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(54) **FOUNDATION BASE**

FUNDAMENT

BASE DE FONDATION

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(56) References cited:
EP-A1- 1 777 348
EP-A1- 1 777 348
EP-A1- 2 189 576
EP-A1- 2 189 576
ES-A1- 2 378 960
ES-A1- 2 381 510
US-A- 5 613 808

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Description

PURPOSE OF THE INVENTION

[0001] The present invention refers to a foundation base made in concrete for use in offshore wind farms.

STATE OF THE ART

[0002] The installation of wind farms at sea is known and forecasts of great growth in the application of this technology in the coming years have been confirmed. Wind farms built at sea are certainly more expensive, logically depending on the depth of the water in which they are located, but the quality of the wind is better, more constant, its speed higher and turbulence lower and, consequently, the number of hours of production is higher and this, added to the higher air density at sea level, generates higher income than wind farms on land, compensating for the extra initial investment cost.

[0003] The trend for using higher power, larger wind turbines in order to reduce the unit cost of the installed power has been a constant factor in wind turbine development and is, if anything, even more marked in the case of offshore wind farms adapted to the particularly demanding marine conditions. This in turn means a significant increase in the stresses and requirements placed on the foundation/shaft substructure supporting the wind turbines, which, added to their use in sites of variable depth, demands the development of a foundation/shaft substructure adapted to a wide range of depths and for wind turbines of higher power and larger size, while avoiding increasing the complexity and cost of this foundation/shaft substructure.

[0004] In some marine wind farms located in areas where the width or thickness of the sheet of water is limited gravity-based structures (GBSs) are used, comprising structural concrete footings, often with pedestals, that use dry construction, i.e. on dry land. Once constructed, they are transported and anchored using barges and/or marine cranes at installation point for this substructure.

[0005] The mode of construction of this type of gravity-based structure uses formwork and falsework in a dry port or dock, involving the use of a large amount of labour, as well as having large spaces available in the port, as well as cranes with heavy lifting capacity. Additionally, it is necessary to flood the dry dock to float the foundation and drain it again subsequently and, in addition, the method for installing this foundation on the underwater bed limits the depth at which the foundation can be laid, the power and size of the wind turbine that can be installed on this foundation and, therefore, the costs of the foundation system, shaft and wind turbine soar, making the installation of wind turbine farms non-viable on underwater beds where the width of the sheet of water tends to be medium or high.

[0006] Documents EP2189576 and EP1777348 describe gravity foundation having buoyancy cells which are ballasted and guided by means of pontoon capstans until a seabed.

[0007] The construction method for the foundation base enables the construction of the aforementioned base to be automated, reducing the personnel and time required to execute the construction method.

SUMMARY

[0008] The present invention seeks to resolve one or more of the disadvantages stated previously by means of a foundation base constructed on a floating structure as claimed in the claims.

[0009] One purpose of the embodiment is to provide a foundation base used as a gravity-based structure made in reinforced concrete, using a submersible structure equipped with sliding formwork for the purpose to confine the concrete and enable it to be given an essentially quasi-pyramidal caisson form, the cross-section of which decreases with increasing height of the foundation base which, in turn, includes internal cells or holes to increase the buoyancy of the foundation base.

[0010] Another aspect of the embodiment is to provide a foundation base that includes a transition component on which to locate the shaft for a wind turbine tower, at least one connector for transmitting forces between the transition component and the foundation base, with this transition component embedded in the foundation base.

[0011] A further aspect of the embodiment is to provide a hollow section, essentially frustoconical transition component made in steel.

[0012] Yet another aspect of the embodiment is to provide a method for transporting the foundation base to the anchoring point by towing once the foundation base has been extracted from the floating structure by means of partial sinking of the latter.

[0013] Still another aspect of the embodiment is to supply a shaft alignment piece for a tower and a set of bolts for load transmission.

