METHOD OF INSTALLING PILES FOR RESISTING UPWARD SOIL MOVEMENTS

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Fig. 7

Fig. 8

Fig. 9

3 Sheets-Sheet 3

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This invention relates to pile and foundation constructions and methods for installing same in such form that same will provide effective means not only for the usual purpose of supporting buildings or other structures, but also the additional purpose of preventing undesired displacement and upward movements of the soil through which the piles are driven.

In the construction of foundations for large buildings and other purposes, under certain design conditions, deep piles must be excavated to provide space for sub-basement foundations. Where the soil in which such foundations are to be constructed is of an unstable nature such that it will move objectionably under differences in pressure and where structures exist near or adjacent to the construction site so as to be endangered by the consequent relief of soil pressures in the vicinity, it may be necessary to make provision against upheavals of the soil in the areas where deep foundations are being constructed.

Heretofore when such problems have arisen, it has oftentimes been the practice to install a caisson such that it will be provided at its lower portion with a bell formation at the level of the hardpan layer in the earth, such caisson being reinfected down into the bell formation and arranged in such a way that the uplift forces in the surrounding earth are transferred to and resisted by the caisson shaft when the uplift pressure of the earth is applied to the base slab of the foundation at the top of the caisson. The uplift pressure thence being transferred down to the bell formation, and upward movement of the latter being in turn resisted by the load of clay or other earth thereupon.

However, the installation of such caissons is often not possible because of inconveniences and expense factor or because of the soil conditions at the hardpan level, which may be of granular or permeable character, not suited for constructing the bell formation particularly in the presence of water.

In accordance with the present invention, the above-mentioned problem is overcome by controlling the upheaval of the surrounding earth by the use of piles or the like of a type which will herein be referred to as "uplift piles," that is, piles or the like which are so constructed and installed as effectively to resist the upward movement of the surrounding soil by anchoring the lower ends of the piles or pile groups in bedrock, while the upper ends are anchored in the concrete footing for the structure being built thereon. In accordance with preferred forms of the invention, with the lower ends of the piles anchored in bedrock, post-tensioned reinforcing means is provided, such means being anchored with respect to the bedrock and extending up through the pile to the region of the top of the piles and there anchored with respect to the concrete footing. Thus any upward pressures which tend to be applied by the soil surrounding the pile to the underside of the concrete footing, will be effectively resisted, because the concrete footing will be effectively anchored by the post-tensioned pile structures to the bedrock below the soil. Also to some degree, since the pile is securely anchored against rising, it will resist rising of the surrounding soil by reason of frictional resistance of the soil against the sides of the pile end by reason of the pressure of the soil against the boot on the lower end of the pile shell. Danger to any surrounding buildings or structures, due to the tendency of the soil to shift into the area or pit for the new construction, will thus be prevented, because such soil will be held against upheaval and thus retained against release of its pressure which holds in place the soil adjacent the surrounding building foundations.

The invention makes possible pile constructions which can carry out the above-mentioned purposes while making possible increased speeds of foundation construction with reduced costs and without interfering with the usual purpose of normal piles of providing reliable load-bearing supports firmly resistant against the heavy downward pressures of buildings or other structures when completed and resting thereon.

Various further and more specific objects, features and advantages of the invention will appear from the description given below, taken in connection with the accompanying drawings, illustrating by way of example preferred forms of the invention.

In the drawings:

FIG. 1 is a vertical sectional view of a typical pile and foundation installation embodying the invention;
FIG. 2 is a view showing the lower end portion of one of the piles partially in section, and a preferred means for anchoring same in bedrocks;
FIG. 3 is an enlarged view of one typical and possible form of anchorage means for the lower end of the pile, this view being shown in section taken substantially along line 3—3 of FIG. 5;
FIG. 4 is an elevational view of the lower end portion of said anchorages means;
FIG. 4a illustrates in perspective certain of the separate portions of the assembly of FIG. 4;
FIG. 5 is a horizontal sectional view taken substantially along line 5—5 of FIG. 4;
FIG. 6 is a horizontal sectional view substantially along line 6—6 of FIG. 3;
FIG. 7 is a vertical sectional view of a portion of the concrete footing for a building and also showing in vertical section the upper portion of the pile cast thereon, together with the upper end anchorage means and tension-applying means for the post-tensionable reinforcements extending up through the pile;
FIG. 8 is a top plan view of such upper anchorage and post-tensioning means;
FIG. 9 shows an alternative construction for the upper portion of the pile and with the reinforcement-anchoring and tension-applying and adjusting means located above the concrete footing and resting thereon.

Referring now to FIG. 1, a plurality of pile shells are indicated at 10. As shown, these comprise helically corrugated sectional step-tapered pile shells of a well-known type, but it will be understood that pile shells or pipe of various other forms may be used.

