

WICK DRAIN SYSTEM WITH AIR LIFT

BACKGROUND OF THE INVENTION

- There is a need to be able to consolidate soft saturated soils and make them stronger so that they will support roads, runways or other structures. It is also necessary to prevent soft soils failing by liquefaction and flow. Such liquefaction is typically brought about by earthquakes or other loadings that cause the soil to tend to compact and thus develop excess pore pressures that lower their shear strength and cause them to become unstable and fail. Such failures may take the form of flows.
- One example of structures that are particularly liable to problems are tailings dams. These are impoundments of ground up waste rock and soil from the mining process. As they are formed hydraulically the material used to construct them is poorly consolidated. It is also of a highly variable nature, built layer upon layer and with highly different permeability between these layers. The layers are typically not uniform but may form lenses.
- Soft saturated soil-like material contains water in its voids. Loading this material by any means will cause the water pressure in the voids to increase. This loading may be by an increase in a surface load, an earthquake or a vehicle passing thereover. The stability of the material is enhanced if the pressure of the water in the voids is reduced.
- In a number of cases the water pressure in the voids is in excess of the hydrostatic head. Under these circumstances a means to permit this excess water pressure to be relieved will increase stability. One such means is to install wick drains in the soft soils.
- In current practice, the wick drain is a long linear device unwound from a coil. The wick drain is pushed into the ground using a specialized installation machine. The wick drain is of the form of a long ribbon that may be pushed into the soft ground for many metres. The ribbon has an internal spreader typically made of plastic which is surrounded by a geotextile filter fabric. The spreader is designed to keep the sides of the geotextile filter fabric spaced apart and permit water to flow within the wick. In section the wick may be typically 80 mm wide and 12 mm thick.
- The installation process involves feeding the wick drain through a mandrel and attaching it to an anchor plate at the end of the mandrel. The mandrel, together with the wick drain, is then pushed into the ground to depth. The mandrel is then withdrawn leaving the wick behind as it is held by the anchor plate at the bottom of the hole. The wick drain is then cut off at the surface.
- The presence of the wick drain facilitates the drainage of excess pore water pressure laterally into the wick and up to the surface. This process continues until the water pressure decays and approaches the hydrostatic pressure that exists below the surface.
- In cases where the process of consolidation needs to be accelerated or where a consolidation level in excess of that afforded by the normal loading of the soil is required, it is common to load the surface. This is commonly achieved with a pre-loading process by building up a layer of rock or soil on the surface. If the surface is weak this may require the use of a geotextile covering to the surface being consolidated followed by layers of sand and then rock to build up the loading without local surface failure. This is an expensive and

time consuming process. It is also one that may have to be reversed to change the surface level to that desired at the completion of consolidation. This means double handling of the pre-loading material.

5 The invention is fundamentally different from that described by Konon in US Patent 4,883,589 in which a single air injection tube is installed within what is otherwise a conventional wick drain. The injected air would in this case rise within the wick drain and pressurise it thus restricting or actually preventing water from entering it from the ground. The efficiency of such a system is therefore very poor.

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The invention is also fundamentally different from that described by Goughnour in US Patent 6,312,121 B1. In one embodiment of this, two conduits are shown. One is for air injection at the base of the wick drain in the zone between the filter cloth spreader. The other also terminated at the base of the wick drain between the spreader and connected to a
15 scavenge pump to lift fluids from the base of the wick drain. The two tubes are not however connected to act as an air lift pump. This embodiment has the same limitations as that of Konon in that air is delivered under pressure into the zone within the filter fabric thus preventing water ingress. In another embodiment within Goughnour patent two conduits are used with one carrying water down the wick drain and through an eductor
20 pump which draws water from the base of the wick drain. The second conduit takes the pumped and scavenged water to surface. This is not an air lift pumping system as described in this patent application.