[0014] The construction of foundation bases for offshore wind turbines by means of a floating structure reduces the space needed in port for these and also reduces the need for cranes to move the foundation bases as they are carried on the floating structure.

[0015] The floating structure is partially sunk to facilitate extraction of the foundation base by towing once construction of the foundation base is complete.

[0016] Consequently, the construction of a foundation base by means of the use of a floating structure minimises the necessary resources of space, labour and lifting systems for the gravity-based foundation base.

[0017] The foundation base provides an assembly with the buoyancy and stability required to be transported by floating it on the surface of the water before sinking it.

[0018] The foundation base provides stability to the wind turbine support tower in its installed position, thanks to its own weight and the weight of the ballast, and ensures appropriate transmission of loads to the underwa-

ter bed.

[0019] The gravity-based foundation base on an underwater bed to support a wind turbine in the installed position comprises a foundation caisson having a geometry in the form of a quasi-pyramidal caisson, the section of which decreases as the height of the foundation base increases, and which includes internal buoyancy cells and a transition component of tapered frustoconical form on top of the foundation caisson.

[0020] The foundation base is manufactured by means of a floating- or semi-floating structure of the floating dock, vessel with submersible platform, submersible pontoons guided from fixed structures, etc. type.

[0021] The stepped foundation caisson includes a set of hollow, sealed cells that can be connected together and are configured to be ballasted with sand and/or water.

[0022] Yet another aspect is to use a floating- or semi-floating-type structure for manufacturing reinforced concrete caissons to manufacture foundation caissons having a geometry in the form of a quasi-pyramidal caisson, the section of which decreases as the height of the foundation base increases, and which includes internal buoyancy cells.

BRIEF DESCRIPTION OF THE FIGURES

[0023] A more detailed explanation of the invention is given in the following description based on the attached figures:

- Figure 1 shows a perspective view of a foundation base;
- Figure 2 shows a perspective view of a transition component;
- Figure 3 shows a transverse cross section of the foundation base;
- Figure 4 shows a perspective view of the gravity-based foundation base on an underwater bed to support a wind turbine in the installed position;
- Figure 5 shows an elevation view of a structure for manufacturing reinforced concrete of the floating type; and
- Figures 6a to 6c show the steps in manufacturing a floating reinforced concrete caisson as per the state of the art.

DESCRIPTION OF AN EMBODIMENT

[0024] In relation to Figures 1 to 5, an embodiment is shown of a gravity-based foundation base 11 for an offshore wind turbine that comprises a foundation caisson 12 itself having a geometry essentially in the form of a quasi-pyramidal caisson, including, in turn, internal cells or holes 31 to increase the buoyancy of the foundation base 11 and a transition component 13 essentially of frustoconical form tapered upwards in the installed position.

[0025] The transition component 13 enables the connection to be made between the foundation base 11 and a wind turbine support tower shaft 41 which is also tapered in the upward direction in the installed position; at least one tower shaft 41 alignment flange 22 which makes it possible to prevent undesired inclinations once the foundation base 11 has been anchored to the underwater bed at the installation point; and at least one connecting bolt 21 for transmission of loads between the transition component 13 and the foundation base 11.

[0026] The foundation caisson 12 is arranged in an essentially quasi-pyramidal form in an ascending direction in the installed position, the section of which decreases as the height of the foundation base 11 increases. The stepped foundation caisson 12 includes a set of hollow, sealed cells 31, with the cells 31 connected to each other and floodable.

[0027] The geometry in plan and elevation view of the foundation caisson 12 can vary depending on conditions such as the type of underwater bed, the dynamic conditions of the water and the atmosphere, the power and size of the wind turbine, etc.

[0028] The transition component 13 is inserted by one of its ends through the top part of the foundation caisson 12, with the opposite end of the transition component 13 remaining free. Arranged at the end of the transition component 13 in contact with the foundation base 11 is a set of connecting bolts 21 responsible for transmitting loads to the foundation base 11 and guaranteeing adherence between the transition component 13 itself and the foundation base 11.

