

Directional Soil Coring and Sampling Apparatus and Method

Related Application

[001] The present invention claims priority to Singapore patent application no. 10202204047U filed on 19 April 2023, the disclosure of which is incorporated in its entirety.

Field of Invention

[002] The present invention relates to a directional soil coring and sampling apparatus and method. In particular, this invention relates to forward directional drilling to obtain underground soil samples.

Background

[003] A conventional directional core drilling method involves steering a drill head into a ground to create a pilot drill path according to a planned trajectory for mining minerals or prospecting for oil and gas; core samples of soil are then collected, for example, at the end of the planned trajectory for soil analysis. For this method to work, the soil has to be sufficiently stiff to provide a differential reaction at a steerable drill head in order to steer the drill head along the planned trajectory; it is thus unsuitable for soft soils. Besides a radius of curvature of the planned trajectory is often in the range of several kilometers; in urban built-up environment, there is space limitations and thus makes this conventional directional core drilling unsuitable for use in an urban environment.

[004] In an urban environment, another conventional method known as horizontal directional drilling (HDD) has been in use, for eg., by contractors to lay pipelines. This method enables installation of pipelines and utilities beneath obstructions, such as, roads, rivers, buildings and so on, without a need to remove or reposition such above-ground obstructions. HDD also requires a pilot drill path; often, such a drill path is usually made up of straight tangents and a long radius arc, with the pilot drill path starting from an entry point to an opposite, exit point located at the other side of the ground. In practice, the pilot drill path is formed by actuating a pilot drill along the planned trajectory, and the pilot drill path is then enlarged by backward or reverse drilling, that is, with a borehead being

actuated to move along the pilot drill path from the exit point to the entry point. This method does not allow for extraction of cored soil samples along the pilot drill path.

[005] It can thus be seen that there exists a need to provide another directional drilling apparatus and method to conduct underground directional soil coring and soil sampling. The underground soil may be relatively soft or stiff.

Summary

[006] The following presents a simplified summary to provide a basic understanding of the present invention. This summary is not an extensive overview of the present invention, and is not intended to identify key features of the invention. Rather, it is to present some of the inventive concepts of this invention in a generalised form as a prelude to the detailed description that is to follow.

[007] The present invention seeks to provide an underground soil boring, soil coring and soil sampling apparatus and method. Preferably, this apparatus and method is suitable to obtain undisturbed soil samples in both soft and hard grounds.

[008] In one embodiment, the present invention provides a directional soil coring and sampling apparatus comprising: a steerable drill head, which is connectable at an end of a drill pipe, with the steerable drill head and the drill pipe being rotatable by a pipe drilling machine to form a pilot drill-path according to a predetermined profile; and a forward reamer, which is connectable to an end of a distal drill pipe, and the forward reamer is rotatable to enlarge the pilot drill-path to form a bored path of a predetermined bore diameter; wherein the drill pipe is made of an aluminium tube of a predetermined length and outside diameter, and the drill pipe is extendable in series with a plurality of drill pipes, with one end of each of the drill pipe being formed with a pin screw connection (PSC) and an opposite end being formed with a matching box screw connection (BSC).

[009] Preferably, the forward reamer comprises 3 regions, namely, a stem region, a conical region and a guide region, with the guide region being located at a forward location and formed with a diameter substantially matching that of the pilot drill path. Preferably, the

guide region is configured in an oblong cylindrical shape, with a front tip thereof being deposited with an abrasive material. Preferably, the guide region comprises two parts that are joined by a pin screw connection (PSC) and a matching box screw connection (BSC) of a predetermined size, so that the PSC and BSC allow the front tip to be removeably replaced when the abrasive material is worn out.

[0010] Preferably, the conical region of the forward reamer comprises a front conical region, a centre cylindrical region and a rear conical region. Preferably, the front conical region subtends a conical angle that is smaller than a conical angle subtended by the rear conical region. Preferably, a conical surface of the front conical region is formed with a plurality of spiral bands of abrasive material. Preferably, the forward reamer further comprises an internal, longitudinal bore which leads to outlets formed on both the front and the rear conical regions, with the outlets on the front conical region located between the spiral bands of the abrasive materials. Preferably, a cylindrical surface of the centre cylindrical region is formed with a cylindrical band of abrasive material or a hard-facing material.

[0011] In another embodiment, the above apparatus further comprises a coring head joined to a soil extractor subassembly, with the soil extractor subassembly being threadedly connectable to a drill pipe.

