

FLOATING PLATFORM AND METHOD OF ASSEMBLY

TECHNICAL FIELD

5 The present invention relates generally to floating platforms and methods of assembling floating platforms. In particular, the invention relates to floating platforms that are moored in shallow and/or calm water bodies.

BACKGROUND OF THE INVENTION

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 When floating platforms are deployed in water bodies such as lakes, dams, shallow water bodies and etc., these floating platforms will be subjected to lateral forces arising from wind, waves or currents. In order to minimise lateral movements and maintain stability, these floating platforms are usually connected to dolphin structures that surround a perimeter of the floating platforms and/or are anchored to a floor of the water body.

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 However, when the size of the floating platform increases to accommodate larger loads, the number and/or size of the dolphin structures will also need to be increased accordingly to support the floating platform and prevent the larger lateral forces from destabilising the floating platform. This results in an increase in costs and foot print size that causes more disturbance on the floor of the water body.

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 Further, as the dolphin structures are rigid, the weight of the floating platform and any loads on the floating platform including lateral forces acting on the floating platform will be transmitted to the floor of the water body. This is undesirable and potentially leads to soil settlement issues, especially when the floor of the water body is soft.

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 The deficiencies of the dolphin structures have spurred development of alternative platform designs such as the tension leg platform (TLP). In a TLP design, a buoyant hull supports the platform using an intricate mooring system that keeps the TLP in place. The buoyancy of the hull offsets the weight of the platform and clusters of tension legs secure the structure to a foundation on the seabed. The foundation is kept stationary by piles driven into the seabed.

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While the weight of the platform is not transmitted to the seabed in the TLP design, the foundation of the TLP nevertheless experiences vertical stresses arising from increased tension in the tension legs due to lateral forces arising from winds, waves or currents disturbances. This may result in long pile length in the TLP design to ensure soil capacity, hence the TLP is generally not applicable for shallow water deployment.

The present invention seeks to overcome the above problems by providing a stable floating platform that is able to withstand lateral forces with minimal disturbances to the floor of the water body even though the floating platform is moored to the floor. Such floating platforms would be suitable for deployment in shallow and/or calm waters or where the floor of the water body is expected to be soft, without causing soil settlement issues.

SUMMARY OF THE INVENTION

The above and other problems in the art are solved and an advance in the art is made in accordance with this invention.

A first advantage of a floating platform in accordance with this invention is that the floating platform mitigates soil settlement at the site of deployment.

A second advantage of a floating platform in accordance with this invention is that the floating platform has a small footprint size.

A third advantage of a floating platform in accordance with this invention is that the floating platform is stable and able to reduce lateral movements arising from lateral forces like wind, waves and currents.

A fourth advantage of a floating platform in accordance with this invention is that the floating platform is suitable for deployment in shallow water.

In accordance with a first aspect of the invention, the invention comprises a floating platform for deployment on a water body, the floating platform comprises a buoyant platform that is configured to float on the water body, a gravity base that is configured to be submerged in the water body, one or more tethers that couple the buoyant platform to the gravity base, wherein a weight of the gravity base or part thereof is

transmitted to the buoyant platform, and one or more piles that is configured to be installed into a floor of the water body, wherein the gravity base is movably coupled to a portion of the one or more piles above the floor of the water body such that the gravity base is movable along a vertical axis of the one or more piles when a lateral force acts on the buoyant platform.

In accordance with embodiments of the first aspect of the invention, the one or more tethers each comprises a high tensile line.

In accordance with embodiments of the first aspect of the invention, the floating platform further comprises one or more mooring lines that couples the buoyant platform to land, the floor of the water body or a fixed structure.

In accordance with embodiments of the first aspect of the invention, the floating platform further comprises one or more dolphin structures that is coupled to the buoyant platform, wherein the one or more dolphin structures anchors the floating platform to the floor of the water body.

In accordance with embodiments of the first aspect of the invention, the buoyant platform further comprises one or more airbags to provide buoyancy.

In accordance with embodiments of the first aspect of the invention, the buoyant platform comprises one or more tether access shafts that is defined between a top surface and a bottom surface of the buoyant platform for receiving the one or more tethers.

In accordance with embodiments of the first aspect of the invention, the buoyant platform comprises one or more winches for adjusting a length of the one or more tethers between the buoyant platform and the gravity base.