[0029] At the opposite, free, end of the transition component 13 is a wind turbine tower shaft 41 alignment piece or flange 22.

[0030] With respect, now, to Figure 5, this shows a structure 51 for manufacturing floating reinforced concrete caissons of the caisson vessel type where the foundation caisson 12 is manufactured compartmented into cells 31 capable of being ballasted or flooded and unballasted, being manufactured sheltered from the waves.

[0031] The structure 51 can also be of the semi-floating structure, floating dock, vessel with submersible platform, submersible pontoons guided from fixed structures, etc. type.

[0032] The caisson vessel 51 comprises a pontoon with four towers so as to always have the necessary buoyancy and to control the combination of caisson vessel/foundation base at all times. The foundation caisson 12 is constructed in reinforced concrete in the caisson vessel 51, without interfering with the traffic in the port where it is moored.

[0033] The lateral towers are capable of being ballasted and unballasted to guarantee the naval stability of the combination of caisson vessel/foundation base. Metal structures are arranged on each of the towers, in a truss structure to support the superstructure and the sliding formwork by means of a set of winches. A support pon-

toon is the working platform enabling dry manufacture on its deck of the foundation caisson 12 and the first few metres of the transition component 13. This pontoon is then progressively sunk as the erection of the foundation base 11 progresses.

[0034] With respect, now, to Figures 6a to 6c, the process of manufacturing the caisson 12 includes the placement of a reinforcement mesh for the base slab on the support pontoon, concreting the base slab, descending sliding of the formwork and the start of concreting of the foundation caisson shaft and concreting of the shaft until completion. Curing of the concrete is performed directly by submerging the caisson 12 in the water. This procedure does not impair the characteristics or durability of the concrete.

[0035] Launching of the caisson 12 is achieved by immersing the support pontoon. On occasions, launching is a critical operation for the naval stability of the floating structure 51 and of the caisson 12. Once the caisson has been launched, the caisson 12 is towed to its installation position.

[0036] Once the foundation is out of the caisson vessel 51 and moored in the port, the transition component 13 is placed, having previously arranged the tower shaft 41 alignment flange 22 and the connecting bolts 21.

[0037] If necessary, the foundation base/tower shaft assembly would be ballasted to achieve the appropriate freeboard for transfer by towing to its final installation position, where the underwater bed area 14 has previously been prepared for seating the foundation base 11, as shown in Figure 1.

[0038] Once the corresponding underwater bed area 14 has been prepared, that is the seating bed on which the foundation base 11 is located by simply allowing it to fall under gravity by means of controlled ballasting to the installation point, such that the preparation of the underwater bed and the seating bed for the foundation base 11 are performed in immediately consecutive operations, without allowing time for the prepared seating bed to undergo alterations due to movements of the water, ensuring perfect seating of the foundation base 11.

[0039] The foundation base 11 determines a structural assembly with a weight and a base that enable seating by gravity on an underwater bed to support a wind turbine arranged on a tower placed on the foundation base.

[0040] However, for an application scenario with seating on a soft underwater bed, a means of anchoring is arranged on the foundation base 11, essentially in the form of piles, for example, to ensure seating under gravity of the foundation base 11.

[0041] The construction procedure for the gravity-based foundation base 11 on a floating structure 51 comprises the following steps:

[0042] Manufacture of the lower or base slab of the foundation base 11 on the floating structure or caisson vessel, construction of the stepped quasi-pyramidal foundation caisson 12 using the sliding formwork installed on the caisson vessel 51. Simultaneous sinking of the lower platform of the floating structure of the caisson vessel 51 on which the foundation base 11 is supported. Once the foundation caisson 12 has been completed, it is extracted from the floating structure of the caisson vessel 51 by towing by floating.

[0043] Once the foundation base is complete, the transition component, the connecting bolts and the wind turbine support tower alignment piece are assembled successively.