[0012] Preferably, the soil extractor comprises a split mould to contain a soil sample; alternatively, the soil extractor comprises an integral mould with a longitudinal split sleeve disposed therein to contain a soil sample. Preferably, the soil extractor further comprises a sleeve sub and a stabilizer threadedly connectable to the sleeve sub; preferably, each of two ends of the sleeve sub is being formed with a box screw connection (BSC); preferably, the stabilizer is configured substantially as a cylindrical shell having two spaced apart cylindrical bands of abrasive material of a predetermined extended diameter D1.

[0013] In another embodiment, the above apparatus further comprises a series of connected outer tubes to line the bored path, with a coring head attached to a terminal end of the outer tube; and a wireline soil extractor is receivable inside the series connected outer tubes, with a lower end of the wireline soil extractor configured with a coring tube for receiving a soil sample. Preferably, the coring tube further comprises a longitudinal split sleeve to receive the soil sample.

5 **[0014]** Preferably, the coring head is configured with a ring of cutting edge comprised of an abrasive material; the ring of the abrasive material may be arranged in a plurality of sectors. Preferably, the abrasive material is formed by coating, depositing, impregnating, welding or brazing the abrasive material onto the coring head.

10 **[0015]** In another embodiment, the present invention provides a method for conducting soil coring and soil sampling comprising, the method comprises: determining an underground location for soil sampling; plotting a drill profile from an entrance pit to reach the underground location for soil sampling; conducting pilot drilling along the drill profile with a steerable drill head attached to an end of a drill pipe, with the drill pipe is being extended during drilling; retrieving the drill pipes and the drill head to the entrance pit, replacing the drill head with a forward reamer and driving the drill pipes to enlarge the pilot drill path to form a bored path; retrieving the drill pipes and the forward reamer to the entrance pit,
15 replacing the forward reamer with a coring head and a soil extractor, and driving the coring head and the soil extractor with the drill pipes into the bored path to obtain a soil sample; and retrieving the drill pipes, coring head, the soil extractor and the soil sample from the underground location.

20 **[0016]** In another embodiment of the above method, after forming a bored path, the method further comprises: driving an outer tube with an end having a coring head and extending the outer tube so that the coring head reaches an end of the bored path; and sending a wireline soil extractor down into an interior bore of the series connected outer tubes, rotating the outer tubes to conduct soil coring, and after a soil sample is received inside a
25 coring tube connected to the soil extractor, retrieving the wireline soil extractor and the soil sample from the underground location.

Brief Description of the Drawings

30 **[0017]** This invention will be described by way of non-limiting embodiments of the present invention, with reference to the accompanying drawings, in which:

35 **[0018]** FIG. 1 illustrates a conventional horizontal directional drilling system that uses reverse drilling to enlarge a pilot drill path;

[0019] FIG. 2 illustrates a horizontal directional drilling apparatus that uses forward reaming according to an embodiment of the present invention;

5 [0020] FIG. 3 illustrates the horizontal directional drilling method shown in FIG. 2 for soil coring and soil sampling;

[0021] FIG. 4 illustrates a forward reamer to create a bored path by forward reaming of a pilot drill path according to an embodiment of the present invention;

10 [0022] FIG. 5 illustrates a coring head with a soil extractor for obtaining a soil sample according to another embodiment of the present invention;

[0023] FIG. 6 illustrates an arrangement of the abrasive material at the coring head shown in FIG. 5;

15 [0024] FIG. 7 illustrates an assembled view of a split mould that forms part of the soil extractor, whilst FIGs. 8 and 9 illustrate the split mould when it is disassembled in two halves;

20 [0025] FIG. 10 and 11 illustrate a pair of pin and aperture aligning and locking mechanism for assembling the two halves of the split mould shown in FIG. 8;

[0026] FIG. 12 illustrates a bored path profile at test site #1 where the soil is soft; FIG. 13 illustrates a soil sample obtained with the above split mould at site #1;

25 [0027] FIG. 14 illustrates a bored path profile at test site #2 where the soil is relative stiff; in addition, FIG. 14 also illustrates pilot drill paths plotted with pitch settings for steering the drill head; and FIG. 15 illustrates a soil sample obtained with the above split mould at site #2; and

30 [0028] FIG. 16 illustrates a wireline soil coring extractor according to another embodiment of the present invention, whilst FIGs. 17 and 18 show two enlarged views of FIG. 16.

