(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 3 118 374 A1**

(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
18.01.2017 Bulletin 2017/03

(21) Application number: **15762413.1**

(22) Date of filing: **11.03.2015**

(51) Int Cl.:
E02B 17/00 *(2006.01)*

(86) International application number:
PCT/CN2015/073980

(87) International publication number:
WO 2015/135471 (17.09.2015 Gazette 2015/37)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
MA

(30) Priority: **14.03.2014 CN 201410095652**

(71) Applicants:
- **CBJ (Hong Kong) Ocean Engineering Limited**
  Macao (CN)
- **Wong, Carlos**
  Macao (CN)

(72) Inventor: **WONG, Carlos**
Macao (CN)

(74) Representative: **Boult Wade Tennant**
Verulam Gardens
70 Gray's Inn Road
London WC1X 8BT (GB)

(54) HOLLOW CYLINDRICAL PIER FOR FIXING OFFSHORE PLATFORM STRUCTURE TO BED AND METHOD OF INSTALLING AND CONSTRUCTING SAME

(57) Provided is a method of installing and constructing a hollow cylindrical pier for fixing an offshore platform structure to the bed, wherein a steel cylinder (101) with an inner diameter slightly greater than the hollow cylindrical pier is driven into the bed (2) until at least the bearing stratum is reached to ensure fixing, and part of the steel cylinder (101) is exposed above the water surface (1); draining ponding inside the steel cylinder (101), and excavating bed sediment inside the steel cylinder (101); cutting off the steel cylinder (101); hoisting a first hollow cylindrical pier section (1A) with a sealed bottom end vertically downwards from the water surface (1) towards the steel cylinder (101), pre-tensioning an overlapping hollow cylindrical pier section on the hollow cylindrical pier section via a shear key structure and then fixedly connecting same with the previous hollow cylindrical pier section, and hoisting same in turn such that after the sealed bottom end of the first hollow cylindrical pier section (1A) reaches near the bottom end of steel cylinder (101), at least part of the lastly hoisted overlapping hollow cylindrical pier section is exposed above the water surface (1); and pouring concrete (107) into a gap between the steel cylinder (101) and the hollow cylindrical piers. Further provided are a method of installing and constructing an offshore platform structure and a hollow cylindrical pier for fixing to the bed and an offshore platform structure.

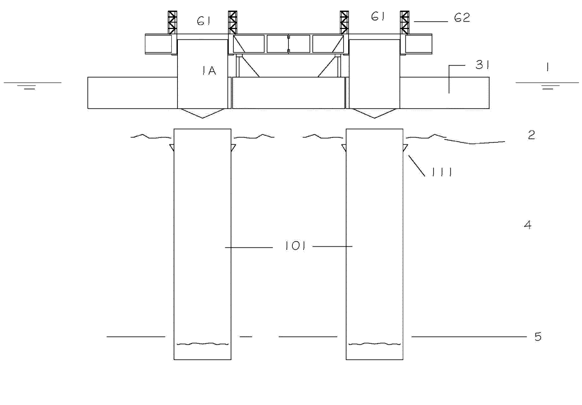

FIG. 3

EP 3 118 374 A1

Description

BACKGROUND

1. Field.

[0001] 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 a steel tube is driven into seabed until reaching the designated depth is employed as a temporary casing during installation of a bottom closed hollow column inserted into the steel tube after the marine deposit inside the steel tube is excavated down to the designated level. After insertion of the bottom closed hollow column, the gap between the steel tube and the hollow column is pressure filled with underwater concrete or cement grout thereby when the concrete and cement hardened the steel tube and the hollow column become an integral unit having the benefits of both friction resistance from the steel tube surface against the soil pressure and end bearing resistance from the hollow column base. It can be classified as a frictional end bearing pile or a deep founding caisson, since most caissons are founded not far away from the seafloor. The operation is carried out in a dry environment, thereby lowering construction costs and improving safety.

2. Related Art.

[0002] Existing foundation types (excluding floating types) in marine environment can be divided into gravity type and pile type. Large scale gravity types are further referred to as caisson of bottom closed or opened type. Traditional caisson foundation requires that the load bearing stratum close to the seafloor so that the top soft material can be removed easily and replaced with sand fill as a regular layer for levelling and for spreading the caisson loads. The bottom closed caisson is then sunk and sit on the levelled sand layer. The voids inside the caisson are usually filled with sand/stone to increase the dead weight so that the caisson is more stable. Open end caisson itself is a cofferdam before the bottom is sealed by concrete plug after it is sunk to the seafloor. Thereafter, the construction steps are similar to the caisson of closed bottom type. Piles carry the loads in a different manner, it carries the horizontal load by bending whilst the gravity type by moving the gravity load center off the C.G. Piles carry the vertical load by end bearing in the case of bored piles and by skin friction in the case of driven piles.

[0003] 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.

Differences in foundation between offshore platform and sea-crossing bridges

[0004] The aforementioned foundation types mostly come from bridge engineering. The bridge foundation is typical to have small portion of gravity loads but significant portion of horizontal loads from wind, wave and earthquake. As a result, overturning moment is the dominant load to resist. The offshore platform foundation has significant gravity loads as well as lateral loads so that both cases have significant effects on the platform. The overturning moment is induced by lateral loads. To resist bending moment in marine environment of thick layer of soft material, piles are effective and relatively cheaper than the caisson foundation which requires the removal of the soft material. The piles mobilize the skin friction resistance of the pile shaft whereas the caisson is put on an excavated hole in the seabed that the soil is loosely contact with the walls and as a result the caisson wall cannot generate meaningful friction. However, a caisson has large bearing area hence, it is good in resisting gravity loads. The present invention takes the merits of both cases, i.e. a foundation offers friction resistance as the piles does and end bearing resistance as the caisson does.

Geological environment

[0005] In seabed where bedrock level is not close to the seafloor and not too deep to be reached by piles, the foundation type should be friction piles.

[0006] In seabed where bedrock level is close to the seafloor or not too deep to be reached by excavation, caisson foundation may be considered.

[0007] In seabed where load bearing stratum level is not too deep to be reached by excavation, the invented foundation type is effective since it takes the advantages of having friction resistance and end bearing resistance of friction piles and caisson respectively.

SUMMARY

[0008] 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 columns that are to be fixed in the seabed, such as a seabed comprising a thick layer of soft marine deposits. The construction method comprises:

A) a steel tube with an internal clear diameter greater than the external diameter of the hollow column by a tolerance margin is driven into the seabed at the designated location until it reaches the design founding level,

B) excavate the materials inside the steel tube down to the founding level,

C) lift the first segment of the bottom closed hollow column into the steel tube which is able to float in the water. Whilst the first segment is held in position, the second segment is added to the column under a locking mechanism achieved by matched cast male and female positioning blocks and shear keys; the jointing procedures are to coat the two joining faces with epoxy resin or equivalent then lower the second segment onto the first segment and compress the joint with prestressing by stressing bars threaded through the two segments. The design length of each individual segment should be such that the assembled column is capable floating in the water. After all segments are assembled, the column is water ballasted to sink to the bottom of the steel tube.

D) the gap between the steel tube and the hollow column and the void underneath the hollow column base are filled by pressure grout with underwater concrete starting from the low points at the base slab gradually pushing the front upward until the said concrete and cement emerging from the gap at the seafloor. After the said concrete and cement gained strength, the steel tube is now bonded to the hollow column and they become a single integral unit.

E) cut the steel tube at the mud line of the seafloor;

[0009] Alternatively, the cutting of the steel tube can be carried out before the installation of the first segment.

[0010] 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 columns that are to be fixed in the seabed, such as a seabed comprising a thick layer of soft marine deposits. The construction method comprises:

A) a steel tube with an internal clear diameter greater than the external diameter the hollow column by a tolerance margin is driven into the seabed at the designated location until it reaches the design founding level,

B) excavate the materials inside the steel tube down to the founding level,

C) lift the bottom closed hollow column in one piece into the steel tube which is able to float in the water thereafter while the column is held in position water ballast is employed to sink the column to the bottom of the steel tube.

D) the gap between the steel tube and the hollow column and the void underneath the hollow column base are filled with pressure grout of underwater concrete and cement starting from the low points at the base slab gradually pushing the front upward until the said concrete and cement emerging from the gap at the seafloor. After the said concrete and cement gained strength, the steel tube is now bonded to the hollow column and they become a single integral unit.

E) cut the steel tube at the mud line of the seafloor;

[0011] Alternatively, the cutting of the steel tube can be carried out before the installation of the hollow column.

[0012] In the method, the steel tube is used as a retaining structure when the marine soil inside the steel tube is removed and during installation of the hollow column. Finally it becomes part of the foundation system integrated with the hollow column contributing its friction resistance to the load carrying capacity in addition to the end bearing capacity of the hollow column which is a caisson by definition. The load carrying mechanism will be at first the load is resisted by the end bearing of the caisson, as the load increases that triggers the yielding of the bearing area immediately mobilizes the skin friction resistance from the steel tube wall. The ultimate load carrying capacity of such a system will be the end bearing capacity+skin friction resistance. Conventional pile capacity is friction resistance and that for caisson is the end bearing capacity.