In accordance with embodiments of the first aspect of the invention, the weight of the gravity base is selected based on a displacement of the buoyancy platform in the water body.

In accordance with embodiments of the first aspect of the invention, a ratio between the displacement of the buoyant platform and a displacement of the gravity base in the water body is selected to be 5:1 (metric tonne (mt):metric tonne (mt)).

5 In accordance with embodiments of the first aspect of the invention, the gravity base comprises a central aperture for receiving the one or more piles.

10 In accordance with embodiments of the first aspect of the invention, the buoyant platform comprises one or more ballast compartments for adjusting buoyancy of the buoyant platform.

In accordance with embodiments of the first aspect of the invention, the floating platform is configured to deploy in shallow water bodies of less than 50 m in depth.

15 In accordance with a second aspect of the invention, the invention comprises a method of setting up a floating platform of this invention in a water body, wherein the method comprises installing one or more piles in a floor of the water body, providing a buoyant platform that is configured to float on the water body, coupling the buoyant platform to a gravity base via one or more tethers, wherein the gravity base is configured
20 to be submerged into the water body, lowering the gravity base into the water body such that a weight of the gravity base or part thereof is transmitted to the buoyant platform via the one or more tethers, and movably coupling the gravity base to a portion of the one or more piles above the floor of the water body, such that the gravity base is movable along a vertical axis of the one or more piles when a lateral force acts on the
25 buoyant platform.

In accordance with embodiments of the second aspect of the invention, the one or more tethers each comprises a high tensile line.

30 In accordance with embodiments of the second aspect of the invention, the step of lowering the gravity base into the water body or movably coupling the gravity base to the one or more piles comprises releasing or tensioning each of the one or more tethers using winches that are installed on the buoyant platform.

In accordance with embodiments of the second aspect of the invention, the method further comprises securing the floating platform to land, the floor of the water body or a fixed structure by one or more mooring lines.

5 In accordance with embodiments of the second aspect of the invention, the method further comprises installing one or more dolphin structures around a perimeter of the buoyant platform or part thereof, and coupling the buoyant platform the one or more dolphin structures, thereby anchoring the floating platform to the floor of the water body.

10 In accordance with embodiments of the second aspect of the invention, the method further comprises selecting the gravity base based on a displacement of the buoyant platform in the water body.

15 In accordance with embodiments of the second aspect of the invention, the method further comprises selecting the gravity base based on a 5:1 (mt:mt) ratio between the displacement of the buoyant platform and a displacement of the gravity base in the water body.

20 In accordance with embodiments of the second aspect of the invention, the method further comprises adjusting the displacement of the buoyant platform by varying buoyancy of the buoyant platform.

BRIEF DESCRIPTION OF THE DRAWINGS

25 Embodiments of the invention is exemplified with reference to the accompanying drawings.

30 FIG. 1a illustrates a floating platform in accordance to an embodiment of the present invention.

FIG. 1b illustrates the floating platform of FIG. 1a when it is subjected to vertical loading.

35 FIG. 1c illustrates the floating platform of FIG. 1b when it is subjected to further vertical loading.

FIG. 1d illustrates the floating platform of FIG. 1c when it is subjected to yet further vertical loading.

FIG. 1e illustrates the floating platform of FIG. 1a when it is subjected to a lateral force.

FIG. 2 illustrates a buoyant platform that is coupled to a gravity base in accordance with another embodiment of the present invention.

FIG. 3 illustrates a floating platform in accordance with yet another embodiment of the present invention.

FIG. 4 illustrates an exemplary method of installing a floating platform of this invention.

DETAILED DESCRIPTION OF THE INVENTION

The present invention will be described hereinafter with reference to the accompanying drawings. It should be noted that the invention may be embodied in many other forms and should not be limited to the illustrated illustrations and disclosure set forth herein to exemplify the invention. In the following disclosure, for simplicity, common features in the various embodiments are identically numbered.

FIG. 1 illustrates a floating platform 100 in accordance to an embodiment of the present invention. The floating platform 100 is deployed in a water body 105 which may be, but not limited to, a river, lake, sea, dam, reservoir or bay. The floating platform 100 comprises a buoyant platform 110, a gravity base 115, a plurality of tethers 120a, 120b and a pile 125 that is installed into a floor of the water body 130. The buoyant platform 110 floats on the water body 105 while the gravity base 115 is submerged in the water body 105 substantially below the buoyant platform 110, and coupled to the buoyant platform 110 by the plurality of tethers 120a, 120b. A portion of the pile 125 protrudes above the floor of the water body 130 and couples to the gravity base 115.