[0044] Similarly, works are carried out to prepare the foundation seating bed on the underwater bed at the installation position and the foundation base is towed by floating to the anchoring point. Finally, the gravity-based foundation base is submerged by controlled flooding, totally or partially filling the foundation caisson 12 cells with sand ballast and/or water.

[0045] In transport by floating of the foundation base/transition component, auxiliary floating structures can be used to improve the buoyancy and stability of the assembly. These auxiliary floating structures are temporarily abutted against and connected to this assembly with appropriate means of anchoring.

Claims

1. A gravity-based **foundation base** on an underwater bed to support a wind turbine in the installation position; wherein said foundation base (11) comprises a foundation caisson (12) having a geometry in the form of a quasi-pyramidal caisson, the section of which decreases as the height of the foundation base (11) increases; the gravity-based foundation base being **characterised in that** said foundation caisson (12) includes internal buoyancy cells (31) which are hollow and sealed and connectable together to be controlled ballasting; and a transition component (13) of tapered frustoconical form on top of the foundation caisson (12).

2. **Base** according to claim 1; **characterised in that** the foundation base (11) is manufactured by means of a floating- or semi-floating structure (51) of the floating dock, vessel with submersible platform, submersible pontoons guided from fixed structures, etc. type.

3. **Base** according to claim 1; **characterised in that** the transition component (13) is adapted to join the foundation base (11) and a wind turbine support tower shaft (41) which is also tapered in the upward direction in the installed position; at least one tower shaft (41) alignment flange (22) cooperates with the transition component (13) in the vertical alignment of the foundation base (11) and the tower shaft (41).

4. Method for manufacturing reinforced concrete caissons of the floating- or semi-floating-type to manu-

facture a gravity-based foundation base (11) on an underwater bed to support a wind turbine in the installation position; wherein the foundation base (11) comprises a foundation caisson (12) having a geometry in the form of a quasi-pyramidal caisson, the section of which decreases as the height of the foundation base (11) increases; the gravity-based foundation being **characterised in that** said foundation caisson (12) includes internal buoyancy cells (31) which are hollow and sealed and connectable together to be controlled ballasting; and a transition component (13) of tapered frustoconical form on top of the foundation caisson (12).

Patentansprüche

1. Schwerkraftbasierter Fundamentsockel auf einem Unterwasserbett, um eine Windturbine in der Installationsstellung zu tragen; wobei der Fundamentsockel (11) einen Fundamentcaisson (12) umfasst, der eine Geometrie in der Form eines quasi-pyramidalen Caissons hat, dessen Querschnitt mit zunehmender Höhe des Fundamentsockels (11) abnimmt; wobei der schwerkraftbasierte Fundamentsockel **dadurch gekennzeichnet ist, dass** der Fundamentcaisson (12) innere Auftriebszellen (31), die hohl und abgedichtet und miteinander verbindbar sind, um gesteuert ballastierend zu sein; und eine Übergangskomponente (13) von verjüngter Kegelstumpfform oben auf dem Fundamentcaisson (12) enthält.

2. Sockel nach Anspruch 1; **dadurch gekennzeichnet, dass** der Fundamentsockel (11) mittels einer schwimmenden oder halbschwimmenden Struktur (51) nach Art des Schwimmdocks, Schiffs mit Tauchplattform, der von festen Strukturen geführten Tauchpontons, etc., hergestellt ist.

3. Sockel nach Anspruch 1; **dadurch gekennzeichnet, dass** die Übergangskomponente (13) dafür angepasst ist, den Fundamentsockel (11) und einen Windturbinentragturmschaft (41), der ebenfalls in der Aufwärtsrichtung in der installierten Stellung verjüngt ist, miteinander zu verbinden; wobei mindestens ein Turmschaft- (41) Ausrichtungsflansch (22) mit der Übergangskomponente (13) bei der vertikalen Ausrichtung des Fundamentsockels (11) und des Turmschafts (41) kooperiert.

