

METHOD FOR INSTALLING A MULTI-SECTION SUCTION CAISSON

Cross-Reference To Related Application

5 [0001] This application claims the benefit of priority of US provisional application No. 61/974,612, filed on 3 April 2014, the content of it being hereby incorporated by reference in its entirety for all purposes.

Technical Field

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[0002] Various embodiments relate to a method for installing a multi-section suction caisson.

Background

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[0003] Suction caissons are hollow cylindrical steel or concrete structures that are used as foundations to support mainly offshore structures such as offshore oil platforms or offshore oil rigs in deep water. Suction caisson is installed into seabed using suction pressure. The principle of the installation technique is to apply suction inside a sealed
20 caisson to create a downward net force and to sink the caisson into seabed soil. The advantages of this technique are that there are no requirements for the seabed soil to be treated and the installation may be done by application of suction without the use of heavy installation machines.

[0004] However, the installation depth of a suction caisson is often influenced by its
25 dimensions and other factors. The penetration depth achieved may not be sufficient to provide the required capacity. This is particularly the case when suction caissons are installed in relatively shallow water.

[0005] When used in relatively shallow water, the suction caissons as mentioned above may not be able to be installed properly because the caissons may not penetrate to the
30 depth required. Large sized caisson structures may then need significantly high driving forces to penetrate into the seabed.

[0006] For suction caissons used in deep water, the hydrostatic water pressure as provided by the water depth may be converted into suction to pull down the suction caissons into the seabed. However, in relatively shallow water, there may not be sufficient suction to allow the suction caissons to penetrate to the required depth.

5 [0007] Another factor affecting the penetration of the suction caissons is soil plug formed inside the suction caissons. When a suction caisson is penetrated into clay, soil may enter into the open ended hollow suction caisson and form a soil plug therein. The soil plug may resist the penetration of the suction caisson. In other words, the soil plug heaves inside the suction caisson and prevent it from further penetration.

10 [0008] Thus, there is a need for a method that enables suction caissons to be installed at either deep or shallow water or even on land to address at least the problems above.

Summary

15 [0009] According to an embodiment, a method for installing a multi-section suction caisson is provided. The method may include positioning a first section of the multi-section suction caisson on an underwater ground; applying a suction pressure to a first inner chamber of the first section, and subsequently removing an amount of soil plug from the first inner chamber; positioning a second section of the multi-section suction
20 caisson in alignment over the first section, wherein the first section has an inner diameter larger than an outer diameter of the second section; and applying the suction pressure to a second inner chamber of the second section.

Brief Description of the Drawings

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[0010] In the drawings, like reference characters generally refer to like parts throughout the different views. The drawings are not necessarily to scale, emphasis instead generally being placed upon illustrating the principles of the invention. In the following description, various embodiments of the invention are described with reference to the
30 following drawings, in which:

[0011] FIG. 1 shows a flow chart illustrating a method for installing a multi-section suction caisson, according to various embodiments.

[0012] FIGs. 2A to 2D show, as schematic cross sectional views, various procedural stages for a caisson (a first section of a multi-section suction caisson) to be installed into a seabed, according to various embodiments.

[0013] FIGs. 3A to 3D show, as schematic cross sectional views, various procedural stages for using another caisson as a second section of the multi-section suction caisson to extend the caisson of FIGs. 2A to 2D, according to various embodiments.

[0014] FIG. 4A shows a schematic cross sectional view of a third section of the multi-section suction caisson used to further extend the caisson of FIGs. 2A to 2D, according to various embodiments.

[0015] FIG. 4B shows a schematic cross sectional view of a top cap positioned over the multi-section suction caisson of FIG. 4A, according to various embodiments.

[0016] FIG. 5A shows a schematic perspective view of a multi-section suction caisson, according to various embodiments.

[0017] FIG. 5B shows (i) a schematic side view and (ii) a schematic top view of Part A of the multi-section suction caisson of FIG. 5A, according to various embodiments.

[0018] FIG. 5C shows (i) a schematic side view and (ii) a schematic top view of Part B of the multi-section suction caisson of FIG. 5A, according to various embodiments.