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Detailed Description

[0029] One or more specific and alternative embodiments of the present invention will now be described with reference to the attached drawings. It shall be apparent to one skilled in the art, however, that this invention may be practised without such specific details. Some of the details may not be described at length so as not to obscure the present invention. For ease of reference, common reference numerals or series of numerals will be used throughout the figures when referring to the same or similar features common to the figures. In the following description, a forward direction refers to a direction for drilling or boring a pilot drill path or a bored path, and rear or reverse refers to an opposite direction from drilling or boring.

[0030] FIG. 1 is a simplified diagram to show a known conventional horizontal directional drilling system **1**, which sets the background art of the present invention. As shown in FIG. **1**, an underground pipeline **44** is to be laid underneath a ground **10**, which has some surface obstructions or land structures, such as, buildings **20**, roads, rivers and so on. A planned underground trajectory of the pipeline is plotted between an entrance pit **30** and an exit pit **32**. A rotatory pipe drilling equipment **34** is then positioned at the entrance pit **30** to drive a drill rod **36** equipped with a drill head (not shown in FIG. 1) into the ground; the drill rod **36** is then successively joined in series as the drill head is driven into the ground along the planned underground trajectory to form a pilot drill-path **40**, until the drill head reaches the exit pit **32**. The drill rods **36** are made of steel tubes and are joined by typical screw connections, which in the present description are called female box screw connections **BSC** and matching male pin screw connections **PSC**; typically, the drill rods **36** are substantially 4m in lengths; as an example relevant to the present invention, the drill rods **36** have an outside diameter of substantially 70 mm (or substantially 2.875 inch) and an internal bore of substantially 55 mm. During horizontal directional drilling, drilling mud is pumped through the internal bore of the drill rods **36** to lubricate the drill head; during the pilot drilling process, the drilling mud is returned to the entrance pit **30** through the annular space between the bore of the pilot drill-path **40** and the outside diameter of the drill rods **36**; the drilling mud may be processed again and re-used. At the exit pit **32**, the extremity end of the drilling rod **36** is then re-connected to both a backward drill **42** and an end of the pipeline **44**. By rotating and pulling the drill rods **36** back to the drilling equipment **34** (in a so-called reverse-drilling process), the pilot drill-path **40** is enlarged to form a bored path

41; at the same time, by retrieving of the drill rods 36, the pipeline 44 is successively pulled into the bored path 41 and the reverse-drilling process stops after the pipeline 44 appears at the entrance pit 30.

5 [0031] FIG. 2 is a simplified diagram to show a horizontal direction drilling (HDD) apparatus 100 or system of apparatus components according to an embodiment of the present invention. In FIG. 2, the surface obstructions or land structures, such as, buildings 20, are shown located on the ground 10. Like the above conventional HDD, a planned underground trajectory for underground soil coring is plotted from an entrance pit 30. A
10 rotatory drilling equipment 34 is then positioned at the entrance pit 30 to drive a drill pipe 136 equipped with a non-magnetic drill head (not shown in FIG. 2) to follow the planned trajectory; the drill pipe 136 is then successively joined in series as the drill head is rotatory driven and pushed into the ground along the planned underground trajectory to form a pilot drill-path 140 to reach a desired underground location at which a soil sample is to be
15 obtained by soil coring; the drill pipes 136 are made of aluminium tubes, for example, of substantially 1.8 – 2m in lengths, with an outside diameter of substantially 70 mm (or substantially 2.875 inch) and an internal bore of substantially 55 mm. As in the conventional HDD, the ends of these drill pipes 136 are also formed with female box screw connections BSC and matching male pin screw connections PSC; in later descriptions,
20 BSC and PSC of relevant sizes are used for threaded connections on component parts used in the present invention. Drilling mud, for example, a bentonite slurry, is pumped through the internal bores of the drill pipes 136 to lubricate the drill head and also to move the drilling debris to the entrance pit 30. After the pilot drill-path 140 is formed, for example, at a diameter of substantially 70 mm, both the drill pipes 136 and the drill head are
25 retrieved into the entrance pit 30. The drill head is then replaced with a forward reamer 160 (as seen in FIG. 2) and the drill pipes 136 are successively extended in series, rotatory driven and pushed along the pilot drill-path 140 to enlarge the pilot drill-path 140 to form a bored path 150 of the desired diameter (for example, of substantially 100 mm) to reach a desired location to collect a soil sample 201, as shown in FIG. 3; the drill pipes 136 are
30 then successively retracted together with the forward reamer 160; at the entrance pit 30, the forward reamer 160 is replaced with a coring head 210 and a series connected soil extractor assembly 270 (as seen in FIG. 3); the coring head 210 and the soil extractor assembly 270 are rotatory driven and pushed along the bored path 150 by extending and driving the drill pipes 136 until the coring head 210 reaches the end of the bored path 150 to collect the

desired soil sample **201**. For example, at the end of the bored path **150**, the drilling pipes **136** are driven an additional distance of substantially 200 mm or more to obtain the soil sample **201** located at the end of the bored path **150**. The process of soil coring will become clearer when FIGs. 4-11 are described below.

