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(54) **Support construction**

(57) The invention relates to a method for connecting a support construction to a pile foundation. In the method a foundation pile is arranged in the bottom and a leg of the support construction is anchored to the foundation pile by arranging a grout in the intermediate space between leg and foundation pile and curing the grout, wherein before the grout is arranged a support body for the leg is lowered onto a stop edge provided on the foundation pile and the leg is then lowered until it finds support on the support body. The invention also relates to a support body applicable in the method.

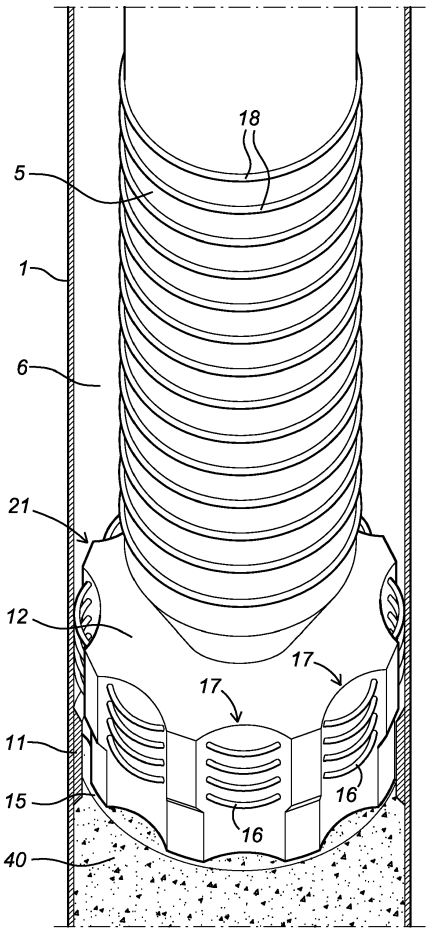


*Fig. 3*

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## Description

**[0001]** The invention relates to a method for connecting a support construction to a foundation, wherein the foundation comprises at least one foundation pile arranged in the seabed. The invention likewise relates to a support element applicable in the method.

**[0002]** The invention will be elucidated hereinbelow with reference to an offshore wind turbine. However, the reference to an offshore wind turbine in no way implies that the invention is limited to the use in the context of such a wind turbine. The method can be applied in a large number of constructions in which a support structure has to be connected to a foundation arranged in a bottom. Non-limitative examples include the connection (offshore if desired) of headstock to a jetty construction, a fender platform to a mooring dolphin, a jacket to a pile foundation, a transition piece to a monopile, and the like.

**[0003]** A wind turbine usually comprises a mast which has to be coupled to a foundation arranged in the seabed in the form of a number of foundation piles arranged in the seabed. For offshore wind turbines, which are placed in relatively shallow water, it is possible to make use of one mast extending from the machinery housing of the wind turbine to the foundation. In addition to such a monopile construction, the support construction of an offshore wind turbine can also comprise a tubular upper part and a lower part in the form of a lattice structure, also referred to as a jacket. A part of the jacket extends under water and supports on the foundation arranged in the seabed.

**[0004]** A known method for connecting a support construction in the form of for instance a jacket to an offshore pile foundation comprises of driving one or more foundation piles into the seabed from an offshore platform and anchoring the jacket on the piles by arranging legs of the jacket in the piles (also referred to as pin piling) or around the piles (also referred to as sleeve piling). Arranging the foundation piles at the desired location in the seabed can if desired be facilitated by making use of a positioning frame (or template), as for instance described in EP2354321. In the case of pin piling the foundation piles take a hollow form so as to be able to receive a part of the legs of the jacket, while in sleeve piling the legs of the jacket take a hollow form so as to be able to receive a part of the foundation piles. For anchoring purposes the intermediate space between the outer wall of a jacket leg and the inner wall of a foundation pile (pin piling) or the intermediate space between the outer wall of a foundation pile and the inner wall of a jacket leg (sleeve piling) is filled with a grout such as a pointing mortar, after which the grout is cured. Pointing mortar or grout comprises a mixture of water and cement, and optionally sand and gravel, to which additives are added if desired, for instance in order to make the mixture watertight after curing. Filling the intermediate space between foundation pile and jacket leg with the grout can be performed by pumping the pointing mortar from the platform to the intermediate space between leg and foundation pile and allowing it to cure therein, this resulting in the connection.

**[0005]** When arranging a support structure such as a jacket on foundation piles it is important that the support structure is properly aligned. Necessary among other things for this purpose is that the upper side of the legs of the support structure is situated at the correct level or height position for each foundation pile. In the known method the correct height level is obtained on the one hand by accurately installing foundation piles and on the other by arranging on the upper side of the foundation piles or on the legs of the support structure shimming plates which can bridge possible height variations so that the alignment of the support structure comes to lie within the applicable tolerances. Following arranging and curing of the grout in the space between the legs of the support structure and the foundation piles it is possible that the shimming plates have to be removed, since otherwise the load transfer between the metal shimming plate and the grout is uncertain over time. Removal of the shimming plates has to take place under water and is therefore labour-intensive and moreover unsafe.

**[0006]** The invention has for its object to provide an improved method for connecting a support construction to a pile foundation, wherein the foundation comprises at least one pile arranged in the bottom and wherein the above stated problems do not occur, or at least do so to lesser extent. The invention has the particular object of providing an improved method for connecting a support construction for a structure located at height, such as a wind turbine, to an offshore pile foundation.

