APPARATUS AND METHOD FOR ROTARY BORED DRILLING

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Abstract
Rotary drilling apparatus comprising at least one kelly bar, interlockable with one or more other kelly bars in end-to-end arrangement such that, in use, a rotational force applied to an uppermost kelly bar is transmitted to each of the kelly bars below it; a tool, for example an auger, having a bore therethrough in which the outer surface of one of said kelly bars can slideably engage; and lifting means for selectively raising and lowering said tool by sliding it over the outer surface of said kelly bars, whereby, in use, said tool is lowered by sliding it over said interlocked kelly bars and attached to a lowermost kelly bar so that a rotational force applied to said lowermost kelly bar is transmitted to the tool, characterised in that at least part of said lifting means is capable of rotation about a longitudinal axis of said kelly bar for synchronous rotation therewith.
APPARATUS AND METHOD FOR ROTARY BORED DRILLING

[0001] This invention relates to the field of rotary bored drilling, an particular but not exclusively to rotary bored piling in low headroom and restricted access conditions, for example where piling is required under bridges or inside existing building structures.

[0002] Bored piling is normally carried out by one of three known techniques, each of which is described in turn below.

[0003] Tripod Bored Piling

[0004] Tripod bored piling is a percussive method in which a tool is repeatedly dropped from a tripod structure in order to create a bore. This method is very labour intensive and slow. For this reason, the market price per metre of pile is typically three or four times the cost of using one of the other two methods described below.

[0005] However, this method does have the advantage of being feasible in low headroom and restricted access conditions.

[0006] Rotary Bored Piling with Kelly Bar

[0007] Rotary bored piling employs a telescopically extendible kelly bar to rotate a short length of auger into the ground. FIGS. 1A-1C show a typical arrangement using this method.

[0008] A short length of auger 1 is attached to the lower end of an innermost kelly bar 2 which in turn is suspended from a kelly rope 3. A number of interlockable kelly bars 4, 5 are nested inside one another as illustrated in FIG. 1A, each kelly bar element being telescopically extendible as shown in FIG. 1B to enable a bore to be drilled in discrete lengths.

[0009] Each of the kelly bars 4, 5 interlocks with the kelly bar inside it so that rotational force applied to the outer kelly bar 4 is translated through the interlocking bars to the innermost kelly bar 2 and hence the auger 1.

[0010] In use, the kelly bars are raised and lowered by the kelly rope attached via a swivel. The digging is commenced by excavating a discrete length of bore equivalent to the length of the auger 1. The auger and excavated soil are removed to the surface and the bore is then progressed by telescopically extending the kelly bars, one by one, to a maximum depth limited by the number and length of kelly bars available.

[0011] Limitations are apparent with the use of this method in low headroom conditions.

[0012] In low headroom conditions (typically less than 4 metres) this method becomes impractical because the length of each kelly bar must necessarily be shortened to fit into the low headroom environment. This problem can be somewhat alleviated by increasing the number of kelly bars nested inside one another to provide further depth to which the bore may be drilled, however, the more nested kelly bars there are, the greater the diameter of the nested kelly bars which, in itself, may be difficult to manage in restricted access conditions.

[0013] Continuous Flight Auger Piling

[0014] Continuous flight auger piling employs an auger which has flights over its full length. In use, the auger is rotated into the ground to the full depth of the intended bore and then withdrawn in one operation.

[0015] The depth of bore which can be drilled using this method is limited to the length of the auger employed. It is possible to extend the depth of the dig by adding additional lengths of auger, although this becomes increasingly less cost effective with reduced headroom, on account of the increased number of auger extensions and therefore of the time required to add and remove each auger extension.

[0016] Using this method, the auger is required to rotate against the frictional resistance of the soil over the entire length of the auger. Likewise, when the auger is extracted from the ground, the frictional resistance of the whole auger’s length must be overcome.

[0017] The diameter of the bore which may be drilled is dependent upon the available rotational torque to drive the auger, and inversely dependent upon the length of the bore to be drilled; accordingly, the diameter and depth which may be bored by the continuous flight auger method is generally much less than could be achieved by a machine of equivalent size and torque employing a rotary piling technique with kelly bar.

[0018] In low headroom or restricted access conditions, the site constraints may limit the size and weight of the construction plant. Accordingly, the diameter and depth of any bore is likely to be significantly less than could be achieved in unrestricted conditions.

