

A GEOTECHNICAL APPARATUS AND METHOD OF USAGE

Field

The present invention generally relates to a geotechnical apparatus and method
5 of usage.

Background

For most geotechnical projects, soft soil needs to be improved using
reinforcement or consolidation (by preloading), or a combination of both
10 methods. For the reinforcement method, geotextiles or geogrids are often
adopted, whereas for the consolidation method, prefabricated vertical drains are
typically used. Sometimes, both the reinforcement and consolidation methods
are used concurrently, but unfortunately, there are presently no products on the
market that may provide both reinforcement and drainage functions.

15 Recently, several methods of using prefabricated vertical drains (PVDs) have
been proposed for improvement of soft clay by preloading. The general
approach is to insert the PVDs into the soft clay, and apply vacuum pressure or
a surcharge load to consolidate the soft clay. However, treatment of very soft
20 materials having high water content is still fairly difficult. Also, another challenge
is how to provide a working platform, on a slurry layer, for carrying out the
required soil improvement works, e.g. vacuum preloading. It is to be appreciated
that conventional methods used to facilitate provision of the working platform
include: (1) capping with sand or other good soil; (2) using geotextile(s); (3)
25 using cement mixing; and (4) de-watering using drainage.

One object of the present invention is therefore to address at least one of the
problems of the prior art and/or to provide a choice that is useful in the art.

30 Summary

According to a 1st aspect of the invention, there is provided a geotechnical
apparatus comprising: a geotextile; and at least one drainage conduit coupled
onto the geotextile and arranged to receive vacuum pressure, wherein in use,
the apparatus is embedded in soil, and vacuum pressure is introduced into the

drainage conduit to enable fluid in the soil to be drawn thereinto to be drained for consolidating the soil.

5 Preferably, the at least one drainage conduit may include a plurality of drainage conduits.

Preferably, the plurality of drainage conduits may be in an evenly spaced arrangement.

10 Preferably, the drainage conduit may be formed of a flexible polymer, which includes plastics.

Preferably, the drainage conduit may be coupled parallel to the longitudinal axis of the geotextile.

15 Preferably, the apparatus may further comprise a geotechnical fabric for coupling the drainage conduit to the geotextile.

Preferably, the geotechnical fabric may include a filter sleeve.

20 Preferably, the coupling may be enabled by gluing or heat melting the geotechnical fabric to collectively the drainage conduit and geotextile.

25 Preferably, the drainage conduit may have a plurality of internal conduits, further comprising at least two electrodes arranged within respective internal conduits, and configured to electrically be operated as anodes or cathodes.

Preferably, each electrode may be formed of titanium, stainless steel, copper, or copper coated with mixed metal oxide.

30 Preferably, the apparatus may be configured to be flexibly arranged into a roll for storage.

35 Preferably, the drainage conduit may include being configured to be fluid permeable.

According to a 2nd aspect of the invention, there is provided a method of using a geotechnical apparatus, which includes a geotextile and at least one drainage conduit coupled onto the geotextile and arranged to receive vacuum pressure, the method comprises: (i) providing the apparatus on a first layer of soil; (ii)
5 providing a second layer of soil on the apparatus to embed the apparatus within the first and second layers of soil; and (iii) introducing vacuum pressure into the drainage conduit to enable fluid in the soil to be drawn thereinto to be drained for consolidating the soil.

10 Preferably, the method may further comprise coupling the drainage conduit to a vacuum pump configured to generate the vacuum pressure.

According to a 3rd aspect of the invention, there is provided a geotechnical apparatus comprising: a geotextile; at least one drainage conduit coupled onto
15 the geotextile and arranged to receive vacuum pressure; and at least two electrodes arranged within the drainage conduit, and configured to electrically be operated as anodes or cathodes, wherein in use, the apparatus is embedded in soil, and vacuum pressure is introduced into the drainage conduit to enable fluid in the soil to be drawn thereinto to be drained for consolidating the soil, and/or
20 the electrodes are operated to electrically direct the fluid in the soil towards/away from the apparatus to be drained.

Preferably, each electrode may be formed of titanium, stainless steel, copper, or copper coated with mixed metal oxide.