**[0007]** According to the invention this object is achieved with a method for connecting a support construction to a pile foundation, wherein a foundation pile is arranged in the bottom and a leg of the support construction is anchored to the foundation pile by arranging a grout in the intermediate space between leg and foundation pile and curing the grout, wherein before the grout is arranged a support body for the leg is lowered onto a stop edge provided on the foundation pile and the leg is then lowered until it finds support on the support body. Because the height position of the foundation pile, and thereby the height position of the stop edge in a foundation pile, and the dimensions of the support body are known, the height level of the upper side of the support body, and thereby the anticipated height level of the underside of a leg of the support structure, can be precisely determined, possibly without shimming plates being necessary. In an embodiment in which an offshore support construction is connected to a pile foundation lying largely under water, the support body is generally lowered under water until it finds support on the stop edge.

**[0008]** The support body and the stop edge preferably have a strength such that they can absorb the loads exerted by the support structure on the support body and the stop edge during installation of the support structure. After the grout has been arranged in the intermediate space between leg and foundation pile and has cured, the support body is however embedded in the cured

grout, this resulting in a preferably monolithic whole which supports on the seabed and on which the leg of the support structure supports. Such a connection is capable of absorbing for a long period of time the enormous dynamic forces - in the order of magnitude of 10,000 kN and more - which are transmitted to a foundation pile per jacket leg.

**[0009]** The stop edge can be formed in simple manner by giving the wall of a hollow foundation pile a local thickened portion, wherein the upper side of the thickened portion forms the stop edge. The height position of the stop edge on or in the foundation pile can be chosen at random, although it will generally be located in the upper part of the foundation pile and preferably relatively close to the upper side of the foundation pile. A suitable distance from the stop edge to the upper side of the foundation pile lies between 1 and 20% of the overall height of the foundation pile, and more preferably between 1 and 10% of the overall height of the foundation pile.

**[0010]** An embodiment of the method according to the invention has the feature that the support body forms a peripheral body and can be lowered into or along the jacket surface of the foundation pile with clearance accessible by the uncured grout. Because the clearance between the jacket surfaces of the support body and the foundation pile is accessible by the as yet uncured grout, when arranged above the support body the grout can also fill the space below and between the support body and the bottom.

**[0011]** An embodiment of the invention provides a method in which the support body is provided with a load-bearing elastic element. Such an element can for instance comprise an elastomer and/or natural rubber. It is recommended that an upper surface of the support body is provided with the load-bearing elastic element. In such an embodiment the load-bearing elastic element functions as a cushion for the underside of the leg, which is after all lowered until it finds support on the load-bearing elastic element of the support body. The direction of inclination of a leg can thus still be adjusted to some extent if necessary during assembly.

**[0012]** In a further embodiment of the invention a method is provided wherein the support body is adjusted in the height. It thus becomes possible to compensate for possible dimensional variations. This also makes it possible to accept lesser dimensional tolerances for the foundation piles. This is also the case for the foundation pile installation tolerances. It also becomes possible for the same foundation pile design to nevertheless apply conventional installation techniques, for instance the usual longer centering pin of one leg in a jacket installation.

**[0013]** The support body can be made height-adjustable in different ways. An embodiment comprises a method wherein the support body is adjusted in the height by stacking a number of adjusting bodies on or under the support body. Another embodiment comprises a method wherein the support body comprises an upper part placed at a distance from a lower part, wherein the intermediate space comprises height-adjusting means and wherein the support body is adjusted in the height by varying the intermediate distance between the upper and lower part using the height-adjusting means. Suitable height-adjusting means comprise for instance threaded rods.

**[0014]** Yet another embodiment provides a method wherein the support body is formed such that it does not become stuck during lowering thereof. This is particularly important when lowering the support body into a hollow foundation pile. A suitable form for the support body wherein jamming is prevented is a support body of which a significant part, for instance an upper half, is convex.

**[0015]** Yet another embodiment provides a method wherein the support body is formed such that it aligns itself during lowering thereof. This is particularly important when lowering the support body into a hollow foundation pile. A suitable form for the support body wherein it becomes more self-aligning is a support body of which a significant part is conical, for instance a lower half. A self-aligning, non-jamming support body comprises for instance a convex upper half and a conical lower half. It will be apparent that the support surface of the stop edge is formed in the present case such that it connects properly to the conical jacket surface of the support body.

**[0016]** Although the method is also suitable for making a sleeve piling connection, an embodiment according to the invention comprises a method wherein the foundation pile is hollow, the support body for the leg is lowered onto a stop edge provided in the foundation pile, and the leg is then lowered into the foundation pile until the leg supports on the support body.

**[0017]** The stop edge is generally located at a predetermined height of the foundation pile and is preferably connected to the peripheral wall of the foundation pile. A load acting on the stop edge is thus transmitted via the peripheral wall of the foundation pile to the seabed. A particularly suitable embodiment comprises a method wherein the stop edge extends in the peripheral direction of the foundation pile.

**[0018]** In order to further improve the transmission of forces between the foundation pile, the stop edge and a support body for the leg resting on the stop edge, an embodiment of the method according to the invention is provided wherein the stop edge runs obliquely relative to the longitudinal direction of the foundation pile. A contact surface with optimal fit is hereby obtained between the support body and the stop edge, wherein the transmission of forces takes place substantially through shearing forces.

