

STRUCTURALLY INTEGRATED MOORING DOLPHINS FOR NEARSHORE DEVELOPMENT

FIELD OF THE INVENTION

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The present invention relates to a floating structure with an integrated mooring dolphin structure for nearshore development. More particularly, the invention relates to a floating structure having an integrated mooring dolphin structure that provides a robust station-keeping solution for floating structure to be deployed in shallow water.

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BACKGROUND OF THE INVENTION

The growing world population and increasing urbanization, coupled with shift and concentration of people to large metropolitan coastal areas, drives the need to utilize the surrounding water basins and sea space for commercial, residential and infrastructure development. These circumstances are exacerbated by the rising sea level and cost of land reclamation.

A cost-effective and resilient solution to these problems is the adoption of floating infrastructure. Among its apparent advantages such as adaptation to the rising sea level, mobility, off-site construction etc., there are certain challenges that have to be addressed in a robust and reliable way. One such challenge is the station-keeping of the floating infrastructure. The station-keeping system must be able to restrain lateral movement of the floating modules under external forces such as the wind, wave and the current while allowing vertical translation of the floating modules due to the tide cycles and rising sea level. Conventional mooring systems can be used to provide the station-keeping for the floating modules. However, conventional mooring systems such as catenary and taut mooring systems are not suitable for large floating modules that are to be deployed in relatively shallow water up to approximately 300m water depth. The application of such conventional mooring systems in shallow water is restricted by their own functional requirements. For example, taut mooring systems require very complex configuration and high number of mooring lines stretching far beyond the footprint of the floating structure. Soft seabed conditions, which are typical for nearshore coastal areas also provide poor holding capacity for the conventional anchors. The catenary mooring lines help to restrain the offsets of the floating structure by their self-weight, however in shallow water, the length of the lines is restricted, making them impractically large and heavy to install and maintain. It is also to be noted that conventional mooring solutions

are not as stiff as they should be, thus resulting in larger offsets which poses additional operational difficulties. The large number of mooring lines may also interfere with one another and dangling mooring lines can be unsightly. These problems are even more pronounced for larger nearshore developments.

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It is therefore desirable to provide a structure and solution that seeks to address at least one of the problems described hereinabove, or at least to provide an alternative.

SUMMARY OF THE INVENTION

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The above and other problems in the art are solved and an advance in the art is made by structures and solutions provided by embodiments in accordance with the invention.

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An advantage of embodiments of a structure and solution in accordance with the invention is that the structure provides a robust station-keeping solution for any floating structures nearshore, or offshore in shallow waters.

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In accordance with an aspect of the invention, a floating structure with an integrated mooring dolphin structure to be installed on a body of water is provided. The floating structure comprises a hull having a top surface and a bottom surface; and at least one integrated mooring dolphin structure comprising a channel extending perpendicularly from the bottom surface of the hull, the channel having an inner surface and an outer surface; a mooring pile having a first part configured to be embedded into a seabed and a second part disposed within the channel to be integrated into the floating structure; a fender system with low friction pad, provided around the second part of the mooring pile; and at least one diaphragm ring disposed on the outer surface of the channel; and wherein the mooring pile is restrained from lateral translation within the channel while able to translate in vertical direction in response to tidal changes in the level of body of water.

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In accordance with embodiments of the invention, the integrated mooring dolphin structure is positioned below the level of body of water when the floating structure is installed on the body of water.

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In accordance with embodiments of the invention, the floating structure comprises a plurality of integrated mooring dolphin structures.

BRIEF DESCRIPTION OF THE DRAWINGS

The above advantages and features of this invention will be further described in the following detailed description with reference to the drawings:

Figure 1a is an illustration of a floating structure comprising at least one integrated mooring dolphin structure in accordance with an embodiment of the present invention.

Figure 1b shows an exploded view of the integrated mooring dolphin structure in accordance with an embodiment of the present invention.