25

According to a 4th aspect of the invention, there is provided a method of using a geotechnical apparatus, which includes a geotextile, at least one drainage conduit coupled onto the geotextile and arranged to receive vacuum pressure, and at least two electrodes arranged within the drainage conduit, and configured
30 to electrically be operated as anodes or cathodes, the method comprises: (i) providing the apparatus on a first layer of soil; (ii) providing a second layer of soil on the apparatus to embed the apparatus within the first and second layers of soil; and (iii) introducing vacuum pressure into the drainage conduit to enable fluid in the soil to be drawn thereinto to be drained for consolidating the soil,

and/or operating the electrodes to electrically direct the fluid in the soil towards/away from the apparatus to be drained.

Preferably, the method may further comprise coupling the drainage conduit to a vacuum pump configured to generate the vacuum pressure.

Preferably, step (iii) may include: providing a similar second geotechnical apparatus on the second layer of soil; providing a third layer of soil on the second apparatus to embed the second apparatus within the second and third layers of soil; and operating the electrodes of the second apparatus cooperatively with operating the electrodes of step (iii) to electrically direct the fluid, wherein the electrodes of the apparatus are configured as anodes, and the electrodes of the second apparatus are configured as cathodes, or the electrodes of the apparatus are configured as cathodes, and the electrodes of the second apparatus are configured as anodes.

Preferably, the fluid may be electrically directed to generally flow in a direction from the anode to the cathode.

According to a 5th aspect of the invention, there is provided a geotechnical apparatus comprising: a drainage conduit arranged to receive vacuum pressure, and configured to be couplable onto a geotextile; and at least two electrodes arranged within the drainage conduit, and configured to electrically be operated as anodes or cathodes.

Preferably, the drainage conduit may have a plurality of internal conduits, and the at least two electrodes are arranged within respective internal conduits.

It should be apparent that features relating to one aspect of the invention may also be applicable to the other aspects of the invention.

These and other aspects of the invention will be apparent from and elucidated with reference to the embodiments described hereinafter.

Brief Description of the Drawings

Embodiments of the invention are disclosed hereinafter with reference to the accompanying drawings, in which:

FIG. 1 is a perspective view of a geotechnical apparatus, according to a first
5 embodiment;

FIG. 2a is a cross-sectional front view of a drainage conduit of the apparatus of
FIG. 1, while FIG. 2b is an enlarged view of a portion of the drainage conduit;
FIG. 3 shows an exemplary scenario for using the apparatus of FIG. 1;

FIG. 4 is a cross-sectional front view of a drainage conduit of a modified
10 geotechnical apparatus, according to a second embodiment;

FIG. 5 shows an exemplary scenario for using the apparatus of FIG. 4.

Detailed Description of Preferred Embodiments

FIG. 1 shows a geotechnical apparatus 100 ("apparatus" hereafter), according to
15 a first embodiment. The apparatus 100 broadly comprises a (sheet of flexible)
geotextile 102, and at least one drainage conduit 104 coupled onto the
geotextile 102. In this case, there are actually four drainage conduits 104 shown
in the example of FIG. 1, but however not to be construed as limiting. The
apparatus 100 (as a whole) is manufactured in a sheet form, and so may flexibly
20 be rolled into a roll for convenience of storage, construction or transportation, if
necessary. Each drainage conduit 104 is arranged to receive vacuum pressure
(via detachable coupling to a pipe 106, which is in turn coupled to a vacuum
pump), and may also be termed as a horizontal drain. Then, the apparatus 100
may also be known as a Geotextile with Horizontal Drains (GHD), and the term
25 may be used changeably hereafter to refer to the apparatus 100. Each drainage
conduit 104 has a longitudinal axis (and thus a length 108), and is fabricated
using a flexible polymer (e.g. polypropylene, or any suitable plastics). Further,
each drainage conduit 104 is arranged to be fluid permeable on its surfaces to
enable fluid to be drawn into the drainage conduit 104 via the said fluid
30 permeable surfaces, when vacuum pressure is introduced. It is to be
appreciated that each drainage conduit 104 is generally similar in construction to
wick drains/band drains.