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[0032] As can be seen from FIG. 2, the pilot drill-path **140** is shown to be made up of substantially straight sections; it is possible that two straight sections are joined by an intervening curved section of a predetermined radius of curvature, for example, of substantially several tens of meters; the radius of curvature of the curved section of the pilot drill path **140** is substantively lower than that formed using the conventional steel drill rods **36**, given that the drill pipes **136** of the present invention made of aluminium tubes are more elastic or flexible; with the conventional steel drilling rods **36**, the radius of curvature is in the range of substantially several km. To drill a straight section of the pilot drill-path **140**, the drill pipes **136** are rotated at relatively high speeds; when a change of direction is desired, the drill speed is temporary ceased and the drill pipes **136** are being orientated, then pushed, possibly in steps, to follow an orientation blade disposed at the pilot drill head, before continuing to drill a continuing straight section of the pilot drill-path **140**. In another embodiment, it is possible to adjust the orientation blade at a steeper pitch angle when drilling through soft soil to effect a change of direction.

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[0033] As can be appreciated, the HDD drilling process **200**, illustrated in FIG. 3, of the present invention described above includes 3 processes: namely, (1) a pilot drilling process, (2) a forward reaming process, and (3) a soil coring process. As will be appreciated, in the present invention, the soil coring process is conducted with the soil extractor **270** or a wireline soil extractor **370**. Now, the forward reaming process is described with reference to FIG. 4. Fig. 4 shows the forward reamer **160** according to an embodiment of the present invention. As seen from FIG. 4, the forward reamer **160** is made up of 3 regions: a stem region **162**, a conical region **164** and a guide region **166**. The guide region **166** is oblong and slender in shape, and has a diameter of substantially a bore size of the pilot drill-path **140**. Preferably, the guide region **166** is made up of two parts **167,168** which are threadedly connected with box screw connection **BSC** and pin screw connection **PSC** of an associated size; part **168** is located at a tip of the guide region **166**, and its front tip is dressed with an abrasive material **180a**; preferably, the abrasive material **180a** may be made of tungsten carbide, industrial diamond, or a similar hard abrasive to reduce wear and tear as the

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forward reamer **160** is rotated and pushed to enlarge the pilot drill-path **140**. When the abrasive material **180a** has worn out, the tip part **168** can be replaced with a new component. The conical region **164** is made up of central cylindrical region **170**, a front conical region **172** and a rear conical region **174**. The front conical region **172** subtends a conical angle that is smaller than a conical angle subtended by the rear conical region **174**, meaning the front conical region **172** defines a longer conical surface than a rear conical surface at the rear conical region **174**; the diameter of the front conical region **172** at the guide region **166** transitions gradually to a diameter **D** at the cylindrical region **170**; as an example, the diameter **D** is substantially 100 mm. In one embodiment, the conical surface of the front conical region **172** has a plurality of abrasive bands **180b** that are spirally formed thereon; the spiral abrasive bands **180b** may be 2 or more in numbers. At the cylindrical region **170**, two or more spaced apart circumferential abrasive bands **180c** are provided thereon; as like the abrasive material **180a**, the abrasive bands **180b,180c** may be made of tungsten carbide, industrial diamonds, or a similar hard abrasive; as an alternative to the abrasive bands **180c**, circumferential bands of hard-facing material may be formed on the cylindrical portion **170**; for example, when the forward reamer **160** is made of carbon or alloy steel, the circumferential hard-facing bands may be formed by carburizing or nitriding. Extending from the rear conical region **174** is the stem region **162**; the stem region **162** has a box screw connection **BSC** for threaded joint to a pin screw connection **PSC** located on an end of an associated drill pipe **136**.