Figure 2 is an illustration showing the direction of loads exerted on the floating structure and the direction of the transfer of loads from the mooring pile to the floating structure.

DETAILED DESCRIPTION

This invention relates to a floating structure with an integrated mooring dolphin structure to be installed on a body of water. Figure 1a illustrates the invention in an embodiment of a floating structure 100 with an integrated mooring dolphin structure 102. Figure 1b shows an exploded view of the integrated mooring dolphin structure 102 in accordance with an embodiment of the present invention.

Referring to Figure 1b, the floating structure 100 comprises a hull 104 having a top surface 104a and a bottom surface 104b; and at least one integrated mooring dolphin structure 102. The integrated mooring dolphin structure 102 comprises a channel 106 extending perpendicularly from the bottom surface 104b of the hull wherein the channel 106 has an inner surface 106a and an outer surface 106b; and a mooring pile 112 having a first part 112a configured to be embedded into a seabed 114 and a second part 112b disposed within the channel 106 to be integrated into the floating structure 100. A fender system 107 with low friction pad is provided around the second part 112b of the mooring pile 112, and at least one diaphragm ring is provided and disposed on the outer surface of the channel. In this configuration, the mooring pile is restrained from lateral translation within the channel while able to translate in vertical direction in response to tidal changes in the level of body of water 116.

The integrated mooring dolphin structure 102 of the present invention can be integrated into any suitable type of floating structure that has a hull. The hull is a watertight enclosure and the space within the watertight enclosure defines an area that can be used to house various services, entertainment functions and activities. The hull may include one or more decks to provide more spaces for housing the various services, entertainment functions and activities. The hull can be of any suitable size, shape and height. The height should be within a range that allows sufficient space to install and support the mooring piles. The hull includes a ballast system that helps to adjust the overall weight of the floating structure, provide stability and helps to keep the floating structure afloat or to lower it to a desired level for repair and maintenance as required. Any suitable type of ballast system may be used without departing from the scope of the invention.

In one embodiment, the channel 106 is in the form of a well provided within the body of the hull and it extends perpendicularly from the bottom surface 104b of the hull 104. In this embodiment, the length of the channel is the same as the height of the hull. In another embodiment, the channel 106 is a standalone channel that extends perpendicularly from the bottom surface 104b of the hull 104. In this embodiment, the channel is positioned juxtapose the watertight enclosure of the hull such that any load that is to be exerted on the mooring pile 112 within the channel 106 can be transferred to the hull 104 of the floating structure. In this embodiment, the channel can be of any suitable length. The channel may have a length that is the same as the height of the hull or a length that is longer or shorter than the height of the hull. In one embodiment, a plurality of the standalone channels is provided around the hull of a floating structure. A plurality of floating structures with similar configurations may be provided, with each floating structure connected to another floating structure through interlocking the standalone channels of one floating structure to the standalone channels of another floating structure.

In all embodiments, the length of the channel should be sufficient to receive a sufficient length of the mooring pile so as to provide a stable station-keeping system that is able to keep the floating structure within designated area. In various embodiments, the internal diameter of the channel is of a size sufficient to receive the mooring pile 112 and the fender system with low friction pad 108 snugly. In this configuration, the mooring pile is restrained from lateral translation within the channel due to limited space between the mooring pile and the inner surface of the channel. This helps to keep the floating

structure within a confined space but allows translation in vertical direction in response to tidal changes in the level of body of water.

5 The mooring pile 112 is a monopile and has a diameter that allows it to be slidably mounted into the channel of the mooring dolphin structure. It also has a shaped top that does not cut into the fender system 107 with low friction pad as the hull may experience some heel and pitch concurrent with shifting tides and/or wave action which causes the floating structure to move in more than 1 plane. The mooring pile 112 is mounted into the channel 106 such that an air column remains between the bottom surface 104b of the hull and the top end of the second part 112b of the mooring pile. The air column provides an area for the floating structure to move in vertical direction in response to tidal changes in the level of body of water. The volume of the air column can be adjusted using the ballast system to provide sufficient area for heave motion of the floating structure in response to the tidal changes.

