

CONSTRUCTION METHOD FOR FIXING HOLLOW COLUMN FOR SUPPORTING MARINE STRUCTURES AND OFFSHORE PLATFORMS TO A SEABED

BACKGROUND

[0001] 1. Field.

[0002] The example embodiment in general relates to a construction method for fixing hollow cylindrical columns for supporting an offshore marine platform thereon, which in turn is adapted to support wind turbines, bridges and marine buildings thereon, to a seabed in a marine environment, and more particularly to a method in which the hollow column is employed as a temporary cofferdam during construction of the pile cap in a dry environment, thereby lowering construction costs and improving safety.

[0003] 2. Related Art.

[0004] A type of commander base on site is needed to support the development of ocean resources that include offshore wind energy, ocean current and tidal energies, ocean fish farms, and even the building of an ocean city, etc. The base may be fixed to the seabed or may be configured so as to float in the water. A drawback of the floating-type base is that mooring the base for the purpose of anchorage is difficult where the water depth is shallower than 50m. The base drifts aimlessly if the mooring lines are broken as this would pose great danger to the public. Hence, a fixed base is often more desirable and offers greater safety than the floating base. Additionally, a stationery fixed platform is desirable in that it offers riders the comfort similar to living on land, as opposed to the boat living on the floating base.

[0005] Applicant's prior art China Pat. Appl. Ser. Nos. 201210038405.9 and 201200104898.8 both describe a process whereby a hard seabed or soft materials in the seabed may be dredged, and may be applied to conditions where the bedrock is close to the seabed surface. In near shore waters, especially at an estuary where thick layers of soil and sand have settled, the removal of soft soil materials is simply not feasible. Accordingly, what is needed is a method of fixing an offshore marine platform to a seabed which includes thick layers of soft materials that typically cannot be completely removed.

[0006] The conventional method for fixing the hollow column to the seabed in preparation for placing a platform deck of an offshore platform thereon utilizes a plurality of piles, whereby the pile cap is typically constructed under water on the seabed. In

construction, a temporary steel cofferdam-type of structure is used to provide a dry working environment within the interior of the hollow column. However, use of a temporary cofferdam is costly. Therefore, what is needed is a method that eliminates the temporary cofferdam so as to drastically lower both cost and construction time. Further, if there is a precast factory on land to produce parts of the platform, with the platform thereafter assembled on top of the already fixed hollow column, improved mass production capabilities and speed of construction is possible.

SUMMARY

[0007] An example embodiment is directed to a construction method for fixing a foundation for supporting waterborne structures such as an offshore platform to a seabed, the foundation having one or more hollow cylindrical columns that are to be fixed to the seabed, such as a seabed comprising a thick layer of soft marine deposits. In the method, a plurality of steel tubes are driven into the founding layer in the seabed at an installation location of the hollow column, the steel tubes having a given free length above sea level, and the hollow column is then lowered down to the seabed so that the steel tubes are within the hollow column. Underwater concrete is injected between the seabed and bottom of the hollow column so as to form a concrete plug. The interior of the hollow column is dewatered so as to be used as a cofferdam, and then the steel tubes are cut above a pile cap level or determined design level. Thereafter, concrete is injected to cast the pile cap so as to complete the foundation.

[0008] Another example embodiment is directed to a construction method for fixing a foundation for supporting waterborne structures such as an offshore platform to a seabed, the foundation having one or more hollow cylindrical columns that are to be fixed to the seabed. In the method, a plurality of steel tubes is driven into the founding layer in the seabed, and the hollow column is then lowered down to the seabed so as to surround the steel tubes. A reinforced concrete plug is then formed in the bottom of the hollow column, the hollow column configured as a cofferdam. The interior of the hollow column is then dewatered, pile cap reinforcement is fixed, and then concrete is cast to form a pile cap.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The example embodiment will become more fully understood from the detailed description given herein below and the accompanying drawings, wherein like elements are represented by like reference numerals, which are given by way of illustration only and thus are not limitative of the example embodiments herein.