[0034] Referring back to FIG. 4, there is an internal bore **d** formed along a longitudinal axis of the forward reamer **160**; through the internal bore **d**, the drilling mud is injected through the drill pipes **136** into the forward reamer **160** and the drilling mud comes out through outlets **176,177** located, respectively on the front and the rear conical surface **172** and **174**, for lubricating the reaming process. On the rear conical surface **174**, there are 3 outlets **177** that are spaced equally part at 120 degrees and, for example, of substantially 19 mm diameter. The number of outlets **177** located at the rear conical surface **174** is kept relatively fewer than the number of outlets **176** located at the front conical surface **172** so that sufficient drilling mud is delivered to the front region of the forward reamer **160** during forward reaming; with this structure of the outlets **176,177**, a small portion of the drilling mud supplied flows out through the outlets **177** to help wash drilling debris to flow back to the entrance pit **30**. At the same time, when the forward reamer **160** is in operation,

drilling debris and drill mud flow through spaces between the forward reamer **160** and the bored path **150**, and they eventually flow back to the entrance pit **30**.

[0035] After the pilot drill-path **140** has been enlarged to the bored path **150** by operating the forward reamer **160**, both the drill pipes **136** and the forward reamer **160** are retrieved back to the entrance pit **30**. The forward reamer **160** at the end of the drill pipe **136** is then replaced by an assembly of the coring head **210** and the soil extractor **270** shown in FIG. 5.

[0036] FIG. 5 shows an exploded view of the assembly of the coring head **210** and the soil extractor **270**. The coring head **210** is configured like a sleeve **212** and a forward annular end of the sleeve **212** is formed with an abrasive material **180d**. Similarly as described above, the abrasive material **180d** may be made of tungsten carbide, industrial diamond or similar hard abrasive. In one embodiment, the abrasive material **180d** is formed in a ring arrangement; in another embodiment, as shown in FIG. 6, the abrasive material **180d** is arranged in four sectors to constitute four cutting blades. The abrasive material **180d** or the cutting blades can be formed by coating, depositing or impregnating in a processing chamber; alternatively, it is also possible that the abrasive sectors or cutting blades are provided in solid pieces and these are welded or brazed onto the forward end of the coring head **210**. Preferably, a second or opposite end of the coring head **210** is formed with a box screw connection **BSC**.

[0037] Connectable to the **BSC** of the coring head **210** is the soil extractor **270** subassembly. As shown in FIG. 5, the soil extractor **270** is made up of a split mould **271**, a sleeve sub **274**, a stabilizer **276** and a bend sub **278** according to an embodiment. FIG. 7 shows the split mould **271** in assembly, whilst FIGs. 8-9 show the split mould **271** being separated in two halves. The split mould **271** is made up of substantially a split annular sleeve **271** with each of two ends being threaded with a pin screw connection **PSC** of an associated size to mate with the **BSC** formed on the coring head **210**. The split annular sleeve **271** is split along a longitudinal axis to form two split halves **271a,271b**, as can be seen in FIGs. 8 and 9. These split halves **271a,271b** are aligned and held together by means of 3 sets of pin **272**-aperture **273** mechanisms, as seen in FIGs. 9-11. In one embodiment, the pins **272** may be threadedly fixed to the split edge on a lower split half **271b** whilst the matching apertures **273** are located on the upper split half **271a**. However, due to symmetry of the split halves **271a,271b**, the pins **272** and the apertures **273** are on opposite sides, and

therefore the upper and the lower halves can be reversibly described. In an alternative embodiment, it is possible that the pins **272** are tight-fitted into the split edge, instead of being threaded fixed. Preferably, the fit between the pins **272** and the mating apertures **273** is a loose fit, so that the split halves **271a, 271b** can be assembled or disassembled relatively easily or quickly at a site of operation.

[0038] From FIG. 5, it is seen that both ends of the split mould **271** are formed with pin screw connections **PSC**; an advantage is to keep the interior bore of the split mould **271** cylindrical and smooth. Also as seen from FIG. 5, the stabilizer **276** is configured as substantially a cylindrical shell and on its exterior cylindrical surface, there are two extended, spaced apart bands of abrasive materials **180e, 180f**. In one embodiment, the bands of abrasive material **180e, 180f** are cylindrically dressed to a diameter of **D1**; in one embodiment, **D1** is substantially an extended diameter **D** (located at the coring head **210**). It is possible that **D1** is a few % larger than the diameter **D**, for example, with the extended diameter **D1** being less than 10% more than the diameter **D**. With **D1 > D**, the stabilizer **276** serves to further ream the bored path **150** during the soil coring process and by so doing the stabilizer **276** makes hugging contacts in the bored path **150**; in this way, during the soil coring process, the stabilizer **276** dynamically stabilizes or centralises the coring head **210**. In one embodiment, the front end of the stabilizer **276** is formed with a pin screw connection **PSC**, whilst the opposite end is formed with a box screw connection **BSC**. With this configuration, the sleeve sub **274** is provided to connect the **PSC** end of the split mould **271** with the **PSC** end of the stabilizer **276**.