4. Verfahren zum Herstellen verstärkter Betoncaissons der schwimmenden oder halbschwimmenden Art, um einen schwerkraftbasierten Fundamentsockel (11) auf einem Unterwasserbett herzustellen, um eine Windturbine in der Installationsstellung zu tragen; wobei der Fundamentsockel (11) einen Fundamentcaisson (12) umfasst, der eine Geometrie in der Form eines quasi-pyramidalen Caissons hat, dessen Querschnitt mit zunehmender Höhe des Fundamentsockels (11) abnimmt; wobei das schwerkraftbasierte Fundament **dadurch gekennzeichnet ist, dass** der Fundamentcaisson (12) innere Auftriebszellen (31), die hohl und abgedichtet und miteinander verbindbar sind, um gesteuert ballastierend zu sein; und eine Übergangskomponente (13) von verjüngter Kegelstumpfform oben auf dem Fundamentcaisson (12) enthält.

Revendications

1. Base de fondation fondée sur la pesanteur sur un lit sous-marin pour supporter une éolienne en position d'installation ; dans laquelle ladite base de fondation (11) comprend un caisson de fondation (12) ayant une géométrie sous la forme d'un caisson quasi- pyramidal, dont la section diminue à mesure que la hauteur de la base de fondation (11) augmente ; la base de fondation fondée sur la pesanteur étant **caractérisée en ce que** ledit caisson de fondation (12) comprend des cellules de flottaison internes (31) qui sont creuses et scellées et raccordables l'une à l'autre pour régler le ballastage ; et un composant de transition (13) de forme tronconique amincie pardessus le caisson de fondation (12).

2. Base selon la fondation (1), **caractérisée en ce que** la base de fondation (11) est fabriquée au moyen d'une structure flottante ou semi-flottante (51) du type à dock flottant, à vaisseau à plateforme submersible, à pontons submersibles guidés à partir de structures fixes, etc.

3. Base selon la revendication 1, **caractérisée en ce que** le composant de transition (13) est adapté pour joindre la base de fondation (11) et un arbre de tour de support d'éolienne (41) qui est également aminci dans le sens ascendant en position installée ; au moins une bride (22) d'alignement de l'arbre (41) de la tour coopérant avec le composant de transition (13) dans l'alignement vertical de la base de fondation (11) et de l'arbre (41) de la tour.

4. Procédé de fabrication de caissons de béton armé du type flottant ou semi-flottant pour fabriquer une base de fondation (11) fondée sur la pesanteur sur un lit sous-marin pour supporter une éolienne en position d'installation ; dans lequel la base de fondation (11) comprend un caisson de fondation (12) ayant une géométrie sous la forme d'un caisson quasi-pyramidal dont la section diminue à mesure que la hauteur de la base de fondation (11) augmente ; la fondation fondée sur la pesanteur étant **caractérisée en ce que** ledit caisson de fondation (12) comprend des cellules de flottaison internes (31) qui sont creuses et scellées et raccordables l'une à l'autre pour

contrôler le ballastage ; et un composant de transition (13) de forme tronconique amincie par-dessus le caisson de fondation (12).