[0010] FIG. 1 is an indicative intermediate construction stage according to an example construction method of fixing a hollow column to a seabed.

[0011] FIG. 2 is an indicative final construction stage according to an example construction method of fixing a hollow column to a seabed.

[0012] FIG. 3 is an indicative sectional view F-F of FIG. 1.

[0013] FIG. 4 is an indicative sectional view G-G of FIG. 1.

[0014] FIG. 5 is an indicative elevation sectional view showing the formation of the pile cap.

[0015] FIG. 6A is an indicative side view showing the shear key at the surface of the steel casing or steel pipe pile in a section of the pile that is expected to be embedded in the concrete plug.

[0016] FIG. 6B is a cross-sectional view taken from line H-H in FIG. 6A to illustrate the layout of shear keys in the steel casing or steel pipe pile.

[0017] FIG. 6C is a magnified view of a portion of the shear keys in FIG. 6A.

[0018] FIG. 7A, 7B, 8 and 9 indicatively show three different skirting options for three different seabed geologies.

[0019] Parts List

1. Sea level
2. Seabed/ seafloor
41. Pile
43. Concrete plug (small pile cap)
44. Concrete pile cap
45. Pre-installed reinforcement steel bars
47. Pile cap reinforcement
48. Lapping steel bars from pile
49. Steel tube (steel pipe pile or steel casing for concrete bored pile)
- 49A. Steel tube in a region in contact with concrete plug 43.
50. Shear key
108. Hollow column
111. Pre-installed lapping bars
112. Top end temporary support
113. Pile head jacking prop
119. Stabilization bracing

- 121. Cantilever plate
- 122. Skirting board
- 123. Stiffener
- 124. Bolt
- 131. L-shaped skirting plate
- 141. Steel ring
- 142. Teething

DETAILED DESCRIPTION

[0020] As used herein, the phrase “present invention” should not be taken as an absolute indication that the subject matter described by the term “ ” is covered by either the claims as they are filed, or by the claims that may eventually issue after patent prosecution; while the term “present invention” is used to help the reader to get a general feel for which disclosures herein are believed as maybe being new, this understanding, as indicated by use of the term “present invention,” is tentative and provisional and subject to change over the course of patent prosecution as relevant information is developed and as the claims are potentially amended.

[0021] Reference throughout this specification to “one example embodiment” or “an embodiment” means that a particular system, method, feature, structure or characteristic described in connection with the embodiment is included in at least one embodiment. Thus, the appearances of the phrases “in one example embodiment” or “in an embodiment” in various places throughout this specification are not necessarily all referring to the same embodiment. Further, the particular systems, methods, features, structures or characteristics may be combined in any suitable manner in one or more example embodiments.

[0022] The term “and/or” may be understood to mean non-exclusive or; for example, A and/or B means that: (i) A is true and B is false; or (ii) A is false and B is true; or (iii) A and B are both true.

[0023] As used in this specification and the appended claims, the singular forms “a,” “an,” and “the” include plural referents unless the content clearly dictates otherwise. The term “or” is generally employed in its sense including “and/or” unless the content clearly dictates otherwise.

[0024] In the drawings, identical reference numbers identify similar elements or acts. The size and relative positions of elements in the drawings are not necessarily drawn to scale.

[0025] Unless the context requires otherwise, throughout the specification and claims that follow, the word "comprise" and variations thereof, such as "comprises" and "comprising," are to be construed in an open, inclusive sense, that is, as "including, but not limited to."

[0026] As used in the specification and appended claims, the terms "correspond," "corresponds," and "corresponding" are intended to describe a ratio of or a similarity between referenced objects. The use of "correspond" or one of its forms should not be construed to mean the exact shape or size.

[0027] As used herein, the term "hollow column" refers to a hollow cylindrical column fixed to the seabed in a body of water on which a wind power turbine, marine building, and/or bridge may be mounted thereon.