[0019] FIG. 5D shows (i) a schematic side view and (ii) a schematic top view of Part C of the multi-section suction caisson of FIG. 5A, according to various embodiments.

Detailed Description

[0020] The following detailed description refers to the accompanying drawings that show, by way of illustration, specific details and embodiments in which the invention may be practiced. These embodiments are described in sufficient detail to enable those skilled in the art to practice the invention. Other embodiments may be utilized and structural, logical, and electrical changes may be made without departing from the scope of the invention. The various embodiments are not necessarily mutually exclusive, as

some embodiments can be combined with one or more other embodiments to form new embodiments.

[0021] Embodiments described in the context of one of the methods or devices are analogously valid for the other methods or devices. Similarly, embodiments described in the context of a method are analogously valid for a device, and vice versa.

[0022] Features that are described in the context of an embodiment may correspondingly be applicable to the same or similar features in the other embodiments. Features that are described in the context of an embodiment may correspondingly be applicable to the other embodiments, even if not explicitly described in these other embodiments.

Furthermore, additions and/or combinations and/or alternatives as described for a feature in the context of an embodiment may correspondingly be applicable to the same or similar feature in the other embodiments.

[0023] In the context of various embodiments, the articles “a”, “an” and “the” as used with regard to a feature or element include a reference to one or more of the features or elements.

[0024] In the context of various embodiments, the phrase “at least substantially” may include “exactly” and a reasonable variance.

[0025] In the context of various embodiments, the term “about” or “approximately” as applied to a numeric value encompasses the exact value and a reasonable variance.

[0026] As used herein, the term “and/or” includes any and all combinations of one or more of the associated listed items.

[0027] As used herein, the phrase of the form of “at least one of A or B” may include A or B or both A and B. Correspondingly, the phrase of the form of “at least one of A or B or C”, or including further listed items, may include any and all combinations of one or more of the associated listed items.

[0028] Various embodiments may provide a multi-section caisson installation method. Such a method may address the limitations of conventional caisson installation methods and may allow caissons to be installed as deep as required.

[0029] Various embodiments may related to geotechnical methods used for foundation construction in deep or shallow water for applications such as mooring anchors, offshore

platforms or structures, break-waters, seawalls, foundations for wind turbines, bridges or large scale buildings constructed over water or wetland.

[0030] Various embodiments may provide an installation method by the use of multi-section caissons, which may be adopted to form a cylindrical foundation with varying cross-section that may provide a highly economical design. High pressure water jet may be used to remove soil plugs.

[0031] Various embodiments may provide a method for installation of suction caissons in either deep or shallow water. The method may include multi-section caissons that may be installed section by section when a suction caisson needs to be installed to a depth in a seabed that cannot be reached by the use of suction alone.

[0032] Various embodiments may provide a method of installing a multi-section suction caisson.

[0033] FIG. 1 show a flow chart 100 illustrating a method for installing a multi-section suction caisson, according to various embodiments. At 102, a first section of the multi-section suction caisson is positioned on an underwater ground. At 104, a suction pressure is applied to a first inner chamber of the first section, and an amount of soil plug is subsequently removed from the first inner chamber. At 106, a second section of the multi-section suction caisson is positioned in alignment over the first section. The first section has an inner diameter larger than an outer diameter of the second section. At 108, the suction pressure is applied to a second inner chamber of the second section.

[0034] In other words, a multi-section suction caisson may be used to construct a caisson, which is a watertight retaining structure used, for example, to work on the foundations of a bridge pier, for the construction of a concrete dam, or for the repair of ships. Such a multi-section suction caisson may be used in shallow water or in deep water. To install a section of the multi-section suction caisson, a suction pressure may be used to draw water and/or air out of an inner chamber of the section to allow that section to move into or penetrate into an underwater ground. With water and/or air drawn out, soil may enter the inner chamber to form a soil plug. The soil plug may subsequently be removed from the inner chamber by eroding the soil therein to create space for the section to move downward and penetrate further into the seabed. The application of the suction pressure and the subsequent removal of soil plug may be repeated to allow the section to penetrate

maximally into the underwater ground, for example, leveling with a surface of the underwater ground. By installing a further section of the multi-section suction caisson into the section already installed in the underwater ground, the multi-section suction caisson may be extended since the further section may have a length longer than that of the already installed section. Multiple further sections, each longer than the installed ones, may also be installed in a similar procedure to further extend the multi-section suction caisson to reach a desired depth.

