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(54) **Title**: METHOD OF FORMING A CONCRETE ANCHOR DEVICE

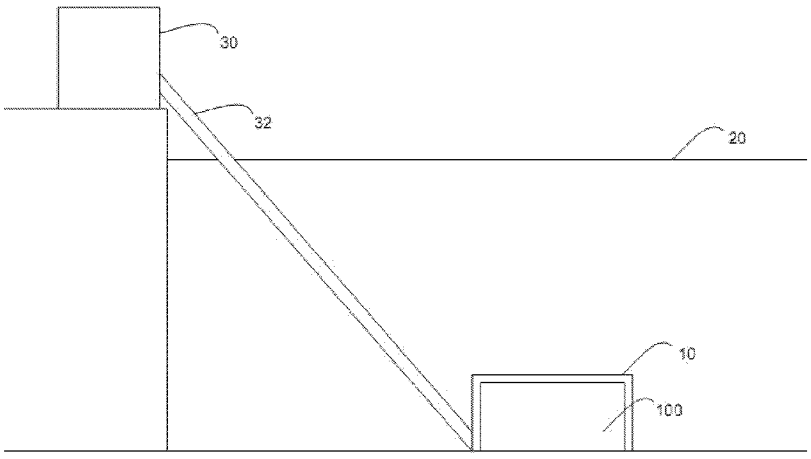

Figure 1

(57) **Abstract**: A method of forming a concrete anchor for underwater deployment. The method comprises the steps of: submerging an at least partially removable mould device in a body of water such that the mould device takes on water; transporting uncured concrete via a conduit into the mould device such that the transported uncured concrete displaces the water from the mould device; and curing the concrete whilst the mould device and concrete are submerged in water.

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Method of Forming a Concrete Anchor Device

The present invention relates to a method of forming a gravity anchor. In particular, but not exclusively, the invention relates to a method of forming and deployment of a concrete anchor.

Anchors are provided for maintaining the position of vessels or underwater devices, such as renewable energy devices. Gravity anchors can be less cost effective than other forms of anchors, such as drag anchors and piling. A gravity anchor provides a holding force which is equivalent to its own weight or less. A drag anchor, on the other hand, can provide a holding force which is equivalent to up to fifty times its own weight.

However, in certain applications, gravity anchors can be a better and/or more cost effective option. For instance, the installation cost involved with a gravity anchor is much lower than that for a drag anchor. Also, in tidal regions with rocky sea beds (where many renewable devices are located), it is often not possible to use drag anchors, and piling in tidal conditions is technically challenging and expensive.

Gravity anchors are typically formed from a dense material such as cast iron, steel or lead. Such dense materials do not “lose” much of their weight in water. However, these materials are expensive and so are typically used only for smaller anchors up to around 50 Tonnes.

Occasionally, anchors have been formed from concrete. However, one disadvantage is that, due to the low density of concrete, a concrete anchor loses around half its weight in water. The holding power of the anchor is defined by its weight underwater (accounting for buoyancy), although suction can increase this if it becomes buried. For instance, a solid concrete anchor of dimensions 10 m

by 5 m by 3.6 m would have a weight in air of 550 Tonnes and a weight in water of 300 Tonnes.

Large concrete anchors, formed in a conventional manner, are difficult and expensive to handle and install. Nevertheless, concrete anchors are still cheaper to build than steel anchors, at less than a third of the cost per unit holding force.

It is desirable to provide improved means of forming, handling and/or installing a concrete anchor that reduces the complexity and cost of the forming, handling and/or installing of the anchor.

Concrete is composed primarily of aggregate, cement and water. Water is mixed with the dry composite which enables it to be shaped and poured and the material solidifies and hardens through a chemical process known as hydration. It is known that the early strength of the concrete is increased if it is kept damp during the curing process. Abnormally fast drying and shrinkage can occur due to factors such as evaporation from wind, which can lead to increased tensile stresses at a time when it has not yet gained sufficient strength, and this can result in greater shrinkage cracking. In practice, water spraying or ponding of the concrete surface is typically carried out.

According to a first aspect of the present invention there is provided a method of forming a concrete anchor comprising the steps of:

submerging an at least partially removable mould device in a body of water such that the mould device takes on water;

transporting uncured concrete via a conduit into the mould device such that the transported uncured concrete displaces the water from the mould device; and

curing the concrete while the mould device and concrete are submerged in water.