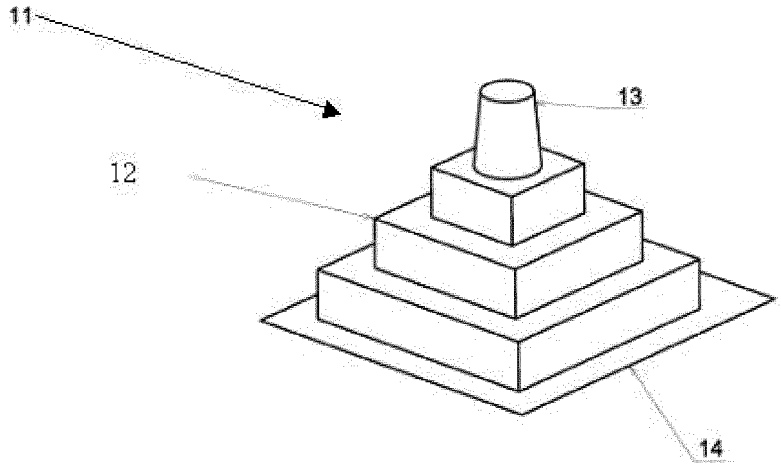

FIG 1

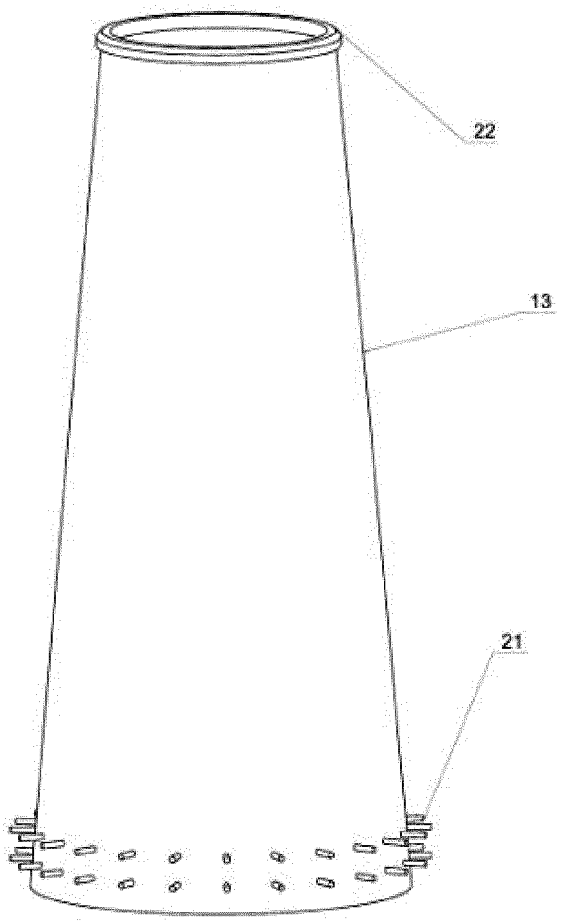

FIG 2

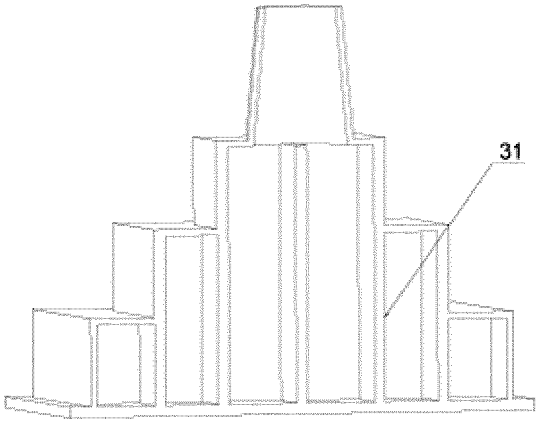

FIG 3