While FIG. 1 shows the floating platform 100 to comprise one pile 125 and two tethers 120a and 120b, the skilled person in the art would understand that one or more

piles may be used to anchor the floating platform 100 and one or more tethers may be used to couple the buoyant platform 110 to the gravity base 115. For simplicity, the terms, pile and one or more piles may be used interchangeably in the description hereinafter. The same applies for the plurality of tethers and one or more tethers.

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Further, although the buoyant platform 110 shown in FIG. 1 is substantially flat and rectangular, this should not be taken to be limiting to the scope of the invention. The skilled person in the art would understand that the buoyant platform 110 may assume other shapes and sizes.

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In some embodiments, the buoyant platform 110 may be a hull structure. Preferably, the hull structure may comprise a large deck space and a hollow inner space that may be used as storage space.

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In another embodiment, the buoyant platform 110 may comprise ballast compartments for adjusting buoyancy of the buoyant platform to vary a displacement of the buoyant platform 110 in the water body 105. The ballast compartments may be filled or emptied with water from the water body 105.

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In yet another embodiment, the buoyant platform 110 may comprise one or more airbags for buoyancy or for enhancing buoyancy.

FIG. 2 shows the buoyant platform 110 in accordance with another embodiment of the present invention. The buoyant platform 110 comprises an upper surface 205 and a lower surface 210. One or more tether access shafts 215a, 215b is defined between the upper surface 205 and the lower surface 210 of the buoyant platform 110 and configured to receive the one or more tethers 120a, 120b. Ideally, each tether access shaft 215 houses one tether 120 that runs vertically between the upper surface 205 and lower surface 210 of the buoyant platform 110.

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The buoyant platform 110 further comprises one or more winches 220a, 220b for controlling a length of each of the one or more tethers 120a, 120b between the buoyant platform 110 and the gravity base 115. Where the buoyant platform 110 is a hull structure, the one or more winches 220a, 220b may be hidden inside the hull structure of the buoyant platform 110.

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In a preferred embodiment, the buoyant platform 110 comprises a plurality of tether access shafts that are located symmetrically such that a lifting centre of the buoyant platform 110 may be aligned with a centre of the base gravity 115. More preferably, the plurality of tether access shafts are located symmetrically and substantially at a centre of the buoyant platform 110.

The gravity base 115 is configured to be submerged in the water body, and preferably directly below the buoyant platform 110 to increase an overturning resistance of the platform. In a preferred embodiment, the shape, size or weight of the gravity base 115 is selected based on factors such as the displacement of the buoyant platform 110 in the water body and environmental conditions at a site where the floating platform 100 is deployed. Where large lateral forces arising from strong wind, wave or current conditions are expected, a heavier gravity base 115 would be required to mitigate lateral movements of the buoyant platform 110.

Further, buoyance forces on the buoyant platform 110 and the gravity base 115 need to be optimised for stability of the floating platform. In a preferred embodiment, a ratio between the displacement of the buoyant platform 110 and a displacement of the gravity base 115 in the water body is 5 : 1 (metric tonne (mt) : metric tonne (mt)).

In some embodiments, the gravity base 115 may be a concrete slab that is selected in accordance to the preceding paragraphs. In another embodiment, the gravity base 115 may be a buoyant structure comprising ballast compartments. This allows a buoyancy of the gravity base 110 to be adjusted by filling or emptying the ballast compartments.

The plurality of tethers 120a, 120b are configured to withstand a pulling down load arising from the gravity base 115 on the buoyant platform 110 and loading including lateral forces on the buoyant platform 110, with consideration of safety factor. In an embodiment, the plurality of tethers 120a, 120b may be high tensile steel wires such as: X70 that has yielding stress greater than 70ksi (482MPa) or similar materials that are commonly used for mooring chains.

The plurality of tethers 120a, 120b may couple the buoyant platform 110 to the gravity base 115 via several ways that are well known in the art. In some embodiments, the plurality of tethers 120a, 120b may couple to the buoyant platform 110 or the gravity

base 115 via semi rigid connections, e.g. flexible joints from FlexJoint™. In other embodiments where the gravity base 115 is concrete, the plurality of tethers 120a, and 120b may be coupled to the gravity base 115 via anchor bolts.