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DISCLOSURE OF THE INVENTION

The invention is to enhance the operation of the wick drain so that drainage may occur to pressures below the hydrostatic pressure. This is achieved by the use of pumping water from the wick drain. The method to do this is by the use of air lifting the water in the wick drain for removal thereof.

Air lifting, or gas lift, as it is termed in the petroleum industry, involves pumping air or gas down a conduit and injecting it into another conduit that is filled with fluid so that it causes bubbles to rise within the second conduit. These bubbles expand as they rise within the second conduit causing the density of the fluid therein to be reduced. This reduced density leads to enhanced fluid inflow from the lower level of the second conduit thus causing a pressure difference that tends to pull fluid into it. Thus, the air lift behaves as a form of pump. The advantage of this system is that it is extremely simple and therefore unlikely to fail. This simplicity of operation is essential for use with such a system as a wick drain as it is not serviceable once installed.

The modes of air lift behaviour are complex. Initially, bubbles will form and float upwards within the second liquid carrying conduit. The bubbles may coalesce so that slug flow occurs. This involves elongated air pockets interspersed with pockets of fluid. An annular layer of fluid tends to remain on the wall of the conduit surrounding such air pockets. As the volume and speed of the upward flow increases, these air pockets may break through into each other. If the flow of air is high compared to that of the liquid being lifted, then mist flow occurs. In this state, droplets are carried upwards within the air stream. The process tends to become less energy efficient when operating in this state.

The location of the gas or air injection point within the second liquid carrying conduit can be as close to the base as the pressure control of the injection system allows so as to prevent the air or gas being lost into the body of the wick drain and the ground.

The invention involves the use of two conduits that are held within the wick drain structure. In one embodiment they are conveniently placed side by side alongside the spreader within the filter fabric sheath. In a second embodiment the conduits are concentric with the outer conduit being ribbed to support the external filter fabric and maintain passages for water flow down the outside of the outer conduit. In the third embodiment the two conduits are cojoined over their length and fitted with ribs to support the external filter fabric. One conduit is used to supply compressed air while the other conduit is used to enable the drainage water and air to be lifted to the surface. Conveniently, both conduits are flexible individual or cojoined plastic tubes that are readily installed within the geofabric filter during the wick drain manufacturing operation.

To make the two conduits into an air lift pump system, the compressed air carrying second conduit must be joined to the water-carrying first conduit and terminated below at depth, but preferably not at the base of the wick drain. The second conduit will be used to carry compressed air to be injected into the first conduit at a height above the base of the second conduit. The injected air from the second conduit will rise within the first conduit causing water to be drawn upwardly from the base of the first conduit and carried to surface. This water will have been gathered from the ground surrounding the wick drain. Thus, instead of water rising within the wick via the space between the spreader and the filter fabric, it

now descends within the wick to the base of the first conduit and is therein carried to the surface by means of the air lift system.

5 One advantage of this process is that the water pressure within the wick drain and the immediately surrounding pores in the ground are negligible. This will enhance the rate of drainage of water from the zone beyond the wick drain by providing a greater potential gradient down which it may flow.

10 Another advantage of this process is that the water pressure may be drawn down to below the level of the ground surface. This reduction in pore pressure has an effect similar to placing a pre-consolidation load upon the surface of the ground. This effect may also be achieved without utilizing the process of laying material on to the ground surface to create the pre-consolidation loading and subsequently having to remove it.

15 Large areas are frequently consolidated by the use of wick drains. The process described may be readily used over large areas also. This may be accomplished by supplying air from one or more compressors to a main manifold pipe which feeds respective secondary pipes that are laid adjacent to each row of wick drains. Air is tapped off the secondary pipes to the second conduits within the wick drains so that they may be used for air lifting. This
20 tapping may advantageously be connected to the wick drain by a flow limiting device and a device to stop flow should the connection to the second conduit be broken.

In many areas the air compressors may advantageously be driven by electricity supplied locally from photovoltaic cells or wind turbines. Doing so reduces the energy requirements
25 significantly from that required to move fill over the site for the purposes of pre-consolidation.

