

"A Mandrel Shoe"

THIS INVENTION relates to a mandrel shoe and more particularly to a mandrel shoe for use in installing vertical drains.

Vertical drains are used as one of a number of methods to drain and consolidate ground upon which construction is to take place. A vertical drain comprises an elongate pre-fabricated plastics corrugated core surrounded by a filter cloth. Water is free to pass through the filter cloth into the corrugations of the plastics core. The corrugations define a series of elongate channels in the core. Water in the vertical drain is forced up through the channels to the surface by the pressure of a surcharge load placed on the ground being consolidated.

Vertical drains are installed in an array covering the area to be consolidated. The drains are spaced 1 to 1.5 metres apart from one another. Thus, many hundreds or thousands of vertical drains need to be installed in a large site. The drains are installed to a depth which varies from 5 to 80 metres and typically to a depth in the range of 10 to 40 metres.

A conventional method of installing vertical drains is by using an installation rig, which is termed a stitcher, such as the one shown in Figure 1 of the accompanying drawings. The stitcher is attached to a standard excavator or crane. A mast in the stitcher is operable to drive a hollow mandrel, through which the vertical drain runs, into the ground to be consolidated.

An anchor plate is used to anchor each drain at the bottom of the ground to be consolidated. The anchor plate must embed itself in the soil to prevent the vertical drain being pulled out from the soil when the mandrel is withdrawn. Typically, a worker will fit a new anchor plate to a portion of the drain projecting out of the bottom of the hollow mandrel. Once the anchor plate is fitted to the drain, installation can commence and the anchor plate which is seated at the bottom the end of the hollow mandrel is driven into the ground. Once the desired depth has been reached, the mandrel is withdrawn and the anchor plate remains in the ground to be consolidated thereby also leaving the vertical drain anchored in place in the ground.

When the mandrel has been fully withdrawn from the ground, a portion of the drain still projects from the ground and this portion is cut to leave a stub of drain projecting from the ground.

The worker must then attach another anchor plate to the end of the drain projecting from the mandrel. In a site in which one million metres of vertical drains are to be installed at an average depth of 20 metres, approximately 50,000 installations will need to be carried out which would require 50,000 anchor plates and 50,000 drain cutting operations and 50,000 fittings of new anchor plates. Clearly, the conventional installation is time-consuming, labour intensive and requires a new anchor plate for each installation.

Another disadvantage of the use of anchor plates is that the anchor plates present a planar surface to the ground when being driven into the ground which creates significant resistance to the passage of the mandrel through the ground.

It is an object of the present invention to seek to provide a mandrel shoe and method of installing vertical drains which do not suffer from the above disadvantages.

Accordingly, one aspect of the present invention provides a mandrel shoe for the installation of vertical drains, the mandrel shoe comprising : a guide channel extending from an upper end of the mandrel shoe to a side opening formed in the mandrel shoe, the guide channel being adapted to direct a length of drain from an upper end of the mandrel shoe towards and out of the side opening, such that an anchoring length of drain projects from the side opening to anchor the drain within the ground.

Another aspect of the present invention provides a mandrel shoe for use with a mandrel for the installation of vertical drains, an upper end of the mandrel shoe being securable to the bottom of the mandrel, the mandrel shoe comprising: a guide channel extending from an aperture in the upper end of the mandrel shoe to an opening formed in the lower end of the mandrel shoe, the guide channel being adapted to direct a length of drain from the mandrel towards and out of the opening; feed means actuable to pay out a predetermined length of drain through the opening as the mandrel shoe is lowered from a position above the ground towards the ground; and cutting means actuable to cut through the drain as the mandrel shoe is withdrawn completely from the ground.

A further aspect of the present invention provides a method of installing vertical drains comprising the steps of: priming a mandrel shoe with a length of drain such that an anchoring length of drain projects substantially sideways from the mandrel shoe; driving the mandrel shoe into the ground to a predetermined depth, the anchoring length of drain being urged into a position against a side of the mandrel shoe as the mandrel shoe is driven into the ground;

releasing the anchoring length from the side of the mandrel shoe to entrap the anchoring length in the ground such that the vertical drain is anchored in place by the protruding anchoring length; and subsequently withdrawing the mandrel shoe from the ground.

Another aspect of the present invention provides a method of installing vertical drains comprising the steps of : priming a mandrel shoe with a length of drain; paying out a predetermined length of drain through an opening in the mandrel shoe as the mandrel shoe is lowered from a position above the ground towards the ground; driving the mandrel shoe into the ground to a predetermined depth; subsequently withdrawing the mandrel shoe from the ground to leave the vertical drain embedded in the ground; and cutting the drain once the mandrel shoe has been fully withdrawn from the ground.

A further aspect of the present invention provides a mandrel shoe for use with a mandrel for the installation of vertical drains, an upper end of the mandrel shoe being securable to the bottom of the mandrel, the mandrel shoe comprising: a guide channel extending from an aperture in the upper end of the mandrel shoe to an opening formed in the lower end of the mandrel shoe, the guide channel being adapted to direct a length of drain from the mandrel towards and out of the opening; and feed means actuable to pay out a predetermined length of drain through the opening as the mandrel shoe is lowered from a position above the ground towards the ground.

A further aspect of the present invention provides a method of installing vertical drains comprising the steps of: priming a mandrel shoe with a length of drain; paying out a predetermined length of drain through an opening in the mandrel shoe as the mandrel shoe is lowered from a position above the ground towards the ground; driving the mandrel shoe into the ground to a predetermined

depth; subsequently withdrawing the mandrel shoe from the ground to leave the vertical drain embedded in the ground.

Another aspect of the present invention provides a method of installing vertical drains using a mandrel shoe having cutting means associated therewith, which method comprises the steps of : priming a mandrel shoe with a length of drain; driving the mandrel shoe into the ground to a predetermined depth; subsequently withdrawing the mandrel shoe from the ground to leave the vertical drain embedded in the ground; and cutting the drain once the mandrel shoe has been fully withdrawn from the ground, said cutting means being operable to cut the drain automatically when the mandrel shoe is clear of the ground.