[0028] As will be described in more detail hereafter, the example construction method for fixing a hollow column to the seabed includes driving steel tubes (also referred to herein as steel pipe piles or "piles") into the founding layer in the seabed, lowering the hollow column to the seabed so as to surround the steel tubes, and forming a reinforced concrete plug in the bottom of the hollow column, the hollow column being configured as a cofferdam. The interior of the hollow column is then dewatered, pile cap reinforcement is fixed, and concrete is finally cast to form a pile cap thereby completing the installation, in preparation for thereafter supporting a to-be-built platform deck of a waterborne structure such as an offshore marine platform thereon. Thus, and unlike the convention method, the hollow column serves as the cofferdam during the construction stage, e.g., without having to employ the typical costly temporary steel cofferdam; moreover, the hollow column is part of the support structure for a waterborne structure such as an offshore marine platform. It is further both safe and efficient.

[0029] In an example, the pile may be a steel pipe pile having a length portion within the pile cap that can be modified so as to be integrated into the reinforcement cage of the to-be-cast pile cap, to be cast in-situ. A temporary pile head jacking prop with level and position adjusting jacks is fixed to the top of the pile to support the hollow column. A monitoring camera may be used to investigate the bottom of the hollow column so as to

determine if there are any large voids or gaps. If found, these voids and gaps are filled with sand gravel.

[0030] The concrete plug that is formed is not purely for stopping water coming in, as in the conventional construction method. Rather, the concrete plug also provides support to the hollow column. This is because reinforcement steel bars are pre-installed at the bottom of the hollow column in gaps between piles. These reinforcement steel bars translate the conventional concrete plug into a reinforced concrete slab. In an alternative, the bottom part of the concrete plug extends in a radial direction a short distance. To enhance the bond between the concrete plug and the piles, an expected section of the pile that is to be embedded in the concrete plug may be welded with triangular-shaped shear keys.

[0031] In an alternative, the bottom of the hollow column may be installed with a skirting. The skirting includes a steel plate having a diameter larger than that of the hollow column, so as to prevent an excessive loss of concrete sideways during casting of the concrete plug. The skirting includes a cantilever plate with stiffeners and is fixed by bolts to the bottom end of the hollow column. The skirting has a steel skirting board that is oriented approximately perpendicular to the cantilever. In a further alternative, the skirting may be embodied as a steel ring with teething extending from the end of the hollow column. In yet a further alternative, the skirting may be embodied as a plurality of radially-distributed L-shaped steel plates bolted to the end of the hollow column.

[0032] As will be shown hereafter, the example construction method eliminates the need for a costly temporary cofferdam and also eliminates the need for underwater execution; hence, employment of the example method at an installation location substantially reduces the construction risks and substantially improves the quality of works.

[0033] General concepts of the example embodiment having been described above, the following FIGS. 1-9 should be referred to for describing an example method of fixing an offshore marine platform adapted to support wind turbines, bridges and marine buildings thereon to a seabed which may include a thick layer of soft materials within a marine environment. The example method is based on fixing a precast, reinforced, concrete hollow cylindrical column having a diameter in a range of about 8-10m or larger to a seabed using a plurality of steel pipe piles or "piles". The example embodiment suits a seabed overlain with a layer of soft material, which is common in a near shore seabed.

[0034] FIGS. 1, 2 and 5 illustrate an example embodiment of the method as directed to a near shore application. It is understood that a person of skill in the art is capable of extending this example application to any similar type of water zones. It should be clear that the construction vessels used in this example could be of any similar construction vessels; hence, details of their function are omitted herein for purposes of brevity.

[0035] Initially, a plurality of pile 49 are sunk at the location of hollow column 108, e.g., for example, four (4) or more steel piles 49 may be arranged within the internal space of a hollow column 108 and driven into the seabed 2 to the suitable stratum. The piles 49 could be oriented vertically or inclined, so long as they do not hinder the insertion of the hollow column 108 downward into seabed 2 so as to enclose the piles 49. When all the piles 49 are installed, stabilization bracing 119 is prepared for stabilizing each pile 49 position, e.g., bracing 119 is bolted to the piles 49 after the insertion of the hollow column 108 enclosing the group of piles 49. As shown on the figures, the bracing 119 can be configured in a triangular pattern or any other geometry.