**[0019]** When the length of a support structure leg is greater than the height available in the foundation pile, an embodiment of the method according to the invention is provided wherein, once the foundation pile has been arranged in the bottom, possibly excessive bottom material is removed from the interior or from around the foundation pile.

**[0020]** Further advantages of the method according to the invention are achieved in an embodiment wherein

the level of the upper side of the foundation pile is determined after the foundation pile has been arranged in the seabed and more particularly wherein the height of the support body is adjusted such that the possible installation height difference between different foundation piles for a support construction can be compensated, this such that the level of the underside of the leg substantially corresponds to the most desirable level of the underside of the other legs after the leg has been lowered onto the support body. The desired height of all support structure legs is in this way obtained in simple manner.

**[0021]** The support body can in principle be manufactured from any material. Because the dimensions thereof, and more specifically the height, are preferably adapted to the desired height level of the upper side of a support structure leg, in an embodiment of the invention a method is provided wherein the support body is manufactured in situ and, as the case arises, above water level. According to an embodiment of the invention, the support body can comprise a container filled with self-curing material. The preferably flexible container, for instance a big bag, is lowered into the pile to a desired depth and there suspended, whereby a hard support body is formed.

**[0022]** It is also possible to already arrange the support body in or around a foundation pile above water and/or on land. The support body can also consist here of a material which is itself already hard, for instance steel.

**[0023]** Another embodiment relates to a method wherein the support body comprises a preformed concrete support body. Such a material allows in situ forming above water level. The preforming above water moreover allows the dimensions of the support body to be precisely determined. It is also possible according to the invention to form the support body under water from underwater concrete or other self-curing material.

**[0024]** In yet another embodiment the method has the feature that the support body comprises reinforcing bars which extend in the peripheral direction. The reinforcement not only provides for the required strength and dimensional stability but, in a further improved embodiment wherein the support body is provided with recesses which run in the longitudinal direction of the peripheral body and which are bridged by reinforcing bars, a better anchoring is moreover achieved between the support body and grout arranged and cured around it.

**[0025]** Yet another embodiment relates to a method wherein the support body forms a monolithic whole with the cured grout after the grout has been arranged in the intermediate space between leg and foundation pile. This can for instance be achieved by adapting the composition and properties of the support body and the grout to each other and having them be as closely similar to each other as possible.

**[0026]** The invention is particularly suitable for connecting a support construction for a structure located at height, such as for instance a wind turbine, to an offshore pile foundation. Such an embodiment of the method differs from the above described method only in that a foundation pile is arranged in the seabed.

**[0027]** In addition to the above described method, the invention also relates to a support body configured to be applied in a method according to the invention, wherein the support body forms a peripheral body and can be lowered into or along the jacket surface of the foundation pile with clearance accessible by the grout.

**[0028]** The support body preferably comprises a preformed concrete support body, more preferably provided with reinforcing bars which still more preferably extend in the peripheral direction. In an embodiment the support body is provided with recesses which run in the longitudinal direction of the peripheral body and which are bridged by the reinforcing bars.

**[0029]** An embodiment of the support body according to the invention comprises a load-bearing elastic element, preferably an upper surface of the support body. In another embodiment the support body is height-adjustable, preferably in that the support body comprises a number of adjusting bodies and the support body is adjustable in the height by stacking the adjusting bodies on or under the support body. Another suitable embodiment comprises a support body, an upper part of which is placed at a distance from a lower part, wherein the intermediate space comprises height-adjusting means and wherein the support body is adjustable in the height by varying the distance between the upper and lower part using the height-adjusting means. The advantages of these embodiments of the support body have already been described above in the context of the invented method, and will not be repeated here.

**[0030]** The invention will now be elucidated in more detail with reference to the drawings, without otherwise being limited thereto. In the figures:

Fig. 1 shows schematically a jacket of a wind turbine placed on a foundation of piles as according to the prior art;

Fig. 2 shows a schematic cross-section of a connection between a foundation pile and leg of a jacket obtained with an embodiment of the method according to the invention;

Fig. 3 is a schematic perspective view of the embodiment shown in figure 2; and

Fig. 4A-4E show schematic cross-sections of a number of embodiments of a support body according to the invention.

**[0031]** Referring to figure 1, a jacket 2 of a wind turbine 3 is shown arranged as according to the prior art on a foundation in the form of a number of hollow foundation piles 1 arranged in the seabed. The known method for offshore connection of jacket 2 to foundation piles 1 protruding several metres from seabed 4 comprises of driving one or more foundation piles 1 into seabed 4 from an offshore platform (not shown) and anchoring the jacket 2 on piles 1. As shown, the anchoring can take place by arranging legs 5 of jacket 2 in piles 1 (pin piling) or, in a

variant which is not shown, by arranging legs 5 around piles 1 (sleeve piling). For the purpose of anchoring legs 5 on piles 1 in pin piling the intermediate space 6 between the outer wall of a jacket leg 5 and the inner wall of a pile 1 is filled with pointing mortar (grout), which is then cured. The pointing mortar can for instance be pumped from the platform (not shown) or other vessel to intermediate space 6 and injected therein.

**[0032]** As shown in more detail in the inset of figure 1, the correct height level of the upper side of the support structure legs 5 is obtained by providing legs 5 on the upper side with a stop plate 7 and by arranging shimming plates 8 between stop plate 7 and the upper side of foundation piles 1, which plates can bridge possible relative height variations of foundation piles 1 so that the alignment of support structure 2 comes to lie within the applicable tolerances. After arranging and curing of the pointing mortar in space 6 the shimming plates 8 are removed.