Submerging the mould device in a body of water may include submerging the mould device at an underwater location at or near where the anchor is to be deployed. The underwater location may include locating the anchor in contact with a sea bed, river bed or the like. Alternatively, submerging the mould device in a body of water may include locating the mould device in a location remote from the location where the anchor is to be deployed, but near to land. For example, the mould device may be submerged near a pier.

Advantageously, the method of forming a concrete anchor when the mould device is submerged in a body of water, which includes the location where the anchor is to be deployed means that the payload capacity of a vessel or lifting device required to move the anchor to the deployment location is greatly reduced compared with anchor systems manufactured on land.

It will be appreciated that whilst uncured concrete is delivered to the moulding device that natural elements such as water and air within the mould device may be displaced by the concrete.

The method may include transporting the uncured concrete from a land based location, wherein land is located adjacent the body of water. The method may include running the conduit from the land based location to the mould device. The method may include orienting the conduit such that the conduit runs downwards from the land based location to the mould device.

The conduit may have a first end located at an entry to the mould device. The method may include positioning the first end at a lower region of the mould device. The method may include positioning the first end within the mould device such that the first end remains immersed in the uncured concrete during transporting of the concrete.

The method may include controlling orientation of the conduit. Controlling orientation of the conduit may include fixing the conduit at one or more points along its length. As such, it will be appreciated that the conduit may comprise one or more fixing points along its length. The first end of the conduit may include a fixing point. The fixing points may be attachable to a lifting device. As such, the weight of the conduit and or concrete may be supported during the method of forming the concrete anchor

The method may include fixing the first end of the conduit at an entry to the mould device. Alternatively the method may include inserting the first end of the conduit within the mould device, wherein the first end may freely move within the mould device. As such, the first end may be manoeuvred during delivery of uncured concrete to the mould device. The conduit may comprise an articulated pipe.

The method may include assembling the mould device on land and then locating the mould device in the body of water.

The mould device may include one or more reinforcing members configured to form part of the formed anchor. The reinforcing member may comprise a reinforcing beam. The reinforcing beam may comprise steel. Alternatively, the reinforcing member may comprise a chain. The chain may be pre-tensioned.

The mould device and the cured anchor may comprise mooring points. The reinforcing members may double as mooring points.

The mould device may include one or more lifting members configured to form part of the formed anchor. One or more of the reinforcing members may double as lifting points. Alternatively, the lifting member may be connected to one or more reinforcing members. The lifting member or lifting point may comprise an eye member. The lifting points may be located proximate ends of the anchor.

Alternatively, or in addition the lifting points may be displaced from ends regions of the anchor. The lifting points may be distributed over the anchor surface such to minimise stresses in the concrete anchor during lifting.

The method may include configuring the mould device to form an anchor having a base that includes friction increasing means. The friction increasing means may comprise a roughened base surface, and/or a base surface of greater area or the like. For example, the base may comprise a skirt which increases the base area or catches into the seabed. The skirt may comprise steel. Alternatively, the mould may comprise a sacrificial base configured to shape the underside of the anchor to have friction increasing means, for example in the shape of corrugations, steps or feet. Alternatively, the base may be substantially flat and may be removable or non-removable from the cured anchor.

Alternatively or in addition to a base comprising friction increasing means, the method may comprise preparing an underwater surface upon which the anchor will rest, for example the seabed, river bed or the like, preparation may include applying a quantity of loose material on the underwater surface. The loose material may comprise, for example gravel or aggregate material. As such when placing the anchor on the quantity of loose material, the loose material will displace to fill any voids and to provide a substantially level surface upon which the anchor can rest and therefore aids in securely seating the anchor on an underwater surface.

Alternatively, the method may comprise injecting concrete under the base of the anchor when the anchor is located on an underwater surface, for example a seabed, river bed or the like. The concrete may be injected to the base via the centre of the anchor after deployment.

The mould device being at least partially removable relate to the at least the sides of the mould device defining the shape and size of the anchor are removable. A base section may be removable or non-removable.