[0036] A temporary pile head jacking prop 113 with level adjusting jacks is then fixed to the top of the steel piles 49. The prop 113 is made by cutting the top of the steel piles 49 to a required level, then welding a thick steel plate to the pile head and placing a jack on the plate.

[0037] For this example four-pile configuration, after the piles 49 are fixed to the seabed 2, an installation vessel hoists the hollow column 108, which has been precast on land, and inserts the hollow column 108 into the group of piles 49 down to the seabed 2 so that the piles 49 are arranged within the interior of the hollow column 108. When the piles 49 and hollow column 108 meet an alignment tolerance, the wall of the hollow column 108 should enclose the pile group without touching any of the piles 49. In the case of seabed 2 having a soft layer, and as shown in FIG. 1, part of the wall of the hollow column 108 penetrates the seabed 2. Thereafter the stabilization bracing 119 is installed.

[0038] As shown in FIG. 3, at an appropriate level the hollow column 108 is installed with a temporary cross frame 112, which may be fixed to the wall of the hollow column 108 by welding or bolting. The cross frame 112 is supported by the pile head jacking support 113, the level of which is adjustable so that the hollow column 108 level can be adjusted to the required level above sea level 1.

[0039] A monitoring camera may be used to inspect if there are any gaps between the wall of the hollow column 108 and the seabed 2. If gaps are discovered, sand gravel is

added to fill the gaps. A tremie pipe is then used to inject tremie concrete (underwater concrete) into the bottom of the hollow column 108 to form a concrete plug 43. Concrete plug 43 is adapted to prevent water from coming in. As shown on FIG. 1, the concrete migrates outward under a gravity effect and is confined by a skirting plate.

[0040] With reference to FIG. 4, the bottom end of the wall of the hollow column 108 is pre-installed with reinforcement steel bars 45, such that the conventional mass concrete plug is translated into reinforced concrete slab. Thus, the conventional mass concrete plug 43 serves as a small pile cap capable of supporting the weight of the hollow column 108, and its buoyancy, plus any construction loads during construction.

[0041] The small pile cap/concrete plug 43 provides a water stop function that allows dewatering inside the hollow column 108. Accordingly, the wall of the hollow column 108 now functions in the role of a cofferdam to stop water from entering therein.

[0042] Workers may now gain access down to the bottom of the hollow column 108. In a dry working environment, the steel piles 49 are cut at the required level. The pile head is then modified as is now in this technology so that it can be integrated into the pile cap reinforcement cage. This may involve breaking the concrete to expose reinforcement bars (in the case where piles 49 are concrete bored piles), or welding reinforcement bars 48 to the steel piles 49 as lapping bars. As best shown by FIG. 5, the pile cap reinforcement 47 is fixed and lapping bars are screwed into pre-installed steel bar connectors (not shown) in the inner face of the hollow column 108; since such is well known in the art, details thereof are omitted for brevity. Concrete is then poured or injected to cast a formal pile cap 44, as illustrated in FIGS. 2 and 5.

[0043] After the formation of the pile cap 44, the construction vessels can be withdrawn. The hollow column 108 is now standing firm in the sea and is prepared for the platform deck construction thereon. Referring to FIG. 5, a plurality of lapping bars 111 may be pre-installed for connection to the platform deck.

[0044] For concrete bored piles which require steel casing, the steel casing is filled with reinforced concrete from the level of pile cap 44 down to the bottom of the bored hole.