More specifically, the apparatus 100 is directed at applications of geotechnical
35 methods relating to addressing civil and environmental engineering problems by

using the geotextile 102 and drainage conduits 104 to assist in accelerated settlement of soft/fine grained soil (e.g. peat, clay or silts) for geotechnical projects (e.g. land reclamation/construction). In use, the apparatus 100 is embedded in soil, and vacuum pressure is introduced into the drainage conduits 104 to enable fluid (e.g. water) in the soil to be drawn thereinto to be drained for consolidating the soil (i.e. by reducing the overall pore water pressure). So, the apparatus 100 uses the method of vacuum preloading to induce soil settlement and consolidation. Specifically, using the apparatus 100 enables soil settlements to be accomplished in an accelerated time frame and minimise long term residual settlements of the soil to within acceptable limits.

The geotextile 102 may be 4.4 metres wide and 0.4 mm thick, but it will be appreciated that other suitable dimensions are possible, depending on intended applications. Also, the width and thickness of each drainage conduit 104 are respectively 200 mm and 6 mm, but again are just example dimensions. The four drainage conduits 104 are in an evenly spaced arrangement on the geotextile 102, such that the centre-to-centre spacing between the respective drainage conduits 104 is about 1.0 metre (or about 0.8 metre, in terms of edge-to-edge measurement). So, the width of each drainage conduit 104 (in this case) is about 0.2 metre. In FIG. 1, there are correspondingly four rows of the drainage conduits 104. Also, each drainage conduit 104 is coupled to be substantially parallel to the longitudinal axis of the geotextile 102, i.e. arranged along the length of the geotextile 102. Next, FIG. 2a shows a cross-sectional front view of a drainage conduit 104, while FIG. 2b is an enlarged view 200 of a portion of the drainage conduit 104. Particularly, each drainage conduit 104 has a plurality of internal conduits 202, as depicted in FIGs. 2a and 2b. The plurality of internal conduits 202 is regularly arranged into two top and bottom rows, and each internal conduit 202 is generally rectangular in cross-section. Vacuum pressure is introduced into the plurality of internal conduits 202 of each drainage conduit 104, when using the apparatus 100 during soil consolidation. In addition, the apparatus 100 comprises a layer of geotechnical fabric (e.g. a filter sleeve) 110 to enable the drainage conduits 104 to be coupled to the geotextile 102. The geotechnical fabric 110 is fluid permeable. More specifically, as seen in FIG. 2b, the coupling is enabled by gluing (using any suitable adhesives), or heat melting the geotechnical fabric 110 directly onto the drainage conduits 104

and geotextile 102 to form an integrated and rigid drain panel. Since the geotechnical fabric 110 is affixed to every fins of each drainage conduit 104, the geotechnical fabric 110 therefore does not substantially indent into grooves of the plurality of internal conduits 202 under pressure imposed by the weight of soil to be consolidated. That is, the apparatus 100 is purposefully devised so that the resulting structural arrangement is beneficially not affected by soil pressure. To reiterate, the apparatus 100 may be formed into suitable dimensions as required, or may be fabricated from other appropriate materials depending on applications.

10

The geotextile 102 functions as a supporting platform for the drainage conduits 104, so that the apparatus 100 can easily be provided and placed as one whole working sheet on top of a first layer of soil/soft clay, before a second layer of soil/soft clay is then deposited on the apparatus 100 to embed the apparatus 100 for soil consolidation. In this manner, positions of the drainage conduits 104 (fixed and supported on the geotextile 102) are secured within the layers of soil/soft clay during the deposition. Vacuum pressure is introduced into the drainage conduits 104, immediately subsequent to the apparatus 100 been covered by second layer of soil/soft clay to begin the soil consolidation. In this way, consolidation of the first and second layers of soil/soft clay (by drawing fluid present in the soil/soft clay into the drainage conduits 104 to be drained, by action of the introduced vacuum pressure) can be carried out at the same time, concurrent to further new layers of soil/soft clay being deposited on the second layer of soil/soft clay for further consolidation. Advantageously, this significantly reduces an overall total length of time required for soil consolidation. A reduction in the duration of soil settlement is important for the preloading method, because a major disadvantage of conventional preloading methods is the time taken for consolidation takes too long. Moreover, the further new layers of fill materials deposited on top of the apparatus 100, whilst consolidation is carried out on the first and second layers of soil/soft clay (via the apparatus 100), beneficially act as a surcharge load for further consolidating the first and second layers of soil/soft clay (in addition to the drainage action effected due to the vacuum pressure). Overall, this greatly enhances the effect of consolidation, by way of using the proposed apparatus 100. So, the apparatus 100 beneficially provides a method to shorten the time required to complete preloading and also

35

improves efficiency of using existing soil improvement methods. This means that using the proposed apparatus 100 to perform soil consolidation is significantly more time-efficient and cost effective, as compared to conventional solutions.

