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(54) Title: FOUNDATION ELEMENT WITH VARIABLE DEPTH, FOR WIND TURBINE TOWER

(57) Abstract: Variable depth tower foundation element, characterized in that its top surface is completely horizontal and is joined to the bottom portion of a wind turbine tower, and that the central portion of its bottom surface is horizontal and inclines upwards along the sections comprising the area between their lateral edges and said central portion.

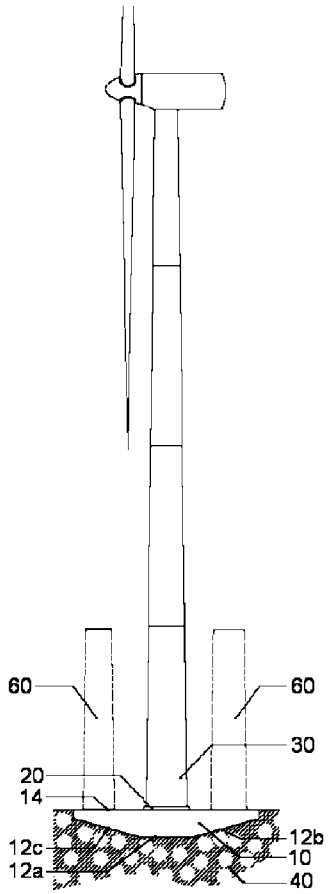

FIG. 2a

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FOUNDATION ELEMENT WITH VARIABLE DEPTH, FOR WIND TURBINE TOWER

DESCRIPTION

FIELD OF THE INVENTION

The present invention refers to foundation elements for wind turbine towers. Said foundation elements also have the particularity of having variable depths, that is, they have a curve or vertex along their length and so do not follow a straight line.

The main sector of application of the present invention is the construction sector, especially concrete, in combination with the renewable energy or green industry, specifically wind power.

BACKGROUND OF THE INVENTION

As is well known, wind turbines are devices capable of generating electric energy with currents of air.

Said wind turbines are large dimension constructions comprising a tower that has a turbine deployed on the top portion.

In fact, wind turbines usually have a height of 60 to 120 meters, and are constructed using heavy materials such as steel and/or reinforced concrete. Likewise, the wind turbines are equipped with large rotor blades (usually between 20 to 45 meters) and with elements such as the rotor and the outer shell (often called a nacelle), which have a significant mass.

For these reasons, a wind turbine has a very high total weight, normally on the order of 150 to 300 tons.

Consequently, in order to bear the considerable gravitational loads caused by the tower and all of the equipment that integrates the wind turbine, as well as resist stress loads commonly produced by wind solicitations, the effect of which is even more important, it is necessary to

build a foundation.

The wind turbine foundations known in the state of the art are structures joined at their top part to the portion of the wind turbine tower, while the bottom part is buried up to a certain depth or, alternatively, supported on the ground on which it is built. This manner enables them to transfer loads to the ground, so guaranteeing tower stability. Said foundations are frequently (although not exclusively) made of reinforced concrete and are commonly (although not exclusively) shoe type direct foundations.

For the sake of simplicity, hereinafter reference will mainly be made to shoes, although the other types of foundations used in wind turbine construction (mainly deep pile cap type foundations) have similar drawbacks to those that will be articulated below in relation to said shoes. Moreover, it must be borne in mind that the teachings of the invention may be applied both to shoes and deep pile cap foundations (which will be described later on in the present document).

Shoes are structures that enlarge the support surface of a construction moment element (that is, an element having a notably superior height than the dimensions of its base, such as, for example, a wind turbine tower) until the ground can support the load being transmitted without difficulty. Shoes are, therefore, elements that distribute the load over quite a large ground surface.

In accordance with the above, the dimensions of the footprint of the wind turbine shoe should be larger than the diameter of the tower, usually reaching an average extension on the order of 10x10 m to 20x20 m (depending, naturally, on the wind turbine tower dimensions and the specific conditions in the case at issue).

Moreover, shoes usually have a square shaped footprint

(although other shapes may also be adopted, such as for example, polygonal, oval or round, this last example having a diameter of 12 to 14 m). Their edge is usually straight (which simplifies excavation and construction procedures), said edge usually having a length of between 2 and 4 meters.