5 The one or more piles 125 set a foundation on the floor of the water body to anchor the buoyant platform 110 via the gravity base 115. In a preferred embodiment, the one or more piles 125 are suction piles or driven piles that are partially embedded in the floor of the water body. The gravity base 115 is movably coupled to the portion of the one or more piles 125 protruding above the floor of the water body. In an embodiment as shown
10 in FIG. 3, the gravity base 115 may comprise a central aperture 300 for receiving the one or more piles 125. As shall be described later, the gravity base 115 is free to move along a vertical axis of the one or more piles 125 towards or away from the floor of the water body.

15 As would be understood by a skilled person in the art, a length of the portion of the one or more piles 125 protruding above the floor of the water body is designed based on factors such as water depth, and environmental conditions and requirements for clearance between a top of the one or more piles 125 to the buoyant platform 110.

20 Further, in designing the pile length, being the portion of the one or more piles 125 that is embedded in the floor of the water body, only the lateral forces on the floating platform 100 need to be considered along with other parameters such as soil resistance in the floor of the water body.

25 The principles of operation of the floating platform 100 are described in the following. Referring to FIG. 1a, the weight of the gravity base 115 constitutes the pulling down load on the buoyant platform 110 that is responsible for stabilising the buoyant platform 110. The gravity base 115 is prevented from sinking onto the floor of the water body by tensile force in the plurality of tethers 120a, 120b arising mainly from the buoyance force on the
30 buoyant platform 110. As can be seen from FIG. 1a, as the weight of the gravity base 115 is cancelled by the buoyance force on the buoyant platform 110, the pile 125 does not bear any vertical loading.

35 FIG. 1b shows the floating platform 100 when subjected to a vertical load on the buoyant platform 110. The vertical loading on the buoyant platform 110 causes the buoyant platform 110 to sink, hence increasing displacement of the buoyant platform

110 in the water body. This in turn results in sinking of the gravity base 115 along the vertical axis of pile 125 towards the floor of the water body. An equilibrium state is reached when the weight of the gravity base 115 is counter-balanced by the tensile forces in the plurality of tethers 120a, 120b arising from the buoyance force on the buoyant platform 110. Again, the pile 125 does not bear the vertical loading on the buoyant platform 110. Therefore, in contrast to the conventional dolphin-based floating platforms, the present invention does not transmit vertical loading to the piles and the floor of the water body, and would be advantageous in mitigating soil settlement issues that plagued conventional dolphin-based floating platforms.

FIG. 1c shows the floating platform 100 when the buoyant platform 110 is subjected to further vertical loading. In this case, the gravity base 115 sinks further along the vertical axis of the pile 125 towards the floor of the water body, and now rests adjacent to the floor of the water body. The weight of the gravity base 115 is still supported by the tensile force in the plurality of tethers 120a, 120b arising from the buoyance force on the buoyant platform 110.

FIG. 1d shows the floating platform 110 when the buoyant platform 110 is subjected to yet further vertical loading. In this case, the gravity base 115 rests on the floor of the water body and the plurality of tethers 120a and 120b slacken and no longer support the weight of the gravity base 115. The weight of the gravity base 115 is distributed across a bottom of the gravity base 115 to minimise pressure on the floor of the water body. The floor of the water body does not bear any further loading even if the vertical loading on the buoyant platform 110 is increased. However, the buoyant platform 110 is no longer stabilised by the gravity base 115.

FIG. 1e shows the floating platform 100 when the buoyant platform 110 is subjected to a lateral force that may arise from winds, waves or currents. In this case, lateral movement of the buoyant platform is minimised by the tensile force in the plurality of tethers 120a, 120b. Dependent on the direction of the lateral force on platform 110, a vertical component of the tensile force may cause the gravity base 115 to rise or sink along the vertical axis of the pile 125 to offset the lateral motion of the buoyant platform 110. Hence, it would be apparent to the skilled person that the pile 125 would be subjected to only a lateral component of the tensile force in the plurality of tethers 120a, 120b. The pile 125 would not experience vertical stresses when the buoyant platform 110 is subjected to lateral forces.