A further aspect of the present invention provides a mandrel shoe for use with a mandrel for the installation of vertical drains, an upper end of the mandrel shoe being securable to the bottom of the mandrel, the mandrel shoe comprising : a guide channel extending from an upper end of the mandrel shoe to a side opening formed in a lower end of the mandrel shoe, the guide channel being adapted to direct length of drain from an upper end of the mandrel shoe towards and out of the side opening, such that an anchoring length of drain projects from the side opening to anchor the drain within the ground and a cover element slidably mounted over the mandrel shoe, the cover element having a recess to accommodate the anchoring length between the cover element and the mandrel shoe as the mandrel shoe is driven into the ground, the cover element being adapted to slide relative to the mandrel shoe as the mandrel shoe is subsequently withdrawn from the ground such that the anchoring length of drain projects from the mandrel shoe.

In order that the present invention may be more readily understood, embodiments thereof will now be described, by way of example, with reference to the accompanying drawings, in which:

FIG. 1 is a schematic side view of a standard excavator or crane fitted with a stitcher rig for installing vertical drains;

FIG. 2 is a cross-sectional side view of a mandrel shoe embodying the present invention fitted to one end of a mandrel;

Figure 3 is a cross-sectional side view of another embodiment of the present invention of the mandrel shoe of the present invention fitted to one end of a mandrel;

Figure 4 is a cross-sectional side view of a mandrel shoe of a further embodiment of the present invention fitted to one end of a mandrel, illustrating operative parts of the mandrel shoe in an initial first position;

Figure 5 is a cross-sectional side view of the mandrel shoe of Figure 4, illustrating the operative parts in an intermediate position; and

Figure 6 is a cross-sectional side view of the mandrel shoe of Figures 4 and 5, illustrating the operative parts in a final position.

A mandrel shoe 1 embodying the present invention, as shown in Figure 2, is fitted to the open bottom end of a mandrel 2. The mandrel 2 is hollow and contains a length of vertical drain which is to be installed in ground to be consolidated. The bottom end 3 of the mandrel 2 is fitted with an internal collar 4 which tapers the inner surface of the mandrel 2 towards a central aperture 5.

The mandrel shoe 1 comprises an elongate rectangular housing 6. The top end of the housing 6 is attached to the bottom end 3 of the mandrel 2. The

bottom end of the housing 6 is fitted with a pointed driving head 7 having a knife edge 8 suitable for cutting through ground to be consolidated.

The driving head 7 is securely bolted to the housing 6 by bolts 9.

In the embodiment of the mandrel shoe 1 shown in Figure 2, the mandrel shoe is slightly wider than the mandrel 2. To assist in easy withdrawal of the mandrel shoe 1 and mandrel 2 from the ground to be consolidated once a vertical drain has been installed, the upper surface of the housing 6 which is stepped out from the mandrel 2 is provided with a downwardly and outwardly sloped surface 6A so as to minimise soil resistance during removal of the mandrel shoe from the ground to be consolidated. As will be described in more detail hereinafter, wedge surface 6A also assists in anchoring a vertical drain in the ground.

The housing 6 is formed with a guide channel 10 which is a passageway extending from an aperture 11 in the top end of the shoe 1, aligned with the central aperture 5 in the bottom end 3 of the mandrel 2. The guide channel 10 terminates in a side opening 12 in the region of the driving head 7. From the aperture 11, the guide channel 10 is directed substantially downwardly although slightly toward the side opening 12. In the region of the driving head 7, the guide channel 10 is provided with two bends, each in the same sense, which direct the guide channel 10 toward the side opening at an angle of approximately 65° to a vertical surface of the side walls of the housing 6.

The side opening 12 has an upper surface 13 and a lower surface 14. The upper surface 13 is contiguous with the inner surface of the guide channel 10 and curves round from the guide channel 10 to be flush with the outer surface of the housing 6. Preferably, the lower surface 14 of the side opening 12 is also

contiguous with the inner surface of the guide channel 10 and is flush with the side wall of the housing 6.

The upper surface 13 has a high co-efficient of friction. Thus, the upper surface 13 may be pitted or have some form of corrugation transverse to the guide channel 10 thereon. As will be described in more detail hereinafter, the side opening 12, thus configured, serves as a releasable retaining means to prevent release of the drain or withdrawal of a length of drain into the mandrel shoe as it is driven into the ground.

A substantially vertical shaft 15 is slidably mounted on the housing 6. One end of the shaft 15 projects from the top of the housing 6 adjacent to and substantially parallel with the mandrel 2. The other end of the shaft 15 is located within the housing 6. The end of the shaft 15 inside the housing 6 is formed with a side arm 16, which extends substantially horizontally from the shaft and terminates at a position substantially above the side opening 12.

A blade 17 is fixed to and depends vertically downwardly from the side arm 16 such that slidable movement of the shaft 15 within the housing 6 moves the blade 17 relative to the housing 6 towards or away from the side opening 12. At its extreme of downward movement, the shaft 15 causes a cutting edge 18 of the blade 17 to pass completely over the side opening 12. In this way, the shaft 15 and associated blade 17 may operate as cutting means to cut through the drain. The shaft 15 is spring loaded so as to be biased towards a position in which the blade 17 is in its uppermost position and the maximum distance away from the side opening 12.

The shaft 15 is spring loaded by a tension spring 25 which surrounds a portion of the shaft 15 with respective ends of the spring 25 being secured to an

inner surface of a top plate of the housing 6 and a stop 25 formed on the shaft 15, to bias the shaft 15 upwardly.

Inside the housing 6, the side of the shaft 15 makes contact with a drive roller 19. The sliding movement of the shaft 15 causes the drive roller 19 to rotate. The drive roller 19 is connected to a larger feed roller 20 by a one-way gear mechanism (not shown) which operates as a releasable coupling means. The one-way gear mechanism de-couples the driving force of the drive roller 19 from the feed roller 20 when the shaft is moved downwards with respect to the housing 6, causing the drive roller 19 to rotate in an anti-clockwise direction. When the shaft 15 slides upwardly with respect to the housing 6, moving the blade 17 away from the side opening 12, the drive roller 19 is rotated in a clockwise direction, and the one-way gear mechanism couples the drive roller 19 to the feed roller 20 causing the feed roller 20 to rotate in a clockwise direction. An outer surface of the feed roller 20 projects into the guide channel 10 through a roller window 21. The surface of the feed roller 20 projecting through the window 21 in the guide channel therefore is able to move downwardly with respect to the guide channel 10 but is not able to move upwardly.