[0019] A disadvantage of this technique, particularly in low headroom or restricted access conditions, is that if the auger hits an obstruction whilst drilling it is generally difficult to overcome such an obstruction with lightweight equipment. Furthermore, the auger which completely fills the bore prohibits the use of chiselling techniques which are available to methods which produce an open hole (i.e. the tripod and rotary piling with kelly bar).

[0020] Some of the above-mentioned disadvantages are alleviated by the apparatus described in U.S. Pat. No. 4,530,410 (Kay) in which there is described drilling apparatus comprising a plurality of kelly bars being inter-lockable, the lower portion of each kelly bar being designed to fit into the top end portion of the next lower kelly bar. The apparatus further comprises an auger being slidingly engaged on the kelly bars but driven in rotation by the bars. There is provided lifting means in the form of a carrier, from which the auger is suspended, which encircles the kelly bars but in operation is held against rotation with the kelly bars.

[0021] A number of problems are apparent with the apparatus described in Kay. Firstly, during drilling where no liner is used, the system relies on friction of the outer end portion 55 of the carrier lever 52 with the side of the hole to prevent rotation of the carrier with the auger. It is possible that friction may not be sufficient and the carrier may try to rotate which, in turn, will twist the hoist cable. The carrier is only attached by one hoist cable to the side of the kelly bar and therefore is out of alignment with the load to be lifted. This may cause difficulties owing to the resultant horizontal force pushing the kelly bar and auger laterally against the side of
the hole. Furthermore, the clamping arrangement between the carrier and the auger is relatively complex and reattachment of the carrier after drilling may not be successful.

Furthermore, the joints between the kelly bars may be lax as they simply comprise a square section spigot located in a square section socket. Any laxity of one joint is obviously multiplied over the whole length of the drill string which is extremely undesirable.

Furthermore, as specified in claim 1 of Kay, the auger is slidable lengthwise of the kelly bars but is not rotatable relative thereto. This means that, during drilling, it is principally the weight of the auger alone which produces the downward force necessary to penetrate the soil to enable the auger to dig. This would clearly be a problem if it is desired to drill a hard strata and insufficient downward force is available to force the auger into the ground.

There is thus a need for a drilling method that can be utilised in low headroom and restricted access conditions and which can alleviate the above described problems.

Throughout the present application, the terms “vertical”, “lower”, “lowermost”, “upper” and “uppermost” are relative to the orientation of the bore which it is intended to drill with the apparatus. The lowermost end of the apparatus is therefore the end nearest the bottom of the bore and the uppermost end of the apparatus is the end nearest, the top of the bore or ground level.

According to a first aspect of the present invention, there is provided rotary drilling apparatus comprising

- at least one kelly bar, interlockable with one or more other kelly bars in end-to-end arrangement such that, in use, a rotational force applied to an uppermost kelly bar is transmitted to each of the kelly bars below it;
- a tool, for example an auger, having a bore therethrough in which the outer surface of one of said kelly bars can slide engageably and
- lifting means for selectively raising and lowering said tool by sliding it over the outer surface of said kelly bars,

whereby, in use, said tool is lowered by sliding it over said interlocked kelly bars and attached to a lowermost kelly bar so that a rotational force applied to said lowermost kelly bar is transmitted to the tool, characterised in that at least part of said lifting means is capable of rotation about a longitudinal axis of said kelly bar for synchronous rotation therewith.

Preferably, said lowermost kelly bar is provided with cutting teeth at its lowermost end.

Preferably the apparatus further comprises a tool locking mechanism for locking said tool to said lowermost kelly bar, said tool locking mechanism being engaged by rotation of said lowermost kelly bar relative to said tool in the drilling direction. Ideally, said locking mechanism comprises an inclined keyway on a said lowermost kelly bar engageable with a keyway on the bore of said tool. In engaging the locking mechanism by a partial rotation of the lowermost kelly bar relative to the tool, the weight of the entire apparatus can act through the tool in order to penetrate harder strata than would otherwise be possible.

Preferably, each kelly bar is provided with a longitudinally-extending key.

Preferably, each kelly bar is provided with a spigot at one end and a complementary socket at the other end so that, in use, the spigot of one kelly bar engages in the socket of another. Ideally, said spigot is at the uppermost end of each kelly bar and said socket is at the lowermost end.