[0013] The large space inside the hollow column has significant buoyancy that would compensate portion of the gravity loads that in turn reduces the bearing pressure on the founding stratum, i.e. the founding stratum can be located much shallower than the conventional caisson support. The buried depth of the wall in the present invention is supported by the lateral pressure of the overburden soil, that improves stability.

[0014] The large space inside the hollow column can be used as storage, for example, the space can be used as fresh water tank to store the rain water fell on the platform. Since the void is huge, the stored fresh water can satisfy the drinking water consumption of the staff working and living on the platform. The storage can be used to store oil as well.

[0015] The construction method in the present invention involves no complicated underwater works. The only underwater work is the cutting of the surplus steel tube at the mud line on the seafloor.

[0016] Optionally, the bottom slab of the hollow column is tapered with its apex pointing downward so that the pressure grout of underwater concrete and cement at the low points of the hollow column can be facilitated to flow easily upward to fill the gap.

[0017] Optionally, the bottom of the excavation inside the steel tube is backfilled with a layer of sand/stone to fill any large cavity in the founding layer to stop the large volume loss of injected underwater concrete and cement grout.

[0018] Optionally, the hollow column is fabricated by matched segment casting method, wherein the #i+1 segment is cast against completed #i segment end to end, a so-called matched cast method commonly adapted in bridge construction. The positioning blocks and the shear keys in the completed #i segment will produce matching reversal positioning blocks and shear keys in the matched face of the #i+1 segment.

[0019] Optionally, the matched cast method described in the above is also applied to stressing ducts and stressing blocks for prestressing operation.

[0020] Optionally, the last segment or the end of one single piece hollow column has starter reinforcement bars sticking out from the end for lapping the reinforcement cage of the platform for insitu concreting to form a permanent joint between the hollow column and the platform.

[0021] Optionally, the marine platform is precaast and is transported on sea by an auxiliary floater.

[0022] Optionally, the marine platform and the floater have opening for the insertion of the hollow column, and mechanism to hold the hollow column in position.

[0023] Optionally, brackets are welded to the steel tube for supporting the propping to the marine platform during the forming of insitu concrete joint between the marine platform and the hollow column.

[0024] Optionally, pressure pipes are pre-installed in the hollow column for injection of the underwater concrete and cement grout.

[0025] Optionally, shear keys preferably of triangular shape with the sharp tips pointing downward are welded evenly to the inner face of the steel tube in order to enhance the bond between the steel tube and the hollow column.

BRIEF DESCRIPTION OF THE DRAWINGS

[0026] 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.

FIG. 1 (a) Indicatively shows a steel tube being driven into the seabed by vibro hammer

FIG. 1(b) Indicatively shows the steel tube being driven into the founding stratum and the marine deposit inside the tube is removed

FIG. 1(c) Indicatively shows the surplus length of the steel tube being cut at the mud line level of the seafloor

FIG. 2 Indicatively shows the platform is carried by the auxiliary floater

FIG. 3 Indicatively shows the first segment of the hollow column being lifted into the steel tube

FIG. 4 Indicatively shows the joining of the hollow column segments

FIG. 5 Indicatively shows the pressure grout of underwater concrete and cement to fill the gap and cavity around the assembled hollow columns

FIG. 6 Indicatively shows the assembled segments and the casting of insitu joint between platform and hollow columns

FIG. 7 completed offshore platform with assembled columns

FIG. 8 Indicatively shows the installation of steel tube by vibro hammer mounted on a ship

FIG. 9 Indicatively shows the excavation of soil inside the steel tube

FIG. 10 Indicatively shows the final preparation stage of the steel tube

FIG. 11 Indicatively shows the installation of the hollow column with pre-installed pressure pipes

FIG. 12 Indicatively shows the pressure grout of underwater concrete and cement to fill the gap and cavity around the hollow columns

[0027] Parts List

1. Sea surface
2. Seabed/ seafloor
3. Bed rock
4. Soil strata
5. Founding level / founding statum/ load bearing stratum

11. Offshore platform
21. Hollow column
22. Pre-installed pressure pipes
25. Starter bars
27. Insitu concrete
31. Auxiliary floater
32. Supporting frame
61. Opening for column insertion
62. Temporary structure to contain the hollow column segment
101. Steel tube
102. Sand/stone layer
104. Shear key
105. Vibro hammer
107. Injected concrete and cement grout
109. Surplus section of steel tube
111. Steel bracket
112. Temporary props
113. Hydraulic jack

DETAILED DESCRIPTION

[0028] 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.

[0029] 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.

[0030] 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.

[0031] 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.

[0032] 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.

[0033] 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."

[0034] 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.

[0035] As used herein, the term "hollow column" refers to a hollow cylindrical column fixed in the seabed in a body of water on which a wind power turbine, marine building, and/or bridge may be mounted thereon.

[0036] As will be described in more detail hereafter, the example construction method for fixing a hollow column to the seabed includes driving a steel tube with an internal clear diameter larger than the external diameter of the hollow column by a tolerance margin into the seabed down to the founding stratum, removing the soil inside the the steel tube, inserting the hollow column and lowering the hollow column by water ballast to the founding level. With the pre-installed pressure pipes, pressure grout of underwater concrete and cement are to fill the gap and cavity around the hollow column starting from the low part gradually moving upward until the underwater concrete and the cement grout emerge from the gap at the seabed. The hollow column is then fixed successfully into the seabed and is ready to be integrated with the platform. No underwater works are involved.

[0037] In an example, the platform which is floated in by a auxiliary floater may be rested on the propping supported from brackets welded to the steel tube, or rested on the brackets cast in the top end of the last segment of the hollow column. Prior to the insertion of the hollow column, a monitoring camera may be used to investigate the founding stratum if there are any large voids or gaps. If found, these voids and gaps are filled with sand and gravel.

[0038] Having supported on the the brackets as mentioned above and the level is set by jack action, reinforcement bars are connected to the mechanical splicers embedded at walls of the column opening in the platform, reinforcement bars are fixed and lapped to the starter bars from the top end of the last segment of the hollow column. Insitu concrete is cast for the connecting joint. After the concrete gained strength, temporary props are removed and the floater is disassemble. The platform construction is completed.

[0039] General concepts of the example embodiment having been described above, the following FIGS. 1-12 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 steel tube with an internal clear diameter larger than the external diameter of the hollow column by a tolerance margin say 300mm. The example embodiment suits a seabed overlain with a layer of soft material, which is common in a near shore seabed.

[0040] FIGS. 1-7 and 8-12 illustrate two example embodiments 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.

[0041] Initially, a plurality of steel tube 101 each for the installation of a hollow column 21, e.g., for example, four (4) steel tubes for a platform 11, are driven into the seabed 2 to the founding stratum 5. FIG. 1(a) shows a steel tube 101 is driven into the seabed by a vibro hammer 105. FIG. 1(b) shows the steel tube is driven down to the founding stratum 5 and the marine soil 4 inside the steel tube 101 is removed. FIG. 1(c) shows the surplus steel tube 109 is cut at the mud line level on the seafloor 2. Alternatively, the surplus steel tube 109 may be cut after the installation of the hollow column 21.

[0042] FIG. 2 illustrates a platform 11 with 4 column openings 61 is supported by an auxiliary floater 31 and towed into position aligning the column center with the steel tube center.

[0043] FIG. 3 illustrates the first segment 1A is inserted into the column opening 61 and is able to float in the water.

[0044] FIG. 4 illustrates the fifth segment 5A of the hollow column 21 is stacking on the end of the fourth segment 4A after segments 1A to 4A have been assembled. They are joined by using prestresss to compress two epoxy resin coated matching faces together. The assembled segment length (1A-4A) is designed to be able to float on the water with the added weight of the next segment and in this case is 5A.

[0045] FIG. 5 illustrates a completed hollow column 21 comprising 8 segments 1A to 8A and the gap and cavity and void around the hollow column are filled with pressure grout of umderwater concrete and cement 107. After the underwater concrete and cement grout 107 hardened, props 112 are installed on the brackets 111 around the column 21 supporting the platform 21.

[0046] FIG. 6 illustrates the insitu casting of the joint between the hollow column 21 and the platform 11. The reinforcement bar mechanical splicers (not shown) embedded in the wall of the column openings 61 are reattached with reinforcement bars (not shown) that lap the starter bars 25 to form the reinforcement cage which is then cast with insitu concrete 27 to complete the joint.

[0047] FIG. 7 illustrates the completed platform 11 supported by hollow column 21 integrated with the steel tube 101.

[0048] Another example embodiment is illustrated in FIGS. 8-12 in which,

[0049] FIG. 8 shows a piling vessel using a vibro hammer 105 to drive a steel tube 101 down into the seabed 2 through the soft marine deposit layer 4 and reaches the firm founding stratum 5.

[0050] FIG. 9 illustrates a dredger excavates and removes the soft materials inside the steel tube 101 down to the founding stratum 5.

[0051] FIG. 10 illustrates the surplus length of the steel tube 101 above the seafloor 2 level is cut and taken away.

[0052] FIG. 11 illustrates a bottom closed hollow column which floats in the water and is grabbed and stabilized in a vertical position by a construction vessel is navigated to the position that the center of the hollow column 21 is aligned with the center of the steel tube 101. Gradually loosen the grab and ballast the hollow column 21 with water, the hollow column sinks gradually into the steel tube 101 until it reaches the bottom founding level 5 above the backfilled sand/stone layer (if any). Thereafter, the hollow column's level and position and the verticality are all maintained by the construction vessel.