[0039] As can be appreciated from FIG. 5, in one embodiment, a rear end of the stabilizer **276** is threadably connectable to a proximal end of a drill pipe **136** (the drill pipe is not shown in FIG. 5) via a bend sub **278**. In an alternative embodiment, the rear end of the stabilizer **276** is threaded directly to a proximal end of an associated drill rod **136**.

[0040] Two field tests were carried out to prove the working principle of the above apparatus **100** and the directional pilot drilling, the forward bore reaming and the soil coring/sampling process **200**. The soil at Site #1 (Kranji) was soft marine clay. The pilot drill path (now labelled **140a**) and the bored path (now labelled **150a**) were carried out with a length of substantially 30m and reached a depth of substantially 12m, as shown by a penetration profile in FIG. 12. Due to the soft soil condition, when the forward reamer **160**

was being retrieved or withdrawn, the bored path traced a slightly deviated profile **150b**; in soft soil, this deviated profile **150b** was expected, and this result showed that the depth profiling method used in the above invention was reasonably accurate.

5 [0041] FIG. 13 shows the above split mould **271** was used to obtain the soil sample **201** located at the end of the bored path **150a** at Site #1 (Kranji). FIG. 13 proved that the above directional pilot drilling, forward bore reaming and soil coring processes were successfully carried out in substantially soft marine soil.

10 [0042] FIG. 14 shows the above split mould **271** was used to obtain the soil sample **201** located at the end of a bored path **150c** at Site #2 (Kent Ridge). The soil at Site #2 (Kent Ridge) was relatively stiff. As seen in FIG. 14, the bored path **150c** was carried out with a length of substantially 30m and reached a depth of nearly 10m. The drill path was launched at an entry angle of between substantially 8 and 13 deg. at the entrance pit **30**. In addition,
15 a drill path profile **140b** was plotted to a depth of substantially 14m with the orientation blade at the drill head set at substantially 3% pitch angle. Another drill path profile **140c** was also plotted but with the orientation blade set at substantially 8% pitch angle; when the orientation blade was set at the higher pitch angle, the plotted drill path **140c** has a substantially curved profile. In FIG. 14, a terrain profile of the ground **10** and the plotted
20 drill path profiles **140b,140c** at Site #2 were shown to verify that the drill path profiling method used was reasonably accurate and reliable.

[0043] FIG. 15 shows the split mould **271a,271b** being separated in halves and a soil sample **201** was obtained from Site #2. FIGs. 13 and 15 show that the split mould **271** was
25 successful used in obtaining undisturbed soil samples in both soft and hard grounds; this also proves the working principles of the forward reaming and the soil coring/sampling process **200**, and the coring head **210** and the soil extractor **270** the present invention enabled undisturbed the soil coring and soil sampling to be obtained.

30 [0044] FIG. 16 shows a wireline soil coring extractor system **300** according to another embodiment of the present invention, whilst FIGs. 17 and 18 show, respectively, an upper and a lower part of the wireline soil coring extractor **300**. Like the above embodiment, a drill profile into the ground is planned, and a pilot drill-path **140** is formed according to the drill profile; the drill path **140** is subsequently enlarged with the forward reamer **160** to
35 form a bored path **150**; in the present embodiment, a series of outer tubes **336**, extended via

BSC and PSC threaded connections, is provided to line the bored path **150** and the wireline soil coring extractor **300** is sent down to an end of the outer tubes **336** to obtain a soil sample **301**. As shown in FIG. 16, the soil coring extractor system **300** is made up of the outer tube **336**, an overshot **303**, a soil extractor **370** and a coring head **310**. The method of using the soil coring extractor system **300** is advantageous to obtain multiple soil samples **301** without having to retrieve the outer tubes **336**.

[0045] As can be visualised from FIG. 16, the soil extractor **370** and the coring head **310** are sent down into the outer tubes **336**, preferably by gravity or by a pneumatic means. An upper end of the soil extractor **370** is provided with an overshot coupling **304**. At a location aft of the overshot coupling **304**, two sections of the outer tubes **336** are joined by an adapter pipe **305**; the adapter pipe **305** has an internal step **305a** that cooperates with spring loaded latches **306** that extend from a head assembly **375** of the soil extractor **370**. When the latches **306** are engaged with the step **305a** of the adapter pipe **305**, the soil extractor **370** becomes rotationally fixed with respect to the outer tube **336**. To retrieve the soil extractor **370**, the overshot **303** is sent down inside the outer tube **336** by a wireline **302** to connect with the overshot coupling **304**; in the connection process, the latches **306** are released and by withdrawing the wireline **302**, the soil extractor **370** is retrieved from the ground.