5

Now, a method of using the apparatus 100 is described with reference to FIG. 3, which shows an example scenario 300 of deploying the apparatus 100 for a land reclamation programme. The scenario 300 in FIG. 3 is directed at consolidating soil located under a body of water (e.g. river). Broadly, the method comprises:

10 (i) providing the apparatus 100 on a first layer of soil; (ii) providing a second layer of soil on the apparatus 100 to embed the apparatus 100 within the first and second layers of soil; and (iii) introducing vacuum pressure into the drainage conduits 104 to enable fluid in the soil to be drawn thereinto to be drained for consolidating the soil. More specifically, a first floating barge 302 (carrying at

15 least one roll of the apparatus 100) is deployed on the river and a first layer of (sheets of) the apparatus 100 is laid down on the riverbed, over a required area to be reclaimed. An initial row of sheets of the apparatus 100 (for the first layer) is laid down on the riverbed, arranged substantially parallel to the shoreline of the river, and followed by subsequent further rows of the first layer over the

20 entire area to be reclaimed. It is to be appreciated that adjacent sheets of the apparatus 100 for any two adjacent rows are positioned to overlap each other edge-to-edge wise by about 400 mm. Under the pressure of the soil to be placed on top, the overlapping portions serve as a connection between any two sheets of the apparatus 100. A second floating barge 304 deposits fill materials

25 306 (e.g. soil) on top of the first layer of apparatus 100 provided on the riverbed. The fill materials 306 may functionally act as a sealing layer. Then, a series of drainage pipes 308 (coupled to a vacuum pump station 310 located onshore) are coupled to respective ends of the drainage conduits 104 of the initial row of sheets of the apparatus 100, and said ends of the drainage conduits 104 are

30 fixed in position in the soil using suitable dead weight 312 (e.g. rods). Consolidation of the riverbed, in which the first layer of apparatus 100 is embedded, is commenced by operating the vacuum pump station 310 to introduce vacuum pressure into the drainage conduits 104 of the first layer of the apparatus 100, and is stopped when the required degree of consolidation is

35 determined to have been achieved. Thereafter, a second layer of (sheets of) the

apparatus 100 is laid by the first floating barge 302 on the previously deposited fill materials 306, and subsequently, another layer of fill materials (not shown) is dumped by the second floating barge 304 on the second layer of the apparatus 100, as previously described for the first layer of the apparatus 100. Consolidation of the soil region, where the second layer of the apparatus 100 is embedded in, is then performed similarly as per the first layer of the apparatus 100. Accordingly, the above process of laying down more layers of the apparatus 100 for soil consolidation is performed, *mutatis mutandis*, until the necessary planned land reclamation is completed.

The remaining configurations will be described hereinafter. For the sake of brevity, description of like elements, functionalities and operations that are common between the different configurations are not repeated; reference will instead be made to similar parts of the relevant configuration(s).

In a second embodiment, the apparatus 100 (of FIG. 1) now further includes at least two (first and second) electrodes 400a, 400b arranged within respective internal conduits 202 of each drainage conduit 104 (as depicted in FIG. 4), and the electrodes 400a, 400b are configured to collectively be electrically operated as anodes or cathodes. Hereafter, the apparatus 100 of this embodiment is termed as modified apparatus 100' for easy referencing. The electrodes 400a, 400b are dimensioned to span the length of each drainage conduit 104, and also centrally arranged in the respective internal conduits 202. But other than inclusion of the electrodes 400a, 400b, the configuration and dimensions of the modified apparatus 100' are largely the same as the apparatus 100 of the first embodiment. Each electrode 400a, 400b, if configured to act as an anode, may be formed of titanium, stainless steel, or copper coated with mixed metal oxide. Otherwise, the electrode 400a, 400b may be formed of stainless steel, or copper, if configured to act as a cathode. The modified apparatus 100' may also be termed as an electrical-GHD (i.e. e-GHD), and is used to further accelerate the soil consolidation process by using electro-osmosis, together with vacuum preloading. The term e-GHD may be used changeably hereafter to refer to the modified apparatus 100'.