[0045] In an example, the hollow column 108 may be embodied as a singular reinforced concrete element; however, it is also possible for the hollow column 108 to be divided into several segments. A plurality of concrete shear keys and positioning blocks (both well known art and not shown for brevity) provided at the segment common end faces may be used to hold the segments together by pre-stressed bars. Segments can be assembled on the

construction vessel and hoisted as a singular article for installation. Thereafter the procedures are similar to those described above.

[0046] In order to increase the bond between the surface of the steel pile 49 and the small pile cap/concrete plug 43, the steel pile surface (similarly the steel casing surface in a concrete bored pile configuration) has a plurality of triangular shear keys 50 welded thereto in such an orientation that the sharp angles of the shear keys 50 are pointing downward; this orientation facilitates soil layer penetration. These shear keys 50 may be distributed on the surface of a section of the pile/casing 49A that comes into contact with the small pile cap/concrete plug 43; see FIGS. 6A-6C for example.

[0047] Shear keys 50 in this example are embodied as small triangular-shaped pieces of metal with the sharp angles pointing downward. Although the shear keys 50 offer little resistance to the pile 49/casing being driven downward through the soil layer, the keys 50 provide great resistance to hollow column 108 downward movement; the hollow column 108 is resisted by the surface and mechanical bonds of the shear keys 50. It should be clear that the shape of the shear keys 50 is not limited to that shown in FIGS. 6A-6C; any geometric form that increases the surface area of the contact face between the steel pile 49/steel casing and small pile cap/concrete plug 43 is also feasible.

[0048] The example embodiment is applicable to seabeds having different geological conditions, which may broadly be classified into three (3) categories: 1) a seabed composed of a soft material, mainly marine mud; 2) a seabed composed of sandy clay, and 3) a seabed formed of hard weathered rock. In order to improve contact of the hollow column 108 with the seabed 2, different skirting options are employed based on the category or geological condition of the seabed 2.

[0049] FIGS. 7A and 7B indicatively show a cantilever skirting for application in soft marine deposit. The main function of skirting is to confine the underwater concrete within a skirting board during casting of the concrete plug (small pile cap) 43, although the skirting provides a secondary function of reducing the bearing pressure on the seabed 2 due to the increased contact area. FIG. 7A shows a skirting in a circular form comprising a cantilever plate 121 bolted to the bottom end of the wall of the hollow column 108, with its outer edge at a radius greater than that of hollow column 108. A plurality of stiffeners 123 may be distributed evenly in a circle. The skirting in this example further includes a skirting board 122 attached to the outer edge of the cantilever plate 121. The skirting may

be prefabricated in factory and fixed to the bottom end of the wall of the hollow column 108 by bolts 124.

[0050] FIG. 8 shows another skirting option for sandy seabed. This ring skirting comprises a steel ring 141 bolted to the bottom end of the wall of the hollow column 108. Teething 142 is attached to the steel ring 141. The teething 142 allows the wall of the hollow column 108 to penetrate into the sandy seabed, to make close contact with the seafloor so as to prevent the underwater concrete from escaping sideways during the casting of the concrete plug (small pile cap) 43.

[0051] FIG. 9 illustrates yet another skirting option for a seabed composed of weathered rock. Any kind of penetration cannot be used, since the weathered rock is extremely hard to penetrate. It is impossible for a single skirting to cover a general uneven terrain of the seabed. The solution is to use a plurality of L-shaped skirting plates 131 attached to the bottom end of the wall of the hollow column 108. As shown in FIG. 9, this example skirting is divided into 64 L-shaped skirting plates 131 configured to ride over any uneven terrain in the seabed 2, thereby preventing an excessive loss of underwater concrete during casting of the concrete plug (small pile cap) 43.

[0052] According to the example embodiment above, the installation and construction of marine structures or offshore platforms using the example hollow column 108 eliminates the need for a temporary cofferdam, greatly reducing cost and construction time. Additionally, using the hollow column 108 to guard off water enhances the safety of workers inside the hollow column 108. Further, the formed concrete plug 43 is not merely a mass of concrete, but a specially designed, reinforced concrete plug having dual functions: a first function as a water stop and a second function as a temporary (small) pile cap supporting the hollow column 108 during the construction of the permanent pile cap 44. To enhance the first function, a skirting may be added to the end of the hollow column 108. To enhance the second function, shear keys 50 are welded to the surface of the piles 49 at the section of the piles 49A that is expected to be embedded in the concrete plug 43.