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BRIEF DESCRIPTION OF DRAWINGS

Further features and advantages will become apparent from the following description of the drawings, in which like reference characters generally refer to the same parts, elements or functions throughout the views.

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- Fig. 1 shows the concept of the air lift system according to an embodiment of the invention, where an air-carrying conduit is used to inject air into a water and air carrying conduit at a location above the submerged base of the water-carrying conduit.
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- Fig. 2 is a plan view of a field of wick drains connected by a pressurized air distribution system that receives air from the air compressors.
- Fig. 3 is a side exposed view of a wick drain having installed therein the air lift system of the invention.
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- Fig. 4 shows the wick drain with both conduits and a joiner and terminator block to permit its use in air lift.
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- Fig. 5 shows a wick drain comprising a liquid and air carrying outer conduit and the air injection conduit therein with geofabric filter cloth surrounding ribs on the outer conduit.
- Fig. 6 shows a wick drain comprising cojoined conduits which are ribbed and support geofabric filter cloth on their outside. It also shows the method of connecting the two tubes to form an air lift injection point.
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DETAILED DESCRIPTION OF THE DRAWINGS

Fig. 1 illustrates the concept of the air lift apparatus according to an embodiment of the invention. It is understood that the air-lift system is located within a wick drain. The first conduit (1) extends to some lower level (6) and is submerged below the expected water level (4). Compressed air is delivered to an upper inlet (3) of the second conduit (2) which carries it to an entry point (5) in the first conduit (1), below the water line (4). The air injected into the water within the first conduit (1) causes bubbles (10) to rise within the water. These bubbles flowing upwardly expand in size as the pressure reduces and become rising slugs of air (8) carrying water upwards to discharge from conduit (1) at exit (9). Water is thus drawn into the lower point (6) of the first conduit (1). The mechanism of the air lift is that the density of the column of water in the first conduit (1) is reduced by the air within it to a level where the water pressure at (6) causes inflow into the water-carrying conduit (1).

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Fig. 2 is a plan view of part of a field of air assisted wick drains equipped with the air lift drainage apparatus. Each wick drain, one identified as numeral (16), is supplied with pressurised air from a respective secondary supply line (12, 13, 14, 15) which are in turn fed from the air compressor (18) by a main manifold compressed air line (11). The dashed line (17) represents the nominal boundary of each cell being drained by a wick drain (16). As noted above, the compressor 18 can be powered by the grid, solar cells, wind power, etc. A similar network of pipes can be utilized to gather the water extracted from the wick drains (16) and disposed of as desired.

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Fig. 3 is an elevational view through the ground of a wick drain (16) incorporating the air-lift apparatus of the invention. Air conduit (2) is fed from the compressed air line (15) via a flow control and overflow shut off system shown as numeral (25). Water enters the wick drain (16) near its base at numeral (6). The nominal boundary of the zone being drained by the wick drain (16) is shown as dashed vertical lines (17). The air delivered to the air conduit (2) and water drained by the wick drain (16) are both discharged from conduit (1) at top outlet (9). The potentiometric surface (29) lies between the level (21) at the boundary of the nominal drainage cell (17) and (22) at the outside of the smear zone associated with permeability disturbance brought about by the installation of the wick drain (16). The actual potentiometric level within the wick drain (16) is at numeral (24). The difference between potentiometric level (22) and potentiometric level (24) is brought about by losses in the smear zone adjacent to the wick drain (16). This effect is known as near well bore loss in the jargon of petroleum engineering. A reduced permeability level is located at numeral (27) with a separate potentiometric surface (28) located above this lowered permeability zone.