[0053] FIG. 12 illustrates whilst the hollow column floats inside the steel tube and be constrained by construction vessel (not shown but referred to FIG. 11), a floating batching plant vessel pumps underwater concrete and cement grout into the pre-installed pressure pipes 22 to pressure fill up the gap and cavity between the hollow column 21 and the steel tube 101 and the gap/void with the founding layer 5. After the underwater concrete and the cement grout hardened, the hollow column is fixed in the seabed successfully that provides friction resistance and end bearing resistance to the hollow column 21. The fixing of a hollow column 21 in the thick layer of soft material in marine environment is completed. Platform 11 is then constructed in a similar manner.

[0054] In order to increase the bond between the inner surface of the steel tube 101 and the external surface of the hollow column 21, the steel tube of surface is welded with a plurality of triangular shear keys 104 as shown in the enlarged diagram of FIG. 1(b). Orientation of the triangle shear keys is that the sharp angles of the shear keys 104 are pointing downward; this orientation facilitates penetration in soil layers. These shear keys 104 should be distributed evenly on the surface.

[0055] Steel brackets 111 as illustrated in FIG. 1(b) are welded to the Steel tube several layers around the expected mud line level since the final setting level of the steel tube 101 after hammered into the seabed varies so that several layers should cover the variation to ensure that when the surplus length of the steel tube 109 be cut from the mud line at the seafloor 2, there at least one layer of bracket 111 can be used.

[0056] 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. The present inventive embodiment is effective in all three categories although the hollow column 21 becomes purely a caisson that carries loads in end bearing.

[0057] According to the example embodiment above, the installation and construction of marine structures or offshore platforms using the example hollow column 21 eliminates the need for a temporary cofferdam, and the using of precast hollow column 21 in segments or better in one piece greatly reduce cost and construction time. Additionally, using the hollow column 21 to store fresh water could help to solve the fresh water supply problem for the persona working and living on the platform 11.

[0058] 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 21 into 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.

[0059] 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.

[0060] 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.

[0061] 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.

Claims

1. A construction method for fixing a bottom closed hollow column into seabed and adapted to support a waterborne structure thereon to a seabed, comprising:

a) drive a steel tube, with an internal clear diameter greater than the external diameter of the hollow column by a tolerance margin, into the seabed at an installation location until it reaches the designated founding stratum,

b) excavate and remove the material inside the steel tube down to the designated founding stratum,

c) lift the bottom closed first segment of the hollow column into the steel tube vertically and float in the water; while the first segment is held in position, the second segment is lifted onto the first segment end to end aligned by the matched cast positioning blocks and shear keys; the joining faces of the two segments are coated with epoxy resin or equivalent and the two faces are joined tightly by compression set up by the stressing bars threaded through the preformed ducts across the joining faces; repeat the above steps until the final segment which should expose above the water surface,

d) fill up the gap and cavity between the steel tube and the hollow column and between the hollow column base and the founding stratum by pressure grout of underwater concrete and cement; after hardening, the hollow column and the steel tube become an integral unit that takes the loads by surface friction resistance between the steel tube surface and the soil, and by end bearing resistance from the designated founding stratum in the seabed,

e) cut the steel tube at the mud line level of the seabed; wherein the step e) may be performed before the step c) and after step b), or may be performed after step d).

2. A construction method for fixing a bottom closed hollow column into seabed and adapted to support a waterborne structure thereon to a seabed, comprising:

a) drive a steel tube, with an internal clear diameter greater than the external diameter of the hollow column by a tolerance margin, into the seabed at an installation location until it reaches the designated load bearing stratum,

b) excavate the material inside the steel tube down to the designated founding stratum,

c) lift the bottom closed whole unit of the hollow column into the steel tube vertically and ballast it with water until it sinks to its final depth at the designated founding stratum.

d) fill up the gap and cavity between the steel tube and the hollow column and between the hollow column base and the founding stratum by pressure grout of underwater concrete and cement; after hardening, the hollow column and the steel tube become an integral unit that takes the loads by surface friction resistance between the steel tube surface and the soil, and by end bearing resistance from the designated found-

ing stratum in the seabed,
e) cut the steel tube at the mud line level of the seabed; wherein the step e) may be performed before the step c) and after step b), or may be performed after step d).

3. According to the claims 1 and 2, the hollow column bottom is a conic shape.

4. According to any claim, prior to step c) backfill sad/stone in the bottom of the steel tube.

5. According to claim 1 or 3 or 4, the characteristic of the method in the joining of any two segments is to achieve by complementary male and female shear keys and ducts for prestressing and anchorage from the matched casting of one segment against the end of the completed segment.

6. According to claim 1 or 3 or 4 or 5, the characteristic of the method in the joining of any two segments is achieved by complementary male and female positioning and ducts for prestressing and anchorage from the matched casting of one segment against the end of the completed segment.

7. According to any claim 1, 3, 4, 5 or 6, the characteristic of the method in the joining of any two segments is achieved by complementary male and female shear keys and ducts for prestressing and anchorage from the matched casting of one segment against the end of the completed segment.

8. According to any claim 1, 3, 4, 5, 6 or 7, the characteristic of the method is the segment axial length of the first segment greater than the length of any segment.

9. According to any claim 8, the characteristic of the method in the joining of a series of segments the buoyancy of the series of segments is greater than the sum of dead weight of the series of segments

10. According to claim 2, the characteristic of the method is to backfill the bottom of the steel tube a layer of sand/stone before step c).

11. According to any claim of the above method, steel shear keys in the form of triangle with its sharp angle point downward are welded uniformly in the inner of the face of the steel tube.

12. An offshore waterborne structure especially offshore platform comprising at least one hollow column supporting a beam-and-slab type platform wherein the method includes:

transport the on land prefabricated platform by floater in sea to the installation location,
according to the method of any of the above claims, the platform is joined to the last installed segment of the hollow column or the above water portion of the hollow column by insitu concrete.

13. According to any of the above claims, the last segment of the hollow column or the top end of the single piece hollow column is embedded with starter reinforcement bars for lapping.

14. According to claims 12 or 13, disassembled steel props are erected on the steel brackets welded to the outer face of the steel tube to support the platform with mechanism to level the platform before it is fixed.

15. According to any claim of the above method, pipes are embedded in the wall of hollow column for pumping underwater concrete outside the wall.

16. According to claims 12 to 15, steel shear keys are welded uniformly to the inner face of the steel tube with the sharp angle pointing downward.

17. A waterborne platform especially offshore platform according to the method of claims 1-11, the fixing of hollow column includes the steps:

penetrate to the founding level of a steel tube, locate a bottom closed hollow column with a portion of it exposed above the water surface, and underwater concrete is grouted between the inner face of the steel tube and outer face of the hollow column.

18. According to claim 17, the hollow column is formed with a number of segments and the segments are joined by shear keys.

19. According to claim 17 or 18, steel shear keys in triangle shape are welded uniformly to the inner face of the steel tube with the sharp angle pointing downward.

20. According to claim 18, starter reinforcement bars are installed in the last segment of the hollow column or installed in the top end of the hollow column for lapping.

21. According to claims 17-20, the said platform is installed with pipes in its wall and have egress outlet outside to pump the underwater concrete out.

22. A waterborne structure especially offshore platform wherein the installation method according to claims 12-16 includes:

at least one hollow column and one beam-and-slab type platform formed according to any claims 17-21.

23. According to claim 22, the last hollow column segment or the top end of the one piece column, reinforcement lapping bars are pre-installed.

24. According to claim 22 or 23 the said platform is leveled whilst the platform is supported from underneath props which sit on the bracket welded to the steel tube outside face.

25. According to any of the claims 22-24, pipes for pumping underwater concrete out of the hollow column are pre-installed in the wall and the slab of the hollow column.