[0053] The example embodiment having been described, it is apparent that such may have many varied applications. For example, the method of fixing the hollow column 108 to the seabed 2 as disclosed herein is not limited to the specific example embodiment described above. Various changes and modifications thereof may be effected by one skilled in the art without departing from the spirit or scope of protection. For example,

elements and/or features of different illustrative embodiments could be combined with each other and/or substituted for each other within the scope of this disclosure.

[0054] The present invention, in various embodiments, configurations, and aspects, includes components, methods, processes, systems and/or apparatus substantially as depicted and described herein, including various embodiments, sub-combinations, and subsets thereof. Those of skill in the art will understand how to make and use the present invention after understanding the present disclosure. The present invention, in various embodiments, configurations, and aspects, includes providing devices and processes in the absence of items not depicted and/or described herein or in various embodiments, configurations, or aspects hereof, including in the absence of such items as may have been used in previous devices or processes, e.g., for improving performance, achieving ease and/or reducing cost of implementation.

[0055] The foregoing discussion of the invention has been presented for purposes of illustration and description. The foregoing is not intended to limit the invention to the form or forms disclosed herein. In the foregoing Detailed Description for example, various features of the invention are grouped together in one or more embodiments, configurations, or aspects for the purpose of streamlining the disclosure. The features of the embodiments, configurations, or aspects of the invention may be combined in alternate embodiments, configurations, or aspects other than those discussed above. This method of disclosure is not to be interpreted as reflecting an intention that the claimed invention requires more features than are expressly recited in each claim. Rather, as the following claims reflect, inventive aspects lie in less than all features of a single foregoing disclosed embodiment, configuration, or aspect. Thus, the following claims are hereby incorporated into this Detailed Description, with each claim standing on its own as a separate preferred embodiment of the invention.

[0056] Moreover, though the description of the invention has included description of one or more embodiments, configurations, or aspects and certain variations and modifications, other variations, combinations, and modifications are within the scope of the invention, e.g., as may be within the skill and knowledge of those in the art, after understanding the present disclosure. It is intended to obtain rights which include alternative embodiments, configurations, or aspects to the extent permitted, including alternate, interchangeable and/or equivalent structures, functions, ranges or steps to those claimed, whether or not such alternate, interchangeable and/or equivalent structures,

functions, ranges or steps are disclosed herein, and without intending to publicly dedicate any patentable subject matter.

I claim:

1. A construction method for fixing a foundation having a hollow column adapted to support a waterborne structure thereon to a seabed, comprising:

driving a plurality of steel tubes into the seabed at an installation location for the hollow column, each of the steel tubes having a free length above sea level,

lowering the hollow column down to the seabed so as to be supported on the steel tubes, the steel tubes arranged within the hollow column,

injecting underwater concrete between the seabed and the hollow column bottom to form a concrete plug,

dewatering the interior of the hollow column,

cutting the steel tubes above a level of a pile cap to be formed or at a determined design level,

modifying the pile head so as to be fitted with lapping steel bars integrated into a pile cap reinforcement cage,

fixing the steel reinforcement of the pile cap, and

injecting concrete to cast the pile cap and complete the foundation.

2. A construction method for fixing a foundation having a precast, pre-stressed, reinforced concrete hollow cylindrical column adapted to support an offshore marine platform thereon to a seabed, the offshore platform adapted to support wind turbines, bridges and marine buildings thereon, the method comprising the steps of claim 1.

3. The method of claims 1 or 2, wherein the steel tube is embodied as a steel pipe pile or a steel casing if the pile is a concrete bored pile.

