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**"A vertical drain stitcher"**

THIS INVENTION relates to a vertical drain stitcher.

A vertical drain stitcher refers to the mast or rig which is used for the purpose of installing vertical drains into the soil strata. A vertical drain is a substantially hollow plastics drain which is inserted vertically into ground or soil which is to be drained. The pressure introduced by a surcharge load placed over the area to be treated forces water in the sub-soils and soft clays to move to and up through the drain. It is important that the drain penetrates to a sufficient depth. In typical installations, vertical drains need to be installed to as deep as 50m and may need to be deployed in arrays in which the vertical drains are separated by, typically, 1-2m. Thus, the installation of vertical drains in just a 2500m<sup>2</sup> site could involve as much as 125,000m of vertical drains. The construction equipment that is used to install the vertical drain to the required depths is in the form of a tall mast which is commonly called a "stitcher" within the industry. The stitcher is typically attached to a base machine such as a standard excavator or crane. In some cases, stitchers may be provided with a purpose built base machine. The base machine is used to move and position the stitcher at various installation points and usually also supplies the hydraulic power should the stitcher be hydraulically operated. The stitcher punches a mandrel, containing a length of vertical drain, into the soil to a desired depth.

The first generation of such stitchers used a counter-weight system to drive the mandrel into the soil. Such so-called static systems are now obsolete. The following generation of stitcher used a set of hydraulic motors to drive a chain and sprocket assembly, the chain being attached to the top of the mandrel. A significant drawback to this equipment is that the chain, which is

made up of numerous links, frequently breaks and the speed of mandrel penetration into the soil is slow. Due to the downtime caused by frequent chain breakages, the output (i.e. quantity of vertical drain installed) per week is low.

The most efficient stitcher presently available uses a hydraulic system, the stroke of which is multiplied by a cable passing round a set of pulleys which drives the mandrel. The stroke of the piston is hydraulically controlled by the base machine. The stroke of the piston is in the region of 4.5m. To obtain an installation depth of, for example, 50m, the multiplication factor required by the pulley arrangement is significant but achievable. However, this system is expensive and complicated to manufacture and maintain due to the immense size of the hydraulic cylinder required. Such hydraulic cylinders are not available "off-the-shelf" and must be specially ordered, so the lead time to manufacture a stitcher of this type is prohibitive.

As in cranes, hoists and other construction equipment, in place of using a chain and sprocket drive, it has been proposed to use a cable driven system with hydraulic motors (hydromotors). Since a sprocket cannot be used to drive a cable, the cable is wound around one or more drums to enable the cable to grip the or each drum. Such a cable driven system is disclosed in US-A-5,584,603 in which the stitcher uses a single cable trained around a pair of drums and attached to the mandrel at the ends of the cable which thereby forms a closed loop running from: an attachment point on the mandrel, around a first pulley wheel located at the top of the supporting mast, down to a first drum, around the first drum and onto a second drum, around the second drum and back around the first drum and the second drum a number of times in a figure of eight pattern, then from the second drum to a second pulley wheel located at the bottom of the supporting mast and thence back up to another attachment point on the mandrel. Either or both drums need to be driven by a hydromotor

and the cable trained around both the drums in the complicated figure of eight manner to allow the cable to grip onto and be driven by the hydromotors. Hydromotors are expensive items and it is an object of the present invention to provide a cable driven system which does not require a complex method of training the cable around a driving drum and which only requires a single hydromotor or other driving device to drive and retract the mandrel into and out of the ground.

Although cables do not break as often as chains, they are also subject to fatigue. The resistance to penetration differs with every site condition. When the cable breaks, the full length of the cable has to be replaced in this stitcher due to the closed loop. Both unwinding and winding in the complex figure of eight around both drums is an awkward task on a construction site, a 100m cable weighing approximately 72kg. Further, any maintenance of the drums in this stitcher requires both drums to be fully unwound so as to allow access to the drums. Because the cable is provided in a closed loop and is wound around both drums in the complex figure of eight manner, any such maintenance is time consuming and awkward.

It is an object of the present invention to seek to provide a stitcher which does not suffer from the above mentioned disadvantages.