Thus, the a wind turbine shoe has very large dimensions, which results in its construction costs likewise being very high, normally between 25,000 and 400,000 Euros.

For this reason, frusto-conical shaped and variable depth shoes have recently been proposed in the art, the bottom surface of which is completely horizontal, and on which the top surface is horizontal at the central portion and inclined downward on the sections comprising the area between each of its lateral edges and said central portion. The fact that variable depth shoes have recesses in the lateral portions of their top surface enables reducing the amount of material needed for its construction and, therefore, lowers the installation costs of a wind turbine.

However, these foundations are not drawback free.

Thus, for example, the fact that the top surface of variable depth shoes may not be completely horizontal prevents said portion of the shoe from being used as an assembly or pre-assembly surface for the wind turbine tower. This means that, besides the shoe, a separate assembly or pre-assembly surface would normally be necessary, which would increase costs and construction time.

Furthermore, to install a shoe of this type it is necessary to carry out a more complicated excavation to execute the installation than what is necessary for a shoe with a flat depth given that, among other things, the slope is greater. Likewise, in order for the excavated hole to be adjusted to the shape of the shoe, the top borders of the hole must be notably extended towards the central portion of

said hole. Since there is no material to support the portion of the land located underneath said top borders, it may provoke detachments.

Besides surface shoes, so called deep foundations are occasionally employed in the art, which are similar to direct foundations except that they comprise point elements having a substantially column shape, called piles, which are introduced into the ground until a competent stratum is reached. Said piles are normally made of concrete, although they may also be steel, wood or improved soil, among others.

In order to transfer structural loads towards said piles and obtain the result that said pilots are capable of actuating together with each other, the top portion of said piles (normally called the head) is integrated into an additional foundation element, called a pile cap, which in turn is joined to the structure by its top central portion. As with the shoes, pile caps with constant or variable depths are also known in the state of the art, however, said pile caps, as mentioned above, also have drawbacks similar to those described above in the present document.

Therefore, there is a need for wind turbine foundations (both surface and deep) which, besides being able to support the gravitational loads generated by all of the wind turbine components, wind solicitations and torque, may be made with the least possible amount of material so as to minimise construction costs. Likewise, it is desirable to develop foundations having a top surface that can be used as a platform for assembly or pre-assembly of the components of the wind turbine tower, that can also be built over excavations with out the danger of detachments, and that are as simple as possible.

SUMMARY OF THE INVENTION

An object of the invention is to provide a foundation

element, with variable depth, for wind turbine towers, that solves all of the aforementioned problems of the prior art.

More specifically, the present invention proposes a foundation element for a wind turbine tower having a completely horizontal top surface that is joined to the bottom portion of a wind turbine tower, and having a bottom surface that is supported by the ground (or sunk into said ground to a certain depth) comprising a horizontal central portion and upwardly inclined sections comprising the area between each of their lateral edges and said central portion.

A can be seen, the foundation elements in accordance with the present invention have recesses in the lateral portions of their bottom surface, which enables reducing the amount of material required for its construction, thus lowering costs.

Likewise, the specific configuration of the foundation element in accordance with the invention simultaneously enables its top surface, being completely horizontal, to be used as an assembly or pre-assembly platform for the components of the wind turbine tower.

Moreover, during excavation of the hole designed for lodging a foundation element in accordance with the invention, the shoe excavation reduces the risk of detachment because, thanks to the specific configuration of said foundation element, it is no longer necessary to remove the portion of soil located underneath the top edges of the hole.

Obviously, the specific dimensions that the foundation elements must have in accordance with the invention in order to resist loads, wind solicitations and torque will depend on, among others, the specific features of the wind turbine that they are going to support and the terrain features on which they are going to be built. However, as a correct calculation of the dimensioning of the same can be done using

standard structural calculations well known by a person skilled in the art, it will not be explained in the present document.

Furthermore, it is important to clarify that the foundation elements in accordance with the invention may be any foundation elements, as long as they are interposed between the base of a wind turbine and the building site, and specifically include both a complete shoe of a surface foundation, such as a pile cap of a deep foundation.