A smaller window 22 is situated directly opposite the roller window 21. A small idler roller 23 projects through the smaller window 22 into the guide channel 10. The idler roller 23 is freely rotatable. As will subsequently become apparent, the shaft 15, drive roller 19, feed roller 20, idler roller 23, and the one-way gear mechanism operate as a feed means.

The rig upon which the mandrel 2 and mandrel shoe 1 are mounted is provided with a horizontally projecting plate 30. The plate 30 abuts the mandrel 2 and is located directly above the top end of the shaft 15 projecting from the mandrel shoe housing 6 such that the plate 30 can come into contact with the end

of the shaft 15 as the mandrel shoe 1 is raised, (as will be described hereinafter), so as to push the shaft 15 downwardly relative to the housing 6, and cause the blade 17 to move towards the side opening 12.

In operation, a vertical drain which comprises a plastics corrugated core and a synthetic filter is provided on a reel held on the crane or rig. The drain is fed from the rig into the top of the hollow mandrel 2 and down along the length of the mandrel 2 to the bottom end 3 of the mandrel. The drain is fed through the internal collar 4 and out of the mandrel. Since the mandrel shoe abuts the bottom end 3 of the mandrel 2 and the apertures 5 and 11 are co-aligned, the vertical drain also passes into the mandrel shoe housing 6 and into the guide channel 10. The drain comes into contact with the feed roller 20 and the idler roller 23 projecting into the guide channel through respective windows 21,22 and is pushed through the remainder of the guide channel 10 until the drain projects from the side opening 12. A length of drain, termed the anchoring length, in the region of 200 mm, is pulled out of the mandrel shoe 1. It is preferable for the anchoring length to exceed the vertical distance between the side opening 12 and the wedge surface 6A. Having primed the mandrel shoe 1 in this manner, the mandrel 2 is driven into the ground by the rig. Because the driving head 7 of the mandrel shoe 1 is pointed, the mandrel shoe 1 cuts easily through the soil, certainly more easily than conventional flat plated mandrels fitted with anchor plates.

As the mandrel shoe 1 is driven into the soil, the anchoring length of drain projecting from the side opening 12 is urged into a position against the outer surface of the mandrel shoe 1, such that a section of the anchoring length extends past the wedge surface 6A. The high friction present between the drain and the upper surface 13 of the side opening 12 prevents release of the drain during the downward motion of the mandrel. The friction also prevents the drain from slipping back into the mandrel shoe 1.

When the required depth has been reached, the mandrel 2 is drawn back up by the rig. Upward vertical movement of the wedge surface 6A urges earth (typically soil or soft clay) between the anchoring length of drain and the housing 6, such that the anchoring length projecting from the mandrel shoe, is forced away from the mandrel shoe 1 and becomes entrapped by the surrounding soil and is pulled away from the high friction surface 13 by this initial movement of the mandrel 2 back up through the soil. Since there is no longer a high degree of friction between the drain and the side opening 12, the drain is fed freely through the mandrel shoe 1 as the mandrel shoe 1 is drawn back up through the soil. The anchoring length of the drain initially projecting from the mandrel shoe 1 thereby acts as an anchor means.

When the mandrel shoe is withdrawn fully from the soil, the shaft 15 is brought into contact with the plate 30 projecting from the rig. As the mandrel shoe 1 continues to rise, the plate 30 depresses the shaft 15 into the housing 6 causing the blade 17 to move towards the side opening 12 and eventually causing the cutting edge 18 to cut through the drain at the side opening 12. This action cuts through the drain at a position above ground level to leave a portion of the installed drain projecting from the soil, and an exposed end of un-installed drain located in the mandrel shoe at the side opening 12. In this way, the shoe drain is cut automatically when the mandrel is clear of the ground.

The rig can now be moved to the next point at which a vertical drain is to be installed. The vertical drain is located above the appropriate point and the mandrel shoe 6 is lowered. As the mandrel shoe 1 is lowered, the shaft 15, which is spring loaded, initially remains in contact with the plate 30 such that the blade 17 moves back away from the side opening 12 toward the top of the mandrel shoe 1. As the mandrel shoe 1 moves relative to the initially stationary shaft 15, the shaft

causes rotation of the drive roller 19 in a clockwise direction and, since the feed roller 20 is coupled to the drive 19 by the one-way gear mechanism, also causes rotation of the feed roller 20. The surface of the feed roller 20 projecting through the window 21 is in contact with the vertical drain remaining in the guide channel 10. The clockwise rotation of the feed roller 20 forces another anchoring length of drain out of the guide channel 10 as the mandrel shoe 1 moves downwardly with the shaft 15 still stationary and in engagement with the plate 30. The length of the shaft and the gear ratio between the drive roller 19 and the feed roller 20 result in a length of drain in the order of 200 mm being fed out of the mandrel shoe 1 as the shaft 15 moves back relative to the housing 6 until such time as the shaft 15 is in its uppermost position relative to the housing and disengages from the plate 30. This automatic action thereby provides the mandrel shoe 1 with the next anchoring length of drain for use as the anchoring means for the next installation of vertical drain.

In preferred embodiments of the mandrel shoe, the side opening 12 is provided with a membrane sheath or other sealing means to ensure that the internal workings of the mandrel shoe 1 are fully sealed from the soil to prevent water or the like from penetrating through the side opening 12 into the housing 6.

The flush jointing system between the mandrel shoe 1 and the mandrel 2 creates minimum soil resistance during penetration and withdrawal.

One of the side walls of the housing 6 can be opened to allow easy access to the internal workings of the mandrel shoe.

It should be noted that the above described preferred embodiment of the mandrel shoe is entirely self contained and does not require any electrical or hydraulic power to carry out the steps of cutting the drain and feeding an

appropriate length of drain out of the mandrel shoe. Of course, it is envisaged that separate means for cutting the drain or creating an anchoring means from the drain can be implemented using, for example, hydraulics, pneumatics, electromechanical, electrical, electronic, motorised, other mechanical means such as spring powered, magnetic or the like.

Figure 3 illustrates an alternative embodiment of the present invention, with parts equivalent to those already described with reference to the embodiment illustrated in Figure 2 having the same reference numerals.