Accordingly, one aspect of the present invention provides a vertical drain stitcher comprising: a substantially vertical mast; a mandrel head slidably mounted on the mast for travel along the mast; and a pair of drums each having a core wound with a separate cable, a first cable passing from a first drum up to and around the top of the mast and then down to the mandrel head and a second cable passing from a second drum to and around the bottom of the mast and then up to the mandrel head such that winding in the cable on

the first drum moves the mandrel head to the top of the mast and winding in the cable on the second drum moves the mandrel head to the base of the mast.

Preferably, a single motor is provided to drive both drums.

The use of two separate cables is especially advantageous since both sets of cables do not have to be replaced in the event that there is a cable breakage. Also, since the cable lengths used in the present invention are half the cable length which would be required in a closed loop cable system, the winding and unwinding of cable on site is easier with less downtime. When the motor is disengaged, the drums can freewheel. All the worker on site has to do with a stitcher embodying the present invention is to connect the ends of a replacement cable, one end to a mandrel holder (as will be described later) and one end to a respective drum. The worker can then manually rotate the drum to coil up the replacement cable to take up any slack. It is further preferred to drive the two separate cables by a single driving means.

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:

FIGURE 1 is a view from one side of one stitcher embodying the present invention attached to an excavator;

FIGURE 2 is a front view of the stitcher of Figure 1, the excavator being omitted for clarity of illustration;

FIGURE 3 is a front view of a mandrel head bolted to a mandrel for use with the present invention;

FIGURE 4 is a side view of a mandrel head bolted to a mandrel for use with the present invention;

FIGURE 5 is a detailed view from one side of a top portion of a mast body of the stitcher of Figures 1 and 2;

FIGURE 6 is a side view of a cable drive mechanism embodying the present invention;

FIGURE 7 is a front view of a cable drive mechanism embodying the present invention;

FIGURE 8 is a detailed view from the other side of the top portion of the mast body of the stitcher of Figures 1 and 2;

FIGURE 9 is a front view of the top portion of the mast body of the stitcher of Figures 1 and 2;

FIGURE 10 is a partial view of the bottom portion of the mast body of the stitcher of Figures 1 and 2; and

FIGURE 11 is a partly sectioned view from the one side showing another embodiment of a drive mechanism used in the stitcher of Figures 1 and 2.

Referring to Figure 1, an excavator 1 is shown carrying a stitcher 2 comprising a mast or rig 3 made up of three (or more depending on the depth of installation required) square hollow sections stacked one above the other, the

cross-sectional area of each telescopic section decreasing with height. The mast 3 supports a mandrel to the top of which is attached a mandrel head.

Towards the base of the mast 3, a single hydraulic motor is provided which is preferably a hydraulic radial piston motor 4. The motor 4 is activated by a hydraulic feed 4A from the excavator 1. Referring to Figures 6 and 7, the motor 4 is connected to a pair of rotatable drums 5,6 by a motor shaft 7 housed in a frame 30. The drums 5,6 are mounted on respective shafts 5A,6A which are supported in the frame by roller bearings 31 and 32. A drum gear 5B,6B is mounted on each of the drums 5,6. A drive gear 7B is provided at the end of the motor shaft 7 and is meshed with both of the drum gears 5B,6B so as to rotate the drums 5,6 when the gears 5B,6B are driven by the drive gear 7B. Rotation of the motor shaft 7 by a single motor thereby drives both of the drums 5,6. By way of example only, it is envisaged that the motor 4 may operate at the rate of one revolution per second and the gearing may be selected to turn the drums 5,6 at the rate of 3.5 revolutions per second.

The first drum 5 is wound with a first cable 17 which is secured to the drum at its end. The cable is wound in a clockwise sense (see Figure 7) around the drum 5. The first cable leaves the drum casing in an upward direction toward the top of the mast 3, engages with a guide roller 18 journaled to the mast body and travels up the length of the mast 3 to the tip 19 of the mast.

Referring to Figure 5, a pulley 20 is mounted at the tip of the mast 19. The cable 17 passes over the pulley 20 and down the opposite side of the mast 3 to a mandrel head 21 to which that end of the cable 17 is fixed. Referring to Figures 3 and 4, the mandrel head 21 is a block at the top of the mandrel to which the mandrel 22 is bolted. The mandrel head 21 is provided with two fixing points. Each of the fixing points is adapted to receive and retain an end

of a cable. The mandrel 22 is hollow so as to receive a length of vertical drain 23.