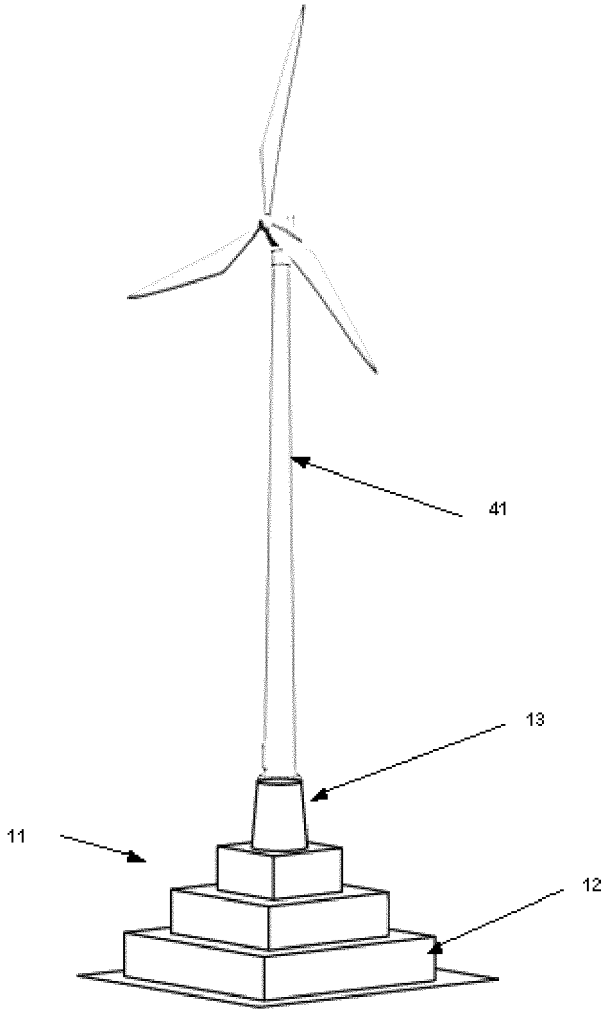

FIG 4

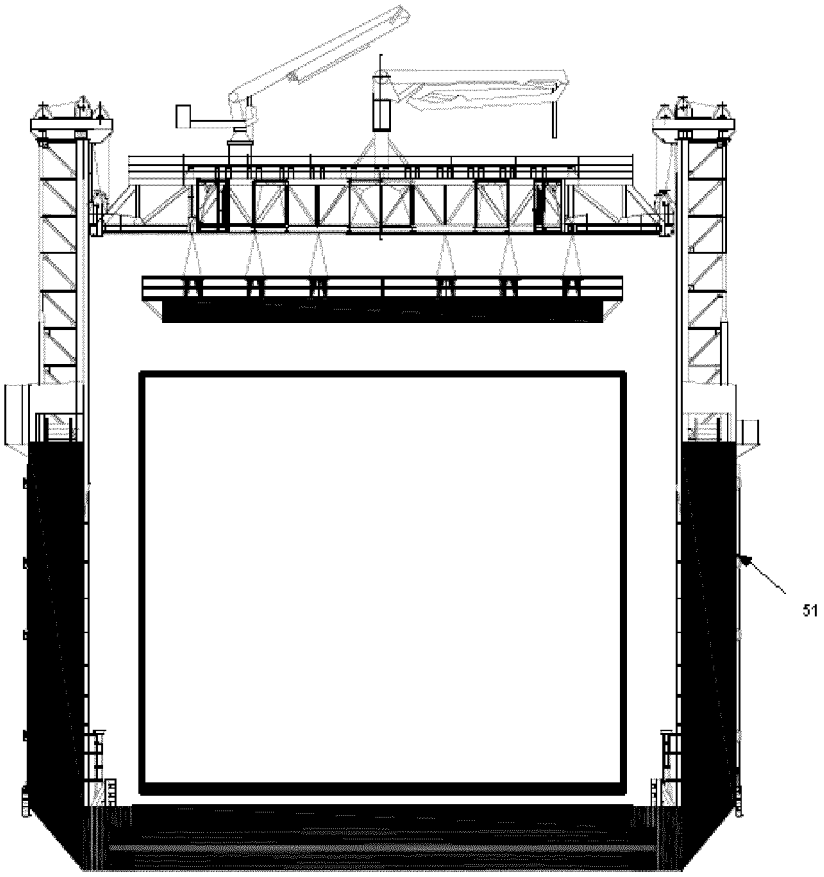

FIG 5

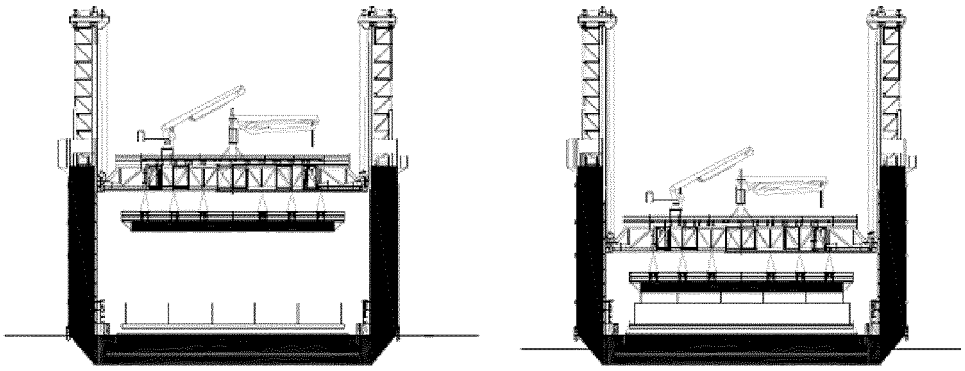

FIG 6a

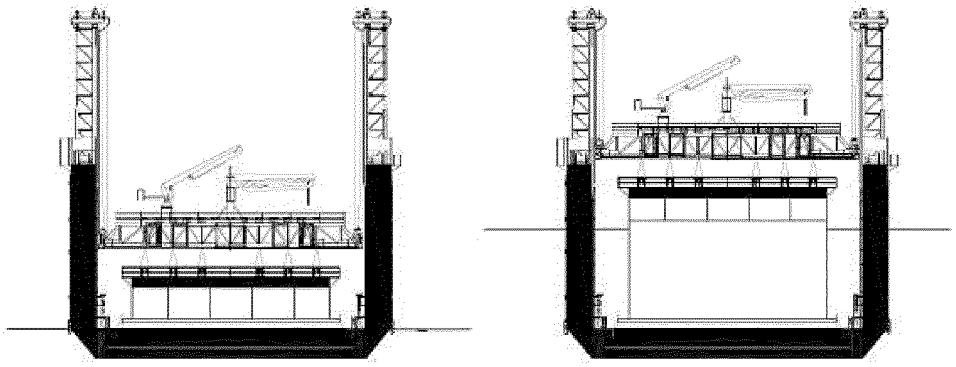

