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(54) **Device and method for cleaning hollow piles that have been provided into a substrate**

(57) The invention relates to a device (1) for cleaning the inside or outside of a hollow pile (2) that has been provided into a substrate, in particular an underwater bottom (3). The device comprises a hollow tube (5), adapted to be lowered into or around the pile (2) by lowering means, the tube being provided at an end with excavating means (7) for dislodging bottom material (3) present inside or outside the pile, with means for upwardly discharging the dislodged bottom material through the hollow tube, and with a plurality of first fluid jet nozzles (75), adapted to eject a fluid against the inner or outer wall of the pile. The invention also relates to an efficient method for cleaning the inside or outside of a hollow pile by using the device, and a jack-up pontoon provided with the device.

EP 2 481 490 A1

Description

[0001] The invention relates to a device for cleaning the inside or the outside of hollow piles that have been provided into a substrate, in particular an underwater bottom. The invention also relates to a method for cleaning the inside of such hollow piles, and to a jack-up platform provided with the device.

[0002] The supporting structure for an offshore windmill typically comprises a tubular upper portion and a lower portion in the form of a trussed structure, referred to as a jacket. A large part of the jacket extends under water where it takes support onto a substrate, which in this example constitutes the underwater bottom.

[0003] The foundation of the jacket is formed by a plurality of hollow and open-ended piles that are pneumatically driven into the underwater bottom by a pneumatic hammer, provided on an off-shore platform, brought to the envisaged location for this purpose. In this process, the inside of the hollow piles fills with underwater bottom material. When all piles have been provided into the substrate according to the desired geometrical pattern, thereby forming the foundation, the jacket is installed onto the foundation formed by the plurality of piles by inserting legs of the jacket into the piles. To this end, the present bottom material needs to be removed from inside the piles. After removal, the hollow piles receive the legs of the jacket, which legs are then secured to the hollow piles by grouting, i.e. by providing grout in the space between the legs and the inner surface of the piles.

[0004] The above manipulations of the known method are time-consuming, and, in a typical case, may take as long as 5 to 7 days to be completed. Also, the strength of the interface between the legs and the inner surface of the piles may be improved.

[0005] The invention has for its object to provide a device and an efficient method using the device for cleaning the inside or the outside of hollow piles that have been provided into a substrate, in particular an underwater bottom.

[0006] The invention provides for this purpose a device, comprising a hollow tube, adapted to be lowered into or around a pile by lowering means, the tube being provided at an end with excavating means for dislodging bottom material present inside or around the pile, with means for upwardly discharging the dislodged bottom material through the hollow tube, and with a plurality of first fluid jet nozzles, adapted to eject a fluid against the inner or outer wall of the pile.

[0007] The tube of the device according to the invention allows to accurately position the excavating means inside or around the pile, as well as the cleaning means in the form of a plurality of first jet nozzles. It simultaneously acts as a means for discharging the excavated bottom material through its central bore. When a volume of bottom material has been dislodged by the excavating means, this volume is discharged through the tube, leaving an inside or outside surface of the pile uncovered. This bare surface is subsequently cleaned by the fluid jets, emitted by the first jet nozzles. The device according to the invention therefore removes bottom material and cleans the inside or outside surface of a pile in basically one operation. The tube is conveniently lowered by lowering means provided on a jack-up platform. Such lowering means may comprises well known equipment, such as a crane, gripping means and the like.

[0008] The device according to the invention is particularly suitable for cleaning the inside of a pile, to which end an embodiment is provided comprising a hollow tube, adapted to be lowered into a pile by lowering means, the tube being provided at an end with excavating means for dislodging bottom material present inside the pile, with means for upwardly discharging the dislodged bottom material through the hollow tube, and with a plurality of first fluid jet nozzles, adapted to eject a fluid against the inner wall of the pile.

[0009] The invention also relates to a method for cleaning (preferably the inside of) a hollow pile that has been provided into a substrate, in particular an underwater bottom, comprising lowering into (or around) the pile a hollow tube, the tube being provided at an end with excavating means for dislodging bottom material present inside (or around) the pile, with means for upwardly discharging the dislodged bottom material through the hollow tube, and with a plurality of first fluid jet nozzles, adapted to eject a fluid against the inner (or outer) wall of the pile; excavate bottom material present in (or around) the pile by operating the excavating means; discharging the dislodged bottom material through the hollow tube; and eject fluid against the inner (or outer) wall of the pile to clean it. A predetermined length of pile can readily be cleaned by gradually lowering the tube into the pile over a distance that covers the desired cleaning length.

[0010] A pile cleaned by the method according to the invention is particularly useful as a foundation for the jacket of a windmill or other large structure. To form such a foundation, the legs of a jacket are lowered into a plurality of cleaned hollow piles and secured to the hollow piles by grouting, i.e. by providing grout in the space between the legs and the inner surface of the piles. By providing a particularly clean inner surface of the piles, the method and device according to the invention in particular allow to establish a strong bond between the grout and these inner surfaces.

[0011] In order to allow covering a substantial circumferential surface of the piles with a limited number of fluid jet nozzles, a preferred embodiment of the device according to the invention comprises means for rotating the hollow tube or parts thereof around a longitudinal axis of the tube. The means for rotating may be arranged to provide a continuous rotation in one direction, or they may be arranged to provide a back and forth rotation over a limited angle.