Whilst the mandrel shoe 1 illustrated in Figure 3 is substantially equal in width to the mandrel 2, it will of course be appreciated that the mandrel shoe may in fact be slightly wider than the mandrel 2 in a similar way to the embodiment illustrated in Figure 2, and that the mandrel shoe 1 may be provided with an upper sloped surface to minimise soil resistance during removal of the mandrel shoe from the ground to be consolidated. It will also be appreciated that the dimensions of the central aperture 5 formed by the internal collar 4 (illustrated as being slightly larger in the embodiment of Figure 3 than the embodiment of Figure 2) is largely immaterial to the operation of the present invention. Likewise, the dimensions of the aperture 11 in the top end of the mandrel shoe 1 are also largely immaterial to the operation of the present invention.

The embodiment of the invention illustrated in Figure 3 does not include cutting means or automatic feed means although it will be appreciated that this embodiment could easily be modified to include cutting and feed means.

As will readily be appreciated from Figure 3, this embodiment of the present invention is provided with a driving head 7 having a different shape to that illustrated in the previous embodiment of Figure 2. The driving head 7 of this

embodiment is substantially symmetrical about the central vertical axis of the mandrel shoe 1 and at its upper end adjacent the lower end of the mandrel shoe 1, is slightly wider than the mandrel shoe 1. The upper end of the driving head 7 is provided with a first rounded shoulder 40 located adjacent the side opening 12 and a second rounded shoulder 41 located adjacent the opposite side of the mandrel shoe 1. The first rounded shoulder 40 is shaped to form a substantially contiguous extension of the lower surface 14 of the side opening 12. In order to maintain the symmetry of the driving head 7 as far as possible, the second rounded shoulder 41 is of generally similar form to the first rounded shoulder 40, although the second shoulder 41 is preferably faired into the outer surface of the housing 6 (at 42) to allow easy withdrawal of the mandrel shoe from the ground once the drain has been installed to its desired depth. The symmetry of the driving head 7 helps to ensure the downward force of the mandrel shoe is substantially coincident with the vertical central axis of the mandrel shoe, thereby preventing the mandrel shoe from straying off its substantially vertical course as it is driven into the ground.

The first shoulder 40, standing proud of the outer surface of the housing 6, just below the opening 12, serves to deflect the earth away from the housing 6 as the mandrel shoe is driven into the ground, thereby protecting the anchoring length of drain from possible damage caused by abrasion between the anchoring length of drain and the surrounding earth as the two move relative to one another.

The driving head 7 illustrated in Figure 3 is also provided with a removable driving tip 43 which is releasably secured to the driving head 7 by way of a threaded spigot 44 mounted on the driving tip 43 which is threadedly received within a corresponding bore formed in the driving head 7. The driving tip 43 is sharpened to a fine point and is preferably made from a very hard material, such as, for example, tungsten carbide. Due to the replaceable nature of the driving tip 43,

should the tip for any reason become damaged, the tip may easily be replaced with a fresh one.

The embodiment of the mandrel shoe illustrated in Figure 3 also includes an alternative releasable retaining means, which may either replace or supplement the upper surface 13 of the side opening 12 having a high coefficient of friction. The alternative releasable retaining means of this embodiment comprises a pivotally mounted element in the form of a cam cleat 45 which projects into the guide channel 10 through an aperture 46 formed in the inner surface of the guide channel 10. The cam cleat 45 is pivotally mounted (at 47) relative to the guide channel 10 and is preferably, though not essentially, of a teardrop shape.

When adopting a first position (illustrated in solid lines in Figure 3) the cam cleat 45 projects only a small way into the guide channel 10 thereby allowing substantially free passage of the drain past the cam cleat 45. In fact, any rotation of the cam cleat 45 in a clockwise direction about its pivot 47 reduces its degree of projection into the guide channel even further so that, as the drain pays out from the mandrel shoe 1 and bears upon the surface of the cam cleat 45, causing rotation in the clockwise direction, the cam cleat 45 allows substantially free passage of the drain. However, as will be appreciated, should the drain for any reason be urged back into the mandrel shoe 1, for example due to the forces imposed thereon during insertion of the mandrel shoe into the ground, the drain will bear upon the surface of the cam cleat 45, causing it to rotate in a counter-clockwise direction about the pivot 46 thereby causing the cam cleat 45 to adopt a second position in which it projects into the guide channel 10 to a greater degree. As will be appreciated, due to the arrangement of the cam cleat 45, and its dimensions relative to the diameter of the guide passage 10 in that region, counter-clockwise rotation of the cam cleat 45 ultimately results in closure of the guide channel 10 to such degree that the drain becomes pinched and hence trapped between the surface of the cam cleat 45 and

the opposing inner surface of the guide channel 10, thereby preventing subsequent movement of the drain back into the mandrel shoe 1. To improve the effectiveness of the cam cleat 45, it is also proposed to provide the outer surface of the cam cleat 45 with a high friction surface, for example a pitted or corrugated surface to increase its tendency to rotate in a counter-clockwise direction when the drain is withdrawn and bears upon the surface of the cam cleat 45.

Figure 4 illustrates a still further embodiment of the present invention but, for the sake of simplicity, does not illustrate the cutting mechanism or the automatic feed mechanism of the embodiment illustrated in Figure 2, or the cam cleat mechanism illustrated in Figure 3, although it will be appreciated of course that these features could also be included in the embodiment of Figure 4.

The mandrel shoe 1 of the embodiment of Figure 4 is generally similar to that illustrated in the embodiment of Figure 3, but is additionally provided with a cover 50 slidably mounted on the outside of the housing 6 for movement relative to the housing 6 along the central axis of the housing 6. In the case that the mandrel housing 6 is substantially cylindrical, then the cover 50 will also be substantially cylindrical, with the internal diameter of the cover 50 being slightly greater than the external diameter of the housing 6. However, in preferred embodiments, the housing 6 of the mandrel shoe is actually square or rectangular in transverse cross-section and so the cover 50 may also have square or rectangular transverse cross-sections to suit.

The lower end of the cover 50 is provided with a driving head 7 which is secured thereto by way of bolts 9.

In the region of the side opening 12, the cover 50 is provided with a drain recess 51 adjacent the housing 6 and running substantially vertically up the

housing 6 from a position substantially adjacent the lower surface 14 of the side opening 12.