FIG 6b

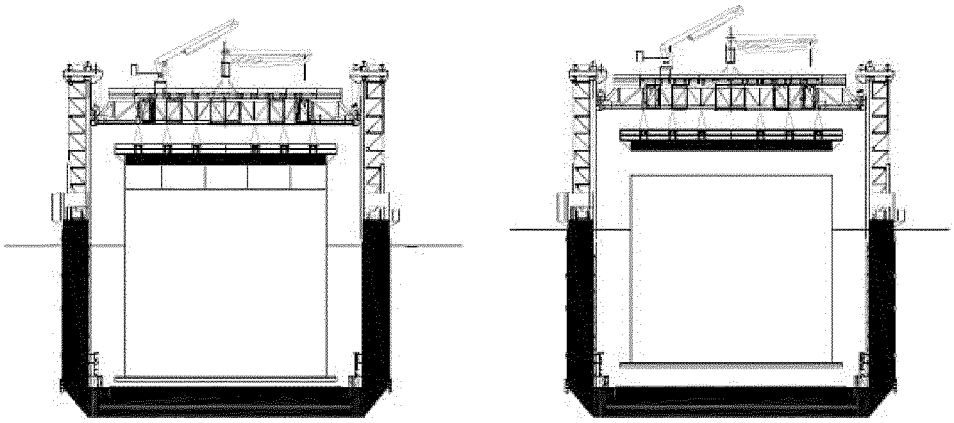

FIG 6c

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- EP 2189576 A **[0006]**
- EP 1777348 A **[0006]**