4. The method as recited in any one of claims 1 through 3, further comprising:

fitting the top of the hollow column with a steel frame resting on a temporary pile head jacking prop fixed to the top of a corresponding steel tube, each prop having one or more level adjusting jacks.

5. The method of claim 4, wherein, prior to injecting concrete into the bottom of the hollow column, the method further comprises:

adjusting level and verticality within a tolerance using the jacks installed at the top of each steel tube.

6. The method as recited in any one of claims 1 through 5, wherein, prior to injecting concrete into the bottom of the hollow column, the method further comprises:

inspecting between the bottom end of the hollow column and the seabed to look for gaps, and

filling any discovered gaps with sand gravel if the gap size exceeds a pre-determined limit

7. The method as recited in any one of claims 1 through 6, further comprising:

fixing reinforcement steel bars exposed from the steel tubes to the bottom of the hollow column at an expected concrete plug formation zone, the reinforcement steel bars serving as reinforcement in the to-be-formed concrete plug after concreting the bottom of the hollow column.

8. The method as recited in any one of claims 1 through 7, wherein a diameter of the bottom part of the concrete plug is larger than that of the hollow column.

9. The method as recited in any one of claims 1 through 8, further comprising:

employing a plurality of shear keys to increase a contact area and bonding between the steel tubes and concrete plug.

10. The method of claim 9, wherein the shear key is configured as an upside down, triangular-shaped steel plate.

11. The method as recited in any one of claims 1 through 8, further comprising:

adding skirting to an end of the bottom of the hollow column to increase bearing area and prevent the underwater concrete from escaping sideways.

12. The method of claim 11, wherein the skirting includes a cantilever plate and a downward skirting board with a plurality of stiffeners adapted to strengthen the cantilever plate, the skirting bolted to the end of the hollow column and having a diameter greater

than that of the hollow column.

13. The method of claim 11, wherein the skirting includes a steel ring with teething that is bolted to the end of the hollow column and with a diameter equal to the hollow column.

14. The method of claim 11, wherein the skirting includes a plurality of L-shaped skirting plates fixed by bolts to the end of the hollow column and having a diameter greater than that of the hollow column, the short arm of the L in each plate pointing downward and the long arm of the L in each plate level.

15. The method of claim 1, wherein the plurality of steel tubes consist of four tubes.

16. The method of claim 1, wherein the hollow column serves as a cofferdam.

17. A foundation having a hollow column adapted to support a waterborne structure thereon, the hollow column to be fixed to a seabed according to the method of claim 1.

18. A method for fixing a foundation adapted to support waterborne structures such as an offshore marine platform, the foundation having one or more hollow columns for supporting the offshore platform thereon that are to be fixed to the seabed, comprising:

driving a plurality of piles into the seabed to the founding level,

lowering a hollow column down to the seabed so as to surround the piles,

forming a reinforced concrete plug in the bottom of the hollow column, the hollow column serving as a cofferdam,

dewatering the interior of the hollow column,

fixing pile cap reinforcement, and

casting concrete to form a pile cap for the upper ends of the piles.

19. The method of claim 18, wherein the piles are configured as steel pipe piles.

20. The method of claim 18 or 19, wherein a diameter of the bottom part of the concrete plug is larger than that of the hollow column.

21. The method as recited in any one of claim 18 through 20, further comprising:
employing a plurality of shear keys to increase a contact area and bonding between the steel tubes and concrete plug.
22. The method of claim 21, wherein the shear key is configured as an upside down, triangular-shaped steel plate.
23. The method as recited in any one of claim 18 through 22, further comprising:
adding skirting to an end of the bottom of the hollow column to increase bearing area and prevent the underwater concrete from escaping sideways.
24. A construction method for waterborne structures including offshore platforms supported by at least one hollow columns adapted to support a beam-and-slab platform deck as part of the offshore platform, comprising:
fixing the hollow column to the seabed as recited in claims 1 or 18, and
continuing installation and construction of the offshore platform from the already fixed hollow columns.