The method may include transporting the formed concrete anchor to the deployment location. It will be appreciated that the capacity of lifting equipment is somewhat reduced, in the region of 50% compared with a land based construction of a concrete anchor. The method may include lifting the concrete anchor using lifting apparatus provided via a bow or moon pool(s) of a vessel positioned above the concrete anchor. The method may include lifting the concrete anchor from the bed of the body of water but keeping the concrete anchor submerged.

The method may include towing the concrete anchor to the deployment location using the vessel. The vessel may be a barge. The vessel may be unpowered. For example, the vessel may be towed and manoeuvred by another powered vessel. As such it will be appreciated that the lifting vessel may be unmanned and thereby helps to alleviate any safety concerns for personnel working with the concrete anchor.

The lifting apparatus may comprise a pulley system to provide a mechanical advantage when lifting the concrete anchor. The method may include locating the pulley system at the vessel. Alternatively or in addition, the lifting apparatus may comprise a crane barge, gantry crane, shear leg crane or the like. Furthermore, the lifting apparatus may comprise, for example, wire winches or chain gypsy winches.

The method may include providing means for remote connection or disconnection of the anchor to the lifting apparatus.

The method may include deploying the concrete anchor to an underwater surface, for example a seabed, river bed or the like.

When deploying the anchor part of a mooring line or chain may also be deployed. Deploying a mooring line or chain may comprise laying a length of mooring line or chain on top of the anchor, wherein the mooring line or chain is also connected to a mooring point. This arrangement may aid installation of main mooring lines. In addition, such an arrangement may allow for the connection of main mooring lines to this short section(s) to take place above the water line.

According to a second aspect of the present invention there is provided a concrete anchor formed using a method according to the first aspect of the invention.

Embodiments of the present invention will now be described, by way of example only, with reference to the accompanying drawings in which:

Figure 1 is a diagrammatic view of a method and apparatus used to form a concrete anchor;

Figure 2 is a diagrammatic view of a method and apparatus used to form a concrete anchor; and

Figure 3 is a diagrammatic view of the anchor being transported to the deployment location.

Figure 1 illustrates the method and apparatus used to form a concrete anchor 100 according to embodiments of the present invention. A mould device in the form of shuttering 10 is submerged or at least partially submerged in a body of water such as the sea 20. The shuttering 10 can be assembled on land and then located in the sea 20.

The shuttering 10 includes a number of reinforcing members (not illustrated), such as beams, reinforcing bars (rebars) or the like and these form part of the formed anchor 100. Also, connected to the reinforcing members are eye members (not illustrated) to assist lifting of the anchor 100 once formed. The reinforcing members may be made of steel.

It can be desirable to increase the friction between the base of the anchor 100 and the sea bed, particularly for scoured rock sea beds. The shuttering 10 can be configured to form an anchor 100 having a base with friction increasing means. The base surface can be formed to be roughened, corrugated or the like. Also, the base surface can be formed to be a greater area than other sections of the anchor 100.

In the illustrated example, the shuttering 10 is located under the surface of a body of water proximate land, for example a harbour or pier side. As such, a concrete mixing device 30 is located on land, such as at the harbour, adjacent to the body of water containing the location where the anchor will finally be deployed, for example the sea 20. In the illustrated example, a conduit, in the form of a pipe 32, connects the mixing device 30 and the shuttering 10 so that uncured concrete can be transported via the pipe 32 to the shuttering 10. The pipe 32 runs downwards from the mixing device 30 to the shuttering 10, and so gravity is sufficient for transporting the uncured concrete although a pump can be provided if required. The pipe 32 is connected to a lower region of the shuttering 10.

Uncured concrete is transported to the shuttering 10. The concrete displaces the water from the shuttering 10. The shuttering 10 comprises sufficient gaps to allow water to exit the shuttering 10. Positioning of the end of the pipe 32 at a lower region of the shuttering 10 causes the pipe end to be immersed in the

uncured concrete during transporting. This helps prevent the cement content being washeded out.

When the shuttering 10 has been filled, the concrete is allowed to cure/set. The wet ambient conditions are beneficial during curing. Additionally, coagulants may be used in the forming process to reduce washout and aid curing. After setting, the shuttering 10 can be removed, such as using divers.