[0012] As mentioned above, a predetermined length of pile can readily be cleaned by gradually lowering the tube into or around the pile over a distance that covers

the desired cleaning length. In a very useful embodiment of the device according to the invention, limiting means are provided that limit the distance over which the tube may be lowered into or around the pile. Such limiting means may be formed for instance by a plurality of cross beams, connected to the tube and extending transverse to the longitudinal direction of the tube. The cross beams are connected to the tube at a distance from the lower end of the tube that is about equal to the desired cleaning length, and are long enough to at some point hit the upper rim of the pile and halt the movement of the tube. This embodiment is particularly useful since unnecessary cleaning is avoided, which in this type of industry saves a lot of money. The legs of a jacket are usually of different length to facilitate inserting the legs into the piles. Indeed, the longer leg is inserted first in a pile and thereafter serves as a pivot point for inserting the next longer leg in a second pile. The present embodiment allows to adjust the cleaning distance for each pile separately by adjusting the limiting means accordingly.

[0013] The excavating means provided at the lower end of the tube may be any means known in the art, such as knives, screws, and scoops to name a few. A preferred embodiment of the device uses excavating means comprising a plurality of second fluid jet nozzles, adapted to eject a fluid into the bottom material present inside or around the pile. The fluid jets emitted from the nozzles readily cut and dislodge the bottom material inside or around the pile. A second beneficial effect is that by injecting water into the bottom material inside or around the pile, a water column is arranged in the space between the substantially coaxially disposed pile and tube. This water column provides more pressure at the lower end of the tube. This additional pressure helps in sustaining an upward flow in the central bore of the hollow tube, in which flow the dislodged bottom material is readily discharged to the upper side of the tube.

[0014] According to an embodiment of the invention, the second fluid jet nozzles are positioned such with respect to the first fluid jet nozzles that they act on the bottom material present inside or around the pile, whereas the first fluid jet nozzles act on the inner or outer wall of the pile to remove any leftover bottom material and other impurities from the inside surface. The first fluid can comprise any substance that is readily ejected from a high pressure jet nozzle and that is adapted to clean the inside or outside surface of a pile, typically made of steel. A particularly suitable first fluid comprises water to which additives, such as for instance abrasive agents and/or cleaning agents are added if desired. A particularly suitable second fluid comprises water.

[0015] In order to avoid rotation of the whole tube of the device, a particular embodiment comprises a device, wherein the excavating means comprise a support structure for the fluid jet nozzles that is provided at the end of the hollow tube and is rotatable around a longitudinal axis of the tube. In this embodiment, the device can be accurately positioned into or around the pile by providing the tube with a number of stabilizers that are arranged along the tube in the longitudinal direction thereof and take support against the inside or outer wall of the pile. By only rotating the support structure for the nozzles, rotation is faster and more accurate.

[0016] A preferred embodiment of the device according to the invention is one wherein the support structure comprises a plurality of arms that at one end thereof are connected to the tube through a bearing, extend outwardly or inwardly at an angle with the longitudinal axes, and at the other end are provided with the first and/or the second fluid jet nozzles. This embodiment accurately positions the fluid jet nozzles where they are needed, that is close to the wall of the pile. The arms of the support structure may be foldable in the radial direction, if desired. By adopting arms that may be folded in or out, the radial dimensions of the excavating means may be chosen in accordance with the radial dimensions of the pile to be cleaned.

[0017] Another embodiment of the invented device has means for rotating the support structure around a longitudinal axis of the tube in the form of at least one hydraulic cylinder provided between the other end of an arm (the radially outer end) and an abutment that is eccentric with respect to the longitudinal axis of the tube. Pushing out or retracting such a hydraulic cylinder will rotate the support structure and move the fluid jet nozzles over some circumferential distance.

[0018] The second fluid jet nozzles of a preferred embodiment of the device are positioned substantially on a slant with the longitudinal axis of the tube. Such a positioning allows a good penetration of the fluid jets into the bottom material inside or around the pile, and extends the distance of the excavating operation further down and even below the lower end of the tube. Preferably, the device is adapted to control and adjust the slanting angle of the fluid jet nozzles according to the needs.

[0019] The first jet nozzles of a preferred embodiment of the device are positioned substantially at a right angle to the longitudinal axis of the tube. In such a position, the fluid jets originating from the nozzles strike the inside wall surface of the pile at a right angle, which maximizes the cleaning force.

[0020] The fluid jet nozzles are adapted to eject fluid jets at a high pressure. Thereto, the fluid jets are at one end connected to a pressure hose which at the other end connects to pressure means, such as a high pressure plunger pump, provided on a jack-up platform for instance. Although any pressure may be used for the purpose, a preferred embodiment of the invented device comprises fluid jet nozzles that are adapted for emitting the fluid under a pressure of at least 100 bar, preferably at least 150 bar, more preferably at least 200 bar and most preferably at least 250 bar. Higher pressures are also possible if desired.

[0021] Another preferred embodiment of the invented device comprises means for injecting a third fluid under a third pressure into the hollow tube for supporting the

upward discharge of the dislodged bottom material through the tube. The third fluid preferably has a lower density than water, whereby this third fluid rises and expands in the central cavity of the tube, thus further supporting the upward flow. A particularly suitable third fluid comprises air. The third pressure can be varied within wide limits, although the discharge efficiency is optimal when the third pressure lies between 2 and 50 bar, more preferably between 4 and 30 bar, and most preferably between 6 and 20 bar.

[0022] The invention also relates to a method for cleaning the inside or outside of a hollow pile that has been provided into a substrate, in particular an underwater bottom, which method makes use of the above described device. Preferred features of the method are described in the appended claims. Other details and advantages of the invention will appear from the following detailed description of the method and the device. This description is given by way of example only, without limiting the invention in any way. The reference numbers relate to the accompanying figures, in which:

figure 1 schematically shows a representation of a particular embodiment of the device according to the invention;
figure 2 schematically shows a view in perspective of a tube equipped with nozzles according to an embodiment of the invention;
figure 3 schematically shows a detailed view in perspective from above of the support structure of the embodiment of figure 2;
figure 4 schematically shows a detailed view in perspective from above of the support structure of figure 2 positioned in a pile;
figure 5 schematically shows a detailed view in perspective from below of the support structure of the embodiment of figure 3; and
figure 6 finally schematically shows a detailed view in perspective from above of the limiting means according to an embodiment.

