

## **MOORING SYSTEM FOR FLOATING QUAY**

The present invention relates to a mooring system for a floating quay, in particular in shallow depths. It is particularly suitable for floating structures or quays storing hydrocarbons or liquefied natural gas (LNG).

- 5 Such structures are in particular of the Floating Storage and Offloading (FSO) or Floating Production, Storage and Offloading (FPSO) type.

The quay orientation is fixed in relation to the sea bed, but it is important that the mooring of such a structure allows relative movement with the sea bed. These  
10 movements are essentially due to the effects of waves, currents, wind and interaction with the ship docking at the floating quay. These movements must remain slight, i.e. such mooring must limit the most extreme of these movements so that they remain compatible with the continuous offloading of fluids, generally via flexible or articulated pipes, and where applicable a footbridge link for persons. It is also  
15 important that the mooring system does not interfere with the ship at the quay.

On floating quays of the prior art, the so-called "soft yoke" method can be used to moor the quay. This technique is used for storage and/or production units (FSO or FPSO) moored at high tide to a "jacket" type anchoring structure around which they  
20 can turn freely. This technique is based on the use of articulated and ballasted arms suspended by one end from a "jacket" type anchoring structure, and at the other end from the floating quay. The "jacket" type structure is of the pylon type, generally a metal trellis rigidly anchored in the sea bed. The suspension of the ballasted arm allows absorption of small relative movements. However such mooring is complex  
25 and costly to implement, and requires the use of heavy structures.

The aim of the invention is to propose a mooring system for a floating quay which is flexible, easy and quick to implement and does not risk interfering with the ships which arrive to dock at the quay. Preferably such a system can be used in a large  
30 range of ground types, in particular relatively soft ground.

According to a first object of the invention, such a mooring system for a floating structure, in particular a floating quay, comprises:

- a submerged ballast

- means for suspending the ballast from said structure
- means for anchoring the ballast,

and the system is characterised in that the anchoring means comprise anchoring chains extending from the ballast, said chains in their extended position, i.e. the ballast being in the highest position, forming a slight angle with the horizontal , typically less than 20°, preferably less than 10°.

Thus the ballast is held close to the bed and does not interfere with the docked ships, even in shallow water. The ballast is suspended, i.e. in a position

corresponding to a slack water level of the lowest tides, and does not touch the bed. The ballast can therefore have vertical movements about a midway position. In this midway position, whatever the water level, the anchoring chains must have a degree of "slack" such that the ballast can rise above the midway position.

Preferably, in the midway position, the anchoring chains rest on the sea bed over the majority of their length.

The anchoring means can also comprise anchoring points on piles embedded in the sea bed, each anchoring chain extending between said ballast and an anchoring point of a respective pile. The use of piles is particularly suitable for a soft sea bed, namely in an estuary. The head of the pile can advantageously lie approximately at the level of the sea bed and thus not constitute a risk of interference with ships. The anchoring point is then carried by the head of the pile.

To limit the risk of interference still further, the anchoring chains which link the piles and the ballast are advantageously fixed in a low part of the ballast.

The ballast is advantageously suspended using a suspension chain. Naturally the suspension chain, like the other chains, can comprise several chains to meet the need for stability or weight of the ballast. This suspension chain advantageously extends upward from the ballast to a suspension point. This suspension point is advantageously part of a support structure, for example a framework, said structure extending preferably longitudinally from a longitudinal end of the floating quay, such

that the suspension point is offset longitudinally relative to the quay hull. Thus no transverse section of the mooring system will hinder the docking of a ship.

The anchoring chains advantageously comprise at least three anchoring chains extending radially from the ballast, such that two successive chains never form between them an angle greater than  $180^\circ$ . Thus the ballast is held horizontally between at least three anchoring points, and its horizontal movements are limited by the slack in the anchoring chains, and as a function of water level. Preferably six chains are typically arranged in a star around the ballast.

To avoid any risk of interference, piles can be arranged such that they avoid the vertical projection of a ship moored at said floating quay, i.e. no pile and no chain is covered by a shadow, projected vertically, of a ship docked at the floating quay. Preferably the pile heads are arranged such that they lie within a vertical docking plane of the ships.

The zone of the support structure forming the suspension point of the ballast advantageously comprises mooring means, for example a bollard or rapid release hooks, for the stern or prow of a ship coupled to the floating quay. This is particularly useful if the support structure allows a longitudinal offset of the suspension point and hence the mooring means. Thus a ship longer than the actual quay can moor at the quay while achieving a suitable arrangement of the mooring means.