The shuttering 10 may be removed completely post-curing. In some applications where the underwater surface (for example sea bed or river bed) is uneven it may be possible to include a base in the shuttering (see figure 2) which remains as part of the anchor and may aid frictional contact of the anchor 100 with the underwater surface at the deployed location.

As illustrated in Figure 3, the formed anchor 100 may be transported to the desired deployment location. Indeed, the forming apparatus is fairly mobile because of the inherent buoyancy effect of the concrete anchor immersed in water. As such the payload capacity of lifting apparatus required to move the anchor is substantially less than a comparative system used to move such an anchor from a land based location. As such moving the anchor to the deployment location means the anchor 100 need never be lifted out of the water.

As shown in Figure 3, a vessel, for example a barge 40 can be used to lift the concrete anchor 100 from the bed of the sea 20 and tow the anchor 100 to the deployment location while keeping the concrete anchor 100 submerged. The barge 40 is manoeuvred to be vertically above the anchor 100.

Lifting apparatus is provided at the barge 40 which comprises a number of winches 42 and possibly pulleys 44 to provide a mechanical advantage when lifting the concrete anchor 100. The winches 42 can be paid out for attachment to the eye members of the anchor 100. The lifting apparatus also includes

means for remote connection and disconnection of the anchor 100 to the lifting apparatus.

The barge 40 itself, with the anchor 100 attached, can then be towed to the deployment location, for example by a tug 50.

It will be appreciated that an anchor 100 according to the present invention is designed to be recoverable from its underwater location. As such, if the anchor 100 ever needs to be recovered, this can readily be done by positioning the barge 40 at the deployment location and paying out the winches 42 for attachment to the anchor 100. The anchor may therefore be moved and reused at a different location.

The present invention provides a number of advantages. The anchor 100 is formed, lifted, transported and deployed whilst submerged in water. This reduces the weight of the anchor 100 that has to be borne by lifting apparatus and so reduces the handling capacity required for the lifting apparatus. If a pulley is used this further reduces the capacity required from the winches. Also, the design of the barge 40 can be simpler. And a barge which can lift heavy weights can be utilised for many other operations at sea.

In addition, the method of forming a concrete anchor underwater provides ambient conditions which assist the curing process.

Furthermore, the deployment of the anchor 100 is rapid and easily and accurately controlled. Similarly, recovery and redeployment of the anchor 100 can also be rapid, easy, accurate and controlled. As such the anchor is reusable at different deployment locations. It will be appreciated that the anchor 100 according to embodiments of the present invention provides an improvement over pile anchors which cannot be reused and drag anchors which can only sometimes be reused.

Whilst specific embodiments of the present invention have been described above, it will be appreciated that departures from the described embodiments may still fall within the scope of the present invention.

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Claims

1. A method of forming a concrete anchor for underwater deployment, the method comprising the steps of:

submerging an at least partially removable mould device in a body of water such that the mould device takes on water;

transporting uncured concrete via a conduit into the mould device such that the transported uncured concrete displaces the water from the mould device; and

curing the concrete whilst the mould device and concrete are submerged in water.

2. A method as claimed in claim 1, wherein the transported uncured concrete displaces air from the mould device.

3. A method as claimed in claim 1 or 2, wherein transporting the uncured concrete is from a land based location, wherein land is located adjacent the body of water.

4. A method as claimed in claim 3, further comprising running the conduit from the land based location to the mould device.

5. A method as claimed in claim 3 or 4, comprising orienting the conduit such that the conduit runs downwards from the land based location to the mould device.

6. A method as claimed in any preceding claim, comprising locating a first end of the conduit at an entry to the mould device.

7. A method as claimed in claim 6, comprising positioning the first end of the conduit at a lower region of the mould device.

8. A method as claimed in claim 6 or 7, comprising positioning the first end within the mould device such that the first end remains immersed in the uncured concrete during transportation of the concrete to the mould device.

9. A method as claimed in any preceding claim comprising controlling orientation of the conduit.

10. A method as claimed in claim 9, wherein controlling orientation of the conduit may include fixing the conduit at one or more points along its length.

11. A method as claimed in claim 10, comprising attaching the fixing points to a lifting device.

12. A method as claimed in claim 10, when dependent on claims 6 to 9, comprising fixing the first end of the conduit at an entry to the mould device.

13. A method as claimed in any preceding claim comprising at least partially removing the mould device from the cured concrete anchor.