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Fig. 4 illustrates a side view of the air-lift system incorporated within a conventional wick drain. The wick drain is surrounded by a filter fabric (31) and carries internally the spreader (30). As is well known, the spreader (30) prevents collapse of the filter fabric (31). The wick drain also carries the first conduit (1) and the air supply conduit (2). Both conduits (1) and (2) are breached and joined into the connection block (32). The lower end of the air supply conduit (2) is not reconnected to the connection block (32), as shown by numeral (34). The first conduit (1) is connected on upper and lower sides of block (32) and it can draw water up at the end (6) in its lower extremity. The connection block (32) allows compressed air from conduit (2) to be injected into conduit (1) so as to facilitate the air lift

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process. The breach in the wick drain is to permit the installation of the connection block (32) therein and is shown sealed by a tape or similar band (33) to prevent soil ingress to the inside portion of the wick drain.

- 5 The inset shows a cross section of the wick drain at line A-A of Fig. 4 on the main drawing. The inset shows the filter fabric (31) surrounding the spreader (30) as well as the conduits (1) and (2). It is understood that the composite wick drain and the air-lift apparatus is installed as a unit into the ground portion to be drained of liquid.
- 10 The incorporation of the air lift apparatus with a conventional wick drain can be accomplished by determining the location where the joint between the water conduit (1) and the air conduit (2) is to be located in the wick drain, i.e., where between the top and bottom ends of the wick drain. This is carried out prior to the installation of the wick drain into the ground. The conduits (1) and (2) are inserted into the filter fabric (31) until the
- 15 respective ends appear at the other end of the tubular-shaped filter fabric (31). The filter fabric (31) is then cut at the location where the joint (32) between the conduits (1, 2) is to be located. Then, the conduits (1, 2) are cut in the filter fabric opening so that the bottom ends of the cut conduits (1, 2) are covered with an adhesive and inserted into the respective openings of the connector block (32). The top end of the bottom portion of the water
- 20 conduit (1) is covered with an adhesive and inserted into the bottom opening of the connector block (32). The bottom portion of the air conduit (2) is not connected to anything. The conduits (1) and (2) can be glued to the connector block (32) with a suitable adhesive. The opening in the filter fabric (31) is then reconnected together with a suitable tape (33) to preserve the integrity of the fabric and prevent inadvertent separation which
- 25 would lead to the ingress of dirt and the like.

It can be appreciated that the air-lift apparatus can be incorporated within the wick drain without using the connector block (32). The conduits (1) and (2) can be fabricated as a unitary item and incorporated into the wick drain. Alternatively, a J-shaped connector (a

30 "T" and a 90 degree angle elbow) can be utilized for connecting the air conduit (2) with the water conduit (1), utilizing an appropriate adhesive or glue.

In practice, the conduits (1) and (2) can be fabricated using a nylon or other suitable piping, and the connector (32) can be fabricated of a nylon material which may be fibre reinforced.

35 It is contemplated that the conduits (1) and (2) will be a flexible piping of about 8 to 15 mm inside diameter and sufficiently long to reach from the top of the wick drain to the bottom thereof. Also, it is contemplated that an air pressure in the range of hydrostatic pressure plus the pressure required to overcome friction within the first air carrying conduit would be suitable for use with the air-lift apparatus of the invention. Thus if the wick drain

40 is at 50 m depth the requirement will initially be for an air pressure of 500 kPa plus say 200 kPa to overcome frictional loss in the pipe, depending on the pipe diameter and the flow rate being used.

Fig. 5 illustrates a cross section of an embodiment of a wick drain using a ribbed outer conduit (40) where the ribs support the filter fabric (41). Within the conduit (40) the air injection conduit (42) hangs. The level of the air injection conduit (42) can be adjusted by

45 pulling up from the base to a suitable level once the wick drain is installed. This type of installation is suitable for high volume flow wick drains. For the diameter of the outer conduit (40) to be large enough to permit these high flows from depth in the ground a fairly rigid tubing needs to be used so as to prevent its collapse from soil pressures. This

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either necessitates a large diameter coil of the wick drain on the installation rig or the construction of the outer conduit which incorporates a radial load stiffening system such as a close helical wire wind within a plastic tube conduit. The latter will permit a radially stiff conduit to be used but which has a reasonably small bending radius.