The floating platform of this invention may be preferably deployed in shallow and/or calm water bodies where water depth is less than 50 m such as a reservoir, lake or bay. Nevertheless, this should not be seen as limiting to the scope of the present invention as the floating platform may also be installed in open water bodies such as sea or ocean. The floating platform may also be installed substantially nearshore. In the event that the floating platform is installed nearshore, the floating platform may be coupled to land via a pier or a floating walkway and the like to facilitate traffic between the land and the floating platform.

For added stability, in some embodiments, the floating platform further comprises mooring lines or dolphin structures that are coupled to the buoyant platform 110. The mooring lines may secure the buoyant platform 110 to land, the floor of the water body or a fixed structure like a pier. The dolphin structures may be constructed around a perimeter of the buoyant platform or part thereof and anchor the floating platform to the floor of the water body.

In another aspect, a method of installing a floating platform of this invention is disclosed. Referring to FIG. 5, a site in a water body is chosen for deploying the floating platform. Preferably, the site has shallow and/or calm water with water depth less than 50 m, though this should not be seen as limiting to the scope of the invention. One or more piles 125 is then installed on a floor of the water body at the chosen site. Numerous types and methods of installing piles are known generally in the art and are not described here for brevity.

In installing the one or more piles 125, a pile length, being the portion of the one or more piles 125 that is embedded in the floor of the water body, is determined based on consideration of only lateral forces on the floating platform 100 that may act on the floating platform at the site along with other parameters such as soil resistance in the floor of the water body.

In some embodiments, a pre-determined portion of the one or more piles 125 protrude above the floor of the water body. The portion of the one or more piles 125 protruding above the floor of the water body is determined based on factors such as water depth, and environmental conditions and requirements for clearance between a top of the one or more piles 125 to the buoyant platform 110.

In the next step, a buoyant platform 110 and a gravity base 115 in accordance to the invention as described earlier are provided and transported to the site. The buoyant platform 110 may be pre-coupled to the gravity base 115 by a plurality of tethers 120a, 120b or the buoyant platform 110 may be coupled to the gravity base 115 on site.

In some embodiments, the method comprises selecting a shape, size or weight of the gravity base 115 based on factors such as displacement of the buoyant platform 110 in the water body and environmental conditions at the site. Where large lateral forces arising from strong wind, wave or current conditions are expected, a heavier gravity base 115 would be selected to mitigate lateral movements of the buoyant platform 110.

In some embodiments, the selection of the gravity base 115 takes into consideration a displacement of the buoyant platform 110 in the water body and/or buoyance forces on the buoyant platform 110. In a preferred embodiment, a ratio between the displacement of the buoyant platform 110 and a displacement of the gravity base 115 in the water body is selected to be 5 : 1 (mt : mt).

The gravity base 115 that is coupled to the buoyant platform 110 is then lowered into the water body and movably coupled to the portion of the one or more piles 125 that protrudes above the floor of the water body. In an embodiment, the buoyant platform 110 that is coupled to the gravity base 115 via the plurality of tethers 120a, 120b may be lifted above the water body and lowered vertically onto one or more piles 125 such that the gravity base 115 is movably coupled to the portion of the one or more piles 125 that protrude above the floor of the water body.

In an embodiment where the gravity base 115 comprises ballast compartments, the gravity base 115 may be sunk by adjusting the ballast so that the gravity base 115 is lowered and movably coupled onto the portion of the one or more piles 125 that protrude above the floor of the water body.

In a preferred embodiment as shown in FIG. 4, the buoyant platform 110 may be floated on the water body with the gravity base 115 released into the water body. The gravity base 115 may then be lowered and movably coupled to the portion of the one or more piles 125 that protrudes above the floor of the water body by adjusting a length of the plurality of tethers 120a, 120b between the buoyant platform 110 and the gravity

base 115. This may be done by operating one or more winches 220 to reel in/out the plurality of tethers 120a, 120b.

5 In some embodiments, the method may further comprise tensioning the plurality of tethers 120a, 120b to a specified tension.

10 In some embodiments, the method may further comprise securing the buoyant platform 110 via mooring lines to land, the floor of the water body or a fixed structure like a pier.

15 In some embodiments, the method may further comprise installing dolphin structures around a perimeter of the buoyant platform 110 or part thereof. The buoyant platform 110 is coupled to the dolphin structures and anchored to the floor of the water body.