[0035] In the context of various embodiments, the term “multi-section suction caisson” may interchangeably be referred to as a caisson, a caisson structure, a suction caisson, a multi-section caisson, a nested caisson, a nested suction caisson, a cascaded caisson, a cascaded suction caisson, a multi-nested caisson, or a multi-nested suction caisson.

[0036] In various embodiments, the underwater ground may mean a ground in deep water or in shallow water. For example, the underwater ground may include a seabed, a river bed, a stream bed, or a reservoir bed.

[0037] In various embodiments, the suction pressure may be generated by a compressor and fed into the first inner chamber and the second inner chamber. The suction pressure may also be converted from hydrostatic water pressure, typically when in deep water.

[0038] In various embodiments, the first section may include a first tubular body with a first removable closed end and a first opposing open end to define the first inner chamber, which may interchangeably be referred to as a first caisson cavity or a first section cavity. In other words, the first section may be of a tubular (hollow) structure with one end closed, that may be removable, and the opposing (or opposite) end opened.

[0039] The second section may include a second tubular body with a second removable closed end and a second opposing open end to define the second inner chamber, which may interchangeably be referred to as a second caisson cavity or a second section cavity. In other words, the second section may be of a tubular (hollow) structure with one end closed, that may be removable, and the opposing (or opposite) end opened.

[0040] In various embodiments, the second section may have a length longer than that of the first section. With this, by installing the second section into the first section, the multi-section suction caisson may be extended. The length of the second section may be

determined based on an additional bearing capacity required by the multi-section suction caisson.

[0041] In the context of various embodiments, the term “diameter” may relate to a cross-section of a tubular structure (e.g., the first tubular body or the second tubular body) that may be at least substantially circular or non-circular. For example, if the tubular structure has a circular cross-section, the diameter may be a measure of a straight line going through the center of the circle connecting two points on the circumference. If the tubular structure has an elliptical cross-section, the diameter may refer to a measure of the longest straight line going through the center of the ellipse connecting two points on the circumference. If the tubular structure has a rectangular cross-section, the diameter may refer to a measure of a straight line going through the center of rectangle and joining diagonally at two right-angled edges on the perimeter. If the tubular structure has an irregular shaped cross-section, the diameter may refer to a measure of the longest straight line going through the center of the irregular shape and joining two points on the perimeter.

[0042] An outer diameter of a tubular structure may be derived from the combination of an inner diameter and a thickness of the tubular structure.

[0043] In various embodiments, the second section may be positioned in alignment over the first section at 106. In other words, the first section and the second section may have their respective central longitudinal axis arranged in line or substantially in line with each other. This way, at least part of the second section may move into the first tubular body of the first section and penetrate into the underwater ground.

[0044] In various embodiments, the step of positioning the first section on the underwater ground at 102 may include positioning the first opposing open end of the first section on the underwater ground. By doing so, water and/or air may initially be occupying the first inner chamber and as the first section moves into the underwater ground, soil from the underwater ground may enter into the first inner chamber through the first opposing open end.

[0045] In various embodiments, the step of positioning the first section on the underwater ground at 102 may further include allowing at least part of the first section to penetrate into the underwater ground under the weight of the first section. It may be appreciated

that when penetrating into the underwater ground via the self-weight of the first section, the suction pressure may not yet be applied to the first inner chamber.

[0046] In various embodiments, the method may further include after applying the suction pressure to the first inner chamber at 104, releasing the suction pressure from the first inner chamber when the first section penetrates no further into the underwater ground due to the soil plug formed in the first inner chamber. The step of subsequently removing the amount of soil plug from the first inner chamber at 104 may include after releasing the suction pressure from the first inner chamber, removing the amount of soil plug from the first inner chamber using a water jet.

[0047] In other words, the step of applying the suction pressure to the first inner chamber and the step of subsequently removing of the amount of soil plug from the first inner chamber at 104 may be carried out sequentially, i.e. one step after the other, and not both these steps at the same time.