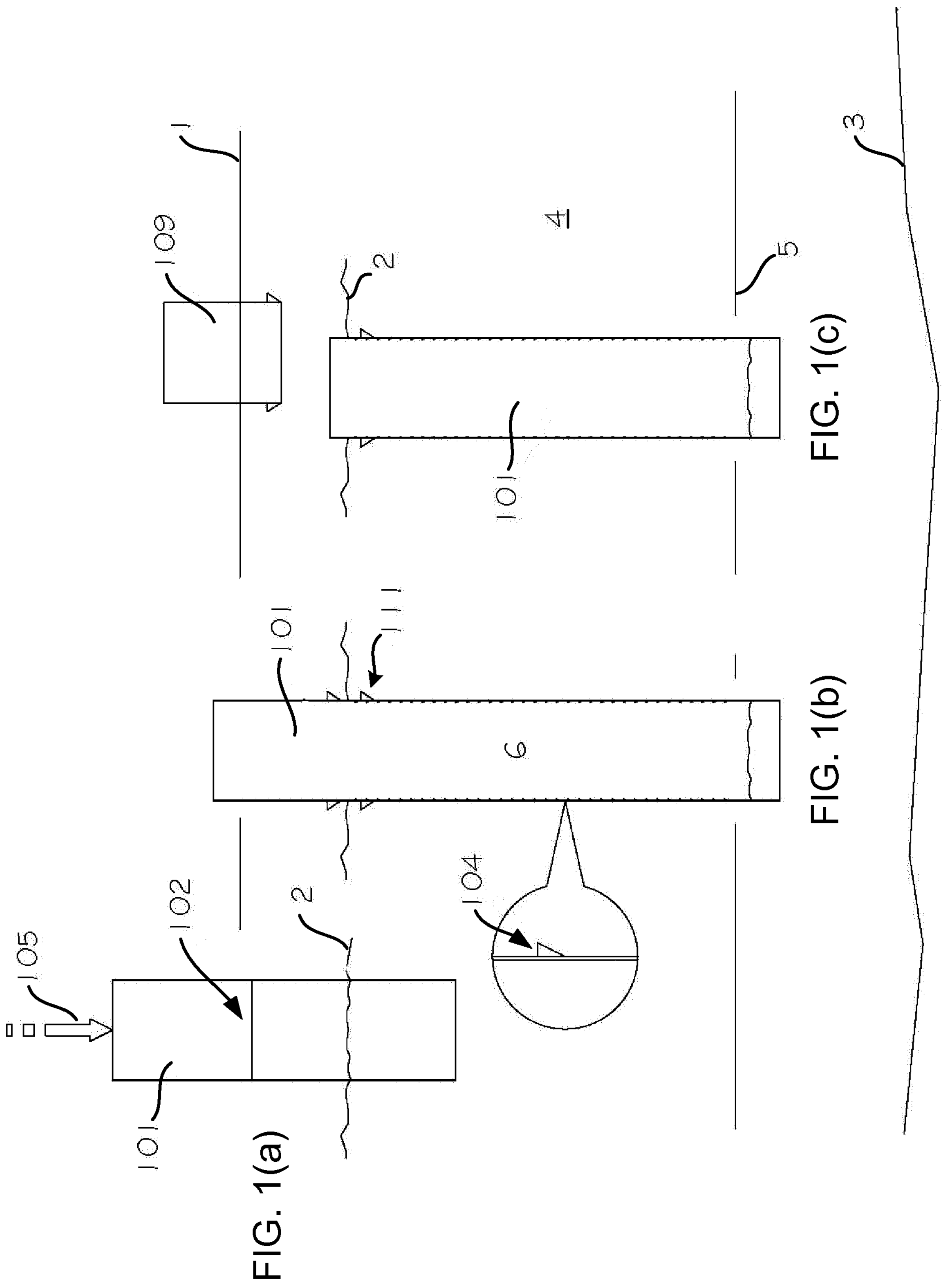

FIG. 1(a)

FIG. 1(b)

FIG. 1(c)