**[0033]** Referring to figure 2, a cross-section is shown of a connection between a foundation pile 1 and a leg 5 of jacket 2 obtained with an embodiment of the method according to the invention. Figure 3 shows a perspective view of the formed connection.

**[0034]** According to the shown embodiment of the invention, a hollow foundation pile 1 is arranged in seabed 4 and a leg 5 of support construction 2 is anchored on foundation pile 1 by arranging a grout in the intermediate space 6 between leg 5 and foundation pile 1 and curing the pointing mortar. Prior to the pointing mortar being arranged, a support body 10 is lowered onto a stop edge 11 arranged in the peripheral direction on the inner wall of foundation pile 1 and leg 5 is then lowered until it finds support on the upper side 12 of support body 10. Stop edge 11 runs obliquely relative to the longitudinal direction 100 of the foundation pile.

**[0035]** The seabed material 40 which may have accumulated in the internal cavity of foundation pile 1 is removed up to the level 13 after foundation pile 1 has been arranged in seabed 4. In the embodiment shown in figures 2 and 3 support body 10 supports directly on seabed material 40, although it is also possible for a cavity filled with pointing mortar to be situated under support body 10. The height 14 of support body 10 is such that the level of the upper side of leg 5 at the position of stop plate 7 substantially corresponds to the level of the upper side of foundation pile 1 after leg 5 has been lowered onto the upper side 12 of support body 10.

**[0036]** Support body 10 is a substantially preformed concrete cylindrical peripheral body with clearance 15, which is accessible by the uncured grout, between the outer surface of support body 10 and the internal jacket surface of foundation pile 1. This also makes it relatively easy to lower support body 10 into foundation pile 1. Support body 10 comprises reinforcing bars 16 extending in peripheral direction. The support body is further provided with recesses 17 which run in the longitudinal direction 100 of peripheral body 10 and which are bridged by reinforcing bars 16. As yet uncured pointing mortar can easily flow from above under support body 10, among other ways via openings 17.

**[0037]** After the pointing mortar has been arranged in the intermediate space between leg 5, foundation pile 1 and optionally seabed material 40, support body 10 forms a monolithic whole with the cured pointing mortar. In order to improve the adhesion between leg 5 and the surrounding pointing mortar, the jacket surface of leg 5 can if desired be provided with peripheral rings 18 (so-called weld beads).

**[0038]** Figures 4A-4E show schematic cross-sections of a number of embodiments of a support body according to the invention. The embodiment shown in figure 4A comprises a support body 10, an upper part 10a of which takes a cylindrical form and a lower part 10b of which is conical. In figures 4A-4E the interface between the lower and upper parts is shown schematically with a broken line. Upper surface 12 of support body 10 comprises a load-bearing elastic element 20 which is received in a recess in upper surface 12. Elastic element 20 is for instance made of a synthetic rubber such as neoprene rubber.

**[0039]** In the embodiment shown in figure 4B an upper part 10a of the support body is provided with a cylindrical cavity 10c in which a leg 5 can be received. A load-bearing elastic element 20 is received in cavity 10c.

**[0040]** In the embodiment shown in figure 4C support body 10 comprises a number of adjusting bodies 10d. Support body 10 is can be adjusted in the height by stacking a number of adjusting bodies 10d on support body 10, whereby the overall height of support body 10 and adjusting bodies 10d is increased. Adjusting bodies 10d for instance comprise preformed concrete disc-shaped bodies which are provided if desired with a number of supports 101.

**[0041]** The embodiment shown in figure 4D is a self-aligning, non-jamming support body with a convex upper part 10a and a conical lower part 10b. It will be apparent that the support surface of stop edge 11 is shaped such that it fits properly on the conical jacket surface of lower part 10b of support body 10.

**[0042]** Another embodiment as shown in figure 4E comprises a support body 10, an upper part 10a of which is placed at a distance from a lower part 10b, wherein the intermediate space 102 comprises height-adjusting means 103. Support body 10 is adjustable in the height by varying the intermediate distance between upper part 10a and lower part 10b using height-adjusting means 103. Height-adjusting means 103 for instance comprise a number of steel threaded rods, although other adjusting means are also suitable.

**[0043]** The method and support body according to the invention allow efficient and reliable connection of a support construction for a structure located at height, such as a wind turbine, to an offshore foundation comprising at least one pile arranged in the seabed.

## Claims

1. Method for connecting a support construction (2) to a pile foundation, wherein a foundation pile (1) is arranged in the bottom (4) and a leg (5) of the support construction (2) is anchored to the foundation pile (1) by arranging a grout in an intermediate space (6) between leg (5) and foundation pile (1) and curing the grout, wherein before the grout is arranged a support body (10) for the leg (5) is lowered onto a stop edge (11) provided on the foundation pile (1) and the leg (5) is then lowered until it finds support on the support body (10).

2. Method as claimed in claim 1, wherein the support body (10) or an upper surface of the support body (10) is provided with a load-bearing elastic element.

3. Method as claimed in any of the foregoing claims, wherein the support body (10) is adjusted in the height.

4. Method as claimed in claim 3, wherein the support body (10) is adjusted in the height by stacking a number of adjusting bodies on or under the support body.

5. Method as claimed in claim 3 or 4, wherein the support body (10) comprises an upper part (10a) placed at a distance from a lower part (10b), wherein the intermediate space comprises height-adjusting means and wherein the support body (10) is adjusted in the height by varying the intermediate distance between the upper and lower part using the height-adjusting means.