[0048] The water jet may be connected to a water hose through a valve disposed on the first removable closed end. The water jet may be used to remove the soil plug by eroding the soil plug. The water jet may interchangeably be referred to as a high pressure water jet or high pressure jet or high pressure water.

[0049] In various embodiments, the method may further include removing the water jet when the amount of soil plug is removed from the first inner chamber. In the context of various embodiments, the phrase "removing the water jet" may mean discontinuing a supply of the water jet.

[0050] The amount of soil plug to be removed from the first inner chamber may include at least one of an amount of soil plug formed toward the first removable closed end, or an amount of soil plug formed in the first inner chamber that prevents the first removable closed end from substantially leveling with a surface of the underwater ground.

[0051] In the context where the underwater ground may be a seabed, the surface of the underwater ground may refer to a mud line of the seabed.

[0052] In various embodiments, the method may further include repeating the steps of applying the suction pressure to the first inner chamber and subsequently removing the amount of soil plug from the first inner chamber at 104 until the first removable closed end is substantially leveled with a surface of the underwater ground.

[0053] In other words, the suction pressure may be applied to the first inner chamber and thereafter, the amount of soil plug may be removed therefrom. If the first section is not penetrated into the underwater ground to a desired depth, the suction pressure may be re-introduced and applied to the first inner chamber. Following that, an amount of soil plug
5 may once again be removed from the first inner chamber. For example, this may be repeated and continued until the first removable closed end may be substantially leveled with the surface of the underwater ground, e.g., when the first section penetrates (or is installed) to the desired depth.

[0054] In one example, the first removable closed end being substantially leveled with
10 the surface of the underwater ground may mean the first removable closed end being just above the surface of the underwater ground and not buried in the underwater ground. In another example, the first removable closed end may be laid flushed against the surface of the underwater ground.

[0055] In various embodiments, the method may further include subsequently removing
15 an amount of soil plug from the second inner chamber.

[0056] In various embodiments, the method may further include after applying the suction pressure to the second inner chamber at 108, releasing the suction pressure from the second inner chamber when the second section penetrates no further into the underwater ground due to the soil plug formed in the second inner chamber.

[0057] The step of subsequently removing the amount of soil plug from the second inner
20 chamber may include after releasing the suction pressure from the second inner chamber, removing the amount of soil plug from the second inner chamber using a water jet. The water jet may be connected to a water hose through a valve disposed on the second removable closed end. The water jet may be described in similar context to the water jet
25 described for the first section.

[0058] In various embodiments, the method may further include removing the water jet when the amount of soil plug is removed from the second inner chamber.

[0059] For example, the amount of soil plug to be removed from the second inner
30 chamber may include at least one of an amount of soil plug formed toward a second removable closed end of the second section, or an amount of soil plug formed in the

second inner chamber that prevents the second removable closed end from substantially leveling with a surface of the underwater ground.

[0060] In various embodiments, the method may further include repeating the steps of applying the suction pressure to the second inner chamber and subsequently removing the amount of soil plug from the second inner chamber until a second removable closed end of the second section is substantially leveled with a surface of the underwater ground.

[0061] In other words, the suction pressure may be applied to the second inner chamber and thereafter, the amount of soil plug may be removed therefrom. If the second section is not penetrated into the underwater ground to a desired depth, the suction pressure may be re-introduced and applied to the second inner chamber. Following that, an amount of soil plug may once again be removed from the second inner chamber. This may be repeated and continued until the second removable closed end may be substantially leveled with the surface of the underwater ground, e.g., when the second section penetrates (or is installed) to the desired depth.

[0062] In various embodiments, the method may further include arranging a top cap over the first section and the second section along the surface of the underwater ground.

[0063] The top cap may, for example, be a removable access door to the second inner chamber. The top cap may be screwed to the second section. The top cap may be placed after completing the installation of the second section. In an example, the top cap may be the second removable closed end. The removable top cap and the high pressure water jet may be used to remove the internal soil plug during the installation of the multi-section suction caisson.

[0064] In various embodiments, the step of positioning the second section in alignment over the first section at 106 may include positioning the second opposing open end of the second section in alignment over the first section with the first removable closed end being removed.