15 The mooring pile may have any suitable length, depending on the water depth, depth of seabed and height of the hull. The length should be sufficient to provide desired anchorage of the mooring pile into the seabed and for mounting into the channel. The length of the second part of the mooring pile that is mounted into the channel is dependent upon various factors including, but not limited to, tidal range, floating structure stability and motion limitation.

25 The fender system 107 with low friction pad may be provided with a single piece of low friction material or with as a plurality of smaller pieces of low friction materials put together into a single piece of material. In one embodiment, the fender system is a jacket fender with low friction pad. The low friction pad of the fender system can have any suitable thickness. The thickness should be sufficient to cushion the impact cause by the lateral translation of the hull onto the mooring pile. The low friction pad may be made of any suitable material known in the art including, but not limited to, Teflon. The low friction pad should also be of sufficient length to be in contact with the mooring pile with tidal changes. In another embodiment, additional low friction pads 108 may also be provided on the inner surface 106a of the channel 106.

35 The diaphragm ring 110 provided on the outer surface 106b of the channel 106 is to cushion the load exerted on the mooring pile. This helps to distribute the load evenly throughout the floating structure. The diaphragm ring 110 may be made of any suitable low friction material known in the art including, but not limited to, Teflon. The diaphragm

ring may be a single piece of material or consists of a plurality of smaller pieces of materials. In one embodiment, the diaphragm ring consists of a plurality of smaller pieces of materials that are stacked into cassettes. This provides ease of maintenance, removal and replacement of the diaphragm ring. The diaphragm ring should cover an area on the channel that is sufficient to effectively cushion the load exerted on the mooring pile. The diaphragm ring may have any suitable thickness to provide sufficient support and resist lateral forces. The diaphragm ring should be positioned at the same area where the fender system with low friction pad is provided. This is to provide maximum cushioning and transferring of the load exerted on the mooring pile to the hull of the floating structure. In one embodiment, the surface area covered by the diaphragm ring on the outer surface of the channel is larger than the surface area covered by the fender system with low friction pad. This is to provide an optimal transfer of load from the mooring pile to the floating structure.

The floating structure of the present invention further includes a hatch opening provided on the top surface of the hull. The hatch opening forms an integral part of the channel. A hatch cover is provided to cover the hatch opening. These features are provided to facilitate repair and maintenance of the fender system with low friction pad. During repair and maintenance, the hatch cover is removed to allow the mooring pile to extend to the top surface of the hull for repair and maintenance work to be done on the fender system with low friction pad that is attached to the mooring pile. The extension of the mooring pile to the top surface of the hull can be done using any methods known in the art including, but not limited to, controlling the ballast system of the floating structure to allow the floating structure to be lowered to a level sufficient for the mooring pile to be extended to the top surface of the hull of the floating structure for repair and maintenance works to be performed above water level. Any suitable type of hatch cover for use on vessels and floating structures can be employed without departing from the scope of the invention.

The mooring dolphin structure 102 of the present invention forms an integral part of the floating structure 100. It is structurally integrated into the hull of the floating structure. The number of mooring dolphin structures provided may vary, depending on the size and weight of the floating structure, water depth, the seabed conditions and the environmental conditions where the floating structure is to be installed. The mooring dolphin structure 102 can be located anywhere within the hull 104 of the floating structure. In one embodiment, the mooring dolphin structure 102 is located at the periphery of the floating structure 100, with the mooring pile 112 enclosed within the

hull 104 of the floating structure. In the exemplary embodiment shown in Figure 1a, four mooring dolphin structures 102 are provided, each disposed at the corner end of the floating structure 100. The mooring dolphin structure of the present invention provides a robust station-keeping solution for floating structures in shallow waters. The term
5 “shallow water” as used herein refers to water with a depth up to approximately 305m.