[0023] Referring to figure 1, a device 1 is shown for cleaning the inside surface 2a of a hollow pile 2 that has been driven pneumatically in an underwater bottom 3. Bottom 3 may comprise any material including clay, silt, sand, and even rock. The pile 2 is part of a foundation for a structure to be erected at sea, such as a windmill. A typical diameter of such a pile amounts to at least 1 m, more preferably at least 2 m, still more preferably at least 4 m and most preferably at least 6 m.

[0024] According to the embodiment shown, the device 1 comprises a tube 5, which is held by a supporting structure 15 of a jack-up pontoon (not shown). For cleaning, the tube 5 is lowered in the pile 2, which typically comprises a thick-walled steel tube. The diameter of the tube 5 obviously is sufficiently small to allow entering the pile 2. Tube 5 may be made out of one piece or may comprise a number of tube sections mutually connected by means of flanges 4. In order to support the tube 5, it may be provided with a number of stabilizers 9 which are arranged distributed in the longitudinal direction 4 of the tube 5 and which take support against the inside wall 2a of the pile 2. Tube 5 is hollow and therefore comprises a central cavity 6, which runs along the entire length of the tube 5.

[0025] Acoording to an embodiment of the invention, the tube 5 is provided at its lower end with excavating means 7 for dislodging bottom material 3 that has accumulated in the pile 2 because of its open lower end 2b. Before the start of the cleaning operation, this bottom material 3 will generally be present inside the pile 2 at a depth 12 that corresponds to the water depth. During cleaning, this depth will gradually increase because bottom material 3 is excavated by the excavating means 7. In figure 1, bottom material 3 has been excavated to an additional depth 13. The cleaning depth can be limited to a predetermined depth by providing the device 1 with limiting means in the form of a plurality of cross beams 11 (see figure 6), that are connected to the tube 5 and supported by members 14, whereby the cross beams 11 extend transverse to the longitudinal direction 8 of the tube 5. The cross beams 11 are connected to the tube 5 at a distance from the lower end of the tube that is about equal to the desired cleaning length, and are wide enough to hit the upper rim 2c of the pile 2 and halt the movement of the tube 2 when the desired cleaning depth has been reached.

[0026] Referring to figures 2 to 5, the excavating means 7 comprise a support structure in the form of 6 arms 70 that at one end thereof connect to a central tube 71 through a flange 72. Arms 70 extend outwardly at an angle 73 with the longitudinal axis 8, and at the other end are provided with supports 74 for accommodating fluid jet nozzles 75. For clarity reasons, only one fluid jet nozzle 75 is shown in figure 3 and another in figure 5. In figures 2 and 4 the fluid jet nozzles are omitted. The support structure is connected to the tube 2 through a bearing 76, thus allowing rotation of the excavating means 7 around the longitudinal axis 8 of the tube 2. In the embodiment shown, the rotation is effectuated by two hydraulic cylinders 77 that are provided between the outer ends of two arms 70 and an abutment 78 that is eccentric with respect to the longitudinal axis 8 of the tube 2. Pushing out the hydraulic cylinders 77 will rotate the support structure and move the fluid jet nozzles 75 over some circumferential distance, which depends on the rotation angle. Retracting the hydraulic cylinders 77 will rotate the support structure in the other direction. In this way, the excavating means 7 may in operation be rotated back and forth around the longitudinal axis 8 of the tube 5 over a certain angle, for instance 30 degrees, while holding the tube 2 at a fixed depth. This will move the fluid jet nozzles 75 along a circular path 79 as shown in figure 4. It is also possible to simultaneously lower the tube 2 and rotate the excavating means 70. In such an embodiment of the cleaning method, the fluid jet nozzles 75 will move

along a spiral.

[0027] The fluid jet nozzles 75 comprise first fluid jet nozzles 75 a, that are adapted to eject a fluid against the inner wall 2a of the pile 2, and second fluid jet nozzles 75b, adapted to eject a fluid into the bottom material 3 present inside the pile 2. The second fluid jet nozzles 75b are positioned such with respect to the first fluid jet nozzles 75 a that they act on the bottom material 3 present inside the pile 2, whereas the first fluid jet nozzles 75a act on the inner wall 2a of the pile 2. Such an action is achieved by positioning the first fluid jet nozzles 75a substantially at a right angle to the longitudinal axis 8 of the tube 2 (or the central tube 71). Such positioning is controlled by a right angle of the supports 74a with respect to the axis 8. In the same fashion, the second fluid jet nozzles 75b are positioned substantially on a slant with the longitudinal axis 8 of the tube 2. Such positioning is controlled by supports 74b that make a nonzero angle with the longitudinal axis 8 of the tube 2.

[0028] The fluid jet nozzles 75 are adapted for emitting a fluid, preferably water under a pressure of at least 100 bar, preferably at least 150 bar, more preferably at least 200 bar and most preferably at least 250 bar. To this end, fluid jet nozzles 75 are connected to a pressure dispensing ring 80, provided on the support structure. Pressure dispensing ring 80 is at one end connected to pressure tubes 81 which connect to a suitable high pressure plunger pump 17, provided on deck of the jack-up platform. At the other end, the pressure dispensing ring 80 is provided with a number of nozzles 82 onto which flexible tubes 83 may be connected that connect to fluid jet nozzles 75. For clarity reasons, only one flexible tube 83 is shown in figure 3 and another in figure 5. In figures 2 and 4 the flexible tubes 83 have been omitted.