[0065] The method may further include prior to the step of positioning the second section in alignment over the first section at 106, removing the first removable closed end from the first section.

[0066] In various embodiments, the method may further include removing the soil plug from substantially in an entirety of the first inner chamber using a water jet. In other

words, high pressure water may be used to remove substantially all the soil inside the caisson cavity to install the nested caissons.

5 [0067] The removal of the soil plug from substantially in the entirety of the first inner chamber may be carried out after removing the first removable closed end from the first section.

[0068] The water jet may be described in similar context to the water jet as described above for the first section and the second section.

10 [0069] In various embodiments, the method may further include providing a plurality of guide bars configured to guide the second section into the first tubular body along a longitudinal axis of the first section.

[0070] With the plurality of guide bars, the second section may be prevented from tilting and may be moved into the first section more efficiently.

[0071] In various embodiments, the method may further include at least one of wedging or binding the first section and the second section.

15 [0072] The first section and the second section may be wedged against each other using a plurality of wedges. When the first section and the second section are in place with installation being completed, these sections may be bound together. For example, grout may be applied between the first section and the second section for the binding.

20 [0073] In various embodiments, the first section, the second section and at least one further section may be part of a sequence of sections of the multi-section suction caisson.

[0074] In other words, the multi-section suction caisson may include a third section, a fourth section and so on, and each of these further sections may be installed (or penetrated) into the underwater ground in similar ways carried out for the second section. For example, the third section may have an outer diameter smaller than an inner diameter of the second section, while the fourth section may have an outer diameter smaller than an inner diameter of the third section, and so on. This way, the first section may be installed first, followed by the second section, and then followed by the third section, and further followed by the fourth section, and so on. The method may thus be related to installing the first section, the second section and at least one further section of the multi-section suction caisson.

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[0075] Moreover, the third section may have a length longer than that of the second section, and the fourth section may have a length longer than that of the third section, and so on. This way, the multi-section suction caisson may be further extended.

[0076] While the method described above is illustrated and described as a series of steps or events, it will be appreciated that any ordering of such steps or events are not to be interpreted in a limiting sense. For example, some steps may occur in different orders and/or concurrently with other steps or events apart from those illustrated and/or described herein. In addition, not all illustrated steps may be required to implement one or more aspects or embodiments described herein. Also, one or more of the steps depicted herein may be carried out in one or more separate acts and/or phases.

[0077] In various embodiments, the multi-section suction caisson may be installed in different steps. As described herein, the water jet may be used to erase or erode the soil plug and allow the caisson to penetrate deeper into the underwater ground.

[0078] The method in accordance with various embodiments may improve penetration depth, which in turn may improve pullout resistance and bearing capacity of the multi-section suction caisson. The multi-section suction caisson (or stepped caisson) makes it possible to change the cross-section of the caisson to achieve an optimized design. As the stepped caisson may be installed in sections, it also makes it possible for a large bearing capacity caisson to be installed using equipment that would not have the capacity if the caisson were to be installed in one piece (i.e. in a single entire structure). The method in accordance with various embodiments may provide an easy (direct or straightforward) design method as the whole structure (the multi-section suction caisson) may be simulated as a shallow foundation.

[0079] Various embodiments may also provide a multi-section suction caisson including a first section configured to be positioned on an underwater ground; a second section configured to be positioned in alignment over the first section, wherein the first section has an inner diameter larger than an outer diameter of the second section, and the second section has a length longer than that of the first section.

[0080] The first section may include a first inner chamber to which a suction pressure and a water jet may be sequentially applied to respectively allow at least part the first

section to penetrate into the underwater ground, and to remove an amount of soil plug from the first inner chamber to facilitate further penetration of the first section.

[0081] The second section may include a second inner chamber to which the suction pressure and the water jet may be sequentially applied to respectively allow at least part
5 the second section to move into the first section and penetrate into the underwater ground, and to remove an amount of soil plug from the second inner chamber to facilitate further penetration of the second section.

[0082] As described above, the first section may include a first tubular body with a first removable closed end and a first opposing open end to define the first inner chamber; and
10 the second section may include a second tubular body with a second removable closed end and a second opposing open end to define the second inner chamber.