The term "chain" must be understood as covering flexible connection means, in particular one or more cables.

A floating quay according to the invention comprises mooring means according to the invention.

Other features and advantages of the invention will arise from the description below which relates to non-limitative examples.

On the attached drawings:

- figure 1 is a plan view of a ship and a floating quay according to the invention, coupled together;
- figure 2 is a cross-section of the ship and quay in figure 1, along line II-II in figure 1, on a larger scale; and
- 5 – figure 3 is a partial longitudinal view in elevation at reference III in figure 1, of a longitudinal end of the floating quay in figure 1, on an even larger scale.

On figures 1 and 2 we see a floating quay 1. This floating quay is moored near the coast in shallow water D5. The floating quay 1 has a hull 100 of approximately  
 10 parallelepipedic form, extending in plan view between two longitudinal edges and two lateral edges 11.

In the example illustrated, a ship 2 is coupled to the quay 1 along a longitudinal edge 3 of the quay 1. The longitudinal edge 3 is fitted with fenders 4 intended to dampen  
 15 the movements and impacts between the ship 2 and the quay 1. The fenders, following their line of contact with the hull of the ship 2, define a vertical docking plane P4.

The floating quay is of the FPSO type, and more particularly the FSRU type (Floating  
 20 Storage Regasification Unit). Thus the quay comprises a tank 6 inside the hull 100 of the floating quay, provided for storage of liquid gas, and a regasification plant. The quay is linked to the land by a pipe 8, 9 which in the example shown is carried by an intermediate pylon 7. The pylon is anchored in the sea bed 5. Between the quay and the pylon, the pipework 8 is flexible or articulated; beyond the pylon in the direction  
 25 of the land, the pipework 9 is rigid.

The quay 1 comprises supporting structures 10 extending at each of its longitudinal ends. In the example shown, each supporting structure 10 here is designed as a framework in the form of an over-mounted beam, and comprises a trellis of metal  
 30 girders. Each supporting structure 10 extends from a respective transverse edge 11 of the quay hull. A ballast 12 is suspended at a distal end 13 of the supporting structure 10 (see figure 3) by a chain 14, this distal end therefore constituting a

suspension point for the ballast. Thus suspended, the ballast is held close to but spaced from the sea bed 5. As shown in figure 3:

- the suspension point 13 is offset longitudinally by a distance D13 of around 40 metres in relation to the transverse edge 11 of the floating quay 1;
- 5 – the surface 15 of the water at the vertical of the suspension point 13 is at a vertical distance D5 of around 16 metres from the sea bed 5;
- the height H12 of the ballast is around 6 metres; and
- the lower face 120 of the ballast 12 is held at a height H120 of around 2 metres above the sea bed 5, which corresponds approximately to distance H1 between
- 10 the bottom 101 of the hull of the quay 1.

The ballast 12 is anchored in the sea bed 5 by six anchoring chains 16 and six piles 17. The six chains and the six piles are arranged symmetrically on either side of a vertical plane P1 central to the hull 100 and passing through the ends 13 of the

15 supporting structures 10. The piles are embedded in the sea bed 5 at a distance of around 40 metres from the vertical of the suspension point 13. The head 170 of each pile is flush with the sea bed. A respective anchoring chain 16 links the head of each pile with the ballast, close to its lower face 120.

- 20 On each side of the median plane P1, a first chain extends perpendicular to plane P1 and two others form with the first, on either side of the first, an angle A16 of around 45°. In the centre position of the ballast 12 between its chains 14, 16 as illustrated on the figures, each anchoring chain 16 has some slack i.e. is not generally tensioned between the head of the respective pile 170 and the ballast 12. Thus as shown in
- 25 figure 3, each chain rests on the sea bed 5 for over 80 to 90% of its length closest to pile 17, then rises in the direction of the ballast. In the example shown, the height H120 represents around 5 to 7% of the length of the anchoring chains 16.

Thus linked to the supporting structure 10 and the piles 17, suspended above the

30 sea bed 5, the ballast 12 can have horizontal or vertical movements even when one or more of its anchoring chains 16 are extended. These movements are however limited by the return forces due to the distance of the ballast from its neutral position and the slack in the anchoring chains.