Likewise, foundation elements in accordance with the invention may have any plan view, for example, square, circle, polygon, etc., on the condition that the depth always varies in the aforesaid specified manner.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other features and advantages of the invention shall be made clear beginning with the following description of an embodiment of the invention, provided only as a non-limiting example, with reference to the accompanying drawings, in which:

Figure 1 shows a schematic lateral view of a variable edged foundation shoe with the top surface inclined, in accordance with prior art;

Figures 2a and 2b show a lateral schematic view and a plan view, respectively, of a foundation element in accordance with a first embodiment of the invention;

Figures 2c and 2d show schematic plan views which display two alternate embodiments of the foundation element displayed in Figures 2a and 2b;

Figures 3a and 3b show a lateral schematic view and a plan view, respectively, of a foundation element in accordance with a first embodiment of the invention; and

Figure 3c shows a schematic plan view of an alternate embodiment of the foundation element displayed in Figures 3a

and 3b.

DETAILED DESCRIPTION OF THE INVENTION

In the figures the same or analogous parts are indicated with the same reference number.

Figure 1 shows air turbine shoe with variable depth 10, in accordance with the prior art, in which the top portion is joined, in this specific embodiment, to base 20 of wind turbine tower 30, said shoe 10 being, furthermore, buried in earth 40, over which it is built in such a way that its top surface is substantially flush with the ground.

However, there are generator towers in the art that lack base 20. There likewise exist shoes that are built above or under the the ground and subsequently covered by soil.

Bottom surface 12 of shoe 10 is completely horizontal while central portion 14a of the top surface is horizontal, inclining downwards along sections 14b and 14c, each one comprising the area between each one of their lateral edges and said central portion 14a.

Figure 2a shows a foundation element, in this case a shoe 10 for an air turbine tower in accordance with a first embodiment of the invention, in which the top portion is joined to base 20 of wind turbine tower 30, said shoe 10 being, furthermore, buried in earth 40, over which it is built in such a way that its top surface is substantially flush with the ground.

In this case top surface 14 of shoe 10 is the one which is completely horizontal, whereas only central portion 12a of the bottom surface is horizontal and forms vertices at the intersection of said central portion 12a with each one of sections 12b, and 12c of the bottom surface. Said bottom surface sections 12b, 12c are comprised between one of the lateral edges and said central portion 12a and, in this embodiment, are straight and inclined upwards.

The completely horizontal shape of top surface 14 of shoe 10 enables said top surface 14 to be used as a pre-assembly or storage platform of, for example, tower sections 60 (shown with dashed lines in figure 2a).

Figure 2b shows shoe 10 having a square shape in accordance with this embodiment of the invention.

Likewise, said figure also represents(with dashed lines)each one of the edges provided on bottom surface 12a, 12b, 12c of shoe 10, which are shaped by the intersection of sections 12b, 12c with central portion 12a (which corresponds to the central square of the dashed lines).

Figure 2c shows an alternate embodiment of the invention in which shoe 10 has a circular shape.

Said figure likewise schematically displays with dashed lines central portion 12a of the bottom surface of said shoe 10.

Figure 2d shows another alternate embodiment of the invention in which shoe 10 has a polygonal (octagonal) shape.

Likewise, said figure also shows (with dotted lines)each one of the edges provided on bottom surface 2a, 12b, 12c of shoe 10, and shaped by the intersection of sections 12b, 12c with central portion 12a (which corresponds to the octagon represented by dashed lines in the figure).

Figure 3a shows a foundation element, in this case a deep foundation pile cap 10, for a wind turbine tower in accordance with a fourth embodiment of the invention, the top portion of which is joined to the bottom portion of wind turbine 30, said pile cap 10 being further joined to piles 15 deployed in a radial manner.

Pile cap 10 is completely buried in earth 40 on which tower is being built.

As in the previous embodiment, top surface 14 of pile cap 10 is the one which is completely horizontal, whereas

only central portion 12a of the bottom surface is horizontal and forms vertices at the intersection of said central portion 12a with each one of sections 12b, and 12c of the bottom surface. Said bottom surface sections 12b, 12c are comprised between one of the lateral edges and said central portion 2a and, in this embodiment, are straight and inclined upwards.