14. A method as claimed in any preceding claim comprising removing at least side walls of the mould device from the cured concrete anchor.

15. A method as claimed in any preceding claim comprising transporting the cured concrete anchor to its deployment location.

16. A method as claimed in claim 15 comprising lifting, towing and lowering the cured concrete anchor to its deployment location.

17. A method as claimed in claim 15 or 16, comprising lifting the concrete anchor from the bed of the body of water whilst keeping the concrete anchor at least partially submerged.

18. A method as claimed in claim 15, 16 or 17, comprising lifting the concrete anchor from the bed of the body of water whilst keeping the concrete anchor at completely submerged.

19. A method as claimed in any of claims 1 to 14, comprising forming the concrete anchor above or at the deployment location.

20. A method as claimed in any of claims 15 to 19, including providing means for remote connection or disconnection of the anchor to lifting apparatus.

21. The method according to any preceding claim, comprising making a mould device comprising a base that includes friction increasing means and at least removable side or sides, wherein the side or sides of the mould device define the shape and size of the anchor.

22. A concrete anchor formed using a method according to any preceding claim.

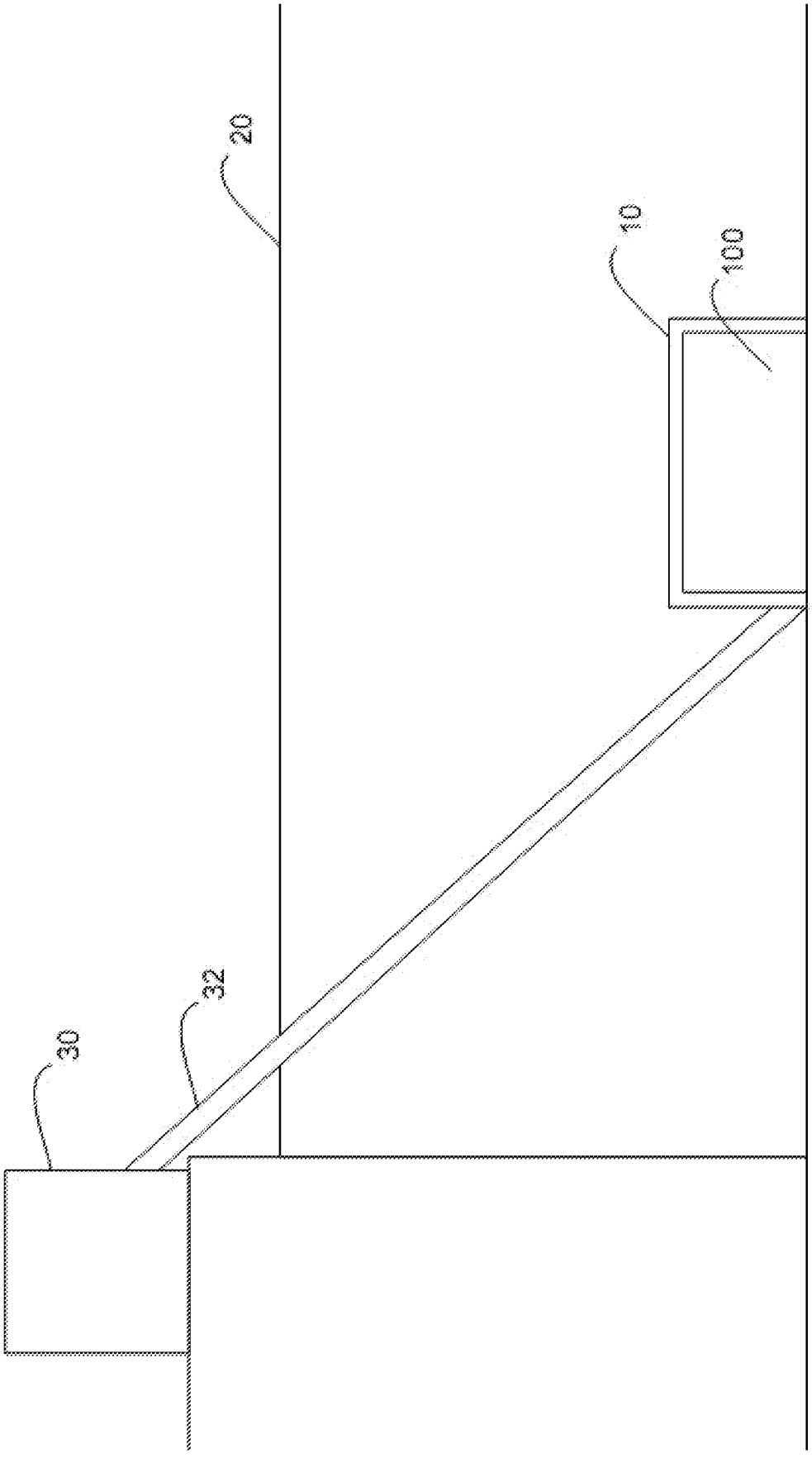

Figure 1

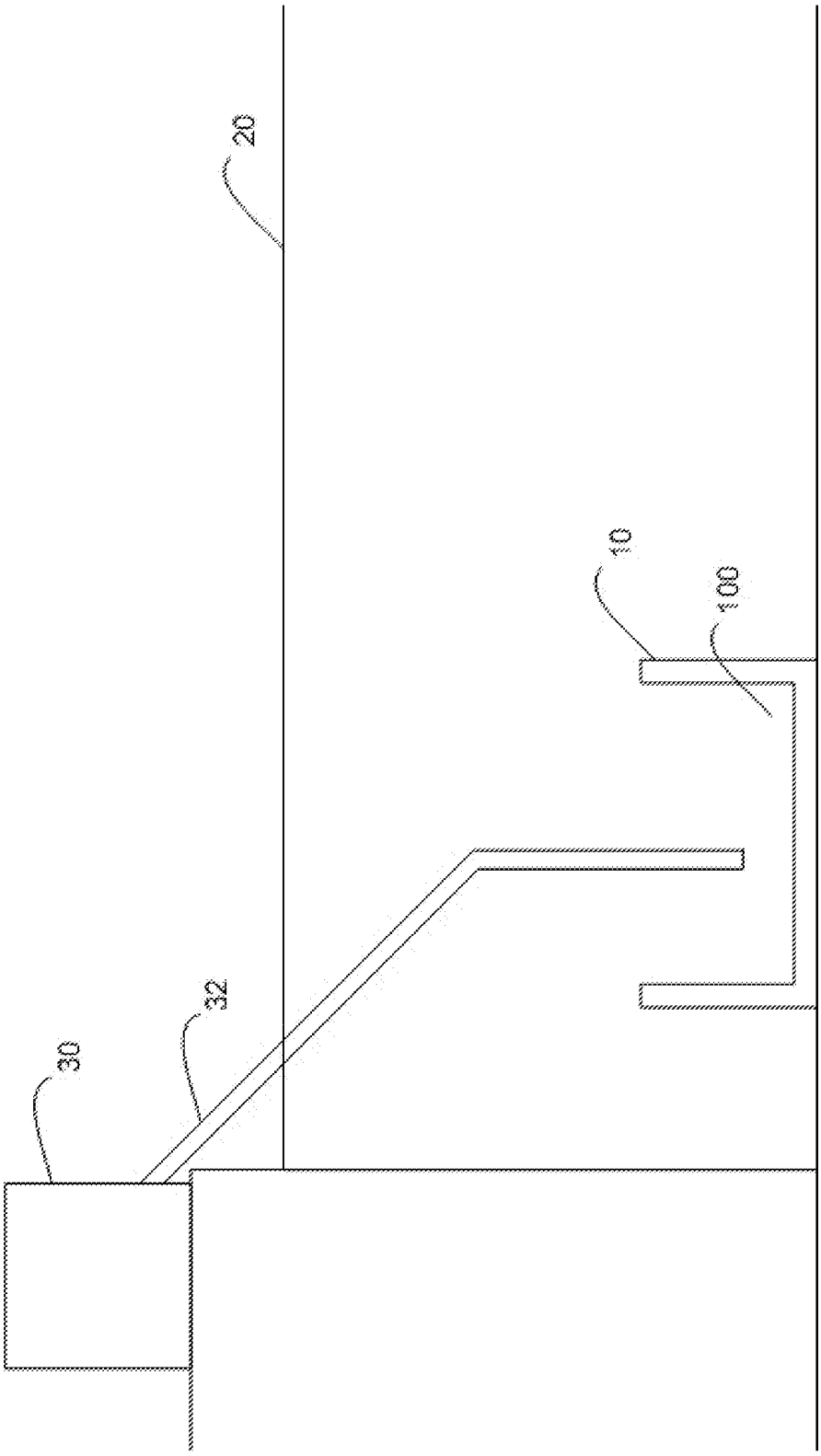

Figure 2

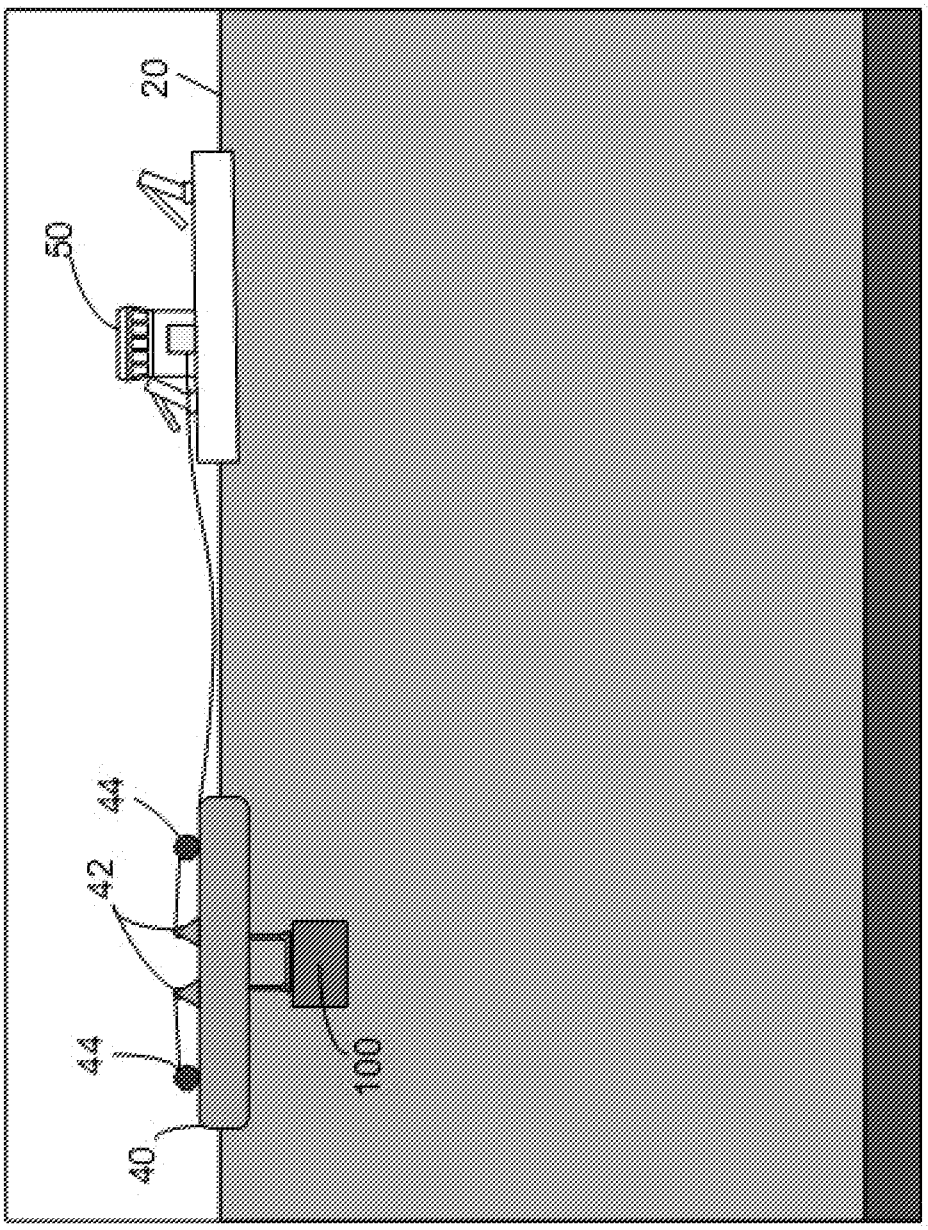

Figure 3