Also even in a position where a chain is extended above the sea bed, and where the ballast is remote from its neutral position, the device presents no risk of interference with any ship coupled to the quay 1, insofar as even the closest pile to the ship lies  
 5 approximately in the docking plane P4.

The length L1 of the hull of the floating quay 1 is L1, here L1 is approximately 175 metres. The ship coupled thereto measures around 290 metres overall. Thanks to the support structures 10, the distance between the suspension points 13 is around  
 10 255 m. Thus since the suspension points comprise bollards or rapid release hooks 19, they provide mooring points 19 adapted to ships which are in particular longer than the quay. This it is possible to have a quay of smaller dimensions, weight and cost.

15 Also the longitudinal offset of the ballasts increases the longitudinal stability of the quay without increasing its weight significantly.

Naturally the invention is not limited to the examples just described and numerous adaptations may be made to these examples without leaving the framework of the  
 20 invention.

Thus although the description refers to a structure at sea, this structure can be located in a lake or river. Consequently the bed may be a sea bed, a lake bed or a river bed.

25 The chains may be replaced by cables. In particular the suspension chain may again be replaced by a link bar, articulated at its suspension point by a universal joint or ball joint. Such a bar may be designed in its lower part to form or contain a ballast.

30 The lengths of chains need not be equal to each other. In addition, the slack of the chains may be dimensioned such that the amplitudes of horizontal movements of the ballast and hence the quay differ depending on direction.

The lengths and distances may vary, in particular as a function of the environment in which the floating quay is moored, but also as a function of its capacity and dimensions, or the dimensions of the ships intending to dock there.

- 5 The description refers to a single ballast for each device. Evidently this does not exclude there being several ballasts. Each ballast may have its own means of suspension. Also each ballast may be linked to a respective pile. Thus the means of suspension are not necessarily strictly vertical but slightly inclined in the direction of each pile.

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The piles may be replaced by other types of anchoring, such as suction anchors or conventional anchors, depending on the type of ground found at the anchoring site.

Also the anchoring means may be adapted to other floating structures intended to be

- 15 moored, in particular in shallow water, and for which a high stability is desired.

## Claims

1. System (10, 12 - 17) for mooring a floating structure (1) to a bed (5), comprising:
  - 5 - a submerged ballast (12),
  - means (13, 14) for suspending the ballast from said structure,
  - means (16, 17) for anchoring the ballast,
 characterised in that the anchoring means comprise chains (16) extending from the ballast, each chain in its extended position forming with the
   
10 horizontal an angle of less than 20°.
2. System according to claim 1, characterised in that each chain in its extended position forms with the horizontal an angle of less than 10°.
- 15 3. System according to claim 1 or 2, characterised in that each chain rests on the bed (5) for a majority of its length, preferably 80 to 90% of its length.
4. System according to any one of claims 1 to 3, characterised in that the anchoring means comprise piles (7), each chain (16) extending between said
   
20 ballast (12) and a respective pile.
5. System according to claim 4, characterised in that the piles are arranged within a docking plane (P4).
- 25 6. System according to any one of claims 1 to 5, characterised in that each anchoring chain (16) extends from a low part (120) of the ballast (12).
7. System according to any one of claims 1 to 6, characterised in that the ballast suspension means comprise a suspension chain (14) or an articulated arm
   
30 extending upward from the ballast.
8. System according to claim 7, characterised in that the floating structure comprises a support structure (10), the ballast being suspended from a suspension point (13) of said support structure (10), said structure extending

longitudinally from a longitudinal end (11) of the floating structure (1) such that the suspension point (13) is offset longitudinally (D13) in relation to said end (11) of said structure (1).

- 5 9. System according to claim 8, characterised in that the suspension point (13) comprises mooring means (19) for a ship (2).
10. System according to any one of claims 1 to 9, characterised in that the  
10 anchoring means comprise at least three anchoring chains (16) extending radially from the ballast (12) such that two successive chains never form between them an angle (A16) greater than 180°.
11. System according to claim 10, characterised in that it comprises at least six  
15 chains (16) arranged in a star around the ballast (12).
12. Floating structure, characterised in that it comprises an anchoring system according to any one of claims 1 to 11.
13. Floating structure according to claim 12, characterised in that it comprises, at  
20 each of its two opposite ends (11), an anchoring system according to any one of claims 1 to 11.
14. Floating structure according to claim 12 or 13, characterised in that it is a floating quay, in particular a quay selected from types FSO, FPSO or FSRU.