The cover 50 is illustrated in Figure 4 in its initial driving position in which it encloses the housing 6 of the mandrel shoe 1. In this position, the lower end 52 of the recess 51 is substantially contiguous with the lower surface 14 of the side opening 12. The upper end 53 of the recess 51 opens into a cover side opening 54. The cover side opening 54 is spaced vertically from the lower end 52 of the recess 51 by a distance substantially equal to the length of the anchoring length of the drain. In this way, as will be seen from Figure 4, the anchoring length of the drain may be located in the recess 51, between the cover 50 and the outer surface of the housing 6 so as to terminate at a position substantially adjacent to the cover side opening 54. The upper surface 55 of the cover side opening 54 is sloped upwardly and outwardly from the outer surface of the housing 6.

When the cover 50 assumes the initial driving position illustrated in Figure 4, the mandrel and the mandrel shoe may be driven substantially downwardly into the ground, during which time the anchoring length of drain lying adjacent the outer surface of the housing 6 is protected from abrasion by the passing earth by virtue of being located in the recess 51.

Once the mandrel shoe has been inserted into the ground down to the desired depth, as with previously described embodiments of the present invention, the mandrel and mandrel shoe may then be withdrawn from the ground. As the mandrel and mandrel shoe begin to be withdrawn from the ground, due to the weight of the cover 50 and due to the frictional force between the cover 50 and the surrounding earth, the cover 50 remains substantially stationary relative to the surrounding earth and so the mandrel shoe 1 is effectively withdrawn from the cover 50. In this way, the vertical separation between the cover side opening 54

and the side opening 12 of the mandrel shoe is gradually reduced and so the end of the anchoring length of drain which was originally located substantially adjacent the cover side opening 54 bears upon the sloping upper surface 55. Further relative movement between the anchoring length of the drain and the sloping upper surface 55 causes the anchoring length of the drain to be urged outwardly away from the housing 6 of the mandrel shoe, through the cover side opening 54 and into the surrounding earth (illustrated in Figure 5).

The further withdrawal of the mandrel shoe 1 from the ground results in further relative movement between the housing 6 and the cover 50 until such time as the cover side opening 54 is located substantially adjacent the housing side opening 12 at which time stop means (not illustrated) prevent further relative movement between the housing 6 and the cover 50, such that the cover 50 assumes the withdrawal position illustrated in Figure 6. In this position, it will be seen that the sloping upper surface 55 is substantially contiguous with the upper surface 13 of the housing side opening 12. Still further withdrawal of the mandrel shoe from the ground causes the cover 50 also to be withdrawn from the ground (further relative movement from the cover 50 and the housing 6 being prevented by virtue of the stop means) and the drain is then paid out from the mandrel shoe, in a manner substantially identical to that described with reference to previous embodiments.

It is to be appreciated that whilst the invention has been described with reference to specific embodiments, various modifications could be effected without departing from the scope of the invention. For example, it is envisaged that a locking mechanism may be provided to lock the shaft 15, of the embodiment illustrated in Figure 2, relative to the mandrel shoe housing 6 to prevent movement of the blade 17 towards the opening 12 as the mandrel is withdrawn from the

ground. Such a locking mechanism may be disengaged once the tip of the shaft 15 emerges from the ground.

It is also envisaged that the side opening 12 may be located in a sloped face of the pointed driving head of the mandrel shoe.

Furthermore, it is also envisaged that the automatic feeding and cutting mechanism of the present invention may be used on conventional apparatus, in conjunction with conventional anchor plates. In such an arrangement, workers would still have to secure an anchor plate to the bottom of the next drain to be installed, but as the mandrel is retrieved, the drain could automatically be cut to a desired length, and the next length of drain would be partially fed out ready for connection to an anchor plate. In such an embodiment the guide channel could be straight.

It is envisaged that the mandrel shoe of the present invention may be formed integrally with a mandrel. Additionally, a conventional mandrel could be provided with a side opening so that the vertical drain can be anchored by a length of the vertical drain projecting from the side opening in the mandrel. Such a modified mandrel should preferably also be provided with a pointed head to ease its passage through the ground. For such a modified mandrel, the guide channel comprises the internal channel of the mandrel and its entry into the side opening formed in the mandrel.

**CLAIMS:**

1. A mandrel shoe for the installation of vertical drains, the mandrel shoe comprising: a guide channel extending from an upper end of the mandrel shoe to a side opening formed in the mandrel shoe, the guide channel being adapted to direct a length of drain from an upper end of the mandrel shoe towards and out of the side opening, such that an anchoring length of drain projects from the side opening to anchor the drain within the ground.

2. A mandrel shoe according to claim 1, wherein a releasable retaining means is provided which is adapted to prevent movement of the anchoring length from or into the mandrel shoe as the mandrel shoe is driven into the ground, but to allow substantially free passage of the drain through the mandrel shoe as the mandrel shoe is withdrawn from the ground.

3. A mandrel shoe according to claim 2, wherein the releasable retaining means comprises an upper surface of the side opening with a high coefficient of friction, said upper surface engaging the drain as the mandrel shoe is lowered into the ground with sufficient friction to prevent movement of the anchoring length from or into the mandrel shoe as the mandrel shoe is driven into the ground, and disengaging the drain as the mandrel shoe is withdrawn from the ground.

4. A mandrel shoe according to claim 3, wherein said releasable retaining means further comprises a lower surface of the side opening with a lower coefficient of friction such that free passage of the drain through the mandrel shoe is permitted as the mandrel shoe is withdrawn from the ground.

5. A mandrel shoe according to claim 3 or 4, wherein said upper surface is pitted or corrugated transversely to the guide channel.

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6. A mandrel shoe according to any one of claims 2 to 5, wherein the releasable retaining means comprises a pivotally mounted element projecting into the guide channel and adapted to rotate from a first position which allows substantially free passage of the drain through the guide channel and out of the side opening to a second position which prevents free passage of the drain through the guide channel and into the mandrel shoe.
7. A mandrel shoe according to claim 6, wherein the pivotally mounted element is urged into said second position under the action of the drain bearing upon it as the drain is withdrawn into the mandrel shoe.
8. A mandrel shoe according to claim 7, wherein the surface of the pivotally mounted element has a high coefficient of friction.
9. A mandrel shoe according to claim 8, wherein the surface of the pivotally mounted element is pitted or corrugated transversely to the guide channel.
10. A mandrel shoe according to any preceding claim, wherein the upper end of the mandrel shoe is stepped out from the mandrel by a wedge surface.
11. A mandrel shoe according to any preceding claim, wherein the mandrel shoe is part of a mandrel.
12. A mandrel shoe according to any preceding claim, further comprising feed means adapted to pay out a predetermined length of drain through the opening as the mandrel shoe is lowered from a position above the ground towards the ground.