As shown in an example scenario 500 of FIG. 5, when in use, a number of sheets of the modified apparatus 100' are arranged at different layers (i.e. different depths) in the soil to be consolidated. In FIG. 5, four sheets 502, 504, 506, 508 of the modified apparatus 100' are shown for sake of discussion here.

5 Specifically, the respective electrodes 400a, 400b of alternating sheets of the modified apparatus 100' are configured to have the same electrical polarity. For example, in FIG. 5, the respective electrodes 400a, 400b of the first and third sheets 502, 506 are operated to be positively charged, whereas the respective electrodes 400a, 400b of the second and fourth sheets 504, 508 are operated to

10 be negatively charged. Hence, in this manner, different pairs of anodes and cathodes are formed, as it will be appreciated. This means that a minimum of two sheets of the modified apparatus 100' are to be used, if it is desirable to do soil consolidation process by using electro-osmosis, since at least one pair of anode and cathode needs to be formed. The respective electrodes 400a, 400b

15 of the different sheets 502, 504, 506, 508 of the modified apparatus 100' are then electrically operated, so that water in the soil is electrically induced and directed to generally flow in a direction from an anode to a cathode (based on the working principles of electro-osmosis), e.g. water is driven to flow from the first sheet 502 to the second sheet 504, or from the third sheet 506 to the fourth

20 sheet 508, as illustrated in FIG. 5. The water driven to the associated sheets 504, 508 of the modified apparatus 100', electrically operated as cathodes, is then drained via the corresponding drainage conduits 104 of said sheets 504, 508 of the modified apparatus 100'. In this way, consolidation of soft soil via the modified apparatus 100' is carried out under double actions: via vacuum

25 consolidation and electro-osmosis, used sequentially or simultaneously.

So broadly, a method for using the modified apparatus 100' comprises: (i) providing the modified apparatus 100' on a first layer of soil; (ii) providing a second layer of soil on the modified apparatus 100' to embed the modified

30 apparatus 100' within the first and second layers of soil; and (iii) introducing vacuum pressure into the drainage conduits 104 to enable fluid in the soil to be drawn thereinto to be drained for consolidating the soil, and/or operating the electrodes 400a, 400b to electrically direct the fluid in the soil towards/away from the modified apparatus 100' to be drained. Specifically, step (iii) includes:

35 providing a second (similar) modified apparatus 100' on the second layer of soil;

providing a third layer of soil on the second modified apparatus 100' to embed the second modified apparatus 100' within the second and third layers of soil; and operating the electrodes 400a, 400b of the second modified apparatus 100' cooperatively with operating the electrodes 400a, 400b of step (iii) to electrically
5 direct the fluid, wherein the electrodes 400a, 400b of the modified apparatus 100' are configured as anodes, and the electrodes 400a, 400b of the second modified apparatus 100' are configured as cathodes, or alternatively, the electrodes 400a, 400b of the modified apparatus 100' are configured as cathodes, and the electrodes 400a, 400b of the second modified apparatus 100'
10 are configured as anodes.

In summary, the apparatus 100 (i.e. GHD) and modified apparatus 100' (i.e. e-GHD) are disclosed, and their methods of usage have been described. The GHD 100 and e-GHD 100' may beneficially find useful geotechnical applications
15 in countries, such as Singapore or China, for land reclamation or other soft soil improvement projects, because the GHD 100 and e-GHD 100' are specifically devised to address existing construction difficulties for projects relating to large scale soft soil improvement or land reclamation using soft soil. Hence, the proposed GHD 100 and e-GHD 100' have great commercial potential and usage
20 in practical applications. Moreover, the GHD 100 and e-GHD 100' may also allow conventional construction processes to be simplified to increase productivity, thereby saving associated construction costs.