[0083] For example, upon completion of the installation of the multi-section suction caisson in accordance with various embodiments, at least part of the second tubular body may overlap the entire first tubular body. In other words, the entire first tubular body may
15 form a ring over the at least part of the second tubular body.

[0084] The multi-section suction caisson may further include a top cap arranged over the first section and the second section. The top cap may include at least one connector configured to connect a water source or a suction pressure source or a waste channel for removed soil and water/air. For example, the at least one connector may be in a form of a
20 valve.

[0085] The multi-section suction caisson may further include a plurality of wedges configured to wedge the first section and the second section. Each of the plurality of wedges may be arranged spaced apart at substantially equidistance from an adjacent wedge. The plurality of wedges may be arranged around the first tubular body at the first
25 removable closed end. For example, the plurality of wedges may include six wedges.

[0086] The multi-section suction caisson may further include a plurality of guide bars configured to guide the second section into the first tubular body along a longitudinal axis of the first section. Each of the plurality of guide bars may be arranged spaced apart at substantially equidistance from an adjacent guide bar. The plurality of guide bars may be
30 arranged extending from the first tubular body at the first removable closed end. For example, the plurality of guide bars may include four guide bars up to twelve guide bars.

[0087] The second section may further include a flange extending outwardly from the second removable closed end. The flange may include a plurality of holes configured to receive the plurality of guide bars.

[0088] An example of a method of installing a multi-section caisson in accordance with various embodiments may be described as follow.

[0089] FIGs. 2A to 2D show schematic cross-section views 200, 220, 240, 260 of a caisson 202 being installed into a seabed 204. The caisson 202 may be a first section of a multi-section suction caisson, in accordance with various embodiments.

[0090] In FIG. 2A, the caisson 202 is positioned on a mud line 206 and the caisson 202 is allowed to penetrate into the seabed 204 under the caisson 202's self weight. After the self-weight penetration, a suction pressure may be applied to an inner chamber 208 of the caisson 202 to allow the caisson 202 to be penetrated further into the seabed 204 with air/water 210 being displaced from the inner chamber 208.

[0091] As the caisson 202 penetrates into the seabed 204, soil from the seabed 204 may enter into the inner chamber 208 of the caisson 202. When the caisson 202 could no longer penetrate any deeper into the seabed 204 as shown in FIG. 2B, the suction pressure may be released. The prevention of further penetration may be due to a soil plug 222 formed in the inner chamber 208 of the caisson 202.

[0092] A water hose 242 may then be connected to the inner chamber 208 of the caisson 202 through a valve 244 as shown in FIG. 2C. Using a high pressure water jet through the water hose 242, the soil plug 222 may be eroded. The high pressure water jet may be applied until a required amount of soil plug 222 is removed from the inner chamber 208 of the caisson 202. At this point, the water hose 242 may be disconnected from the inner chamber 208 of the caisson 202.

[0093] A suction pressure may be applied again into the inner chamber 208 to allow the caisson 202 to penetrate into a required depth as shown in FIG. 2D.

[0094] The procedures as described in FIGs. 2B to 2D may be repeated until the caisson 202 could not penetrate any deeper.

[0095] In case a higher bearing capacity is required, the caisson may be extended by using another caisson as a second section of the multi-section suction caisson, in accordance with various embodiments, as shown in schematic cross-section views 300,

320, 340, 360 of FIGs. 3A to 3D. This second section may have an outer diameter smaller than the inner diameter of the first section (the caisson 202) such that the second section may be loosely fitted to the first section. The second section may be of a length that is longer than the first section. The length required for the second section may be calculated
5 based on the additional bearing capacity.

[0096] As shown in FIG. 3A, the second section 302 may be installed by firstly removing a top cap 304 of the first section (the caisson 202). The soil plug 306 inside the inner chamber 208 of the first section 202 may be at least substantially completely removed using a high pressure water jet 322 as shown in FIG. 3B. The high pressure water jet 322
10 may be provided through a water hose (e.g., water hose 242 of FIG. 2C).