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13. A mandrel shoe according to claim 12, wherein said feed means comprises a shaft, the shaft being moveable relative to the mandrel shoe and engageable with part of a crane or rig on the surface of the ground.

14. A mandrel shoe according to claim 13, wherein said feed means further comprises releasable coupling means adapted to couple the shaft to the drain to pay out the drain as the shaft is moved in one direction, and to de-couple the shaft from the drain so that no movement of the drain results from movement of the shaft in the opposite direction.

15. A mandrel shoe according to claim 14, wherein said releasable coupling means comprises a feed roller, the feed roller being engageable with the drain.

16. A mandrel shoe according to claim 15, wherein the feed means further comprises an idler roller, the idler roller being engageable with the drain.

17. A mandrel shoe according to claim 15 or 16, further comprising a drive roller in engagement with the shaft, and wherein said releasable coupling means comprises a one-way gear mechanism connecting the drive roller to the feed roller.

18. A mandrel shoe according to any preceding claim, further comprising cutting means actuatable to cut through the drain as the mandrel shoe is withdrawn completely from the ground.

19. A mandrel shoe according to claim 17, wherein said cutting means is actuatable to cut through the drain at a position above ground level.

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20. A mandrel shoe according to claim 18 or claim 19, wherein said cutting means comprises a shaft, the shaft being moveable relative to the mandrel shoe and engageable with part of a crane or rig on the surface of the ground.

21. A mandrel shoe according to claim 20, wherein said cutting means comprises a blade associated with the moveable shaft, the blade being moveable across said opening.

22. A mandrel shoe for use with a mandrel for the installation of vertical drains, an upper end of the mandrel shoe being securable to the bottom of the mandrel, the mandrel shoe comprising: a guide channel extending from an aperture in the upper end of the mandrel shoe to an opening formed in the lower end of the mandrel shoe, the guide channel being adapted to direct a length of drain from the mandrel towards and out of the opening; feed means actuable to pay out a predetermined length of drain through the opening as the mandrel shoe is lowered from a position above the ground towards the ground; and cutting means actuable to cut through the drain as the mandrel shoe is withdrawn completely from the ground.

23. A mandrel shoe according to claim 22, wherein said feed means comprises a shaft, the shaft being moveable relative to the mandrel shoe and engageable with part of a crane or rig on the surface of the ground.

24. A mandrel shoe according to claim 23, wherein said feed means further comprises releasable coupling means adapted to couple the shaft to the drain to pay out the drain as the shaft is moved in one direction, and to de-couple the shaft from the drain so that no movement of the drain results from movement of the shaft in the opposite direction.

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25. A mandrel shoe according to claim 24, wherein said releasable coupling means comprises a feed roller, the feed roller being engageable with the drain.

26. A mandrel shoe according to claim 25, wherein the feed means further comprises an idler roller, the idler roller being engageable with the drain.

27. A mandrel shoe according to claim 25 or claim 26, further comprising a drive roller in engagement with the shaft and wherein the releasable coupling means comprises a one-way gear mechanism connecting the drive roller to the feed roller.

28. A mandrel shoe according to any one of claims 22 to 27, wherein said cutting means is actuatable to cut through the drain at a position above ground level.

29. A mandrel shoe according to any one of claims 22 to 28, wherein said cutting means comprises a shaft, the shaft being moveable relative to the mandrel shoe and engageable with part of a crane or rig on the surface of the ground.

30. A mandrel shoe according to claim 29, wherein said cutting means comprises a blade associated with the moveable shaft, the blade being moveable across said opening.

31. A mandrel shoe according to any preceding claim, further comprising a substantially pointed driving head.

32. A mandrel shoe according to claim 31, wherein the driving head is provided with a removable driving tip.

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33. A mandrel shoe according to claim 31 or claim 32, wherein the upper region of the driving head is wider than the mandrel shoe.
34. A mandrel shoe according to any preceding claim, further comprising a cover element slidably mounted over the mandrel shoe, the cover element being slidable from a first position in which the anchoring length of drain is located between the cover and the mandrel shoe to a second position in which the anchoring length projects through an opening in the cover element.
35. A mandrel shoe according to claim 34, wherein the cover element is adapted to urge the anchoring length of drain away from the outer surface of the mandrel shoe and through the opening in the cover element as the cover element slides from said first position to said second position.
36. A mandrel shoe according to claim 34 or 35, wherein the cover element is adapted to slide from said first position to said second position as the mandrel shoe is withdrawn from the ground.
37. A method of installing vertical drains comprising the steps of: priming a mandrel shoe with a length of drain such that an anchoring length of drain projects substantially sideways from the mandrel shoe; driving the mandrel shoe into the ground to a predetermined depth, the anchoring length of drain being urged into a position against a side of the mandrel shoe as the mandrel shoe is driven into the ground; releasing the anchoring length from the side of the mandrel shoe to entrap the anchoring length in the ground such that the vertical drain is anchored in place by the protruding anchoring length; and subsequently withdrawing the mandrel shoe from the ground.

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38. A method according to claim 37, wherein the step of priming the mandrel shoe includes the step of feeding the anchoring length through a side opening in the mandrel shoe.

39. A method according to claim 38, wherein the anchoring length is held in position with respect to the mandrel shoe due to a frictional force between the side opening and the drain, the frictional force being sufficient to prevent movement of the anchoring length from or into the mandrel shoe as the mandrel shoe is driven into the ground.

40. A method according to any one of claims 37 to 39, wherein the anchoring length is located between the mandrel shoe and a cover element slidably mounted thereover whilst the mandrel shoe is driven into the ground.

41. A method according to any one of claims 37 to 40, wherein said step of releasing the anchoring length from the side of the mandrel shoe is effected by upwards movement of the mandrel shoe.

42. A method according to claim 41, wherein said upwards movement of the mandrel shoe drives earth between the anchoring length and the mandrel shoe.

43. A method according to claim 41 as dependent upon claim 40, wherein said upwards movement of the mandrel shoe causes relative movement between the cover element and the mandrel shoe, such that the anchoring length of drain projects from the side of the mandrel shoe and is entrapped in the ground.