When using the GHD 100, installation of prefabricated vertical drains (PVDs) is
25 no longer required. Respective sheets of the GHD 100 may be placed on the fill materials, in a layer by layer manner, during the fill placement process. Once a layer of the GHD 100 is placed, vacuum pressure can be applied immediately through the associated drainage conduits 104 to induce soil consolidation. This is a huge advantage compared to using the PVDs, where vacuum or surcharge
30 load can instead only be applied after all the layers of fill materials have been deposited in place. Moreover, further layers of fill materials placed on top of a layer of the GHD 100, which is already embedded in the soil, may contribute to surcharge preloading. It is to be appreciated that although horizontal drains are occasionally used for soil improvement, usage of horizontal drains *per se*
35 however tends to be rather unreliable and ineffective. The reason is because

positions of the horizontal drains cannot be securely fixed in the soil, and so the necessary soil improvement cannot be performed as intended. This problem is exacerbated in situations where the soil characteristic is extremely soft. So, the above reasons are why horizontal drains are not commonly used for soil improvement. Advantageously, the proposed GHD 100 then overcomes those problems. By using the GHD 100, the positions and spacing of the drainage conduits 104 are thus substantially fixed, via being coupled onto the geotextile 102.

To further accelerate soil consolidation, electro-osmosis may also be used together with vacuum preloading. But one difficulty of deploying electro-osmosis in conventional methods lies with installing necessary electrodes. In contrast, for the proposed GHD 100, electrodes may easily be embedded into the GHD 100 during fabrication to result in the proposed e-GHD 100'. In use, multiple layers of the e-GHD 100' is arranged, in soil to be consolidated, so that immediate top and bottom layers of the e-GHD 100' together form a pair of anode and cathode (i.e. see FIG. 5). When the various layers of the e-GHD 100' are electrically operated, free water in the soil will be electrically induced and driven to generally flow from an anode to a cathode, and then subsequently drained via the drainage conduits 104 of the associated e-GHD 100'. In this manner, the efficiency of soil settlement and consolidation is much enhanced and improved.

Separately, since the drainage conduits 104 are prefabricated, the quality of device construction is controlled and much assured. Because the drainage conduits 104 are coupled onto the geotextile 102, installing the GHD 100 and e-GHD 100' is thus simpler and, positioning of the drainage conduits 104 (when embedded within the soil) is also much more reliable. Furthermore, the geotextile 102 of the GHD 100 and e-GHD 100', when embedded in the ground to be consolidated, usefully act as a reinforcement layer to enhance the bearing capacity of the soft ground. Thus, using the proposed GHD 100 and e-GHD 100' not only simplifies the construction process, ensuring that the drainage conduits 104 (or the drainage conduits 104 with electrodes 400a, 400b) are installed evenly and cost-effectively, but also provides reinforcement to the soft and weak ground.

While the invention has been illustrated and described in detail in the drawings and foregoing description, such illustration and description are to be considered illustrative or exemplary, and not restrictive; the invention is not limited to the disclosed embodiments. For example, the drainage conduit 104 may also
5 include a flat or cylindrical plastic core; indeed the drainage conduit 104 may come in a variety of sizes and shapes to meet requirements for consolidating a variety of soils and sites. Correspondingly, the plurality of internal conduits 202 may also be arranged in other shapes and configurations, if desired.

Claims

1. A geotechnical apparatus comprising:
a geotextile; and
5 at least one drainage conduit coupled onto the geotextile and arranged to receive vacuum pressure,
wherein the apparatus is configured to be flexibly arranged into a roll for storage
wherein in use, the apparatus is embedded in soil, and vacuum pressure
10 is introduced into the drainage conduit to enable fluid in the soil to be drawn thereinto to be drained for consolidating the soil.
2. The apparatus of claim 1, wherein the at least one drainage conduit includes a plurality of drainage conduits.
- 15 3. The apparatus of claim 2, wherein the plurality of drainage conduits are in an evenly spaced arrangement.
4. The apparatus of any preceding claims, wherein the drainage conduit is
20 formed of a flexible polymer, which includes plastics.
5. The apparatus of any preceding claims, wherein the drainage conduit is coupled parallel to the longitudinal axis of the geotextile.
- 25 6. The apparatus of any preceding claims, further comprising a geotechnical fabric for coupling the drainage conduit to the geotextile.
7. The apparatus of claim 6, wherein the geotechnical fabric includes a filter sleeve.
- 30 8. The apparatus of claim 6 or 7, wherein the coupling is enabled by gluing or heat melting the geotechnical fabric to collectively the drainage conduit and geotextile.