[0097] The second section 302 may then be positioned and installed using a suction pressure applied in an inner chamber 308 of the section section 302. To allow the second section 302 to penetrate maximally into the seabed 204, the procedures for installing the first section 202 (FIGs. 2B to 2D) may be similarly performed for the second section 302
15 such that air/water 362 is displaced from the inner chamber 308 of the second section 302.

[0098] If necessary, a third section 402 may be used as shown in a schematic cross-section view 400 of FIG. 4A. The third section 402 may have an outer diameter smaller than an inner diameter of the second section 302 such that the third section 402 may be
20 loosely fitted to the second section 302. The third section 402 may be of a length that is longer than the second section 302. The length required for the third section 402 may be calculated based on the additional bearing capacity. To allow the third section 402 to penetrate maximally into the seabed 204, the procedures for installing the second section 302 (FIGs. 3A to 3D) may be similarly performed for the third section 402.

[0099] Subsequent or further sections may be installed to further extend the multi-section suction caisson. The installation of each subsequent section may be performed in a similar manner for installing the second section 302 and/or the third section 402.
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[0100] Cement grout may be used to grout the sections (e.g., the caisson 202, the second section 302 and the third section 402) together.

[0101] A top cap 422 may also be used as shown in a schematic cross-section view 420 of FIG. 4B. Finally, a cylindrical foundation with varying cross-section may be formed.
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[0102] Various connections between different sections of caissons may be provided. For example, in case the multi-sections of the caisson need to be connected together, the following method as shown in FIGs. 5A to 5D may be adopted. FIG. 5A shows a schematic perspective view 500 of a multi-section suction caisson 502. FIG. 5B (i) shows a schematic side view 520 of Part A 504 of the multi-section suction caisson 502, while FIG. 5B (ii) shows a schematic top view 522 of Part A 504 of the multi-section suction caisson 502. FIG. 5C (i) shows a schematic side view 540 of Part B 506 of the multi-section suction caisson 502, while FIG. 5C (ii) shows a schematic top view 542 of Part B 506 of the multi-section suction caisson 502. FIG. 5D (i) shows a schematic side view 560 of Part C 508 of the multi-section suction caisson 502, while FIG. 5D (ii) shows a schematic top view 562 of Part C 508 of the multi-section suction caisson 502.

[0103] The multi-section suction caisson 502 may be described in the context of the multi-section suction caisson described in various embodiments and the multi-section suction caisson as described in FIGs. 2A to 2D and FIGs. 3A to 3D.

[0104] In FIG. 5D, six steel triangle-shaped wedges 564 may be preinstalled by casting with the same spacing at a top half to about one meter of the outside of Part C 508. In other words, each of the six steel triangle-shaped wedges 564 may be positioned at substantially equidistant from an adjacent steel triangle-shaped wedge 564. Each of the six steel triangle-shaped wedges 564 may have one end 566 embedded in an upper portion 568 of Part C 508 and may extend upwardly, as indicated by a directional arrow 50, such that the opposite end 570 of each of the six steel triangle-shaped wedges 564 may be at a distance of about one meter from a top surface 572 of Part C 508. For example, Part C 508 may be described in the context of the first section 202 of FIGs. 2A to 2D and the first section described in various embodiments. Part C 508 may be in a form of a cylinder.

[0105] Under the gravity of the multi-section suction caisson and a dragging force applied by a suction on Part B 506, Part B 506 may be forced into the wedges 564 in Part C 508.

[0106] For example, Part B 506 may be described in the context of the second section 302 of FIGs. 3C and 3D and the second section in accordance with various embodiments. Part B 506 may be in a form of a cylinder having a flange 544 extending outwardly from

one end of Part B 506. Part B 506 may have a length that is longer than Part C 508. With grout applied in between Part B 506 and Part C 508, the two parts may be locked together.

[0107] Part A 504 and Part B 506 may be connected using screws as Part A 504 may be removable. For example, Part A 504 may be described in the context of the top cap 422 of FIG. 4B and the top cap in accordance with various embodiments. Part A 504 may also include connectors 524. The connectors 524 may, for example, facilitate the connection of a water hose to the multi-section suction caisson 502.