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Fig. 6 illustrates in part A of the figure a cross section of an embodiment of a wick drain using two cojoined conduits (51), for air injection and (52) for air and water lifting both extruded in a flexible plastic unit (50) which is ribbed with the exception of one side (in this case at the right side) which is thicker. The flexible plastic unit (50) incorporates ribs

10 in the extrusion that support the filter fabric sheath (53).

In part B of the figure the cross section is shown with a transverse air transfer hole (54) created by drilling or by heat from the right hand side through the air injection conduit (51) into the air and water carrying conduit (52). This hole (52) is plugged at the outside. This

15 plug (55) is shown in the figure as being a screw in plug with an hexagonal type recess in the top. The plug (55) could also be fixed in place with adhesive or by heat welding. The purpose of the transverse hole (54) is to permit the transfer of air from the air carrying conduit (51) to the air and water carrying conduit (52) above the base of the wick drain. It is not necessary to block the air carrying conduit below the air transfer hole (54) as

20 hydrostatic head should prevent air loss from the end of air carrying conduit (52).

In all of the embodiments described the flow of water is down the wick drain. In the case of that in Fig. 4 the flow is within the wick drain and around the spreader. In the case of that of Fig. 5 and Fig. 6 the flow is between the filter fabric and the outside of the conduit.

25 It should be appreciated that in Fig. 5 and Fig. 6 that the filter fabric supporting ribs may be replaced by an external spreader of different form.

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WHAT IS CLAIMED IS;

1. A method of extracting water from a wick drain embedded in soil and at least partially below the water table, comprising:
 - 5 allowing the water to enter the wick drain through a filter along at least part of its length and to flow downwards within the wick drain to an extraction point near the bottom end thereof;
 - forcing a pressurized gas into a gas carrying conduit which passes down the wick drain to enter into a water carrying conduit at a location below the water level therein and above its bottom end;
 - 10 whereby the pressurized gas forms bubbles in said water and causes the water to rise to an outlet of said water carrying conduit, thereby extracting the water from the wick drain by gas lifting the water.
- 15 2. The method of claim 1, further including using a connector block for joining the water carrying conduit to the gas carrying conduit, where two ends of a severed water carrying conduit are inserted into respective holes of the connector block and one end of the gas carrying conduit is inserted into the connector block, and using an internal bore of the connector block to connect the gas conduit to the severed water conduit.
- 20 3. The method of claim 1, further including using a gas carrying conduit installed within the water carrying conduit and forcing gas from the end of the gas carrying conduit at a level some distance above the lower end of the water carrying conduit so as to cause an air lift of water to take place within the carrying water conduit.
- 25 4. The method of claim 1, further including cojoined conduits, one to carry gas and one to carry water which are linked by a cross drilled hole at some distance above their base so that air from the air carrying conduit may exit into the water carrying conduit and cause air lift pumping to take place therein.
- 30 5. The method of claim 3 and claim 4 where the outer surface of the conduit(s) are either ribbed or covered with a spacer so as to support a filter sheath over the length of the wick drain and to permit the downward flow of water within the wick drain between the conduit(s) and the filter.
- 35 6. The method of claim 1, further including consolidating the ground surrounding the wick drain by utilizing the wick drain and air lift pumping to speed the rate of water drainage and to lower the water pressure within the wick drain, and in particular to lower the water pressure within the wick drain to below a hydrostatic pressure existing below the ground surface.
- 40 7. The method of claim 1, further including incorporating the gas carrying conduit and the water carrying conduit of the air lift system into the wick drain prior to installation of the wick drain into the ground.
- 45 8. The method of claim 2, further including connecting the connector block within the wick drain by cutting the gas and water conduits and installing a connector block which joins the gas carrying conduit to the water carrying conduit and terminating

the air carrying conduit below it thus diverting the compressed air to the water carrying conduit.