9. The apparatus of any preceding claims, wherein the drainage conduit has a plurality of internal conduits, further comprising at least two electrodes arranged within respective internal conduits, and configured to electrically be operated as anodes or cathodes.

5

10. The apparatus of claim 9, wherein each electrode is formed of titanium, stainless steel, copper, or copper coated with mixed metal oxide.

11. The apparatus of any preceding claims, wherein the drainage conduit
10 includes being configured to be fluid permeable.

12. A method of using a geotechnical apparatus, which includes a geotextile and at least one drainage conduit coupled onto the geotextile and arranged to receive vacuum pressure, the apparatus configured to be flexibly arranged into a
15 roll for storage, the method comprises:

- (i) providing the apparatus on a first layer of soil;
- (ii) providing a second layer of soil on the apparatus to embed the apparatus within the first and second layers of soil; and
- (iii) introducing vacuum pressure into the drainage conduit to enable fluid
20 in the soil to be drawn thereinto to be drained for consolidating the soil.

13. The method of claim 12, further comprises:
coupling the drainage conduit to a vacuum pump configured to generate the vacuum pressure.

25

14. A geotechnical apparatus comprising:
a geotextile;
at least one drainage conduit coupled onto the geotextile and arranged to receive vacuum pressure; and
30 at least two electrodes arranged within the drainage conduit, and configured to electrically be operated as anodes or cathodes,
wherein the apparatus is configured to be flexibly arranged into a roll for storage,
wherein in use, the apparatus is embedded in soil, and vacuum pressure
35 is introduced into the drainage conduit to enable fluid in the soil to be drawn

thereinto to be drained for consolidating the soil, and/or the electrodes are operated to electrically direct the fluid in the soil towards/away from the apparatus to be drained.

5 15. The apparatus of claim 14, wherein each electrode is formed of titanium, stainless steel, copper, or copper coated with mixed metal oxide.

16. A method of using a geotechnical apparatus, which includes a geotextile, at least one drainage conduit coupled onto the geotextile and arranged to
10 receive vacuum pressure, and at least two electrodes arranged within the drainage conduit, and configured to electrically be operated as anodes or cathodes, the apparatus configured to be flexibly arranged into a roll for storage, the method comprises:

(i) providing the apparatus on a first layer of soil;
15 (ii) providing a second layer of soil on the apparatus to embed the apparatus within the first and second layers of soil; and
(iii) introducing vacuum pressure into the drainage conduit to enable fluid in the soil to be drawn thereinto to be drained for consolidating the soil, and/or operating the electrodes to electrically direct the fluid in the soil towards/away
20 from the apparatus to be drained.

17. The method of claim 16, further comprises:

coupling the drainage conduit to a vacuum pump configured to generate the vacuum pressure.

25

18. The method of any of claims 16-17, wherein step (iii) includes:

providing a similar second geotechnical apparatus on the second layer of soil;

providing a third layer of soil on the second apparatus to embed the
30 second apparatus within the second and third layers of soil; and

operating the electrodes of the second apparatus cooperatively with operating the electrodes of step (iii) to electrically direct the fluid,

wherein the electrodes of the apparatus are configured as anodes, and the electrodes of the second apparatus are configured as cathodes, or the

electrodes of the apparatus are configured as cathodes, and the electrodes of the second apparatus are configured as anodes.

19. The method of claim 18, wherein the fluid is electrically directed to
5 generally flow in a direction from the anode to the cathode.

20. A geotechnical apparatus comprising:
a drainage conduit arranged to receive vacuum pressure, and configured
to be couplable onto a geotextile; and
10 at least two electrodes arranged within the drainage conduit, and
configured to electrically be operated as anodes or cathodes,
wherein the apparatus is configured to be flexibly arranged into a roll for
storage.

15 21. The apparatus of claim 20, wherein the drainage conduit has a plurality of
internal conduits, and the at least two electrodes are arranged within respective
internal conduits.