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Pile and Pile Installation Method

5       The invention relates to a drilled pile and a method of installing such a pile.

10       It is known to provide drilled piles - generally known as minipiles - having a diameter in the range from 150 to 250 mm and a load carrying capacity up to about 1400 kN. Working loads up to about 600 kN are standard. Minipiles generally consist of steel reinforcement embedded in grout. Such minipiles can be installed to depths in excess of 30 m through many types of soil and  
15       rock and are particularly useful for projects where access is difficult or space restricted. They are used, for example, for underpinning sensitive buildings, for building extensions and for new constructions. However, minipiles do not provide a solution to foundation  
20       problems where the piles need to have a load carrying capacity substantially in excess of the normal maximum capacity of 1400 kN. In those circumstances, engineers have to consider alternatives such as displacement piles which are driven into the ground by hammering, or large  
25       diameter bored piles. These alternatives are not always acceptable or even possible, however, because of the associated vibration, ground disturbance and noise, or because there is insufficient space for the access of large equipment.

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      Viewed from one aspect the invention provides a drilled pile having a diameter greater than 300 mm and an allowable load capacity exceeding 2500 kN, which load capacity derives mainly from a bundle of longitudinal  
35       members comprising solid steel bars located in a drilled hole.

Viewed from another aspect the invention provides a method of installing a pile, comprising drilling a hole and inserting therein a pile having a diameter greater than 300 mm and an allowable load capacity exceeding  
5 2500 kN, which load capacity derives mainly from a bundle of longitudinal members comprising solid steel bars.

Because the pile is drilled there can be a minimum  
10 of ground disturbance and noise, whilst a high load capacity can be achieved.

Preferably the bundle of longitudinal members includes a steel grout tube, which may be of  
15 substantially the same diameter as the solid steel bars. This may be used to introduce grout into the drilled hole, preferably as a post grouting step after the hole has already been grouted by a tremie method. The steel grout tube is particularly advantageous in ensuring that  
20 no voids exist within the pile or between the pile and the ground. The steel grout tube may for example be an outer tube-a-manchette grout tube.

In the preferred embodiments, the solid steel bars  
25 have a total cross-sectional greater than 15 000 mm<sup>2</sup>. Thus, three or four round bars of 90 mm diameter may be provided, to give total cross-sectional areas of about 19 100 mm<sup>2</sup> and 25 500 mm<sup>2</sup> respectively.

30 It may be possible to arrange the solid steel bars in various ways. For example, if the bundle of longitudinal members comprises four members, these may be arranged in a square. Preferably, the bundle of longitudinal members comprises a group of inner members  
35 arranged substantially centrally of the bundle, and a plurality of outer members arranged outwardly of the group of inner members. In a preferred embodiment the

bundle of longitudinal members comprises four inner members arranged about the central longitudinal axis of the bundle such that when viewed in cross-section their centres define the corners of a square, and four pairs of outer members disposed outwardly of the inner members, each pair of outer members being arranged such that when viewed in cross-section the corners of a square are defined by their centres and the centres of the two adjacent inner members. Such an arrangement can fit neatly into a circular drilled hole. Where a steel grout tube is provided, this is preferably one of the inner longitudinal members, so that grout can be injected near the central axis of the bundle. In a preferred method a grout tube is positioned in a space between adjacent pairs of outer longitudinal members. It may have a diameter smaller than the solid steel bars so that it fits easily in the available space and it may be made of plastics such as PVC. The grout tube may be used to carry out initial grouting by the tremie method. Preferably, two such grout tubes are provided in diagonally opposed locations, but this is not essential.

Preferably the longitudinal members are laterally spaced from each other by spreaders provided at longitudinal intervals. The spreaders may be in the form of grids having openings corresponding to the diameter of the longitudinal members. The grid may have square shaped openings for receiving the inner longitudinal members and U-shaped openings for receiving the outer longitudinal members. In order to keep the bundle of longitudinal members central in the drilled hole, at least one (and preferably more than one) of the spreaders may have a plurality of guide members. Each guide member may be in the form of a curved bar or plate extending longitudinally and arranged to engage the wall of the drilled hole or more usually the wall of a casing placed in the drilled hole. A spreader may for example

have four guide means at 90° intervals.

It is preferred for the longitudinal members to be substantially circular in cross-section, for example of 50 mm diameter. The solid bars may include ribs to enhance their grip in grouting material. The removable grout tube or tubes may have a diameter of 20 mm. The pile may for example have a diameter up to 800 mm, achieving a load capacity in excess of 5000 kN. A preferred pile has a diameter of between 400 and 450 mm. This can achieve a load carrying capacity in excess of 3700 kN.