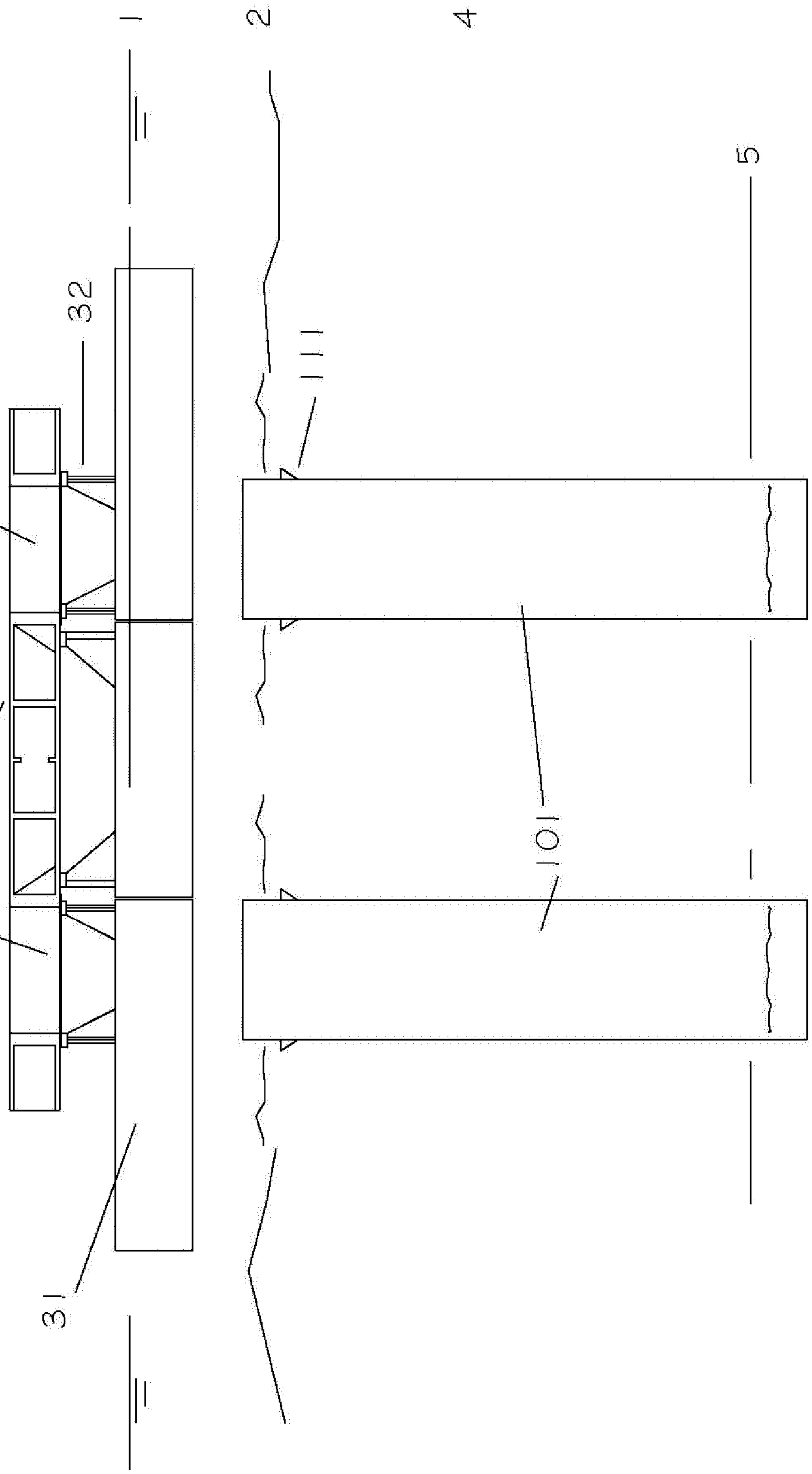

FIG. 2

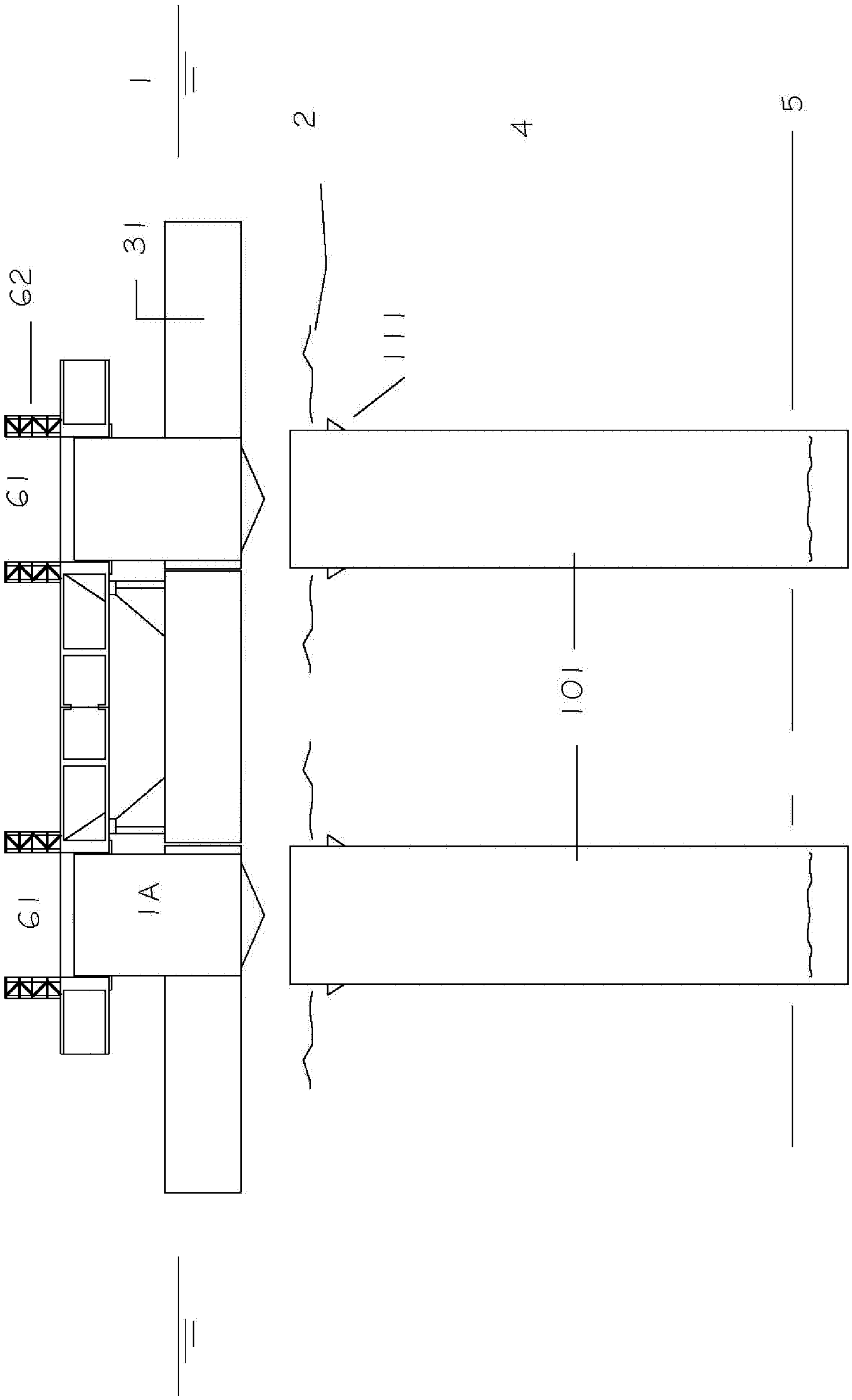

FIG. 3

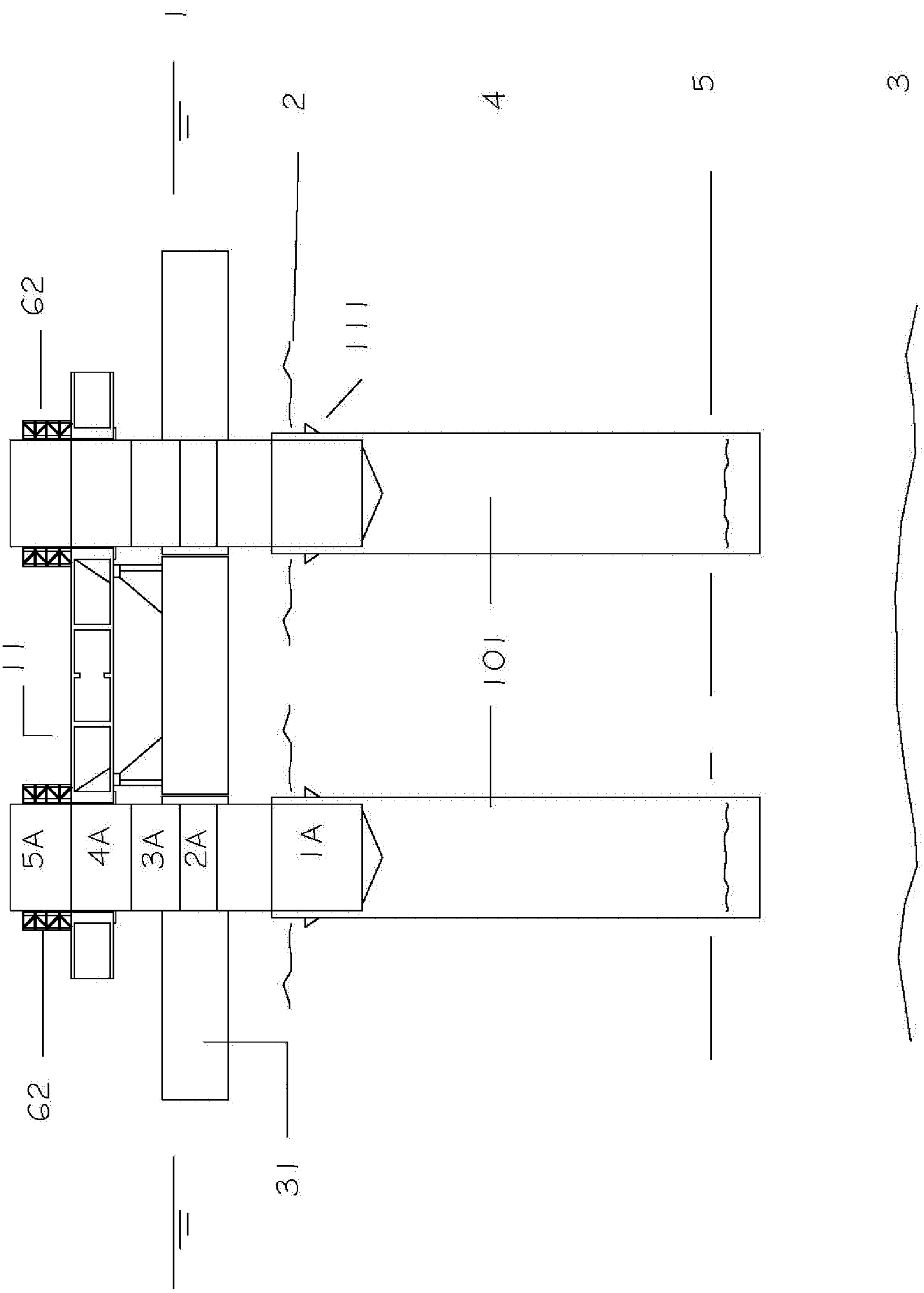

FIG. 4

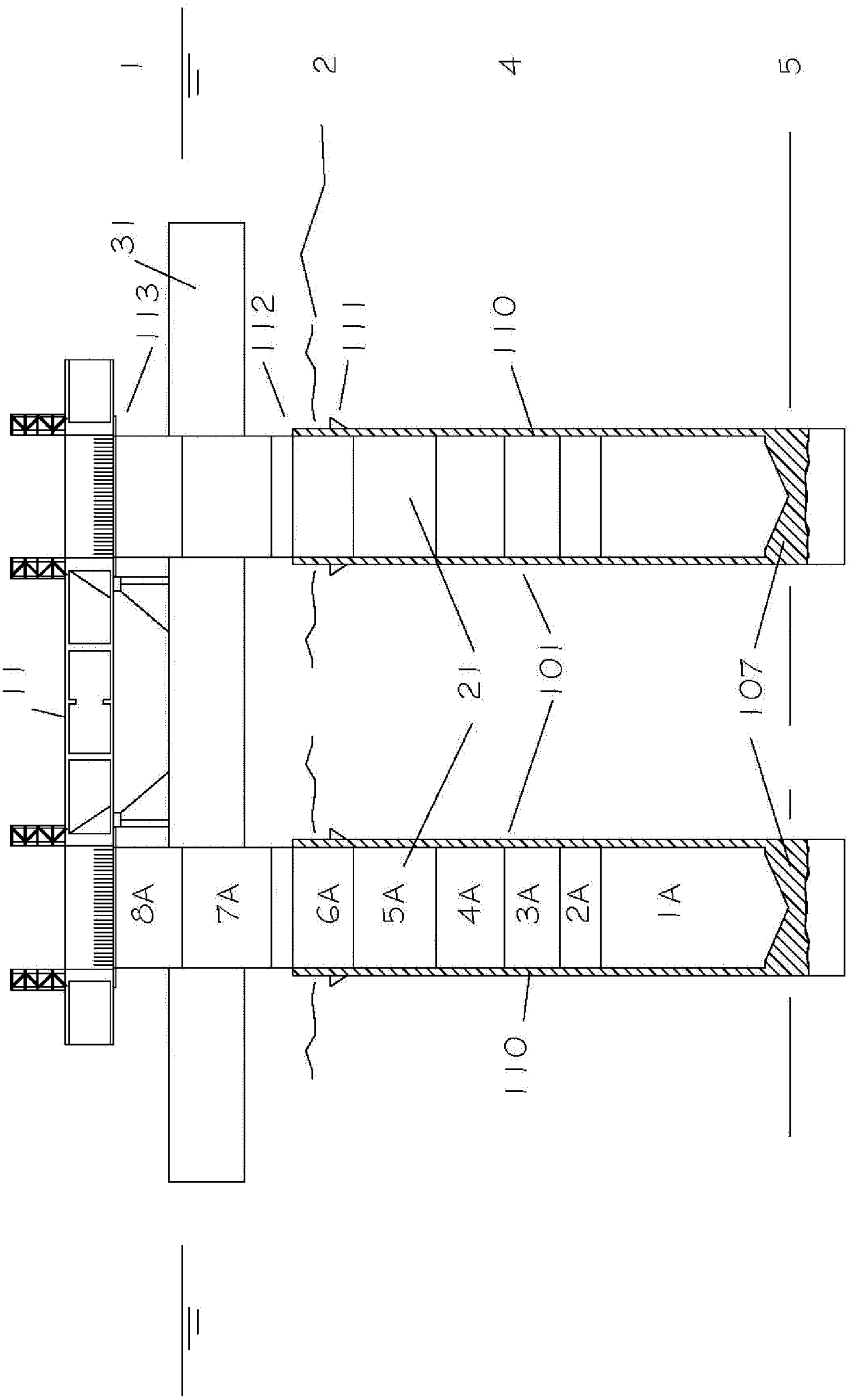

FIG. 5

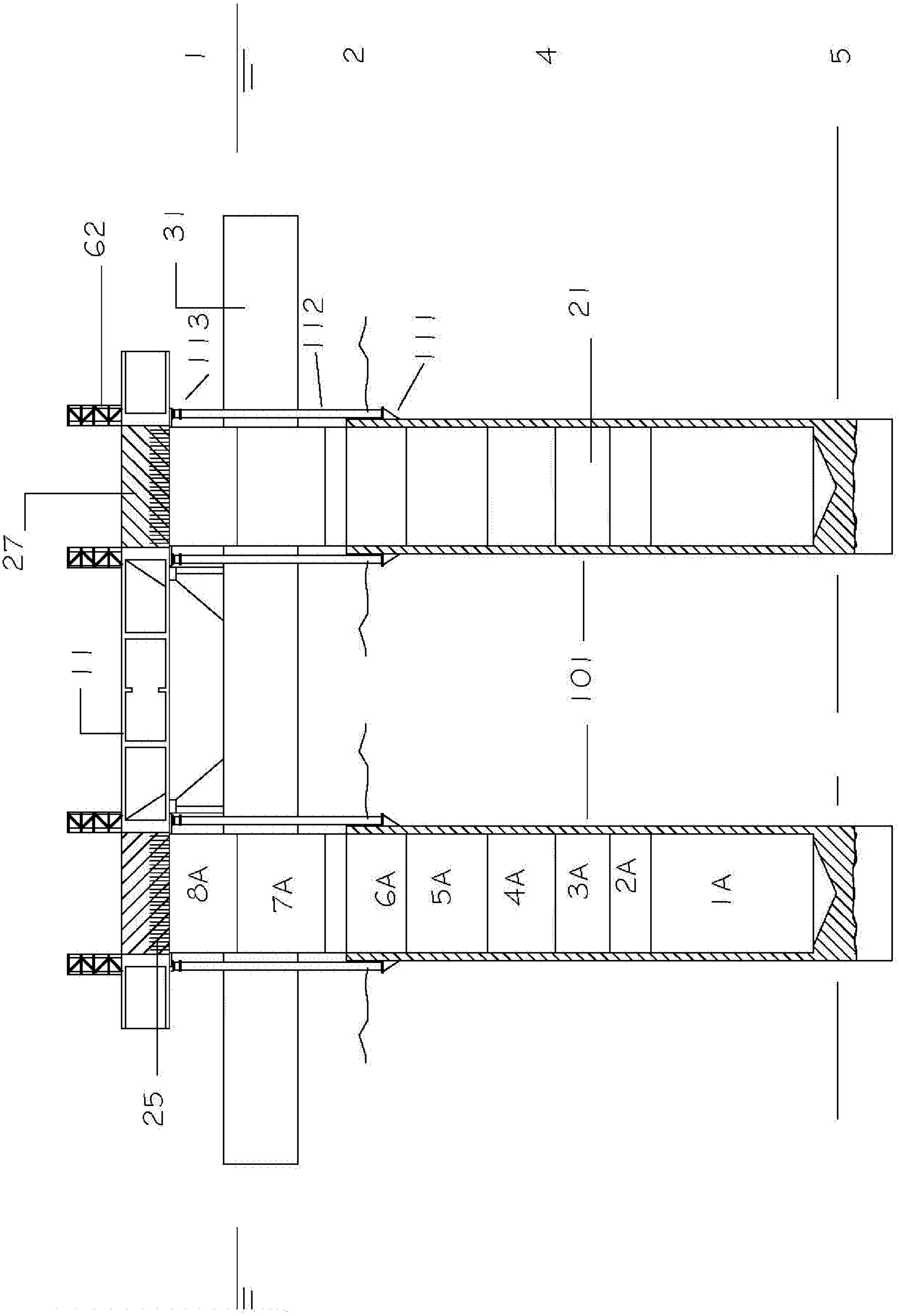

FIG. 6

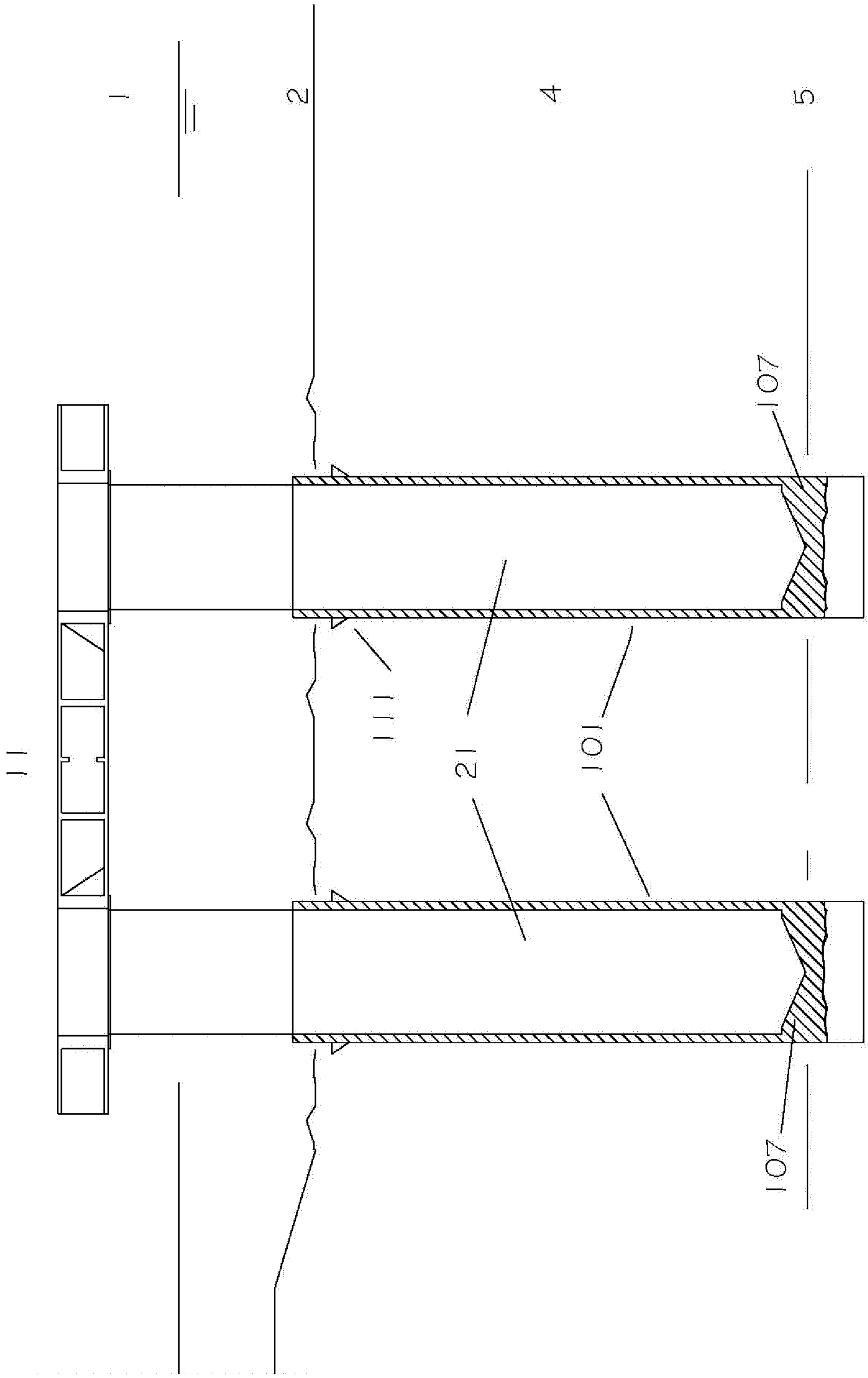

FIG. 7

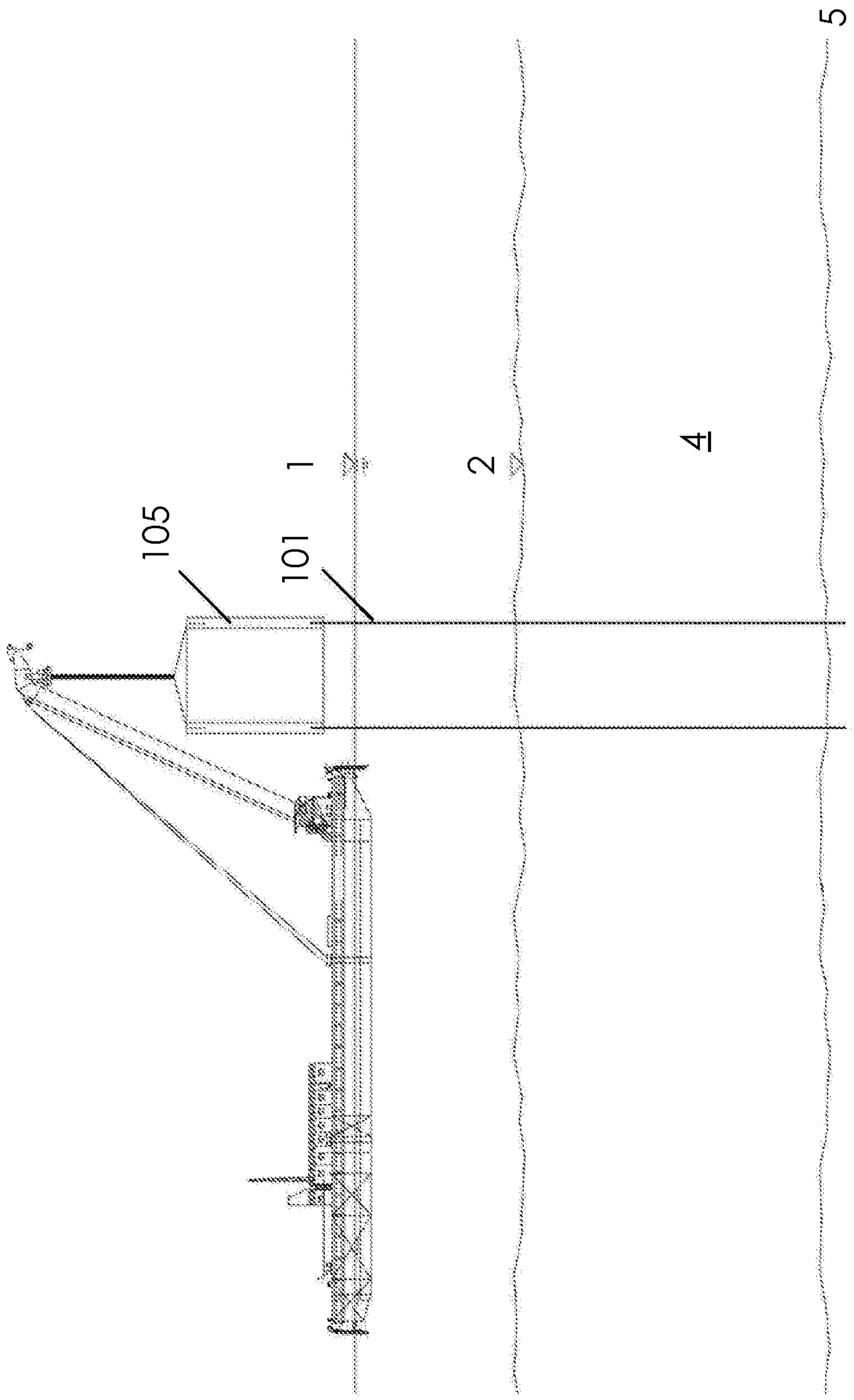

FIG. 8

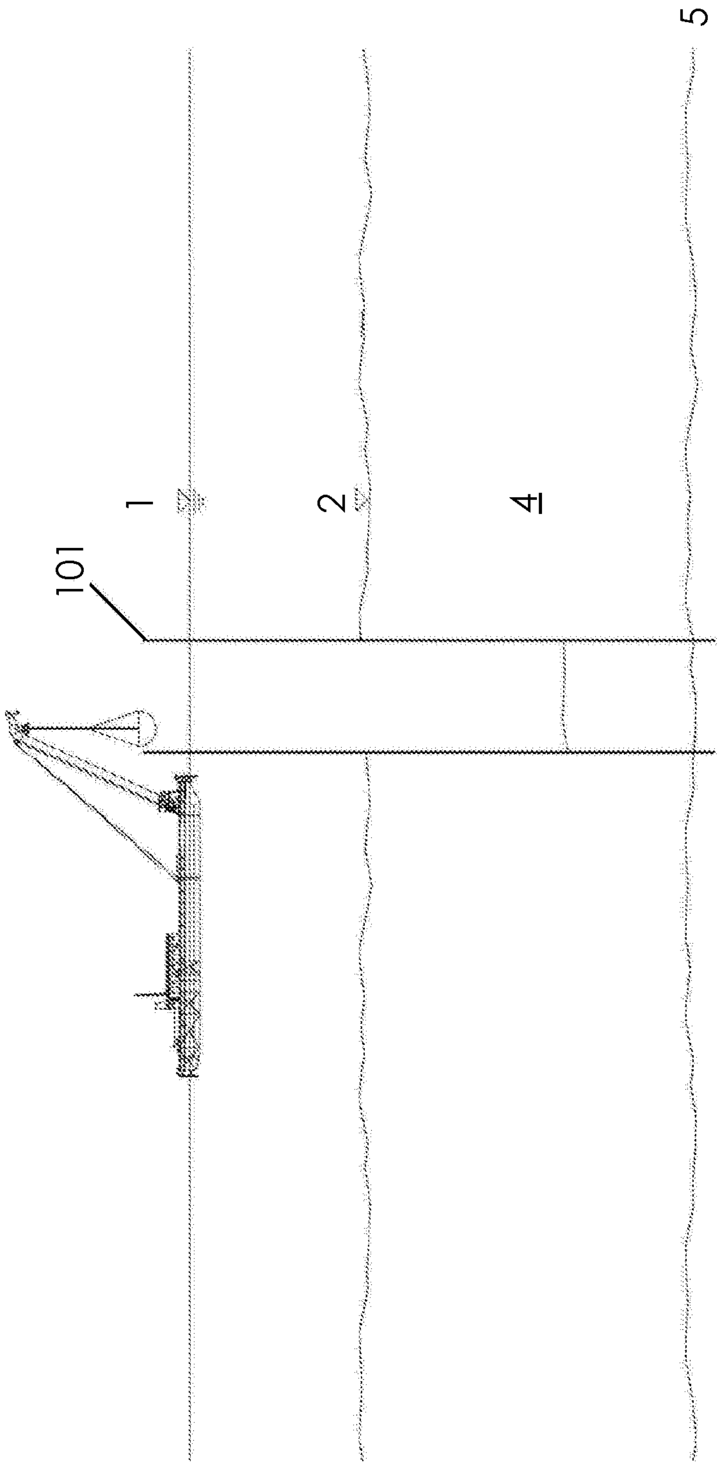

FIG. 9

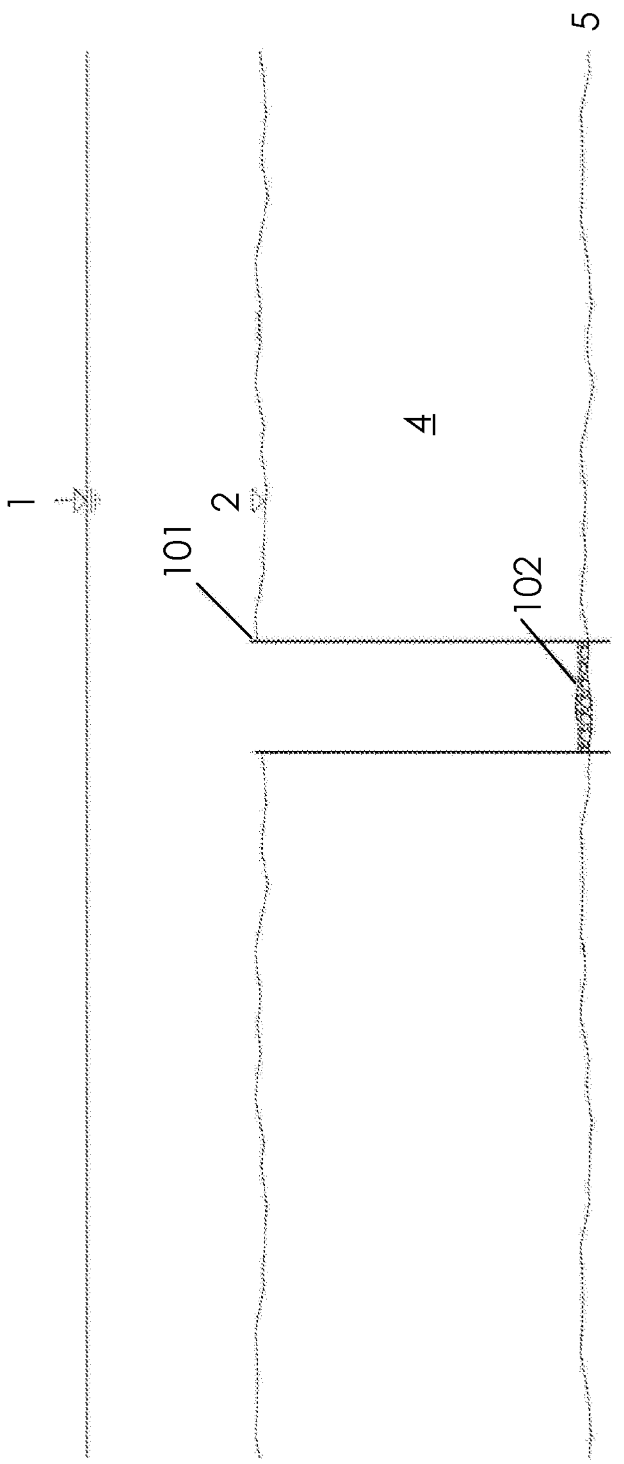

FIG. 10

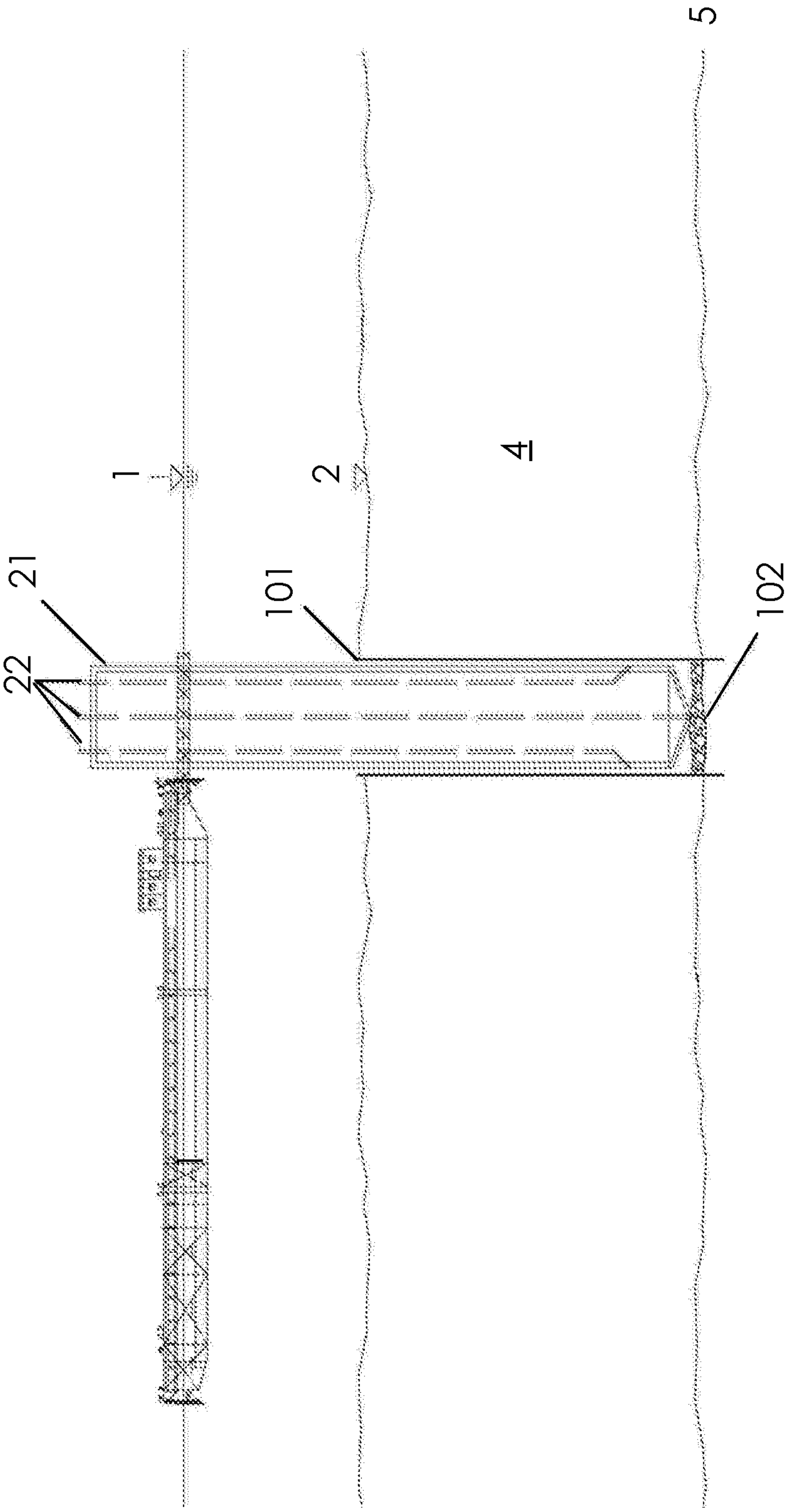

FIG. 11

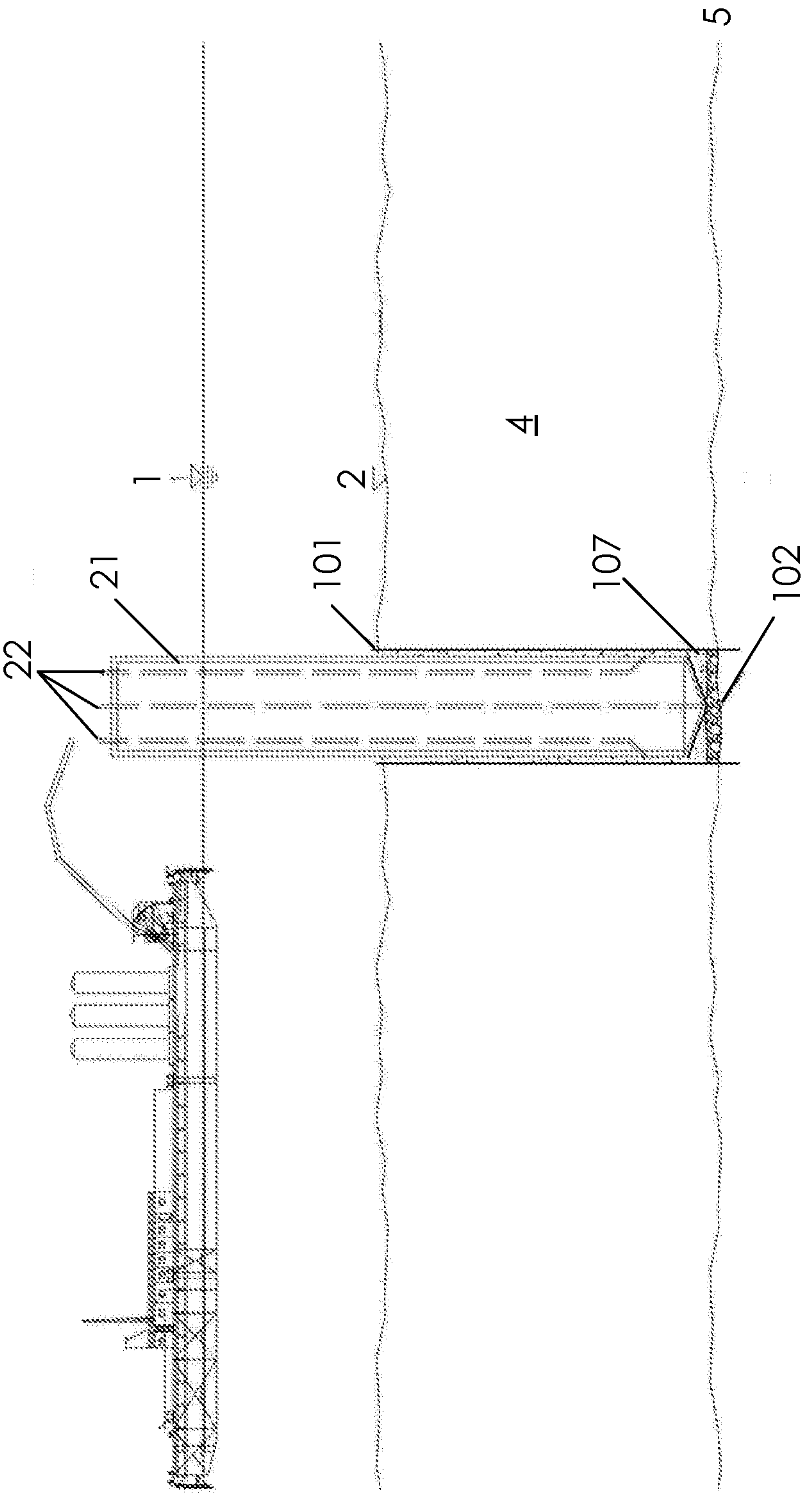

FIG. 12

INTERNATIONAL SEARCH REPORT	International application No. PCT/CN2015/073980

A. CLASSIFICATION OF SUBJECT MATTER