When necessary, and before the installation is completed, the earth is excavated, as indicated at 11, down to a point just below where the tops of the piles are to be cut off or terminated, and to the full depth of the required foundation footing, care being taken that the sides of the excavation are suitably supported or braced to protect the surrounding building foundations or utilities from damage due to shifting of the soil.

The pile shells 10 may be installed at the desired locations by the procedure of wet rotary pre-excavation, followed by the installation of the shells into the wet rotary pre-excavation holes, and then driving the shells to refusal through the clay or other soil indicated at 12, and into the hardpan below, as indicated at 13. In installing such shells, methods may be followed like or similar to those disclosed in the U.S. patent to Linton Hart, No. 2,663,152, granted December 22, 1953. As the next step, an inner sleeve as shown at 14 in FIG. 2, is installed in each pile shell 10, such sleeve being provided on its ex-
terior with suitable guide fins at various points, two of which are indicated at 15, to insure that it will remain approximately concentric with the shell 10. The shells when driven are, in accord with usual practice, provided at their lower ends with suitable closure plates or so-called boots. In the particular form shown in FIG. 2 (although other forms may be used) the boots may comprise circular discs as at 16 secured in place as by a plow ring or the like 17, welded thereto and to the lower edge of the pile shell. When being installed, it will be understood that this boot plate has no central aperture, but a central opening for the upper end of the shell.

After installation of the inner sleeve 14, concrete as at 18 is introduced into the shell around the outside of the sleeve 14 until the space between the two is solidly filled, thus forming a solidly filled pile shell, except for the center core, through which subsequent operations hereinafter described are accomplished.

Suitable drilling means is now introduced down into the sleeve 14 for drilling a central aperture as at 19 through the boot plate 16. Then an additional tube as at 20, which may be formed of telescoping sections, may be set in place and lowered or the hardpan or other soil and eventually lowered, if desired, for a short distance into the bore hole to be formed in the bedrock 21. The tube 20 acts as a connecting tube between the lower end of the pile per se and the bore hole which is to be formed in the bedrock, but in some cases the character of the hardpan or soil may be such that the tube 20 may be dispensed with.

After the hole 19 has been drilled through the boot 16, and the tube 20, if used, has been lowered down through this hole, then by drilling or chipping, the bore hole is carried down through the hardpan or the refusal soil below the lower end of the pile shell, and thence, for example by using a milling bit or other suitable bit, the hole is drilled into the bedrock 21 for a suitable distance to provide for adequate engagement of the lower anchorage assembly hereinafter described with the rock in the bore hole, and to assure that uplifting forces on the pile will be effectively resisted.

The uplift pile assembly is now ready to receive the lower anchorage assembly, the details of one suitable example of which, among other possibilities, are shown in FIGS. 4–6 inclusive. Such assembly comprises one or preferably a plurality of elements 23 in the form of steel rods or preferably cables, as shown in the drawings, these elements being securely attached at their lower ends in nose portions 24 by any suitable known form of anchorage material, indicated at 25. A plurality of wedge bars as at 26 respectively are slipped over each cable or rod so that they will extend down at their lower ends into contact with the nose portions, these wedge bars being formed with side surface portions as at 27 which will come into contact with each other as shown in FIG. 5.

A pipe or tremie 28 is now slid down centrally within the assembly to provide a withdrawable conduit for introducing grout. Finally, in making up the anchorage assembly, gripper bars as at 29 are placed in the spaces of sector-shaped cross-section between each pair of the wedge bars 26. The assembly of parts may then be tied together in any suitable manner as by surrounding same at various points by strands of soft iron wire or rope, or any other simple securing means, to retain the parts together until the assembly is lowered into place. The nose portions 24 engage the bottom of the bore hole. The cables or rods 23 at their upper ends may then be cut off at proper length for attachment to the upper anchorage assembly hereinafter described.

Such upper anchorage assembly, one typical and suitable form of which among other possibilities is shown in FIGS. 7 and 8, may now be installed. This assembly as shown comprises suitable screw anchor means as indicated at 30, one being applied to the upper end of each of the cables or rods 23. Such screw anchors may be of a suitable known type, acting to secure the upper ends of the cables or rods 23 to screw elements as at 31. If desired, before the screw anchors 30 are put in place, a supporting plate 32 may be slipped over the upper ends of the cables in position to rest upon surface 33 of the concrete within the upper end of the pile shell 10. Then after the screw anchors are secured in place on the cables, they may be surrounded by a casing 34, welded, if desired, at its lower edge to the supporting plate 32 and having welded to the top thereof a cover-plate 35. Then lock washers 36 are placed over the upwardly protruding threaded portions of the screw elements 31 and nuts 37 are screwed down in place thereon.