44. A method according to any one of claims 37 to 43, wherein the or each anchoring length of drain is approximately 200mm in length.

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45. A method according to any one of claims 37 to 44, further comprising the step of paying out the anchoring length of drain from the mandrel shoe as the mandrel shoe is lowered from a position above the ground towards the ground.
46. A method according to claim 45, wherein said paying out step is effected by movement of a moveable shaft relative to the mandrel shoe, the shaft engaging part of a crane or rig on the surface of the ground.
47. A method according to any one of claims 37 to 46, comprising the further step of cutting the drain once the mandrel shoe has been fully withdrawn from the ground.
48. A method according to claim 47, wherein the drain is cut at a position above ground level to leave a length of the installed drain protruding from the ground.
49. A method of installing vertical drains comprising the steps of : priming a mandrel shoe with a length of drain; paying out a predetermined length of drain through an opening in the mandrel shoe as the mandrel shoe is lowered from a position above the ground towards the ground; driving the mandrel shoe into the ground to a predetermined depth; subsequently withdrawing the mandrel shoe from the ground to leave the vertical drain embedded in the ground; and cutting the drain once the mandrel shoe has been fully withdrawn from the ground.
50. A method according to claim 49, wherein said paying out step is effected by movement of a moveable shaft relative to the mandrel shoe, the shaft engaging part of a crane or rig on the surface of the ground.



51. A method according to claim 49 or claim 50, wherein the drain is cut at a position above ground level to leave a length of the installed drain protruding from the ground.

52. A method according to any one of claims 49 to 51 comprising the step of fixing anchor means to the predetermined length of drain paid out from the mandrel shoe.

53. A mandrel shoe for use with a mandrel for the installation of vertical drains, an upper end of the mandrel shoe being securable to the bottom of the mandrel, the mandrel shoe comprising: a guide channel extending from an aperture in the upper end of the mandrel shoe to an opening formed in the lower end of the mandrel shoe, the guide channel being adapted to direct a length of drain from the mandrel towards and out of the opening; and feed means actuable to pay out a predetermined length of drain through the opening as the mandrel shoe is lowered from a position above the ground towards the ground.

54. A method of installing vertical drains comprising the steps of: priming a mandrel shoe with a length of drain; paying out a predetermined length of drain through an opening in the mandrel shoe as the mandrel shoe is lowered from a position above the ground towards the ground; driving the mandrel shoe into the ground to a predetermined depth; subsequently withdrawing the mandrel shoe from the ground to leave the vertical drain embedded in the ground.

55. A mandrel shoe for use with a mandrel for the installation of vertical drains, an upper end of the mandrel shoe being securable to the bottom of the mandrel, the mandrel shoe comprising : a guide channel extending from an aperture in the upper end of the mandrel shoe to an opening in the lower end of the mandrel shoe, the guide channel being adapted to direct a length of drain from the mandrel



towards and out of the opening; and cutting means adapted to cut through the drain as the mandrel shoe is withdrawn completely from the ground.

56. A method of installing vertical drains using a mandrel shoe having cutting means associated therewith, which method comprises the steps of : priming a mandrel shoe with a length of drain; driving the mandrel shoe into the ground to a predetermined depth; subsequently withdrawing the mandrel shoe from the ground to leave the vertical drain embedded in the ground; and cutting the drain once the mandrel shoe has been fully withdrawn from the ground, said cutting means being operable to cut the drain automatically when the mandrel shoe is clear of the ground.

57. A mandrel shoe for use with a mandrel for the installation of vertical drains, an upper end of the mandrel shoe being securable to the bottom of the mandrel, the mandrel shoe comprising : a guide channel extending from an upper end of the mandrel shoe to a side opening formed in a lower end of the mandrel shoe, the guide channel being adapted to direct length of drain from an upper end of the mandrel shoe towards and out of the side opening, such that an anchoring length of drain projects from the side opening to anchor the drain within the ground and a cover element slidably mounted over the mandrel shoe, the cover element having a recess to accommodate the anchoring length between the cover element and the mandrel shoe as the mandrel shoe is driven into the ground, the cover element being adapted to slide relative to the mandrel shoe as the mandrel shoe is subsequently withdrawn from the ground such that the anchoring length of drain projects from the mandrel shoe.

58. A mandrel shoe substantially as herein described with reference to and as shown in Figure 2 of the accompanying drawings.



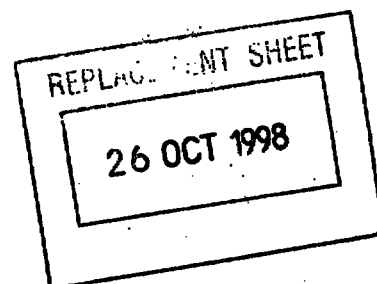
59. A mandrel shoe substantially as hereinbefore described with reference to and as shown in Figure 3 of the accompanying drawings.
60. A mandrel shoe substantially as herein described with reference to and as shown in Figures 4, 5 and 6 of the accompanying drawings.
61. A method of installing vertical drains substantially as herein described.
62. Any novel feature or combination of features disclosed herein.



AMENDED CLAIMS

[received by the International Bureau on 26 October 1998 (26.09.98);
original claims 22, 37, 49 and 53-56 amended;
remaining claims unchanged (5 pages)]

20. A mandrel shoe according to claim 18 or claim 19, wherein said cutting means comprises a shaft, the shaft being moveable relative to the mandrel shoe and engageable with part of a crane or rig on the surface of the ground.
21. A mandrel shoe according to claim 20, wherein said cutting means comprises a blade associated with the moveable shaft, the blade being moveable across said opening.
22. A mandrel shoe for use with a mandrel for the installation of vertical drains, an upper end of the mandrel shoe being securable to the bottom of the mandrel, the mandrel shoe comprising: a guide channel extending from an aperture in the upper end of the mandrel shoe to an opening formed in the lower end of the mandrel shoe, the guide channel being adapted to direct a length of drain from the mandrel towards and out of the opening; feed means actuable to pay out a predetermined length of drain through the opening under the action of the mandrel shoe being lowered from a position above the ground towards the ground; and cutting means actuable to cut through the drain as the mandrel shoe is withdrawn completely from the ground.
23. A mandrel shoe according to claim 22, wherein said feed means comprises a shaft, the shaft being moveable relative to the mandrel shoe and engageable with part of a crane or rig on the surface of the ground.
24. A mandrel shoe according to claim 23, wherein said feed means further comprises releasable coupling means adapted to couple the shaft to the drain to pay out the drain as the shaft is moved in one direction, and to de-couple the shaft from the drain so that no movement of the drain results from movement of the shaft in the opposite direction.