[0029] In an embodiment of the method according to the invention, hollow pile 2 is cleaned by gradually lowering the hollow tube 5 into the pile 2. Lowering may be carried out continuously or may be done in a number of discrete steps, for instance of a few cm. When the tube 5 is in position, the support means carrying the arms 70 and the fluid jet nozzles 75 is rotated back and forth over an angle of 30 degrees for instance. Since the 6 arms 70 are regularly spaced in the circumferential (rotational) direction, the arms 70 are spaced apart by an angle of 30 degrees, and the back and forth rotation causes a complete 360 degree coverage of a circumferential ring 79 of the tube 2. The second fluid jet nozzles 74b emit a fluid jet directed downward under an angle and into the bottom material 3. This material 3 is hereby effectively fluidised and/or cut into pieces, which dislodged bottom material 3 is then discharged upwardly through the cavity 6 of hollow tube 5, as shown in figure 1 by arrow 30. The first fluid jet nozzles 74a eject a fluid against the inner wall 2a of the pile 2 at a position which is higher than the operating position of the second fluid jets, and therefore a position for which bottom material 3 has already been substantially removed by the action of the second fluid jets. Fluid jets emitted by the first fluid jet nozzles 74a readily clean the inner surface 2a of tube 2.

[0030] In order to support the discharge of the bottom material 3 through the cavity 6 of the tube 5, the device 1 preferably comprises means (not shown) for injecting air under a third pressure into the cavity 6 of the hollow tube 5 at the lower end thereof, for instance at the height of the excavating means 7. These means comprise feed lines (not shown) that are arranged on or in tube 5 and are connected at the upper end to a compressor (not shown) on the jack-up platform. The feed lines debouch at the other end into cavity 6 of the tube 5 through air inlet valves. The compressor ensures that air is carried under a third pressure through the feed lines and enters the flow 30 of bottom material at the lower end of the tube 2. Because the compressed air has a lower density than the material flow in cavity 6, the air rises as bubbles in the tube 5, whereby the upward flow is supported, and the excavating efficiency increased. The third pressure produced by the compressor preferably lies between 2 and 50 bar, more preferably between 4 and 30 bar, and most preferably between 6 and 20 bar. The sucked up bottom material 3 travels through the cavity 6 and is led through pipe 13 to a container 31 on the jack-up platform for storage.

[0031] The invention as described by the above embodiment provides a device and an efficient method for cleaning the inside of hollow piles that have been provided into a substrate, in particular an underwater bottom. The cleaned pipes are preferably used as a foundation for a windmill.

Claims

1. Device for cleaning a hollow pile that has been provided into a substrate, in particular an underwater bottom, the device comprising a hollow tube, adapted to be lowered into or around the pile by lowering means, the tube being provided at an end with excavating means for dislodging bottom material present inside or around the pile, with means for upwardly discharging the dislodged bottom material through the hollow tube, and with a plurality of first fluid jet nozzles, adapted to eject a fluid against the inner or outer wall of the pile.

2. Device according to claim 1, adapted for cleaning the inside of a hollow pile that has been provided into a substrate, in particular an underwater bottom, the device comprising a hollow tube, adapted to be lowered into the pile by lowering means, the tube being provided at an end with excavating means for dislodging bottom material present inside the pile, with means for upwardly discharging the dislodged bottom material through the hollow tube, and with a plurality of first fluid jet nozzles, adapted to eject a fluid against the inner wall of the pile.

3. Device according to claim 1 or 2, comprising means for rotating the hollow tube or parts thereof around a longitudinal axis of the tube.

4. Device according to claim 1, 2 or 3, comprising limiting means for the distance over which the tube may be lowered into or around the pile.

5. Device according to any one of claim 1 - 4, wherein the excavating means comprise a plurality of second fluid jet nozzles, adapted to eject a fluid into the bottom material present inside or around the pile.

6. Device according to claim 5, wherein the second fluid jet nozzles are positioned such with respect to the first fluid jet nozzles that they act on the bottom material present inside or around the pile, whereas the first fluid jet nozzles act on the inner or outer wall of the pile.

7. Device according to claim 5 or 6, wherein the excavating means comprise a support structure for the fluid jet nozzles that is provided at the end of the hollow tube and is rotatable around a longitudinal axis of the tube.

8. Device according to claim 7, wherein the support structure comprises a plurality of arms that at one end thereof are connected to the tube through a bearing, extend outwardly or inwardly at an angle with the longitudinal axes, and at the other end are provided with the first and/or the second fluid jet nozzles.

9. Device according to claim 8, wherein the means for rotating the support structure around a longitudinal axis of the tube comprise a hydraulic cylinder provided between the other end of an arm and an abutment that is eccentric with respect to the longitudinal axis of the tube.

10. Device according to any one of the preceding claims, wherein the first fluid jet nozzles are positioned substantially at a right angle to the longitudinal axis of the tube.

11. Device according to any one of claims 5-10, wherein the second fluid jet nozzles are positioned substantially on a slant with the longitudinal axis of the tube.

12. Device as claimed in any one of claims 5-11, wherein the fluid jet nozzles are adapted for emitting the fluid under a pressure of at least 100 bar, preferably at least 150 bar, more preferably at least 200 bar and most preferably at least 250 bar.

13. Device as claimed in any of the preceding claims, comprising means for injecting a third fluid under a third pressure into the hollow tube for supporting the upward discharge of the dislodged bottom material through the tube.

14. Device according to claim 13, wherein the means for injecting the third fluid are adapted for emitting the third fluid under a pressure ranging between 2 and 50 bar, more preferably between 4 and 30 bar, and most preferably between 6 and 20 bar.

15. Device as claimed in any of the preceding claims, wherein the dimensions of the excavating means are adapted to enter a tube having a diameter of at least 1 m, more preferably at least 2 m, still more preferably at least 4 m and most preferably at least 6 m.