6. Method as claimed in any of the foregoing claims, wherein the foundation pile is hollow, the support body for the leg is lowered onto a stop edge provided in the foundation pile, and the leg is then lowered into the foundation pile until the leg supports on the support body.

7. Method as claimed in any of the foregoing claims, wherein the stop edge extends in the peripheral direction of the foundation pile and the stop edge preferably runs obliquely relative to the longitudinal direction of the foundation pile.

8. Method as claimed in any of the foregoing claims, wherein the support body is manufactured in situ and, as the case arises, above water level.

9. Method as claimed in any of the foregoing claims, wherein the support body comprises a preformed concrete support body.

10. Method as claimed in any of the foregoing claims for connecting a support construction (2) for a structure located at height, such as for instance a wind turbine (3), to an offshore pile foundation, wherein a foundation pile (1) is arranged in the seabed (4).

11. Support body configured to be applied in a method as claimed in any of the foregoing claims, wherein the support body comprises a peripheral body which can be lowered into or along the jacket surface of a foundation pile with clearance accessible by a grout.

12. Support body as claimed in claim 11, wherein the support body comprises a preformed concrete support body provided with reinforcing bars.

13. Support body as claimed in claim 11 or 12, wherein the support body (10) or an upper surface of the support body (10) comprises a load-bearing elastic element.

14. Support body as claimed in any of the claims 11-13, wherein the support body (10) is adjustable in the height.

15. Support body as claimed in claim 14, wherein the support body (10) comprises an upper part (10a) which is placed at a distance from a lower part (10b), wherein the intermediate space comprises height-adjusting means and wherein the support body (10) is adjustable in the height by adjusting the intermediate distance between the upper and lower part using the height-adjusting means.