Likewise, the completely horizontal shape of top surface 14 of shoe 10 enables said top surface 14 to be used as a pre-assembly or storage platform of, for example, tower sections 60 (shown with dashed lines in figure 3a). Said top surface 14 is covered with filler material 50 when there is no longer any need to use it as a pre-assembly or storage platform.

As can be seen in Figure 3b, pile cap 10, in accordance with this embodiment of the invention has a circular plan. Likewise, central portion 12a of bottom surface 12a, 12b, 12c of said pile cap 10 corresponds to the central circle drawn with dashed lines, and each one of piles 15, to which said pile cap 10 is joined, corresponds to one of the smaller circles drawn with dashed lines and arranged on the periphery of the pile cap.

Figure 3c shows an alternate embodiment in which pile cap 10 has a polygonal (octagonal) shape.

Said figure also represents (with dashed lines) each one of the edges provided on bottom surface 12a, 12b, 12c of pile cap 10, and shaped by the intersection of sections 12b, 12c with central portion 12a (which corresponds to the octagon represented by dashed lines in said figure). The circles traced in dashed lines correspond, in turn, to each one of piles 15, to which pile cap 10 is joined.

The embodiment of the invention described herein is provided exclusively by way of an explanatory example and is

not limiting. For a person skilled in the art other embodiments and modifications that are within the scope of the invention will be obvious, such as those defined in the attached claims.

Thus, for example, to a person skilled in the art, it will be obvious that it is possible to foresee the foundation elements in accordance with the invention, be they shoes or pile caps, with plans having different geometric shapes. In this way, a pile cap type foundation element can be provided, for example, with a square shaped plan.

In any case, the top surface of a foundation element in accordance with the invention may or may not be covered with soil when there is no longer any need to use the top surface of said foundation element as a pre-assembly or storage platform.

Furthermore, it will also be obvious to a person skilled in the art that a pile cap in accordance with the invention can be joined to different types of piles, for example, concrete steel or wood piles or columns of improved soil, such as gravel columns, Deep Soil Mixing or similar.

CLAIMS

1. Foundation element (10) of variable depth for a wind turbine tower, characterized in that top surface (14) is completely horizontal and joined to the bottom portion of a wind turbine tower, and that bottom surface (12a, 12b, 12c) is supported by ground (40), or sunk into said ground (40) to a certain depth, and, furthermore, said bottom surface (12a, 12b, 12c) has a horizontal central portion inclined upward in sections(12b, 12c) comprising the area between each the lateral edges of each one and said central portion (12a).

2. Foundation element in accordance with claim 1, characterized in that its bottom surface forms vertices at the intersection of said central portion (12a) with each one of bottom surface sections (12b, 12c) and that said bottom surface sections (12b, 12c)are straight and are inclined upwards.

3. Foundation element in accordance with either of the previous claims, characterized in that it has a square shaped plan view.

4. Foundation element in accordance with any of the previous claims, characterized in that it has a circular or polygonal shaped plan view.