16. Jack-up pontoon provided with a device as claimed in any of the claims 1-15.

17. Method for cleaning the inside or outside of a hollow pile that has been provided into a substrate, in particular an underwater bottom, comprising lowering into or around the pile a hollow tube, the tube being provided at an end with excavating means for dislodging bottom material present inside or around the pile, with means for upwardly discharging the dislodged bottom material through the hollow tube, and with a plurality of first fluid jet nozzles, adapted to eject a fluid against the inner or outer wall of the pile; excavate bottom material present in the pile by operating the excavating means; discharging the dislodged bottom material through the hollow tube; and eject fluid against the inner or outer wall of the pile to clean it.

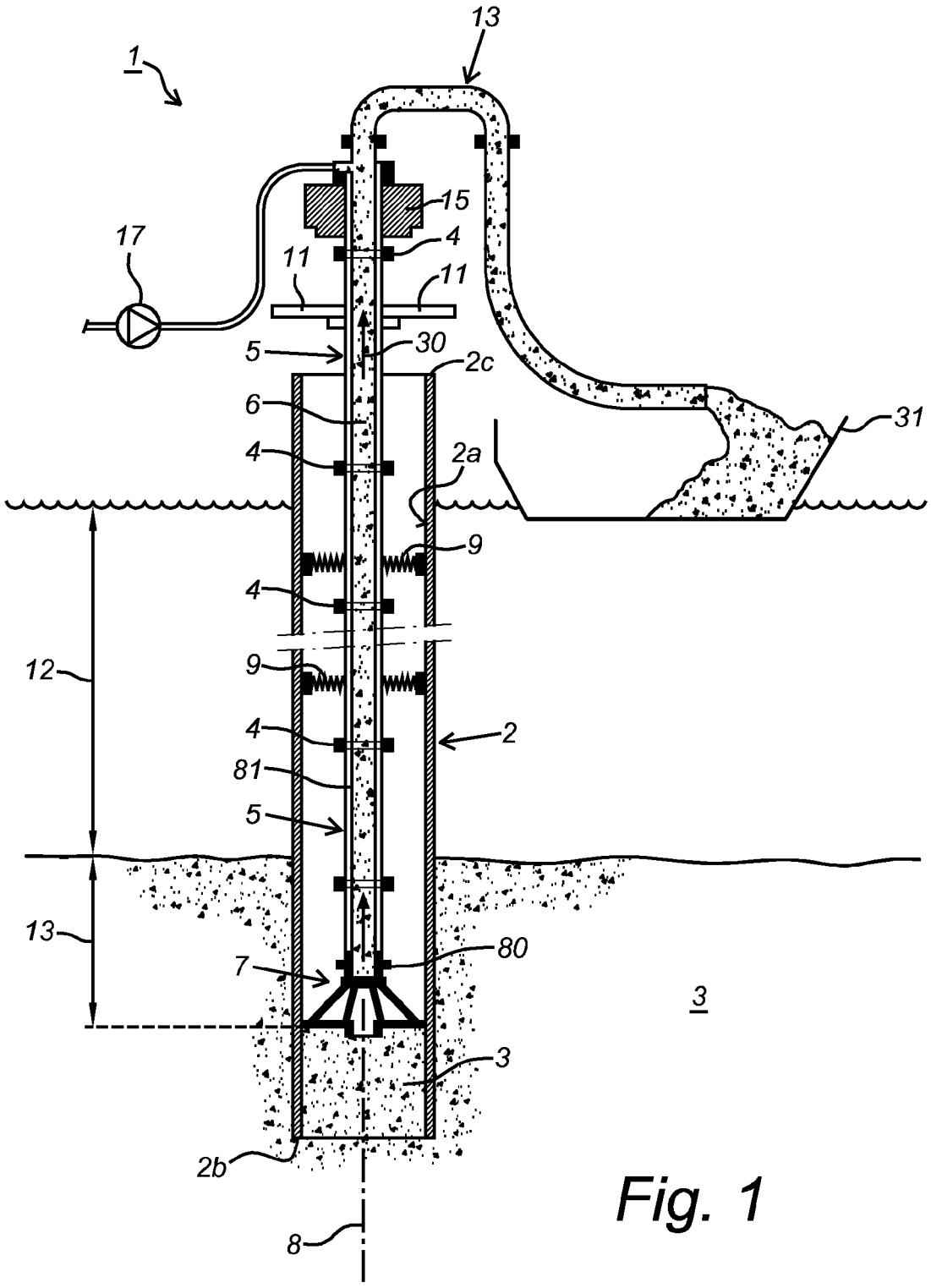

Fig. 1

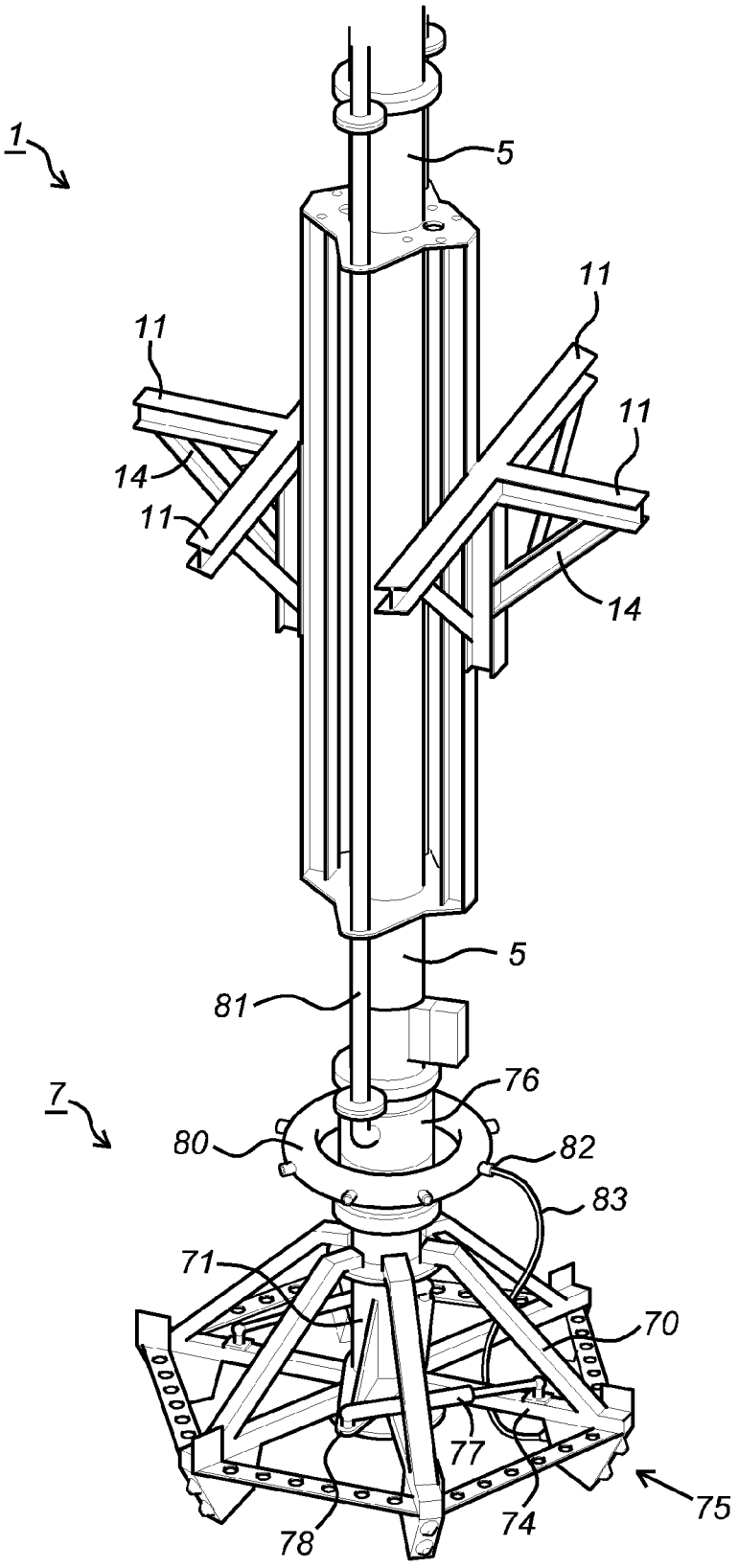

Fig. 2

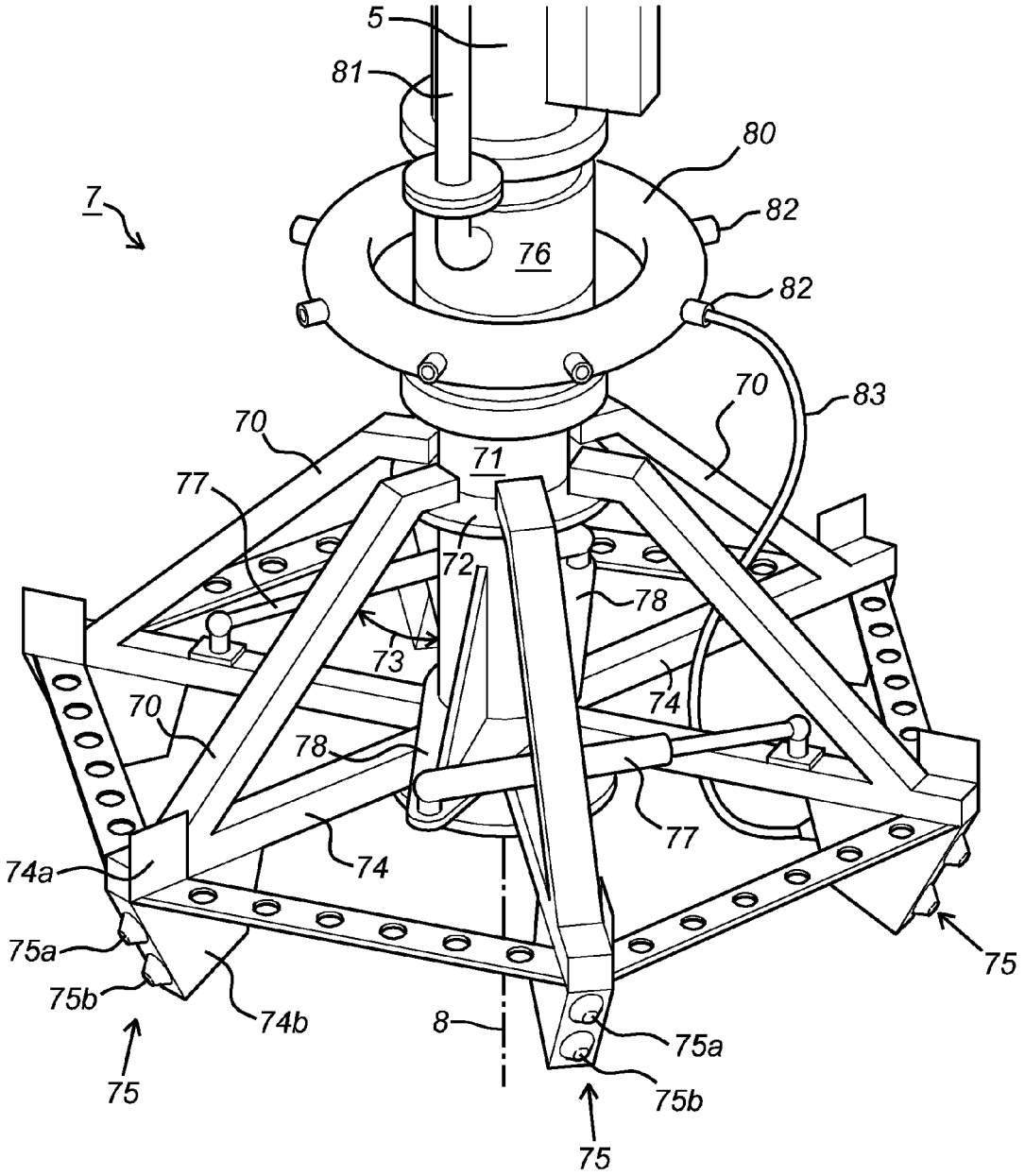
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Fig. 3