E02B 17/00 (2006.01) i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

E02B 17; E02D 27

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CPRSABS; VEN; CNKI: construct, sea area, structure, CBJ OCEAN PLATFORM ENGINEERING CORP., building, cylinder pier, sleeve, install, platform, fan; HUANG, Canguang; guard barrel, steel barrel, generator, method, bridge, seas, marine, sea, offshore, outshore, water, concrete, post, pillar, shell, pile, dowel, ground, subgrade, foundation, pole, base, cap, main W body, barrel, cylinder, drum, cushion, bowl

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CN 103255752 A (CBJ OCEAN PLATFORM ENGINEERING CORP.), 21 August 2013 (21.08.2013), claims 1 and 14, and figures 1-17	1-25
A	CN 102251530 A (NO.2 ENGINEERING CORPORATION LIMITED OF CR20G), 23 November 2011 (23.11.2011), the whole document	1-25
A	CN 1472400 A (CHINA RAILWAY MAJOR BRIDGE ENGINEERING GROUP CO., LTD.), 04 February 2004 (04.02.2004), the whole document	1-25
A	KR 101134780 B1 (DAELIM IND CO., LTD.), 13 April 2012 (13.04.2012), the whole document	1-25
A	JP 2013224529 A (KAJIMA CORP. et al.), 31 October 2013 (31.10.2013), the whole document	1-25

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
28 May 2015 (28.05.2015)	**16 June 2015 (16.06.2015)**
Name and mailing address of the ISA/CN: State Intellectual Property Office of the P. R. China No. 6, Xitucheng Road, Jimenqiao Haidian District, Beijing 100088, China Facsimile No.: (86-10) 62019451	Authorized officer **YAN, Junxia** Telephone No.: (86-10) **62084950**

Form PCT/ISA/210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2015/073980

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
CN 103255752 A	21 August 2013	None	
CN 102251530 A	23 November 2011	CN 102251530 B	03 October 2012
CN 1472400 A	04 February 2004	CN 1186503 C	26 January 2005
KR 101134780 B1	13 April 2012	KR 20110072755 A	29 June 2011
JP 2013224529 A	31 October 2013	None	

Form PCT/ISA/210 (patent family annex) (July 2009)

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- CN 201210038405 **[0003]**
- CN 201200104898 **[0003]**