Each of the cables or rods 23 is then tensioned by screwing down the nuts 37. The cables or rods may be tensioned singly or in pairs, or all simultaneously as preferred. After the tensioning is done, the upper ends of the pile shell 10 may then be lowered to a point at the cement footing as shown at 50 in FIG. 9 before the post tensioning of the piles is carried out. In this case, the concrete footing may be poured just prior to tensioning of the piles.

At this stage, cement grout may be introduced down through the pipe 28 under pressure and by the use of suitable known grouting procedure, so that as said pipe is raised, grout will penetrate and become set in the cavities between the various parts of the lower anchorage means for the respective post tensioned cables or rods 23. A plurality of wedge bars 26 engage the rock laterally and in the bedrock formation. Thus further upward movement of the wedge bars 26 and of the nose portions 24, as well as of the rods or cables 23, will be prevented and the latter will all become fixed and anchored at their lower ends and thus heavily post-tensioned by reason of the fact that the upper ends thereof are secured under heavy tension in the upper anchorage means above described.

In some cases, it may be preferable to pour the concrete footing as shown at 50 in FIG. 9 before the post-tensioning of the piles is carried out. In this case, the
pyle shell as at 10' may extend up to the level of the top surface of the footing and with a top anchorage assembly as indicated at 51 positioned to rest upon the top surface of the concrete in the pyle shell, and also on the surrounding top surface of the footing, if desired. The assembly 51 may be otherwise similar to that shown in FIG. 7. With this arrangement it will be possible to adjust and readjust the degree of post-tensioning as may be required from time to time as conditions change during the construction work and as the construction of the building on the footing proceeds.

Although certain particular embodiments of the invention are herein disclosed for purposes of explanation, 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. Method of installing a pile construction adapted to support a structure and also to resist upheaval of the soil surrounding the pile, which method comprises: introducing a pile shell down to a firm bearing in the earth; introducing a filling of concrete in said shell, but leaving a hole extending downward therethrough; introducing drilling means through said hole and boring therewith a hole down for a substantial distance into bedrock as well as through any earth intervening between the lower end of the pile and said bedrock; withdrawing the drilling means; introducing an assembly including anchorage means for engaging the bedrock in the hole bored therein and for resisting upward displacement of said assembly, said assembly including a post-tensionable element or elements extending from such anchorage means up to the top of the pile shell; providing anchoring means at the upper end of said element or elements and applying and maintaining tension in said element or elements at least substantially equal to the upheaval forces which the pile construction is to resist, such tension being maintained between said lower anchorage means and the upper portion of the pile which becomes post-stressed thereby under compression.

2. Method of installing a pile construction adapted to support a structure and also to resist adjacent soil upheaval, which method comprises: driving a booted pile shell down to a firm bearing in the earth; introducing a pipe into said shell and extending down to the boot therein; introducing a filling of concrete into the space between said pipe and shell; using bore means extending down through said pipe for boring therewith a hole through the boot and down for a substantial distance into bedrock as well as through earth intervening between the boot and such bedrock, a connecting tube being introduced effectively to connect said pipe with the hole bored in the bedrock; introducing through said pipe, tube and hole an assembly including anchorage means for engaging the bedrock in the hole bored therein and for resisting upward displacement of said assembly, said assembly including a post-tensionable element or elements extending from such anchorage means up to the top of the pile shell; providing anchoring means at the upper end of said element or elements and applying and maintaining heavy tension in said element or elements between said lower anchorage means and the upper portion of the pile which becomes thereby post-stressed under compression.

3. Method of installing a pile and concrete footing construction adapted to support a structure and also to resist upheaval of the soil surrounding the pile, which method comprises: driving a pile shell into the earth; and introducing a filling of concrete in said shell, leaving a hole therethrough, such concrete being allowed to set in the shell to provide a rigid pile; using drilling means extending downward through said shell and boring therewith a hole down for a substantial distance into bedrock as well as through any earth intervening between the lower end of the pile and such bedrock; casting in engagement with the upper end of the shell and the filling of concrete, a concrete footing for supporting said structure and bearing against a substantial area of the surrounding soil, such footing and filling being affixed to one another; introducing an assembly including anchorage means for engaging the bedrock in the hole bored therein, said assembly including a post-tensionable element or elements extending from such anchorage means up to the top of the pile shell; providing anchoring means at the upper end of said element or elements and applying and maintaining a heavy tension in said element or elements between said lower anchorage means and the upper portion of the pile, the upper end of the anchoring means being exposed to permit adjustment of said forces; and the pile becoming post-stressed under compression upon tensioning said element or elements.

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