At least in its preferred forms, more than 60% of the allowable load capacity of the pile is derived from the bundle of longitudinal members comprising solid steel bars. In one preferred embodiment, about 75% of the allowable load capacity is so derived.

A preferred embodiment of the invention will now be described by way of example and with reference to the accompanying drawings, in which:

Figure 1 is a view of a pile according to the invention installed in the ground;

Figure 2 is a cross-section on the lines II-II of Figure 1;

Figure 3 is a cross-section on the lines III-III of Figure 1;

Figure 4 is a cross-section on the lines IV-IV of Figure 3; and

Figure 5 is a perspective view of part of the pile before it is installed.

The pile 1 comprises a bundle of eleven solid steel bars 2 of circular cross-sectional shape and a hollow steel grout tube 3 also of circular cross-sectional shape. The bundle is received in a drilled or bored hole 11 lined by a perforated casing 10 down to bedrock level R. In this example, the solid bars 2 and the grout tube 3 have a diameter of 50 mm, the casing 10 has an outer diameter of 403 mm and the hole 11 has a diameter of 450 mm down to bedrock and 365 mm in the bedrock itself.

Each solid bar 2 is made up of a plurality of lengths connected end to end by couplers 4, for example of the Lenton (R.T.M.) type. As seen in Figure 1, the couplers 4 are offset such that adjacent solid bars 2 do not have a coupler at the same vertical position. There are thus twelve longitudinal members altogether, with a group of four inner members arranged about the central longitudinal axis of the bundle, and four pairs of outer members disposed outwardly of the inner members. The grout tube 3 is one of the inner members. The longitudinal members are laterally spaced from each other by spreaders 5 provided at longitudinal intervals of e.g. 4000 mm. Each spreader is in the form of a grid defining four square openings for the four inner longitudinal members and, outwardly thereof, eight U-shaped openings for the outer longitudinal members. As seen in Figure 2, each spreader 5 has grid elements 6 which pass through the central longitudinal axis of the bundle and extend radially beyond the periphery of the bundle. As seen in Figure 5, the grid elements 6 have at each radial end a longitudinally extending and curved guide member 7 for keeping the bundle central in the casing 10 and the drilled hole 11. A plurality of links 8 are provided at longitudinal intervals, for example 300 mm, for holding the longitudinal members together.

A pair of grout tubes 14 are each located in a corner space between adjacent pairs of outer longitudinal members. The tubes 14 are provided at diagonally opposite corners and have a diameter smaller than that of the longitudinal members so that they can fit neatly into the corner spaces. In this example, the tubes have a 20 mm diameter and are made of PVC.

The pile is provided with a pile cap 9 consisting of a capping plate 12 and vertically arranged stiffener plates 13 welded thereto. Four holes 16 of e.g. 50 mm diameter are provided in the capping plate to allow access for the grout tubes 14 and a vibrator for the grout. Four windows 17 are provided in the stiffener plates to allow welding of the outer longitudinal members to the capping plate. The top of the drilled hole 11 is closed at ground level by a steel ring plate 15.

The method by which the pile is installed will now be described. A 450 mm hole 11 is drilled into the ground and is lined with the steel casing 10 having a nominal external diameter of 403 mm. The casing is terminated at the bedrock level R (if reached) and further drilling to penetrate typically 5500 mm into bedrock is carried out. The drilled hole is flushed and cleaned up by water and air. The bundle of longitudinal members, including the eleven solid steel bars 2 and the hollow steel grout tube 3, is installed in the hole, together with the two PVC grout tubes 14. The casing 10 is perforated with eight 7 mm diameter holes spaced at 45° intervals round its circumference at 2 meter vertical intervals.

The hole is filled with cement grout by a tremie method using the PVC tubes 14. This involves pumping grout into the tubes such that the grout is introduced

at the bottom of the pile at all times.

Before the tremie grout has set, post grouting is carried out by sealing the top of the casing and then  
5 lowering into the steel grout tube 3 an inner steel grout tube (not shown) having a diameter approximately half of that of the steel grout tube 3, hereinafter referred to as the outer tube 3. In this example, the inner tube has a diameter of 25 mm. The inner tube has  
10 an end portion formed with holes in the side wall and located between a lower seal in the form of a pair of rubber packers and an upper seal in the form of a pair of rubber packers. The outer tube 3 is formed with side openings (not shown) at vertical intervals, for example  
15 three 8 mm diameter openings at 1000 mm intervals. The side openings are covered by rubber sleeves. The combination of the outer tube 3 and the inner tube is known as a tube-a-manchette.

20 The inner tube is lowered down to the base of the pile and cement grout is introduced in the post grouting step until one of the following criteria is met:

- 25 (a) a pressure equal to twice the overburden pressure is reached;
- (b) grout seeps from the void between the casing 10 and the ground at ground level; or
- (c) the grout intake reaches 100 litres.