[0046] As seen in FIG. 17, at a location aft of the head assembly **375**, the soil extractor **370** has a set of bearings **308**. With the bearings **308**, a lower part of the soil extractor **370** becomes rotationally free with respect to the outer tube **336**; in other words, during soil coring, a coring tube **371** located at a lower part of the soil extractor **370** remains non-rotatable as both the outer tube **336** and the coring head **310** are being rotated; during soil coring, a soil sample **301** is received into the coring tube **371**. The coring head **310** has a ring of abrasive material **180g** (not shown in FIGs. 16-18), which may be formed by coating, depositing, impregnating, welding or brazing; preferably, the abrasive material **180g** is similarly arranged as seen in FIG. 6 to form a soil coring or cutting edge; preferably, the abrasive material **180g** is dressed to a diameter of substantially that of the bored path **150**.

[0047] As seen in FIG. 18, near the coring head **310**, the outer tube **336** has two bands of stabilizer **337**; similar to the above description, the bands of stabilizer **337** are dressed with the abrasive material **180** or the hard-facing material **180c**; the hugging contact provided

by the bands of stabilizer **337** whilst the outer tube **336** is being rotated during soil coring in the bored path **150** helps to stabilize the soil coring process at the coring head **310**.

[0048] At a lower end of the coring tube **371**, a core gripper assembly **390** is provided to break the soil sample **301** from the ground before the soil extractor **370** is being retrieved. The core gripper assembly **390** is made up of a grip case **391**, a split collar **392** and a stop ring **393**. The grip case **391** has a tapered socket surface and it cooperates with a mating tapered surface located on the split collar **392**; the stop ring **393** defines a travel distance of the split collar **392**. Preferably, the tapered surfaces on the grip case **391** and the split collar **392** are hardened. After a soil coring process has been performed and the soil extractor **370** is about to be pulled up from inside the outer tube **336**, the split collar **392** squeezes on the soil sample **301** and breaks the soil sample **301** from its connection to the ground; in this manner, the soil sample **301** is retained inside the coring tube **371** in an undisturbed state after the soil extractor **370** has been retrieved from the ground.

[0049] Preferably, the soil extractor **370** together with the coring tube **371** are freely slidable inside the outer tube **336**; to facilitate the sliding motion of the coring tube **371** inside the outer tube **336**, a band of stabilizer **376** is provided on the coring tube **371**.

[0050] While specific embodiments have been described and illustrated, it is understood that many changes, modifications, variations and combinations of variations disclosed in the text description and drawings thereof could be made to the present invention without departing from the scope of the present invention; for example, it is possible to provide the coring tube **371** with an internal, longitudinally split sleeve to contain the soil sample **301**; similarly, the split mould **271** can be configured as an integral mould **271c** (not shown in the drawings) and an internal, longitudinal split sleeve is provided inside the integral mould **271c** to contain the soil sample **201**; in this manner, the longitudinally split sleeves located inside the coring tube **371** or the integral mould **271c** will facilitate easy extraction of the soil sample **201**, **301** in an undisturbed state.

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CLAIMS:

1. A directional soil drilling, soil coring and soil sampling apparatus comprises:
a steerable drill head, which is connectable at an end of a drill pipe, with the steerable drill head and the drill pipe being rotatable by a pipe drilling machine to form a
5 pilot drill-path according a predetermined profile; and
a forward reamer, which is connectable to an end of a distal drill pipe, and the forward reamer is rotatable to enlarge the pilot drill-path to form a bored path of a predetermined bore diameter;
wherein the drill pipe is made of an aluminium tube of a predetermined length and
10 outside diameter, and the drill pipe is extendable in a series of connected drill pipes, with one end of each of the drill pipe being formed with a pin screw connection (PSC) and an opposite end being formed with a matching box screw connection (BSC).
2. The apparatus according to claim 1, wherein the forward reamer comprises 3
15 regions, namely, a stem region, a conical region and a guide region, with the guide region being located at a forward location and formed with a diameter substantially matching that of the pilot drill path.
3. The apparatus according to claim 2, wherein the guide region is configured in an
20 oblong cylindrical shape, with a front tip thereof being deposited with an abrasive material.
4. The apparatus according to claim 2 or 3, wherein the guide region comprises two parts that are joined by a pin screw connection (PSC) and a matching box screw connection (BSC) of a predetermined size, so that the PSC and BSC allow the front tip to be
25 removeably replaced when the abrasive material is worn out.
5. The apparatus according to any one of claims 2 to 4, wherein the conical region comprises a front conical region, a centre cylindrical region and a rear conical region.
- 30 6. The apparatus according to claim 5, wherein the front conical region subtends a conical angle that is smaller than a conical angle subtended by the rear conical region.
7. The apparatus according to claim 5 or 6, wherein a conical surface of the front conical region is formed with a plurality of spiral bands of abrasive material.