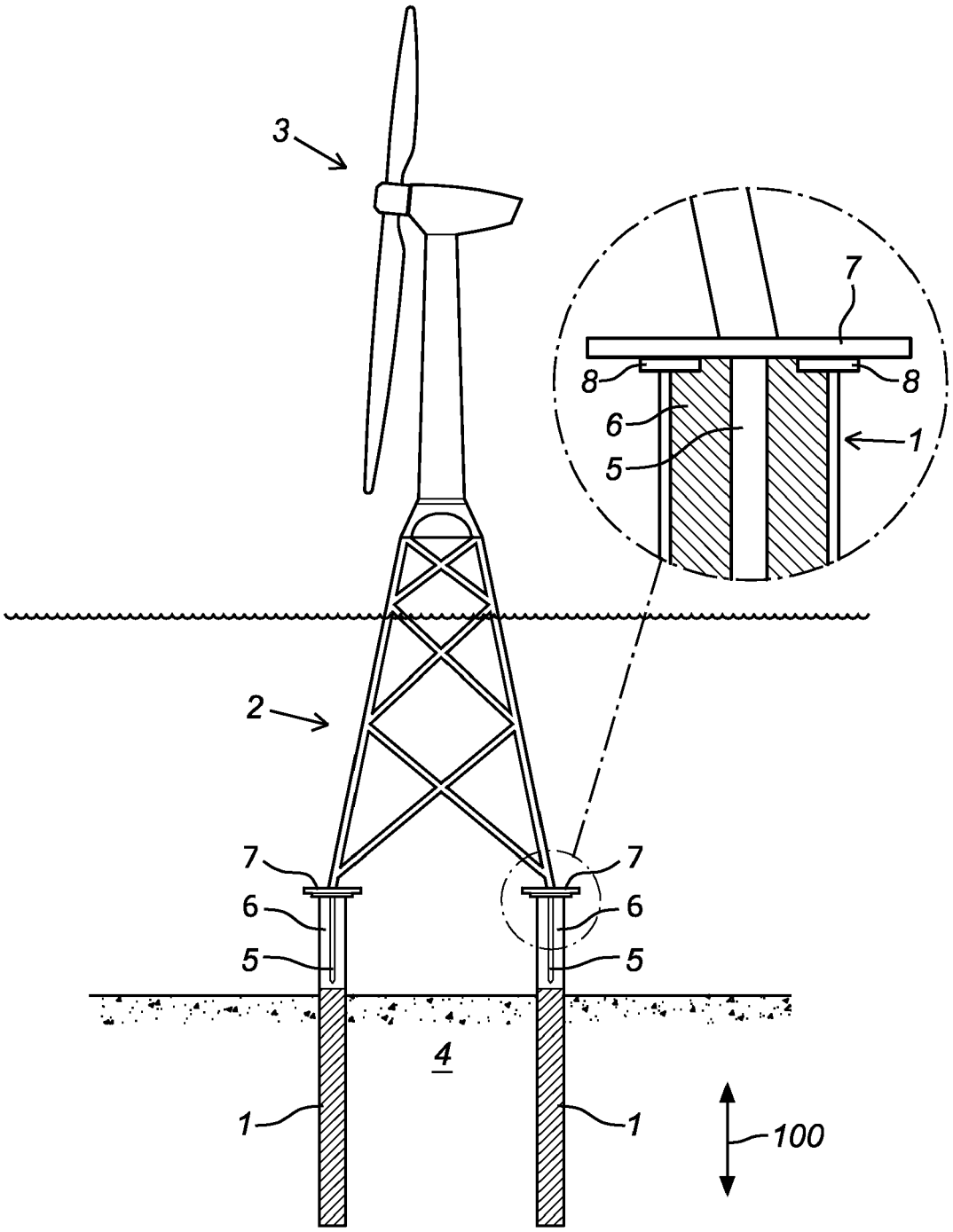


Fig. 1

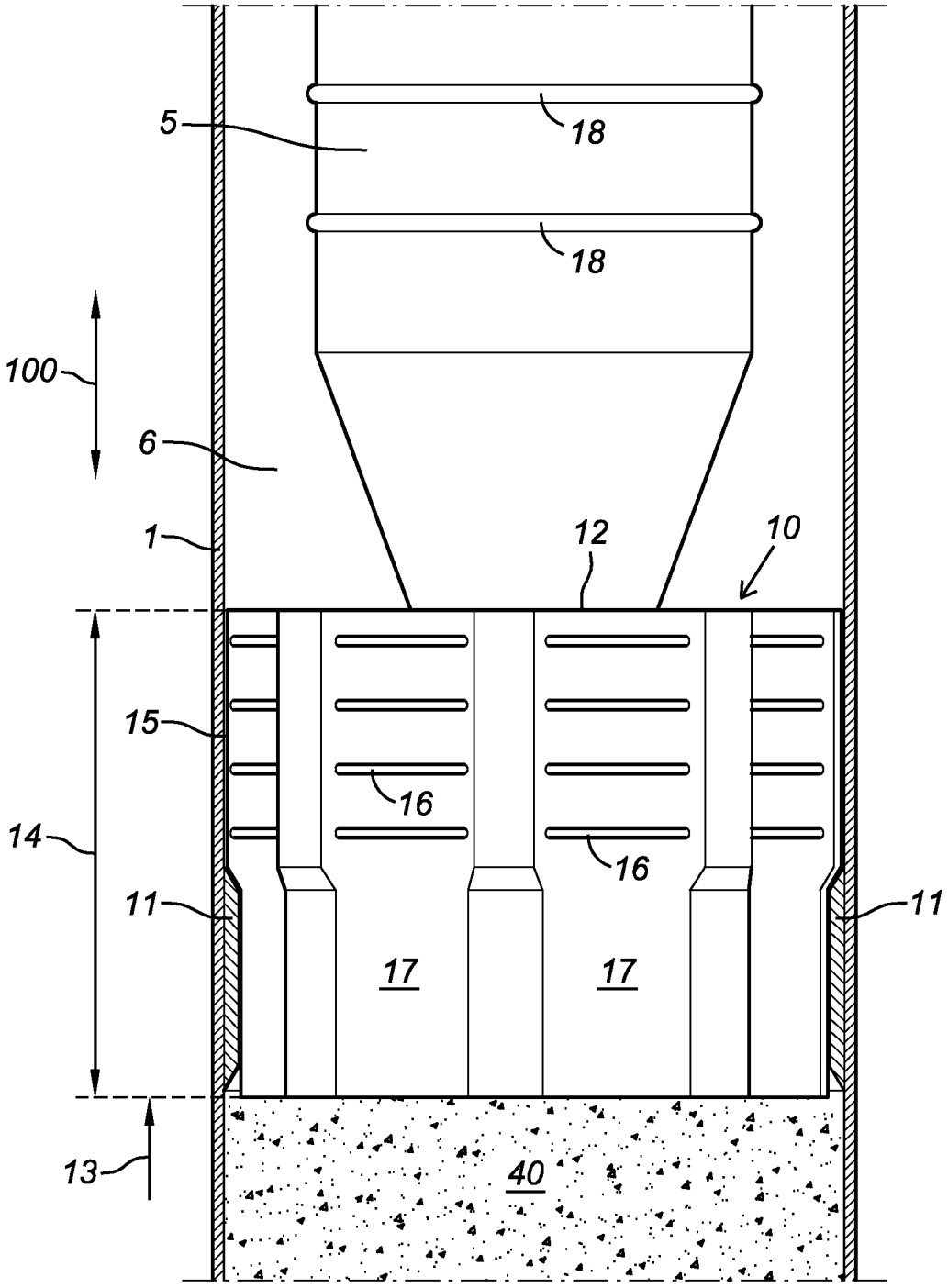


Fig. 2

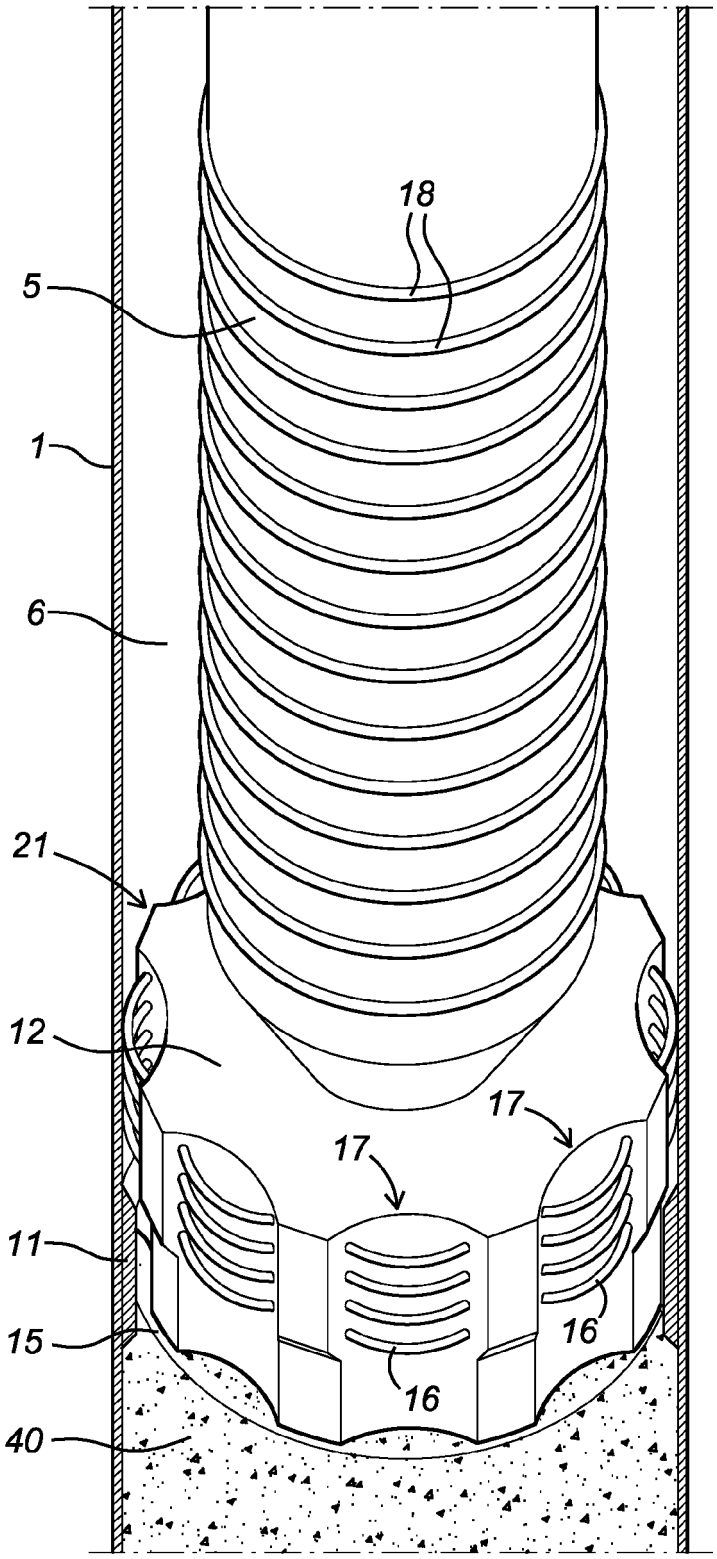


Fig. 3

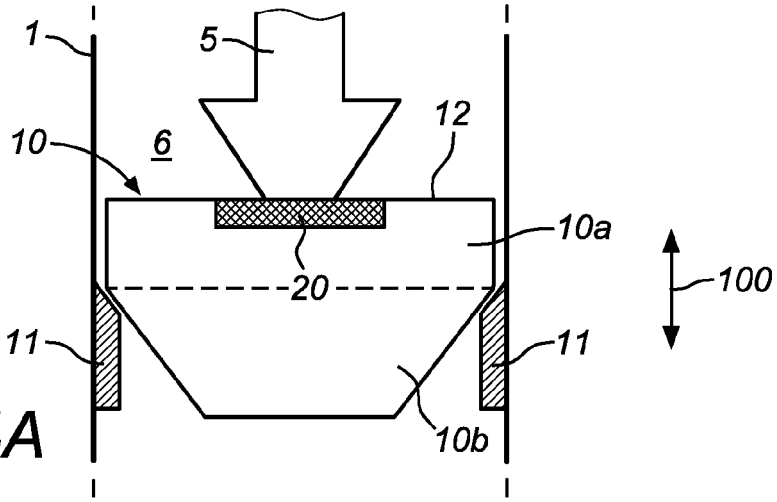


Fig. 4A

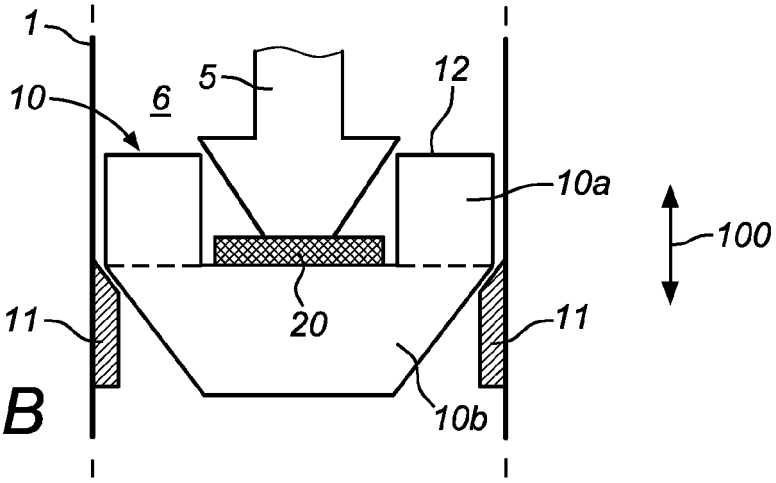


Fig. 4B

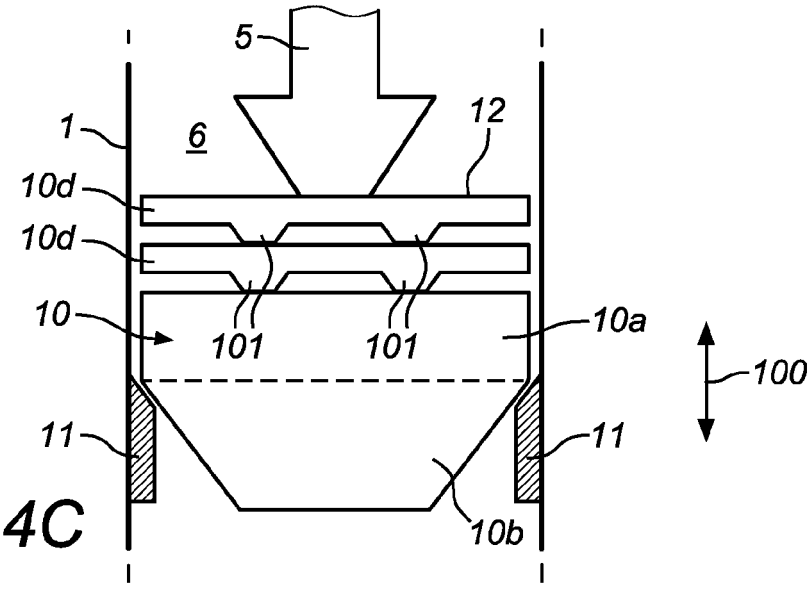


Fig. 4C

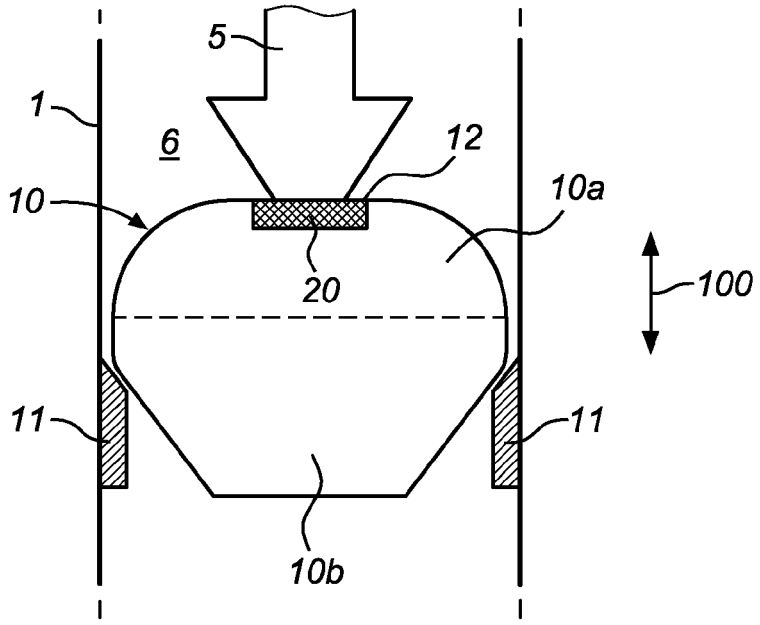
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Fig. 4D