[0108] To avoid tilting of Part B 506 during installation, four to twelve guide bars 510 may be installed on top of Part C 508 and through guide holes 512 of Part A 504. The guide bars 510 may also be aligned upwardly from Part C 508. When installing Part B 506, the guide bars 510 may pass through alignment holes 546 of Part B 506. Nuts (not shown in the figures) may also be used on the guide bars 510 to tie the different parts together.

[0109] While the invention has been particularly shown and described with reference to specific embodiments, it should be understood by those skilled in the art that various changes in form and detail may be made therein without departing from the spirit and scope of the invention as defined by the appended claims. The scope of the invention is thus indicated by the appended claims and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced.

CLAIMS

1. A method for installing a multi-section suction caisson, the method comprising:
5 positioning a first section of the multi-section suction caisson on an underwater ground;

applying a suction pressure to a first inner chamber of the first section, and subsequently removing an amount of soil plug from the first inner chamber;

10 positioning a second section of the multi-section suction caisson in alignment over the first section, wherein the first section has an inner diameter larger than an outer diameter of the second section; and

applying the suction pressure to a second inner chamber of the second section.

2. The method of claim 1, further comprising subsequently removing an amount of
15 soil plug from the second inner chamber.

3. The method of claim 1, wherein the step of positioning the first section on the underwater ground further comprises allowing at least part of the first section to penetrate into the underwater ground under the weight of the first section.

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4. The method of claim 1, further comprising

after applying the suction pressure to the first inner chamber, releasing the suction pressure from the first inner chamber when the first section penetrates no further into the underwater ground due to the soil plug formed in the first inner chamber.

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5. The method of claim 4, wherein the step of subsequently removing the amount of soil plug from the first inner chamber comprises

after releasing the suction pressure from the first inner chamber, removing the amount of soil plug from the first inner chamber using a water jet.

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6. The method of claim 5, further comprising removing the water jet when the amount of soil plug is removed from the first inner chamber.

7. The method of claim 1, wherein the first section comprises a first tubular body with a first removable closed end and a first opposing open end to define the first inner chamber; and the second section comprises a second tubular body with a second removable closed end and a second opposing open end to define the second inner chamber; and wherein the second section has a length longer than that of the first section.

8. The method of claim 7, wherein the step of positioning the first section on the underwater ground comprises positioning the first opposing open end of the first section on the underwater ground.

9. The method of claim 7, further comprising repeating the steps of applying the suction pressure to the first inner chamber and subsequently removing the amount of soil plug from the first inner chamber until the first removable closed end is substantially leveled with a surface of the underwater ground.

10. The method of claim 7, wherein the amount of soil plug to be removed from the first inner chamber comprises at least one of an amount of soil plug formed toward the first removable closed end, or an amount of soil plug formed in the first inner chamber that prevents the first removable closed end from substantially leveling with a surface of the underwater ground.

11. The method of claim 2, further comprising
after applying the suction pressure to the second inner chamber, releasing the suction pressure from the second inner chamber when the second section penetrates no further into the underwater ground due to the soil plug formed in the second inner chamber.

12. The method of claim 11, wherein the step of subsequently removing the amount of soil plug from the second inner chamber comprises

after releasing the suction pressure from the second inner chamber, removing the amount of soil plug from the second inner chamber using a water jet.

13. The method of claim 12, further comprising

5 removing the water jet when the amount of soil plug is removed from the second inner chamber.

14. The method of claim 2, further comprising repeating the steps of applying the suction pressure to the second inner chamber and subsequently removing the amount of
10 soil plug from the second inner chamber until a second removable closed end of the second section is substantially leveled with a surface of the underwater ground.

15. The method of claim 14, further comprising arranging a top cap over the first section and the second section along the surface of the underwater ground.

15 16. The method of claim 7, further comprising, prior to the step of positioning the second section in alignment over the first section, removing the first removable closed end from the first section.

20 17. The method of claim 16, further comprising removing the soil plug from substantially in an entirety of the first inner chamber using a water jet.

18. The method of claim 7, further comprising providing a plurality of guide bars configured to guide the second section into the first tubular body along a longitudinal axis
25 of the first section.

19. The method of claim 1, further comprising at least one of wedging or binding the first section and the second section.

30 20. The method of claim 1, wherein the first section, the second section and at least one further section are part of a sequence of sections of the multi-section suction caisson.