30 The above procedure is repeated by raising the inner tube and post grouting at 1000 mm vertical intervals up to 1000 mm below ground level.

In some versions of the pile, the outer casing 10  
35 may be removed before the grout in the pile has hardened.

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In the above description, the pile is described as being founded in rock, but it may alternatively be founded in soil.



CLAIMS

1. A drilled pile having a diameter greater than 300 mm and an allowable load capacity exceeding 2500 kN,  
5 which load capacity derives mainly from a bundle of longitudinal members comprising solid steel bars located in a drilled hole.
2. A pile as claimed in claim 1, wherein the total  
10 cross-sectional area of the solid steel bars is greater than 15 000 mm<sup>2</sup>.
3. A pile as claimed in claim 1 or 2, wherein the  
15 bundle of longitudinal members includes a steel grout tube of substantially the same diameter as the solid steel bars.
4. A pile as claimed in claim 3, wherein the steel  
20 grout tube is an outer tube-a-manchette grout tube.
5. A pile as claimed in any preceding claim, wherein  
the bundle of longitudinal members comprises a group of inner members arranged substantially centrally of the  
25 bundle, and a plurality of outer members arranged outwardly of the group of inner members.
6. A pile as claimed in claim 5, wherein the bundle of  
longitudinal members comprises four inner members  
arranged about the central longitudinal axis of the  
30 bundle such that when viewed in cross-section their centres define the corners of a square, and four pairs of outer members disposed outwardly of the inner members, each pair of outer members being arranged such  
that when viewed in cross-section the corners of a  
35 square are defined by their centres and the centres of the two adjacent inner members.



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7. A pile as claimed in claim 5 or 6 when dependent on claim 3 or 4, wherein the steel grout tube is an inner longitudinal member.
- 5 8. A pile as claimed in any preceding claim, wherein the longitudinal members are laterally spaced from each other by spreaders provided at longitudinal intervals.
- 10 9. A pile as claimed in claim 8, wherein at least one of the spreaders has a plurality of guide members for keeping the bundle of longitudinal members central in the drilled hole.
- 15 10. A pile as claimed in any preceding claim, wherein the longitudinal members are substantially circular in cross-section.
- 20 11. A method of installing a pile, comprising drilling a hole and inserting therein a pile having a diameter greater than 300 mm and an allowable load capacity exceeding 2500 kN, which load capacity derives mainly from a bundle of longitudinal members comprising solid steel bars.
- 25 12. A method of installing a pile, comprising providing solid steel bars with a total cross-sectional area greater than 15 000 mm<sup>2</sup>.
- 30 13. A method of installing a pile as claimed in claim 11 or 12, comprising introducing grout by means of a steel grout tube.
- 35 14. A method of installing a pile as claimed in claim 13, wherein the steel grout tube is an outer tube-a-manchette grout tube.



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15. A method of installing a pile as claimed in any of claims 11 to 14, comprising forming the bundle of longitudinal members as a group of inner members arranged substantially centrally of the bundle, and a plurality of outer members arranged outwardly of the group of inner members.

16. A method of installing a pile as claimed in claim 15, comprising forming the bundle of longitudinal members as four inner members arranged about the central longitudinal axis of the bundle such that when viewed in cross-section their centres define the corners of a square, and four pairs of outer members disposed outwardly of the inner members, each pair of outer members being arranged such that when viewed in cross-section the corners of a square are defined by their centres and the centres of the two adjacent inner members.

17. A method of installing a pile as claimed in claim 15 or 16 when dependent on claim 13 or 14, wherein the steel grout tube is an inner longitudinal member.

18. A method of installing a pile as claimed in claim 16 or 17, comprising introducing grout by means of a grout tube positioned in a space between adjacent pairs of outer longitudinal members.

19. A method as claimed in claim 11, comprising introducing grout by a tremie method, and then post grouting by introducing grout via a steel grout tube provided in the bundle of longitudinal members.

20. A method of installing a pile as claimed in any preceding claim, comprising providing spreaders at longitudinal intervals to space the longitudinal members laterally from each other.



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21. A method of installing a pile as claimed in claim  
20, comprising keeping the bundle of longitudinal  
members central in the drilled hole during insertion  
thereof, by means of a plurality of guide members  
5 provided on at least one of the spreaders.

22. A method of installing a pile as claimed in any of  
claims 11 to 22, wherein the longitudinal members are  
substantially circular in cross-section.

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23. A drilled pile substantially as hereinbefore  
described with reference to the accompanying drawings.

24. A method of installing a pile substantially as  
15 hereinbefore described with reference to the  
accompanying drawings.