8. The apparatus according to claim 7, wherein the forward reamer further comprises an internal, longitudinal bore which leads to outlets formed on both the front and the rear conical regions, with the outlets on the front conical region located between the spiral
5 bands of the abrasive materials.

9. The apparatus according to any one of claims 5 to 8, wherein a cylindrical surface of the centre cylindrical region is formed with a cylindrical band of abrasive material or a hard-facing material.
10

10. The apparatus according to claim 1, further comprises:
a coring head joined to a soil extractor subassembly, with the soil extractor subassembly being threadedly connectable to a drill pipe.

15 11. The apparatus according to claim 10, wherein the soil extractor comprises a split mould to contain a soil sample, with the split mould being threadedly connectable to the coring head.

12. The apparatus according to claim 10, wherein the soil extractor comprises an
20 integral mould and a longitudinal sleeve disposed inside the integral mould to contain a soil sample.

13. The apparatus according to claim 11 or 12, wherein the soil extractor further comprises a sleeve sub and a stabilizer threadedly connectable to the sleeve sub.
25

14. The apparatus according to claim 13, wherein the sleeve sub has each of two ends being formed with a box screw connection (BSC).

15. The apparatus according to claim 13 or 14, wherein the stabilizer is configured
30 substantially as a cylindrical shell having two spaced apart cylindrical bands of abrasive material of a predetermined extended diameter D1.

16. The apparatus according to claim 1, further comprises:

a series of connected outer tubes to line the bored path, with a coring head attached to a terminal end of the outer tube; and

a wireline soil extractor is receivable inside the series connected outer tubes, with a lower end of the wireline soil extractor configured with a coring tube for receiving a soil sample.

17. The apparatus according to claim 16, wherein the coring tube further comprises a longitudinal split sleeve for receiving the soil sample.

10 18. The apparatus according to any one of claims 10 to 17, wherein the coring head is configured substantially as a sleeve, and an annular edge of the sleeve is formed with a ring of cutting edge comprised of an abrasive material.

15 19. The apparatus according to claim 18, wherein the ring of the abrasive material is arranged in a plurality of sectors.

20 20. The apparatus according to claim 18 or 19, wherein the abrasive material is formed by coating, depositing, impregnating, welding or brazing the abrasive material onto the coring head.

21. A method for conducting soil coring and soil sampling comprising:
determining an underground location for soil sampling;
plotting a drill profile from an entrance pit to reach the underground location for soil sampling;
25 conducting pilot drilling along the drill profile with a steerable drill head attached to an end of a drill pipe, with the drill pipe is being extended during drilling;
after conducting the pilot drilling, retrieving the drill pipes and the drill head to the entrance pit, replacing the drill head with a forward reamer and driving the drill pipes to enlarge the pilot drill path to form a bored path;
30 retrieving the drill pipes and the forward reamer to the entrance pit, replacing the forward reamer with a coring head and a soil extractor, and driving the coring head and the soil extractor with the drill pipes into the bored path to obtain a soil sample; and
retrieving the drill pipes, coring head, the soil extractor and the soil sample from the underground location.

22. A method for conducting soil coring and soil sampling comprising:
- determining an underground location for soil sampling;
 - plotting a drill profile from an entrance pit to reach the underground location for
 - 5 soil sampling;
 - conducting pilot drilling along the drill profile with a steerable drill head attached to an end of a drill pipe, with the drill pipe is being extended during drilling;
 - after conducting the pilot drilling, retrieving the drill pipes and the drill head to the entrance pit, replacing the drill head with a forward reamer and driving the drill pipes to
 - 10 enlarge the pilot drill path to form a bored path;
 - driving an outer tube with an end having a coring head and extending the outer tube so that the coring head reaches an end of the bored path; and
 - sending a wireline soil extractor down into an interior bore of the series connected outer tubes, rotating the outer tubes to conduct soil coring, and after a soil sample is
 - 15 received inside a coring tube connected to the soil extractor, retrieving the wireline soil extractor and the soil sample from the underground location.