Preferably, the spigot of one kelly bar is, in use, retained in the socket of another kelly bar by a kelly bar locking means which creates a compressive force between mating faces of said kelly bars.

In a preferred form, said kelly bar locking means comprises folding wedges. Alternatively, said kelly bar locking means comprises tapered inserts moveable into correspondingly-shaped apertures in the socket of one kelly bar and the spigot of an adjacent kelly bar so as to effect vertical movement of said kelly bars relative to one another and a compressive force therebetween.

Preferably, each kelly bar is of substantially circular cross-section, apart from said key.

Preferably, said lifting means comprises hoist ropes lifted by hydraulic lifting means. Ideally, said hydraulic lifting means includes a rotary hydraulic seal.

According to a second aspect of the invention, there is provided a method of drilling a bore using rotary drilling apparatus substantially as described above.

Preferred embodiments of the present invention will now be more particularly described, by way of example only, with reference to the accompanying drawings in which:

FIG. 1A is a side view, partly in section, of prior art apparatus employing telescopic kelly bars;

FIG. 1B is a side view, partly in section, of the apparatus of FIG. 1A with the telescopic kelly bars extended;

FIG. 1C is a section on line C-C in FIG. 1B;

FIG. 2 is a perspective view of two kelly bars of the type employed in the present invention;

FIG. 2A is a cross-sectional view on line A-A in FIG. 2;

FIG. 2B is a cross-sectional view on line B-B in FIG. 2;

FIG. 3 is a perspective view of two kelly bars of the type employed in the present intention, interlocked in end-to-end arrangement;

FIG. 4 is a perspective view of the lowermost kelly bar employed in the present invention;

FIG. 5 is a perspective view of an auger;

FIG. 6A is a section on lines A-A in FIGS. 4 and 5 when the lowermost kelly bar and auger are assembled together;

FIG. 6B is a section on lines B-B in FIGS. 4 and 5 when the lowermost kelly bar and auger are assembled.
together, FIGS. 6A and 6B illustrate the locking effect achieved upon rotation of the lowermost kelly bar in the drilling direction.

[0052] FIG. 7 is a perspective view showing detail of the interface between the adjacent kelly bars shown in FIG. 3;

[0053] FIG. 8 is a view on Arrow A of FIG. 7;

[0054] FIG. 9 is a cross-sectional view on line B-B in FIG. 8;

[0055] FIG. 10A is a side view of the folding wedges arrangement (open);

[0056] FIG. 10B is a side view of the folding wedges arrangement (closed);

[0057] FIG. 11 is a cross-sectional view of an alternative embodiment on line B-B in FIG. 8;

[0058] FIGS. 12A-12C are schematic views of the apparatus in use, showing the raising and lowering of the auger; and

[0059] FIG. 13 is a side sectional view of the hydraulic lifting means.

[0060] The rotary bored drilling method of the present invention uses a kelly bar system to drive a short auger attachment. As with the prior art kelly bar method described above, the method of operation is to excavate or drill a bore incrementally to minimise the forces on the apparatus and therefore to allow a larger diameter bore to be formed than could otherwise be possible with an equivalent continuous flight auger apparatus. The present intention is particularly applicable in low headroom and restricted access conditions in which the prior art methods suffer from the disadvantages described above. Instead of utilising telescopically extendible kelly bars as illustrated in FIGS. 1A-1C, the apparatus of the present invention utilises kelly bars of the type illustrated in FIGS. 2-3.

[0061] Each kelly bar 10 has a substantially circular cross-sectional shape with keys 25, 26 along its length, and is provided at its uppermost end with a spigot 11, having the splined cross-sectional shape shown in FIG. 2A. The lowermost end of the kelly bar 10 is provided with a socket 12 which is of complementary shape to the spigot so that, when two kelly bars 10, 10' are brought together in end-to-end arrangement as shown in FIG. 3, the spigot 11' of the lowermost kelly bar 10' is a close fit within the socket 12 of kelly bar 10.

[0062] The lowermost region of each kelly bar 10, 10' is provided with a locking aperture 13, 13' and the uppermost region of each spigot 11, 11' is provided with a further locking aperture 14, 14'.