20 In some embodiments, the method may further comprise adjusting the displacement of the buoyant platform 110 in the water body. This may be done by varying the buoyancy of the buoyant platform 110. For instance, where the buoyant platform 110 comprises ballast compartments, the buoyancy of the buoyant platform 110 may be varied by adjusting ballast.

25 Although the invention has been described above with reference to several exemplifying embodiments, it will be appreciated that the various changes or modifications may be made without departing from the scope of the invention. Features in the various exemplifying embodiments may be combined to form new embodiments and such embodiments should also fall within the scope of the invention.

CLAIMS

1. A floating platform for deploying in a water body, the floating platform comprising:
a buoyant platform that is configured to float on the water body;
a gravity base that is configured to be submerged in the water body;
one or more tethers that couple the buoyant platform to the gravity base, wherein a weight of the gravity base or part thereof is transmitted to the buoyant platform via the one or more tethers; and
one or more piles configured to be installed into a floor of the water body, wherein the gravity base is movably coupled to a portion of the one or more piles above the floor of the water body such that the gravity base is movable along a vertical axis of the one or more piles when a lateral force acts on the buoyant platform.
2. The floating platform of claim 1, wherein the one or more tethers each comprise a high tensile line.
3. The floating platform of claim 1, further comprising:
one or more mooring lines that couples the buoyant platform to land, the floor of the water body or a fixed structure.
4. The floating platform of claim 1, further comprising:
one or more dolphin structures coupled to the buoyant platform, wherein the one or more dolphin structures anchor the floating platform to the floor of the water body.
5. The floating platform of claim 1, wherein the buoyant platform comprises one or more airbags to provide buoyancy.
6. The floating platform of claim 1, wherein the buoyant platform comprises one or more tether access shafts that are defined between a top surface and a bottom surface of the buoyant platform for receiving the one or more tethers.
7. The floating platform of claim 1, wherein the buoyant platform comprises one or more winches for adjusting a length of the one or more tethers between the buoyant platform and the gravity base.

8. The floating platform of claim 1, wherein the weight of the gravity base is selected based on a displacement of the buoyancy platform in the water body.
9. The floating platform of claim 8, wherein a ratio between the displacement of the buoyant platform and a displacement of the gravity base in the water body is 5:1 (metric tonne (mt):metric tonne (mt)).
10. The floating platform of claim 1, wherein the gravity base comprises a central aperture for receiving the one or more piles.
11. The floating platform of claim 1, wherein the buoyant platform comprises one or more ballast compartments.
12. The floating platform of claim 1, wherein the water body has depth of less than 50m.
13. A method of deploying a floating platform in a water body, wherein the method comprises:
 - installing one or more piles in a floor of the water body;
 - providing a buoyant platform that is configured to float on the water body;
 - coupling the buoyant platform to a gravity base via one or more tethers, wherein the gravity base is configured to be submerged into the water body;
 - lowering the gravity base into the water body such that a weight of the gravity base or part thereof is transmitted to the buoyant platform via the one or more tethers; and
 - movably coupling the gravity base to a portion of the one or more piles above the floor of the water body, such that the gravity base is movable along a vertical axis of the one or more piles when a lateral force acts on the buoyant platform.
14. The method of claim 13, wherein the one or more tethers each comprise a high tensile line.
15. The method of claim 13, wherein the step of lowering the gravity base into the water body or movably coupling the gravity base to the portion of the one or more piles above the floor of the water body comprises reeling in/out each of the one or more tethers using one or more winches that are installed on the buoyant platform.
16. The method of claim 13, further comprising:

securing the floating platform to land, the floor of the water body or a fixed structure by one or more mooring lines.

17. The method of claim 13, further comprising:

installing one or more dolphin structures around a perimeter of the buoyant platform or part thereof; and

coupling the buoyant platform to the one or more dolphin structures, thereby anchoring the floating platform to the floor of the water body.

18. The method of claim 13, further comprising:

selecting the gravity base based on a displacement of the buoyant platform in the water body.

19. The method of claim 18, wherein a ratio between the displacement of the buoyant platform and a displacement of the gravity base in the water body is 5:1 (mt:mt).

20. The method of claim 13, further comprising:

adjusting the displacement of the buoyant platform in the water body by varying buoyancy of the buoyant platform.