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33. A mandrel shoe according to claim 31 or claim 32, wherein the upper region of the driving head is wider than the mandrel shoe.

34. A mandrel shoe according to any preceding claim, further comprising a cover element slidably mounted over the mandrel shoe, the cover element being slidable from a first position in which the anchoring length of drain is located between the cover and the mandrel shoe to a second position in which the anchoring length projects through an opening in the cover element.

35. A mandrel shoe according to claim 34, wherein the cover element is adapted to urge the anchoring length of drain away from the outer surface of the mandrel shoe and through the opening in the cover element as the cover element slides from said first position to said second position.

36. A mandrel shoe according to claim 34 or 35, wherein the cover element is adapted to slide from said first position to said second position as the mandrel shoe is withdrawn from the ground.

37. A method of installing vertical drains comprising the steps of: priming a mandrel shoe with a length of drain such that an anchoring length of drain projects substantially sideways from the mandrel shoe through a side opening formed in the lower end of the mandrel shoe; driving the mandrel shoe into the ground to a predetermined depth, the anchoring length of drain being urged into a position against a side of the mandrel shoe as the mandrel shoe is driven into the ground; releasing the anchoring length from the side of the mandrel shoe to entrap the anchoring length in the ground such that the vertical drain is anchored in place by the protruding anchoring length; and subsequently withdrawing the mandrel shoe from the ground.

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45. A method according to any one of claims 37 to 44, further comprising the step of paying out the anchoring length of drain from the mandrel shoe as the mandrel shoe is lowered from a position above the ground towards the ground.

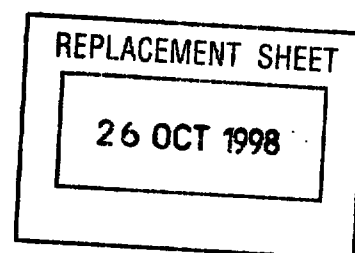
46. A method according to claim 45, wherein said paying out step is effected by movement of a moveable shaft relative to the mandrel shoe, the shaft engaging part of a crane or rig on the surface of the ground.

47. A method according to any one of claims 37 to 46, comprising the further step of cutting the drain once the mandrel shoe has been fully withdrawn from the ground.

48. A method according to claim 47, wherein the drain is cut at a position above ground level to leave a length of the installed drain protruding from the ground.

49. A method of installing vertical drains comprising the steps of : priming a mandrel shoe with a length of drain; paying out a predetermined length of drain through an opening in the mandrel shoe under the action of the mandrel shoe being lowered from a position above the ground towards the ground; driving the mandrel shoe into the ground to a predetermined depth; subsequently withdrawing the mandrel shoe from the ground to leave the vertical drain embedded in the ground; and cutting the drain once the mandrel shoe has been fully withdrawn from the ground.

50. A method according to claim 49, wherein said paying out step is effected by movement of a moveable shaft relative to the mandrel shoe, the shaft engaging part of a crane or rig on the surface of the ground.





51. A method according to claim 49 or claim 50, wherein the drain is cut at a position above ground level to leave a length of the installed drain protruding from the ground.

52. A method according to any one of claims 49 to 51 comprising the step of fixing anchor means to the predetermined length of drain paid out from the mandrel shoe.

53. A mandrel shoe for use with a mandrel for the installation of vertical drains, an upper end of the mandrel shoe being securable to the bottom of the mandrel, the mandrel shoe comprising: a guide channel extending from an aperture in the upper end of the mandrel shoe to an opening formed in the lower end of the mandrel shoe, the guide channel being adapted to direct a length of drain from the mandrel towards and out of the opening; and feed means actuable to pay out a predetermined length of drain through the opening under the action of the mandrel shoe being lowered from a position above the ground towards the ground.

54. A method of installing vertical drains comprising the steps of: priming a mandrel shoe with a length of drain; paying out a predetermined length of drain through an opening in the mandrel shoe under the action of the mandrel shoe being lowered from a position above the ground towards the ground; driving the mandrel shoe into the ground to a predetermined depth; subsequently withdrawing the mandrel shoe from the ground to leave the vertical drain embedded in the ground.

55. A mandrel shoe for use with a mandrel for the installation of vertical drains, an upper end of the mandrel shoe being securable to the bottom of the mandrel, the mandrel shoe comprising : a guide channel extending from an aperture in the upper end of the mandrel shoe to an opening in the lower end of the mandrel shoe, the guide channel being adapted to direct a length of drain from the mandrel

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towards and out of the opening; and cutting means adapted to cut through the drain under the action of the mandrel shoe being withdrawn clear from the ground.

56. A method of installing vertical drains using a mandrel shoe having cutting means associated therewith, which method comprises the steps of : priming a mandrel shoe with a length of drain; driving the mandrel shoe into the ground to a predetermined depth; subsequently withdrawing the mandrel shoe from the ground to leave the vertical drain embedded in the ground; and cutting the drain once the mandrel shoe has been fully withdrawn from the ground, said cutting means being operable to cut the drain under the action of the mandrel shoe being withdrawn clear from the ground.

57. A mandrel shoe for use with a mandrel for the installation of vertical drains, an upper end of the mandrel shoe being securable to the bottom of the mandrel, the mandrel shoe comprising : a guide channel extending from an upper end of the mandrel shoe to a side opening formed in a lower end of the mandrel shoe, the guide channel being adapted to direct length of drain from an upper end of the mandrel shoe towards and out of the side opening, such that an anchoring length of drain projects from the side opening to anchor the drain within the ground and a cover element slidably mounted over the mandrel shoe, the cover element having a recess to accommodate the anchoring length between the cover element and the mandrel shoe as the mandrel shoe is driven into the ground, the cover element being adapted to slide relative to the mandrel shoe as the mandrel shoe is subsequently withdrawn from the ground such that the anchoring length of drain projects from the mandrel shoe.

58. A mandrel shoe substantially as herein described with reference to and as shown in Figure 2 of the accompanying drawings.