[0063] The kelly bars are secured together by inserting a locking means 15 into locking aperture 13 which, when the kelly bars 10, 10' are brought together, is suitably aligned with locking aperture 14' to allow the locking means 15 to be inserted into aperture 13.

[0064] FIGS. 7, 8 and 9 show in more detail how the kelly bars 10, 10' are locked together.

[0065] As shown in FIG. 9, the locking means may take the form of folding wedges 16 which can be inserted into aperture 13 in the direction indicated by the arrow in FIG. 9.

[0066] The folding wedges 16 are shown in more detail in FIGS. 10A and 10B. A conventional arrangement is shown in which base wedges 17, 18 are held together by a screw-threaded bolt 19. A top wedge 20 determines the overall thickness T of the folding wedge arrangement. By rotating the bolt head 21, the base wedges 17, 18 are drawn together by the turning of the bolt 19 until the position illustrated in FIG. 10B (the “closed” position) is reached. Clearly, in the closed position, the folding wedge 16 has a greater thickness T than in the open position illustrated in FIG. 10A.

[0067] Referring again to FIG. 9, the locking apertures 13 and 14' are slightly offset so that, as the bolt 1 of the folding wedges 16 is tightened, the apertures 13 and 14 are pulled into alignment. This ensures a secure joint between the kelly bars 10, 10', and makes the joint less prone to flex during the use of the apparatus of the present invention.

[0068] In an alternative embodiment, as shown in FIG. 11, the locking means may take the form of a bolt 19 connecting two square tapered inserts 17, 19'. Insert 17 is threaded to accept the threaded end of bolt 19'. Insert 18' is not threaded to allow free rotation of bolt 19' therein.

[0069] Insert, 8 is recessed to allow the head of the bolt 19' to be contained wholly within the body of the insert 18'.

[0070] The bolt head is a cap head screw 21 which may be tightened using an Allen key to draw the two inserts together.

[0071] Referring again to FIG. 11, the locking apertures 13 and 14', are slightly vertically offset from one another so that as the bolt 19' joining the tapered inserts 17' and 18' is tightened, the tapered inserts 17 and 18 force the apertures 13 and 14' into alignment and generate a compressive force between the mating faces of kelly bars 10, 10'.

[0072] This makes the joint between kelly bars 10, 10' far less prone to flex during the use of the apparatus of the present invention.

[0073] In the embodiment described herein, the kelly bars 10, 10' have a generally circular cross-sectional shape, however it will be appreciated that the kelly bars could be of any cross-sectional shape suitable for transmitting a rotational force and interlocking with a tool such as an auger (see further description below).

[0074] The kelly bar 22 illustrated in FIG. 4 is the kelly bar which, when the apparatus is in use, is lowermost in the bore which is being drilled. For clarity, this kelly bar 22 will be described as the “tool bar” as it is this kelly bar which needs to engage with a cutting tool when the apparatus is in use. The tool bar 22 has, at its uppermost end, a spigot 11 which can be received into the socket (not shown) of the kelly bar above.

[0075] At the lowermost end of the tool bar 22 are cutting teeth 23 and a short length of auger flight or other shape as desired. Cutting teeth 23 and auger flight 24 are integrally formed with the tool bar 22. The auger flight 24 does not fore the main cutting tool when the apparatus is in use, rather the cutting teeth 23 and auger flight 24 serve to assist in the penetration of the main tool by cutting the central portion of the bore. The keys 25, 26 of the tool bar have an inclined offset portion 27 which, in use, forms a tool locking mechanism which locks the main tool to the tool bar 22.
FIGS. 5, 6A and 6B show the main tool, in this case an auger. The auger 30 differs from conventional augers in that, instead of being permanently fixed to the lowermost Kelly bar (the tool bar), it is slideable over the Kelly bars and can hence be raised and lowered into the bore at will. When it is desired to drill, the auger 30 is lowered and fixed to the tool bar 22 using the tool locking mechanism (i.e. the offset portion 27 shown in FIG. 4), so that the tool bar 22 can transmit rotational force to the auger 30.

When the tool bar 22 and auger 30 are assembled together, as illustrated in FIGS. 6A and 6B, relative rotation of the tool bar to the auger in a locking direction causes the auger 30 to become locked to the tool bar 22 by interaction of the offset key 27 with the keyway 35. The locking direction is the same direction of rotation as the drilling direction. Thus, once drilling begins, the rotation of the tool bar 22, transmitted to the auger 30, only serves to engage the two more closely together.