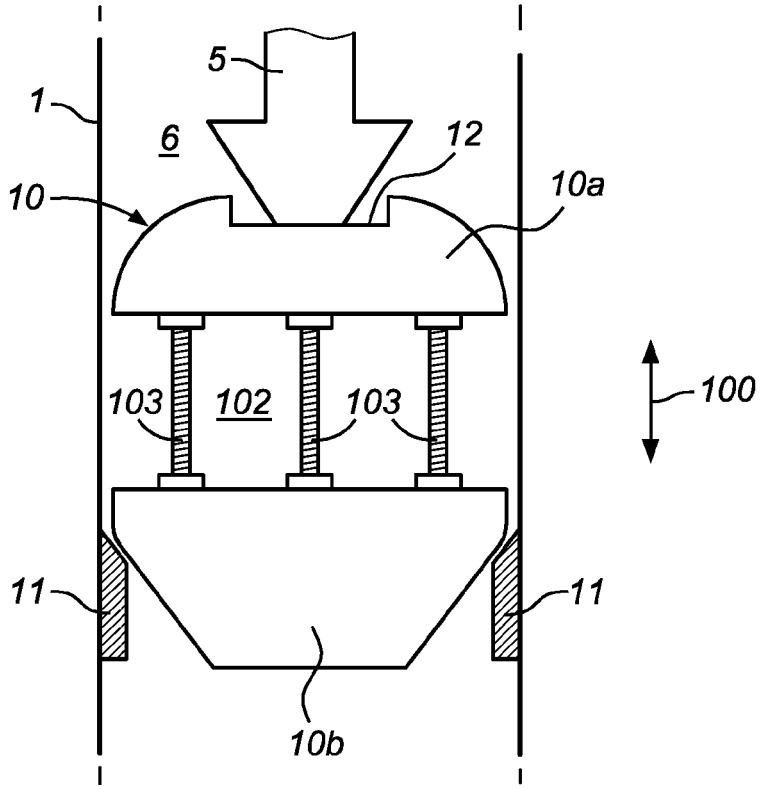
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Fig. 4E

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# EUROPEAN SEARCH REPORT

Application Number
EP 14 17 2473

## 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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TECHNICAL FIELDS SEARCHED (IPC)

E02D

The present search report has been drawn up for all claims

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| Munich | 12 January 2015 | Geiger, Harald |

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## ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 14 17 2473

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## REFERENCES CITED IN THE DESCRIPTION

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### Patent documents cited in the description


- EP 2354321 A **[0004]**