In conventional structure, mooring dolphins extends above the water level and are situated alongside floating structure. In the present invention, the mooring dolphin structure is integrated within the hull of the floating structure rather than situated by the
10 sides of the hull. In particular, the mooring pile of the mooring dolphin structure is situated within the channel and this restrains lateral translation of the floating structure while allowing translation of the floating structure in vertical direction in response to tidal changes in the level of body of water. This is facilitated by the diaphragm ring lined on the outer surface of the channel. External loads that are exerted on the floating structure
15 will be transferred to the mooring pile by pressure loads. The concrete hull is designed to be able to sustain these loads by having the diaphragm ring surrounding the channel. This allows all the mooring dolphin structures to resist the loads regardless of the loads' direction. This is beneficial for the floating structure as the loads will be distributed evenly, thus helping to reduce the weight and cost of the floating structure. Figure 2
20 illustrates how the pressure loads from the mooring pile 112 are transferred to the hull 104 of the floating structure. Arrow 210 shows the direction of the external forces/ motion of the floating structure while arrows 212 shows the direction of the transfer of loads from the mooring pile 112 to the hull 104 of the floating structure.

25 The floating structure with the integrated mooring dolphin structure of the present invention has several advantages. Firstly, the integrated mooring dolphin structure allows for more cost-effective design and/or higher redundancy. Secondly, the structure provides a reliable and robust station-keeping solution to any floating structures nearshore or offshore in shallow waters. The structurally integrated mooring dolphins
30 are located within the hull of the floating structure, allowing for better redistribution of the loads within the floating structure and higher and more uniform stiffness in all directions. This helps to minimize the offsets of the floating structure and the deflection of the mooring pile. Thirdly, structurally integrated mooring dolphins, being located within the perimeter of the floating structure does not require large spaces between the floating
35 structures when connected to form a larger nearshore development. This improves the functionality and the operation of the overall nearshore development.

The above is a description of the subject matter the inventors regard as the invention and is believed that others can and will design alternative embodiments of invention as set forth in the following claims.

CLAIMS

1. A floating structure with an integrated mooring dolphin structure to be installed on a body of water, comprising:

5 a hull having a top surface and a bottom surface; and

at least one integrated mooring dolphin structure comprising:

a channel extending perpendicularly from the bottom surface of the hull, the channel having an inner surface and an outer surface;

10 a mooring pile having a first part configured to be embedded into a seabed and a second part disposed within the channel to be integrated into the floating structure;

a fender system with low friction pad, provided around the second part of the mooring pile; and

15 at least one diaphragm ring disposed on the outer surface of the channel; and

wherein the mooring pile is restrained from lateral translation within the channel while able to translate in vertical direction in response to tidal changes in the level of body of water.

20 2. The floating structure according to claim 1, wherein the integrated mooring dolphin structure is positioned below the level of body of water when the floating structure is installed on the body of water.

25 3. The floating structure according to claim 1, wherein the floating structure comprises a plurality of integrated mooring dolphin structures.

4. The floating structure according to claim 3, wherein the plurality of integrated mooring dolphin structures are provided at the periphery of the floating structure.

30 5. The floating structure according to claim 1, wherein the fender system comprises a plurality of low friction pads.

6. The floating structure according to claim 1, wherein the diaphragm ring comprises a plurality of low friction material pads that are stacked into cassettes.

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7. The floating structure according to claim 1, wherein the diaphragm ring is disposed around the outer surface of the channel where the fender system with low

friction pad is provided within the channel such that any external load that are to be exerted on the floating structure will be transferred from the mooring pile to the diaphragm ring to allow even distribution of the load on the floating structure.

5 8. The floating structure according to claim 1, wherein the hull comprises a hatch opening that forms an integral part of the channel.

9. The floating structure according to claim 8, wherein the hull comprises a hatch cover positioned over the hatch opening.

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10. The floating structure according to claim 1, wherein the channel is in the form of a well provided within the hull.