- 5 9. The method of claim 8, including cutting a filter fabric which defines a filter sheath covering the wick drain, and covering the cut made in the filter sheath of the wick drain so that soil does not enter beneath the filter sheath.
- 10 10. The method of claim 8, whereby the cover of the cut in the filter sheath is made using adhesive tape.
- 11 11. The method of claim 3, where the level of the gas carrying conduit is adjusted by pulling it to the correct level from surface after the installation of the wick drain.
- 15 12. The method of claim 4, where one of a screwed or glued plug is used to seal the gas carrying conduit to gas release outside of the wick drain.
- 13 13. The method of claim 4, where a tight sealing tape bandage is applied around the wick drain to prevent gas release outside of the wick drain.
- 20 14. The method claim 1, further including installing the wick drain in the ground by; feeding the wick drain through a mandrel and attaching the wick drain to an anchor plate; inserting the mandrel into the soil; and withdrawing the mandrel from the soil, while leaving the wick drain inserted in the soil and held thereto by the anchor plate.
- 25 15. A wick drain incorporating an air-lift system therein, comprising:
 - 30 a liquid-carrying conduit having a liquid inlet and a liquid outlet, said liquid inlet for insertion into a liquid to be extracted from said wick drain;
 - a gas-carrying conduit having a gas inlet and a gas outlet;
 - a connection means for connecting said gas-carrying conduit to said liquid-carrying conduit to permit gas to pass from the gas-carrying conduit to the said liquid-carrying conduit;
 - 35 a filter fabric housing said liquid-carrying conduit and said gas-carrying conduit connected thereto; and
 - wherein a gas supplied into the gas-carrying conduit passes from said gas outlet through the connection means into the liquid-carrying conduit and injected into the liquid carried by said liquid-carrying conduit, thereby causing liquid to be drawn into the liquid inlet of said liquid-carrying conduit and carried upwardly to the liquid outlet, whereby the liquid in the wick drain is extracted therefrom.
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- 45 16. The wick drain of claim 15, wherein when said wick drain is installed in the soil, the liquid outlet of said liquid-carrying conduit is located at or above the surface of the soil, and a distance between the connection means and the liquid outlet is greater than a distance between the liquid inlet of the liquid-carrying conduit and the connection means.

17. The wick drain of claim 15, further including a spreader positioned within the filter fabric, and wherein the spreader is configured to keep the filter fabric apart and permit water flow within the wick drain.
- 5 18. The wick drain of claim 15, wherein the conduits have cross-sections that do not overlap with one another.
19. The wick drain of claim 15, wherein one conduit is located inside the other conduit.
- 10 20. The wick drain of claim 15, further including a compressed air line for providing pressurized air to the gas inlet of the gas-carrying conduit.
21. The wick drain of claim 15, further including a flow control and overflow shut off system between the compressed air line and the gas inlet, said flow control
15 configured to control the flow of compressed air into the gas inlet of said gas-carrying conduit.
22. A system for draining water from soil, comprising:
20 a plurality of wick drains installed in a matrix, each said wick drain having a filter fabric enclosing;
a spreader system to prevent the filter fabric from collapsing;
a liquid conduit for carrying the water to be drained, said liquid conduit having a liquid outlet located at a top of said wick drain and a liquid inlet embedded within said water;
25 an air conduit for carrying a pressurized air and for injecting the air into the water in said liquid conduit at a location above the inlet thereof, said air conduit having an inlet located at a top of said wick drain;
each air inlet of each said wick drain of said matrix connected to a pressurized air supply line configured to supply pressurized air to the air inlet of the wick drains,
30 whereby each wick drain receives pressurized air from the air supply line;
an air compressor configured to supply pressurized air to the air supply line.
23. The system of claim 22, further including an air manifold connected to the air supply lines.
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24. The system of claim 22, further including a flow control and an overflow shut off system located between the respective air inlets of the wick drains and the air compressor.

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