Turning again to Figures 6 and 7, the second drum 6 is wound with a second cable 25 which is secured to the drum at its end. The cable 25 is wound in an anti-clockwise sense (see Figure 7) around the drum 6 - i.e. in the opposite sense to the other drum 5. The second cable 25 leaves the drum casing in a downward direction toward the bottom of the mast 3, engages with a guide roller 26 journaled to the mast body and travels down the mast 3 to the bottom of the mast where it engages a pulley 27. The second cable 25 then travels up outside the mast 3 and is fixed at its end to the mandrel head 21.

The vertical drain 23 which is fed through the mandrel head 21 and the mandrel 22 and projects out of the bottom of the mandrel 22. The mandrel is driven into the ground by the mandrel head 21 and as the mandrel 22 gradually penetrates the ground, more vertical drain is supplied to the mandrel by a coil 29 of vertical drain located at the base of the mast 3.

In operation, the mandrel head 21 starts at the top of the mast 3 with the bottom of the mast clear of the ground. A length of vertical drain 23 is deliberately left projecting from the bottom of the mandrel 22 so as to form an anchoring portion for the vertical drain when the vertical drain has reached its desired installation depth. To begin the driving of the mandrel 22 into the ground, the motor 4 is activated to rotate the motor shaft 7 anti-clockwise (as shown in Figure 7) thereby winding in the second length of the cable 25 extending from the drum 6 around the guide roller 26 and bottom roller 27 and up to its point of attachment to the mandrel head. As the drum 6 pays in the length of the second cable 25, the first drum 5 is also being driven by the motor

thereby paying out an equivalent length of the first cable 17 which loops around the upper pulley 24 and is fixed to the mandrel head.

At the end of the first stroke of the mandrel 22 into the ground, the direction of rotation of the motor shaft 7 powered by the motor 4 is reversed so that the drums 5,6 rotate anti-clockwise. The first drum 5 thereby reels in the first length of cable 17 which is looped around the upper pulley 24 now located below the top of the mast such that the mandrel head 21 is drawn back up to the top of the mast. From this point, a second downward stroke of the mandrel 22 into the ground can be initiated by reversing again the direction of the motor 4 and thereby the motor shaft 7 to reel in the second length of cable 25 onto the drum 6 and pay out the equivalent length of the first cable 17 from the first drum 5.

The use of two separate cables is especially advantageous since both sets of cables do not have to be replaced in the event that there is a cable breakage. Also, since the cable lengths used in the present invention are half the cable length which would be required in a closed loop cable system, the winding and unwinding of cable on site is easier with less downtime. When the motor is disengaged, the drums can freewheel. All the worker on site has to do with a stitcher embodying the present invention is to connect the ends of a replacement cable, one end to a mandrel holder (as will be described later) and one end to a respective drum, there is no need for a complex unwinding operation. The worker can then manually rotate the drum to coil up the replacement cable to take up any slack. In the preferred configuration, one drum is void of cable when the mandrel is at the end of either its upstroke or its downstroke. Under these conditions, the replacement of a broken cable becomes an even easier task taking up very little time since there is no unwinding required as the drum is void of cable.

In another embodiment of the invention shown in Figure 11, The reels 5,6 are mounted on a common motor shaft 7 which is supported in the frame by roller bearings 31 and 32 and which is rotatable by the motor 4 via gearing (not shown) provided between the motor 4 and the motor shaft 7. By way of example only, it is envisaged that the motor 4 may operate at the rate of one revolution per second and the gearing may be selected to turn the drive shaft at the rate of 3.5 revolutions per second. Each reel 5,6 is mounted on the motor shaft 7 by a key 8 which extends substantially along the length of the shaft 7. Each of the reels 5,6 is mounted on the shaft 7 via a respective clutch bearing 9,10. The clutch bearings 9,10 are mounted on the shaft 7 such that when the shaft 7 rotates in the clockwise direction, one clutch bearing 9 engages the shaft and drives one of the reels 5 whereas the other clutch bearing 10 free-wheels so that the other reel 6 is allowed to rotate freely in the opposite direction. Similarly, when the shaft 7 is rotated in the anti-clockwise direction, the other reel 6 is driven whereas the other reel 5 is allowed to rotate freely in the opposite direction. Each drum 5,6 comprises a central cylindrical core 11,12 sandwiched on either side by a pair of discs 13,14;15,16 respectively. The cores 11,12 have a predetermined diameter. The discs 13,14;15,16 are spaced apart from one another by a distance equivalent to the diameter of the cables which are wound around the drums 5,6 such that the discs 13,14;15,16 act as guide means to lay each turn of the cable on a single preceding turn on the drum, so that each new turn increases the effective diameter of the core.