The locking mechanism 27 allows a vertical force from the weight of the Kelly bars and the drilling machine (i.e. the apparatus as a whole) to be applied to the auger to assist penetration when digging hard strata.

When it is desired to separate the auger 30 from the tool bar 22, the tool bar 22 is rotated in the reverse direction (i.e. the non-drilling direction) so that the offset key 27 disengages from the keyway 35.

The auger 30 can then be hoisted to the top of the bore, over the outer surface of the interlocked Kelly bars.

The auger 30 comprises a shaft 31 on which are formed auger flights 32. The uppermost end of the auger 30 is provided with hoist ropes 33 which are used to hoist the auger in and out of the bore.

As shown in FIGS. 6A and 6B, the shaft 31 has a bore 34 therethrough, whose internal surface is suitably sized and shaped to be engageable with the outer surface of the Kelly bars 10, 10', 22. The bore 34 need not be the same shape as the outer surface of the Kelly bars (in this case circular), so long as, when a Kelly bar rotates, the rotational force can be transmitted to the auger shaft 31.

The rotational force of the tool bar 22 is transmitted to the auger shaft 31 by means of the interaction between a keyway 35 on the internal surface of the auger shaft 31 and keys 25, 26 on the tool bar 22. Keys 25, 26 are longitudinal protrusions extending along the entire length of each Kelly bar 10, 10', 22.

As well as enabling a rotational force to be transmitted from a Kelly bar to the auger shaft, the bore 34 must also be of sufficient diameter to allow the auger shaft 31 to slide vertically with respect to the Kelly bars (i.e. along their longitudinal axis) The keys 25, 26 guide vertical movement of the auger 30 over the Kelly bars. The bore 34 must also be of suitable diameter and shape to allow partial rotation of the tool bar 22 relative to the auger 30 so as to lock the two together by means of the tool locking mechanism 27.

Lifting means are required to raise and lower the auger 30 using the hoist ropes 33. Ideally, hydraulic lifting means as illustrated in FIG. 13 are employed. In FIG. 13 which shows the rotary drive mechanism, shaded parts indicate parts of the drive mechanism and hydraulic lifting means which rotate, in use, with the Kelly bars and auger. Non-shaded parts remain stationary, in use, with respect to the Kelly bars and auger.

The rotary drive mechanism 50 comprises a winch mechanism 51 which winches the hoist rope 33. The winches 51 are attached to the rotary part of the drive mechanism 50 which is driven by a motor 52 via a ring gear 53. In order to permit an interface between the rotating (shaded) parts and non-rotating (unshaded) parts, a hydraulic seal 54 is provided so that hydraulic fluid can pass from a stationary supply to rotating parts of the apparatus e.g. the winches 51. The rotary drive mechanism 50 is attached to the mast 55 of a piling rig.

The operation of the piling apparatus will now be described with reference to FIGS. 12A-12C. The tool bar 22 is firstly held in position by the piling rig at the site where the bore is to be drilled. The shaft 31 of the auger 30 is slid over the outer surface of the tool bar 22, so that the auger 30 is positioned at the lowermost end of the tool bar 22 and is fixed thereto. A rotational force applied to the tool bar 22 by the piling rig’s drive mechanism is thus transmitted to the auger 30, causing drilling to occur.

As the bore increases in depth, the tool bar 22 will progressively move lower with respect to ground level and to the piling rig. Therefore, after a period of time, it will be necessary to attach a second Kelly bar to the tool bar 22. This is done by inserting the spigot 11 of the tool bar 22 into the socket 12 at the bottom of a Kelly bar 10 and locking the two Kelly bars together (for example, using the Kelly bar locking means illustrated in FIG. 9 or FIG. 11). This action can be repeated periodically as the bore increases in depth, adding more Kelly bars end-to-end.

FIG. 12A shows the auger 30 being lowered to the bottom of a bore 40 which has already been partly drilled. When it reaches the bottom of the bore 40, the auger 30 is fixed to the tool bar 22.

