of method steps which comprises forming an assembly of the pile with a removable reusable high tensile strength prestressing member positioned longitudinally within a bore in the pile, subjecting such member to heavy tension by force reacting against the concrete to subject same to heavy longitudinal compression during placing and driving of the pile, then removing and replacing such member by another member of less strength, and securing the latter member under heavy tension also reacting against the concrete to retain same under longitudinal compression.

2. In the prestressing and driving of a concrete pile, the combination of method steps which comprises forming an assembly of the pile with a removable reusable high tensile strength prestressing cable positioned longitudinally within a bore in the pile and secured at the lower end of the pile by a connection which is releasable upon turning the upper end of the cable in one direction, the strands of the cable being helically wound in a direction to become more tightly wound upon turning the upper end of the cable in said direction, subjecting such cable to heavy tension by force reacting against the concrete to subject same to heavy longitudinal compression, maintaining such tension during placing and driving of the pile, then removing such cable and replacing same by another of less strength and having its strands helically wound in the opposite direction, applying turning force to the upper end of such other cable to cause its lower end to engage said connection and applying tension to the upper end of such other cable by force reacting against the concrete to again subject same to longitudinal compression.

3. In the prestressing and driving of a concrete pile having a longitudinal bore for containing a removable high tensile strength prestressing member, the combination of method steps comprising: forming an assembly of the pile with such member in the bore and secured

at the lower part of the pile by a connection which is releasable by turning movement of the upper end of the member, applying at the upper end of the member tensioning force reacting against the upper end of the pile and thereby subjecting the pile to longitudinal compression, securing the upper end of the member in such tensioned condition to the upper end of the pile, then placing and driving the pile in the desired position in the earth, thereafter releasing the upper end of the member to release such tension and applying turning force to the upper end of the member to release said connection, replacing said member in the bore by another such member having less strength, turning the upper end of the latter member to cause its lower end to be secured in said connection, then tensioning the latter member by a force reacting against

the upper end of the pile and thereby again subjecting the pile to longitudinal compression, and securing the upper end of the latter member in such tensioned condition to the upper end of the pile.

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