Because the spacing between the discs 13,14;15,16 is only the diameter of the respective cable 17,25, as the respective drums wind in the respective cables 17,25, the diameter of the central core 11,12 upon which the cable is being wound effectively increases thereby generating an increased speed of movement of the mandrel head 21 for a given revolutionary speed of the drive

shaft 7. This effective acceleration of the mandrel head 21 in both directions greatly increases the penetration speed of the mandrel 22 and, in turn, increases the speed at which installations of vertical drains 23 can take place. It has been calculated that the average speed of installation for this embodiment of the invention is in the region of 3.5m/sec. It should be noted that typical penetration of speeds for hydraulic stitchers with chain drives are in the region of 1.3m/sec. Of course, it is to be appreciated that the motor 4 need not be hydraulic but could, for example, be pneumatic or electric or any other similar type of motor can be used. Embodiments of the invention are envisaged which do not include the use of clutch bearings 9,10. In such instances, some slack might be encountered in the respective cable which is not being driven at any one time which would result in some loss of efficiency. However, it is to be appreciated that the use of clutch bearings is not essential.

Further, in this embodiment, the cables are not fixed to the mandrel head 21 which, instead, carries a pair of pulleys located one at the top end of the mandrel head 21 and one at the bottom end of the mandrel head 21. This arrangement is shown in Figure 10. The upper pulley 24 receives the cable 17 which is looped around the pulley 24 and directed back up to the tip 19 of the mast 3. The end of the cable 17 is attached to the tip 19 of the mast as shown in Figure 8.

The pulley 20 mounted at the tip of the mast 19 is pivotable within a limited angular range for reasons which are described later. Similarly, the pulley 27 at the bottom of the mast is pivotable within a predetermined angular.

The cable 17 passes over the pulley 20 and down the opposite side of the mast 3 to the mandrel holder 21, loops around the upper pulley 24 and is fixed at the top of the mast 3. The second cable 25 loops around the pulley 27 at the

bottom of the mast and travels up outside the mast 3 and around the lower pulley 28 mounted on the mandrel head 21, then back down the length of the mast 3 and is fixed at the bottom of the mast 3 as shown in Figure 10.

In this embodiment, the pulleys at the top 19 and bottom of the mast 3 must be allowed to pivot through a small angular range since the respective cables 17,25 which are looped around them pass from the pulleys to the mandrel head 21 which can occupy any position along the length of the mast 3. As the mandrel head 21 travels along the length of the mast 3, the angle which the respective cables 17,25 subtend between the respective top and bottom pulleys 20,27 varies. For this reason, the pulleys are allowed to pivot so as to move and follow the small angular changes caused by the movement of the mandrel head 21 along the length of the mast 3.

The upper and lower pulleys 24,28 on the mandrel head 21 provide the system with a 2:1 purchase such that if a 50m stroke is required to insert the vertical drain, then approximately 100m of cable will need to be housed on each of the drums 5,6. The table below provides indications of required drum diameters based on the length of the stroke of the mandrel head, the internal diameter of the drums, the diameter of the cable and also provides an average installation speed (and withdrawal speed) in each case.