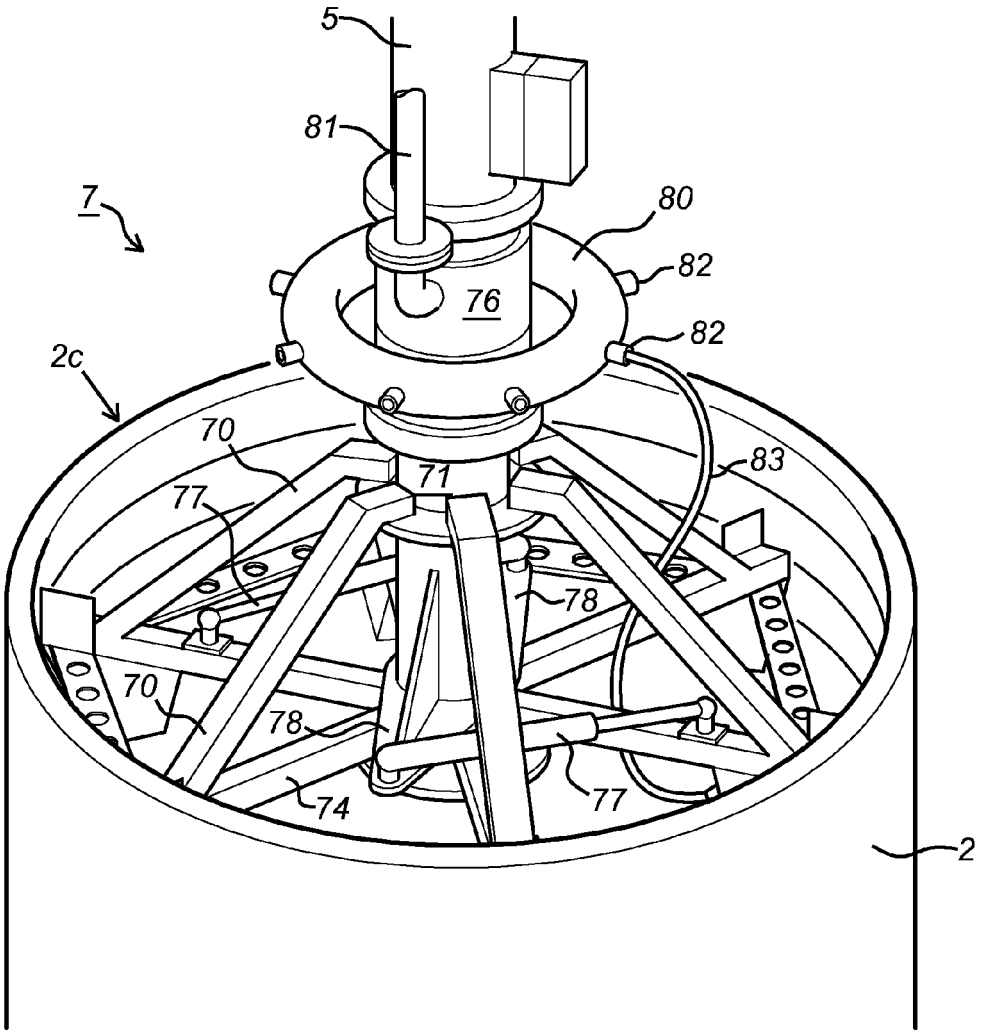

Fig. 4

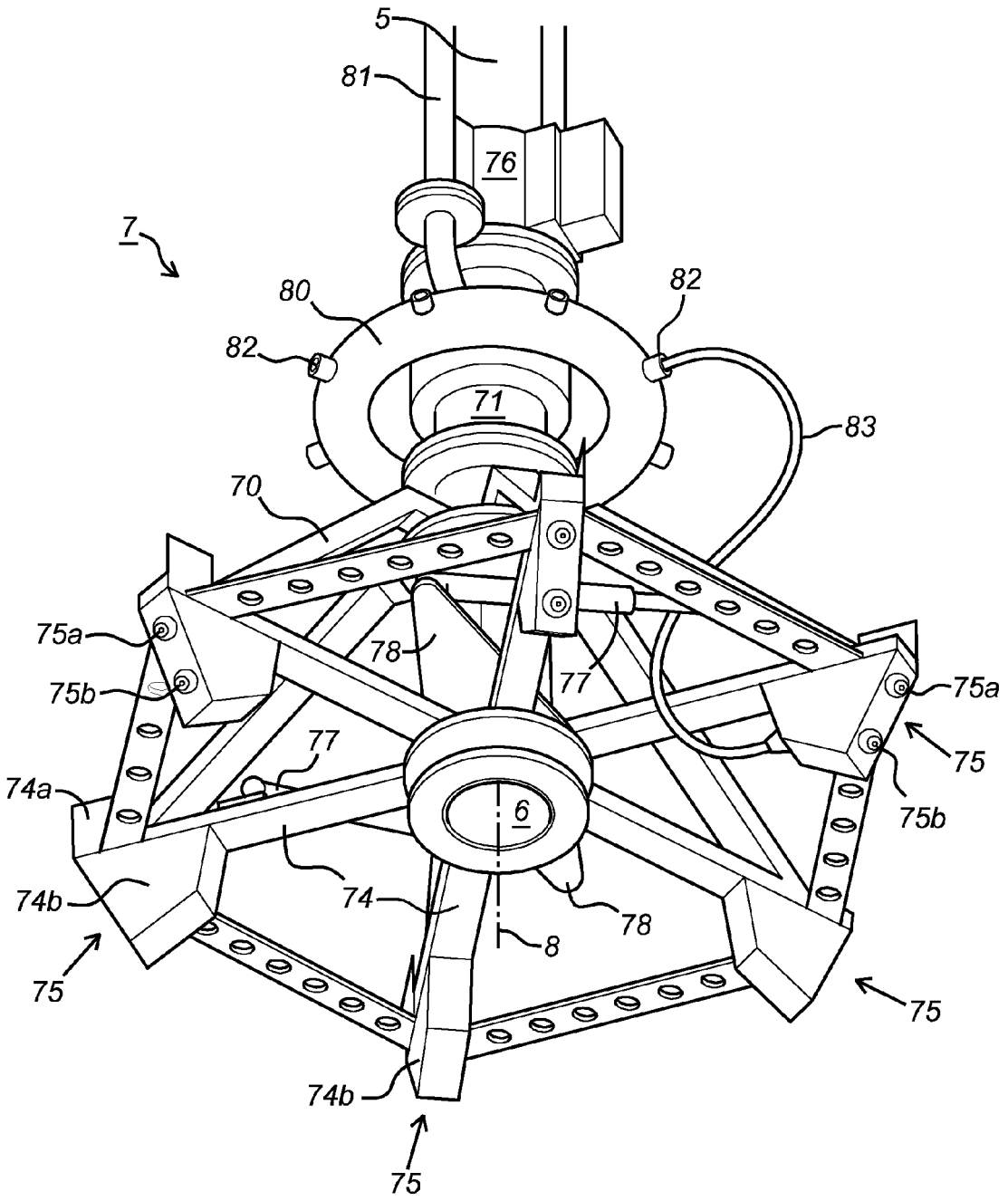
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Fig. 5