As shown in FIG. 12B, a rotational force applied to the uppermost Kelly bar by the piling rig’s drive mechanism (not shown) is transmitted down the bore, from the end of one Kelly bar to the next, until it reaches the tool bar 22 which, in turn, transmits the rotational force to the auger 30. Rotation of the auger 30 causes a digging action which increases the depth of the bore 40.

A significant problem with any continuous flight auger piling method is that excavated soil between the flights of the auger considerably increases the frictional resistance which must be overcome in order to continue drilling. The method of the present invention alleviates this problem as it is easy to raise the auger 30 to the surface, as shown in FIG. 12C, carrying with it a quantity of excavated soil 41. The excavated soil 41 can then be disposed of and the auger 30 returned to the bottom of the bore 40 whereby drilling can be continued. Such action would be more difficult with, for example a conventional continuous flight auger method, where the excavated soil is not removed until after the full depth of the bore has been drilled.

The method of the present invention is therefore much more efficient when used in restricted access or low headroom conditions as it will enable larger diameter piles to be bored than may be possible using conventional techniques. Furthermore, the incremental technique employed
produces a substantially open hole allowing chiselling techniques to be used to overcome hard strata or obstructions.

Although the invention has been described herein in relation to rotary bored piling, the invention could equally be used in other fields, for example, drilling in the oil industry.

1. Rotary drilling apparatus comprising
   at least one kelly bar, interlockable with one or more other kelly bars in end-to-end arrangement such that, in use, a rotational force applied to an uppermost kelly bar is transmitted to each of the kelly bars below it;
   a tool, for example an auger, having a bore therethrough in which the outer surface of one of said kelly bars can slidably engage; and
   lifting means for selectively raising and lowering said tool by sliding it over the outer surface of said kelly bars,
   whereby, in use, said tool is lowered by sliding it over said interlocked kelly bars and attached to a lowermost kelly bar so that a rotational force applied to said lowermost kelly bar is transmitted to the tool, characterised in that at least part of said lifting means is capable of rotation about a longitudinal axis of said kelly bar for synchronous rotation therewith.

2. Rotary drilling apparatus as claimed in claim 1 wherein said lowermost kelly bar is provided with cutting teeth at its lowermost end.

3. Rotary drilling apparatus as claimed in claim 1 or claim 2 further comprising a tool locking mechanism for locking said tool to said lowermost kelly bar, said tool locking mechanism being engaged by rotation of said lowermost kelly bar relative to said tool in the drilling direction.

4. Rotary drilling apparatus as claimed in claim 3 wherein said locking mechanism comprises an inclined keyway on a said lowermost kelly bar engageable with a keyway on the bore of said tool.

5. Rotary drilling apparatus as claimed in any of the preceding claims wherein each kelly bar is provided with a longitudinally-extending key.

6. Rotary drilling apparatus as claimed in any of the preceding claims wherein each kelly bar is provided with a spigot at one end and a complementary socket at the other end so that, in use, the spigot of one kelly bar engages in the socket of another.

7. Rotary drilling apparatus as claimed in claim 6 wherein said spigot is at the uppermost end of each kelly bar and said socket is at the lowermost end.

8. Rotary drilling apparatus as claimed in claim 6 or claim 7 wherein the spigot of one kelly bar is, in use, retained in the socket of another kelly bar by a kelly bar locking means which creates a compressive force between mating faces of said kelly bars.

9. Rotary drilling apparatus as claimed in claim 8 wherein said kelly bar locking means comprises folding wedges.

10. Rotary drilling apparatus as claimed in claim 8 wherein said kelly bar locking means comprises tapered inserts moveable into correspondingly-shaped apertures in the socket of one kelly bar and the spigot of an adjacent kelly bar so as to effect vertical movement of said kelly bars relative to one another and a compressive force therebetween.

11. Rotary drilling apparatus as claimed in any of claims 5-10 wherein each kelly bar is of substantially circular cross-section, apart from said key.

12. Rotary drilling apparatus as claimed in any of the preceding claims wherein said lifting means comprises hoist ropes lifted by hydraulic lifting means.

13. Rotary drilling apparatus as claimed in claim 12 wherein said hydraulic lifting means includes a rotary hydraulic seal.

14. Rotary drilling apparatus substantially as described herein with reference to any appropriate combination of FIGS. 2-13.

15. Method of drilling a bore using rotary piling apparatus as claimed in any of the preceding claims.