**TABLE**

|                                |     |     |      |     |      |      |      |      |      |
|--------------------------------|-----|-----|------|-----|------|------|------|------|------|
| Mandrel head stroke<br>(m)     | 20  | 20  | 20   | 30  | 30   | 30   | 50   | 50   | 50   |
| Reeled cable length<br>(m)     | 40  | 40  | 40   | 60  | 60   | 60   | 100  | 100  | 100  |
| Internal drum diameter<br>(mm) | 300 | 400 | 500  | 300 | 400  | 500  | 300  | 400  | 500  |
| Cable diameter<br>(mm)         | 20  | 25  | 30   | 20  | 25   | 30   | 20   | 25   | 30   |
| Fully wound drum diameter      | 780 | 900 | 1000 | 930 | 1070 | 1200 | 1180 | 1350 | 1490 |

|                            |     |     |     |     |     |     |     |     |     |  |
|----------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|--|
| (mm)                       |     |     |     |     |     |     |     |     |     |  |
| Average drum speed         | 150 | 210 | 270 | 150 | 210 | 270 | 150 | 210 | 270 |  |
| (rpm)                      |     |     |     |     |     |     |     |     |     |  |
| Average installation speed | 2.4 | 3.8 | 5.7 | 2.8 | 4.4 | 6.5 | 3.4 | 5.5 | 7.8 |  |
| (m/s)                      |     |     |     |     |     |     |     |     |     |  |

The average installation speed is calculated as being the speed of the mandrel head at a point halfway through its stroke, i.e. when half of the length of cable on the respective drum has been reeled in. The average drum speed comprises the constant speed of the drum in revolutions per minute. It should be noted that gearing between the motor 4 and drive shaft 7 is available to multiply the motor speed from, for example, 60 rpm to 150, 210 or 270 rpm or as otherwise required.

One advantage of this embodiment is that as the mandrel head 21 reaches the end of its stroke, the effective diameter of the core 11,12 of the driving drum 5,6 is increased thereby increasing the speed of travel of the mandrel head. Thus, for example, as the mandrel head is approaching the end of its stroke driving the mandrel into the ground, the mandrel head will actually be accelerating. This characteristic of the invention serves to increase installation speeds thereby decreasing the time required for each installation.



**CLAIMS:**

1. A vertical drain stitcher comprising: a substantially vertical mast; a mandrel head slidably mounted on the mast for travel along the mast; and a pair of drums each having a core wound with a separate cable, a first cable passing from a first drum up to and around the top of the mast and then down to the mandrel head and a second cable passing from a second drum to and around the bottom of the mast and then up to the mandrel head such that winding in the cable on the first drum moves the mandrel head to the top of the mast and winding in the cable on the second drum moves the mandrel head to the base of the mast.
2. A stitcher according to Claim 1, wherein each drum is mounted on a separate drum shaft.
3. A stitcher according to Claim 2, wherein each drum shaft is provided with a gear.
4. A stitcher according to Claim 3, wherein a motor shaft is provided having a gear and the gear on the motor shaft meshes with both of the gears on the drum shafts.
5. A stitcher according to any one of Claims 1 to 4, wherein the cable wound around the first drum is wound in the opposite direction to the cable wound around the second drum such that driving the single motor in one direction reels in the cable onto one of the drums and pays out the cable from the other of the drums.



6. A stitcher according to Claim 1, wherein the drums are mounted on a common drum shaft.
7. A stitcher according to any preceding claim, wherein each drum has guide means to lay each turn of the cable on a single preceding turn on the drum, so that the turns increase the effective diameter of the core.
8. A stitcher according to Claim 7, wherein the guide means on each drum comprises a pair of discs spaced apart by a distance equivalent to or slightly greater than the diameter of the cable to be laid on the drum.
9. A stitcher according to any preceding claim, wherein the first cable and the second cable are fixed to the mandrel head.
10. A stitcher according to any one of Claims 1 to 9, wherein the mandrel head carries an upper pulley and a lower pulley, the first cable passing from the top of the mast and around the upper pulley and being fixed to the top of the mast and the second cable passing around the lower pulley down to the base of the mast and being fixed to the base of the mast.
11. A stitcher according to any preceding claim, wherein the first cable passes from the first drum up to and around a pulley point at the top of the mast and then down to the mandrel head.
12. A stitcher according to any preceding claim, wherein the second cable passes from the second drum down to and around a pulley point at the base of the mast and then up to the mandrel head.



13. A stitcher according to Claim 6, wherein each of the drums is mounted to the drive shaft by a clutch bearing such that each drum is drivable in a respective direction by the drive shaft and allowed to rotate freely in the opposite direction.

14. A stitcher according to any preceding claim, wherein a single motor is provided to drive both drums.

15. A stitcher substantially as hereinbefore described with reference to and as shown in the accompanying drawings.