5. Foundation element in accordance with claim 1, characterized in that it is a shoe.

6. Foundation element in accordance with claim 1, characterized in that it a deep foundation pile cap.

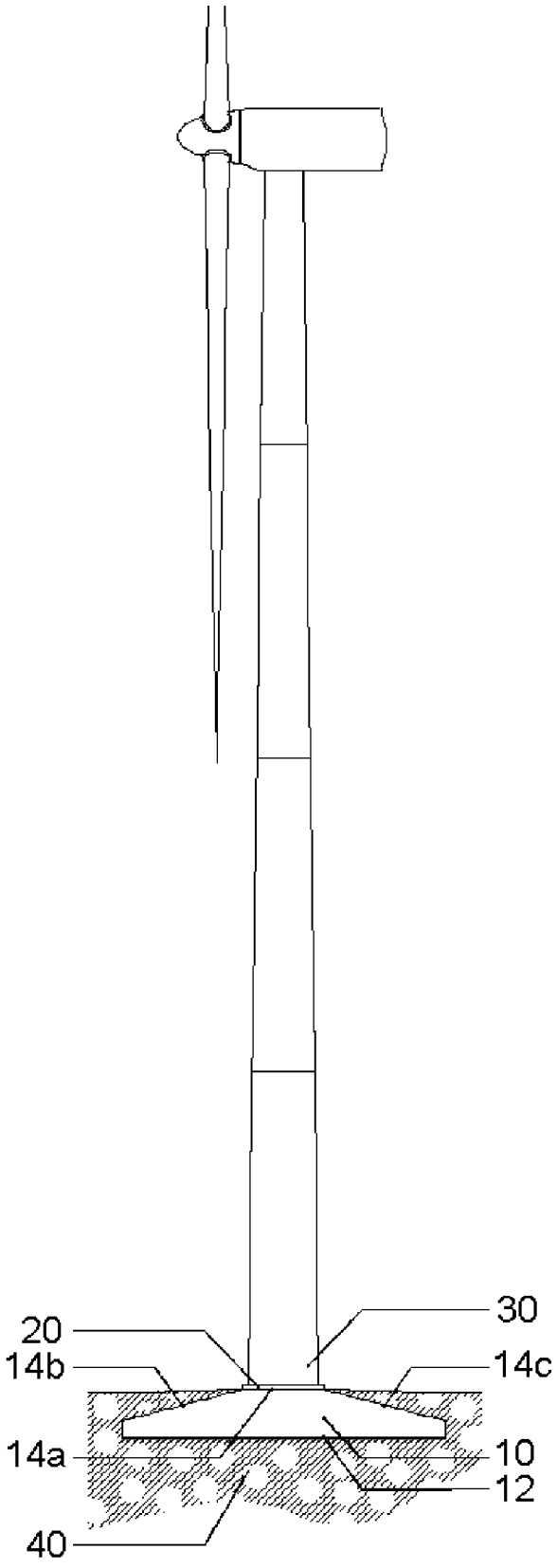

FIG. 1

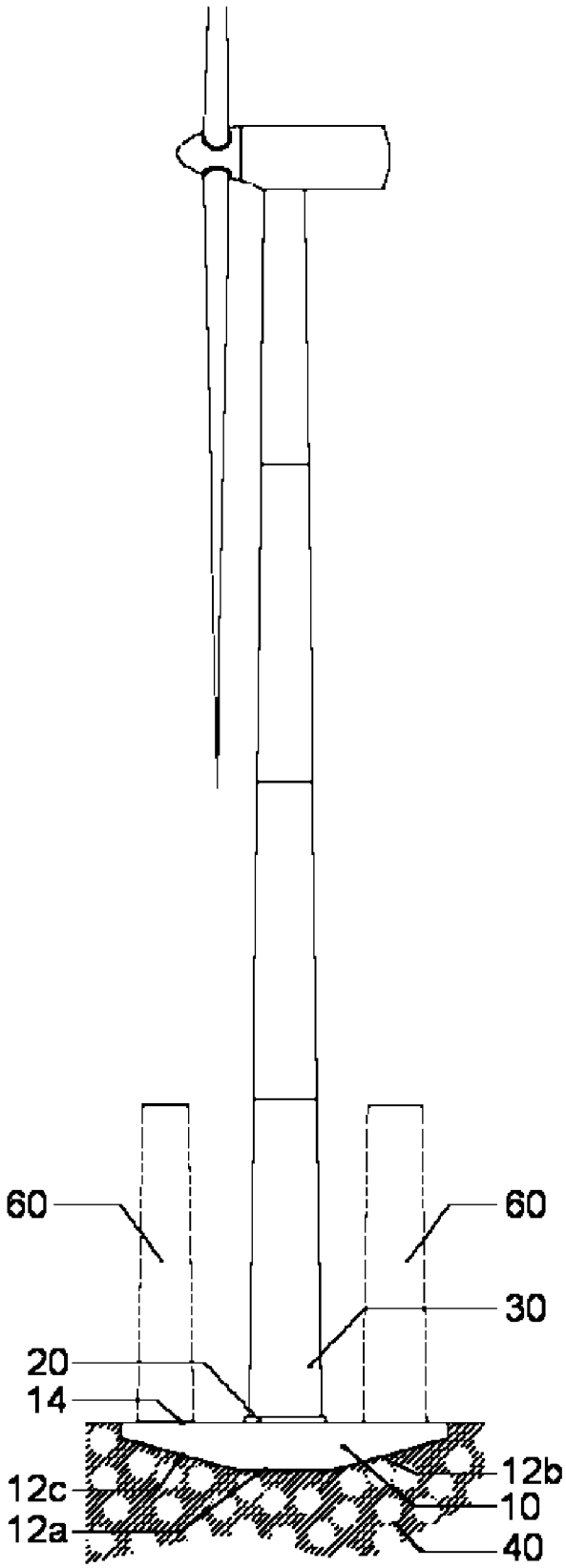

FIG. 2a

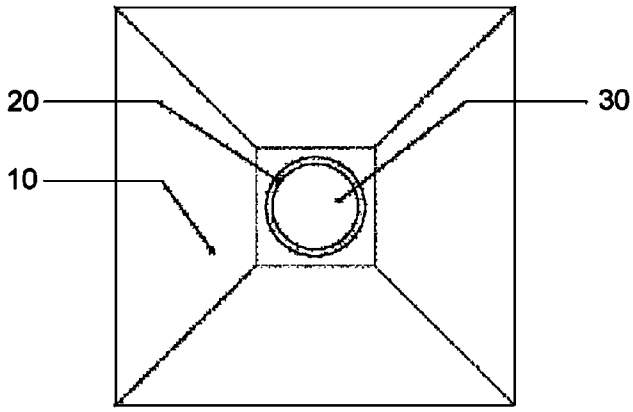

FIG. 2b

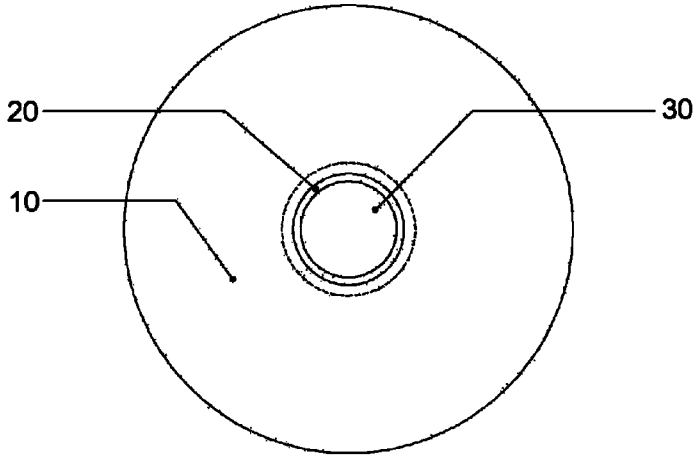

FIG. 2c

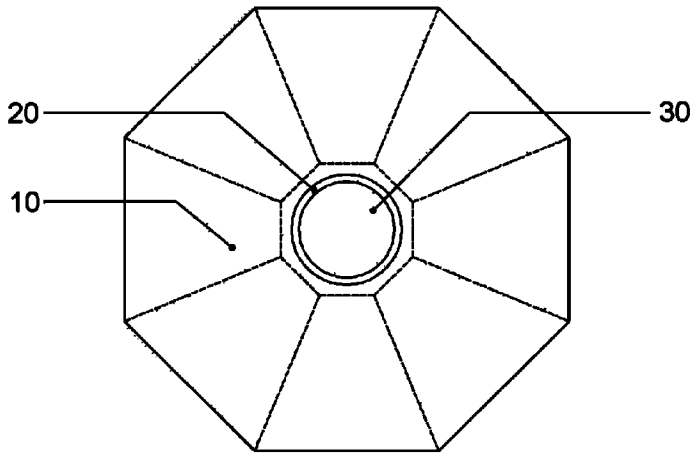

FIG. 2d

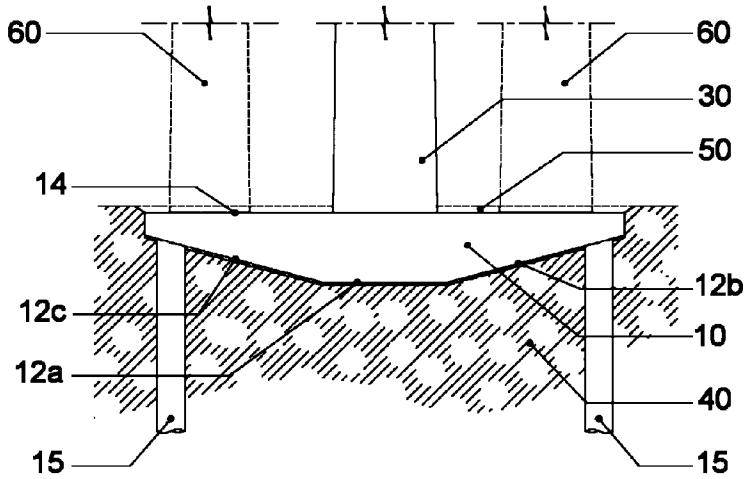

FIG. 3a

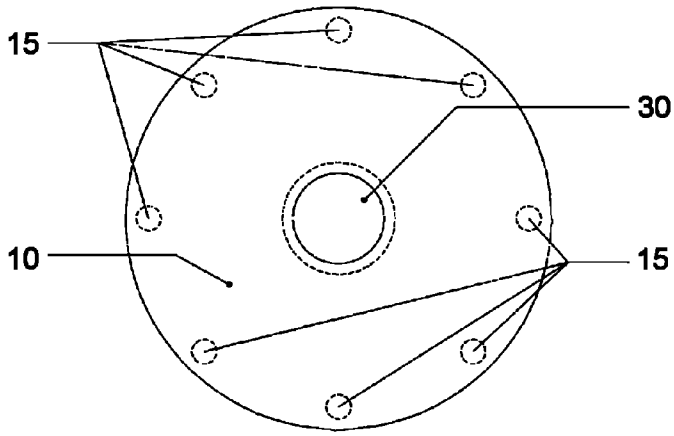

FIG. 3b

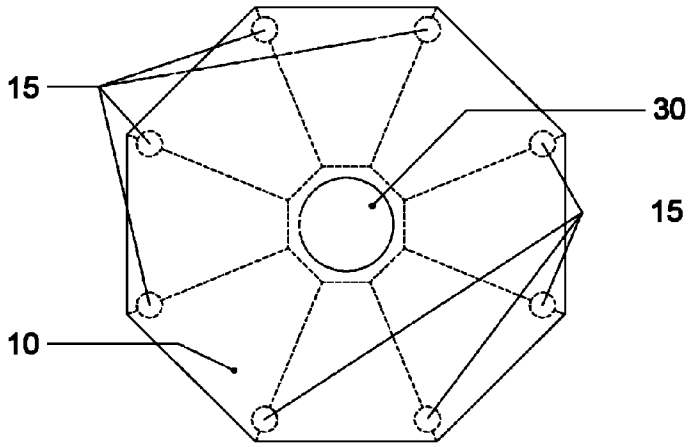

FIG. 3c

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2013/052610

A. CLASSIFICATION OF SUBJECT MATTER
INV. F03D11/04 E02D27/42
ADD.

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)
F03D E02D

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)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2003/170123 A1 (HERONEMUS WILLIAM E [US]) 11 September 2003 (2003-09-11) paragraph [0047]; figure 6	1,4,5
X	AU 20438 83 A (HEDLEY I M; KING W F; MOSSMAN J) 3 May 1984 (1984-05-03) page 4, paragraph 2	1-5
X	US 4 132 082 A (MERJAN STANLEY) 2 January 1979 (1979-01-02) column 3, line 6 - line 17; figures 1,2,12,14	1-5
X	FR 2 916 248 A1 (ALEXANDROFF GEORGES [FR]; ALEXANDROFF GREGOIRE [FR]) 21 November 2008 (2008-11-21) page 8, line 21 - line 32; figure 2	1,6

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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"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
13 May 2013	21/05/2013

Name and mailing address of the ISA/	Authorized officer
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2013/052610

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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