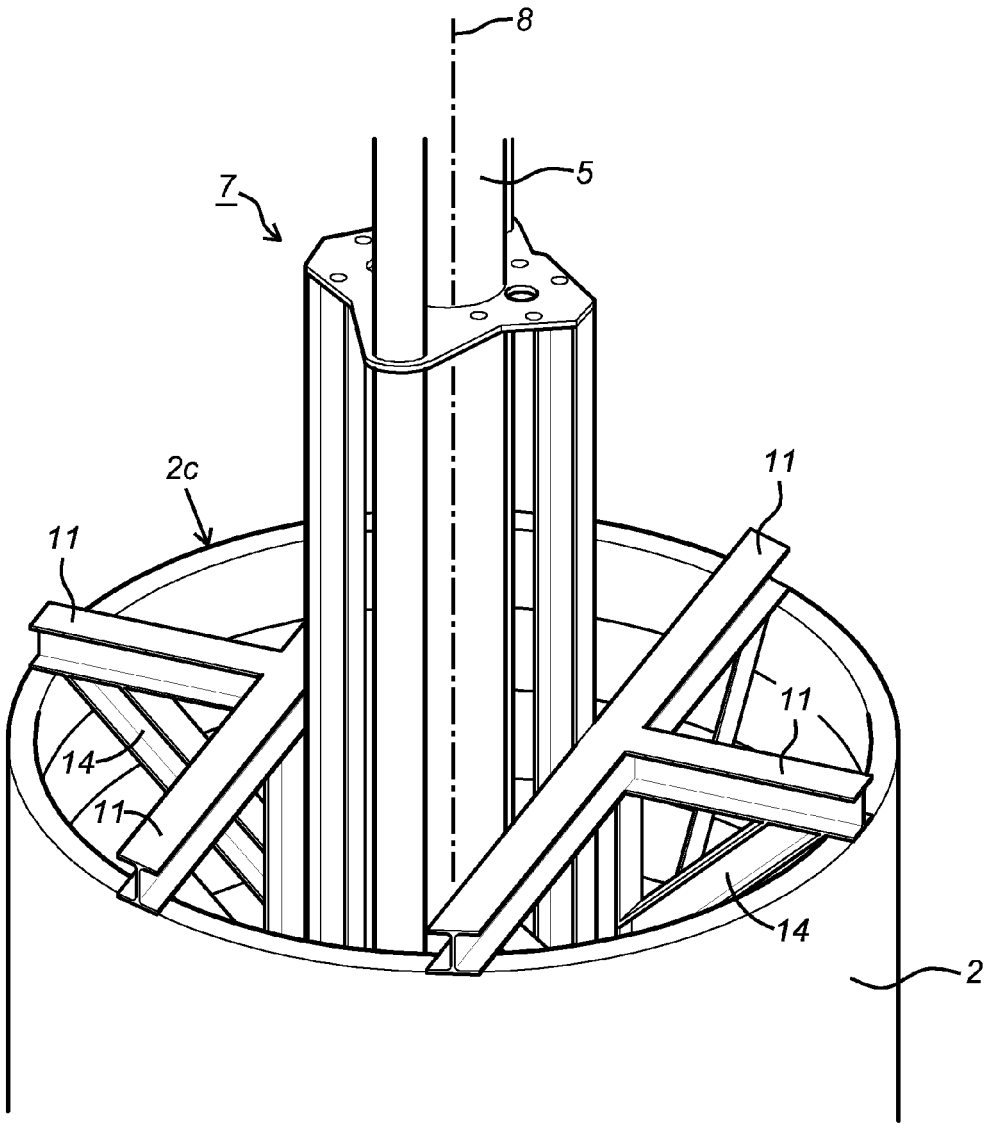

Fig. 6

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EUROPEAN SEARCH REPORT

Application Number
EP 11 15 2680

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	7 July 2011	Leroux, Corentine

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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07-07-2011

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