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(54) **SCOUR PROTECTION FOR AN UNDERWATER BOTTOM ALONGSIDE A QUAY WALL, AND METHOD FOR PROVIDING THE SAME**

(57) A scour protection for an underwater bottom alongside a quay wall is disclosed. The scour protection comprises a foundation/leveling layer of rocks with a size distribution conforming to 100 < D_{n50} < 225 mm, and a plurality of prefabricated reinforced concrete slabs, adjacently positioned on top of the foundation/levelling layer and leaving a gap between edges of the slabs. A method for providing the scour protection is also described.

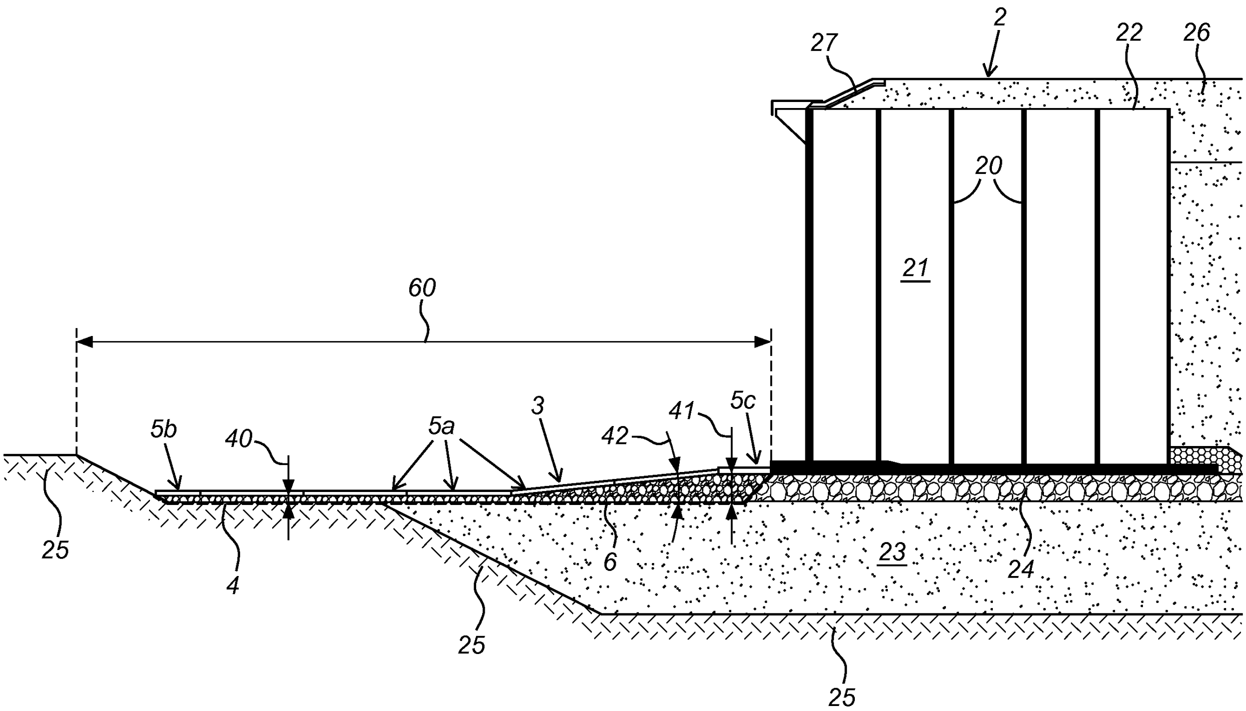

Fig. 2

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Description

BACKGROUND OF THE INVENTION

[0001] The present invention relates to a scour protection for an underwater bottom extending alongside a quay wall. The invention further relates to a method for providing such scour protection.

[0002] Marine transport is ever increasing, both in quantity and size. The last decade has seen developments in the shipping industry characterized by an increase in capacity. Vessels are becoming larger and larger in order to be able to carry as much load as possible. The increasing size of freight carriers and cruise ships has an important impact on harbor infrastructure, as docking basins need to be made deeper and quay walls stronger. In addition, the larger vessels presently being developed are equipped with far more power than known hitherto. The flow velocities against the quay walls and the harbor underwater bottom in front of the quay wall that are associated with the larger and more powerful propellers used on these vessels are anticipated to increase at such level that important damage may be caused to the quay walls and harbor underwater bottoms in particular. This damaging effect becomes more of a problem since modem vessels tend to have secondary propulsion systems such as bow and stem thrusters in order to increase their maneuverability, in particular while berthing.

[0003] Scour protection of underwater bottoms in harbors is known. Existing scour protection at the toe of a quay wall may comprise a granular protection, to which may be added liquid asphalt mastic for additional strength. Other known scour protection comprises mattresses of concrete blocks, rock or fibrous stone asphalt. These mattresses are easily applied to an underwater bottom, and for most applications provide sufficient strength, among other factors due to the flexible nature of a mattress. These materials however may not always provide adequate protection, or may not be available at the site.

[0004] It is an aim of the present invention to provide a scour protection for an underwater bottom extending alongside a quay wall that is more efficient than the known scour protection.

BRIEF SUMMARY OF THE INVENTION

[0005] The above and other aims are provided by a scour protection for an underwater bottom alongside a quay wall in accordance with claim 1. The scour protection of the invention comprises a foundation/leveling layer of rocks with a size distribution conforming to $100 < D_{n50} < 225$ mm, and a plurality of prefabricated reinforced concrete slabs, adjacently positioned on top of the foundation/levelling layer and leaving a gap between edges of the slabs. It has turned out that a foundation/leveling layer in accordance with the invention provides a reliable and adequate support for the concrete slabs, and that the gap between edges of the slabs is instrumental in the long term protection offered by the invention.

[0006] The known classically used scour protection in the form of mattresses or granular protection requires large and heavy rocks up to 1-5 tons to withstand the typical thrust forces generated by a vessel. These rocks may not be readily available and further need to be applied in rather thick layers. This reduces the maximum available water depth alongside the quay wall. The scour protection of the present invention does not have this drawback. Known granular protection may also need accurate installation and leveling. The scour protection thickness and density thus obtained is rather arbitrary and depends to some extent on the experience of the crane driver. Quality control tests performed upon completion of the works by the client or the contractor, in particular measurements of minimal thickness and density may result in a wide and undesirable variation. The scour protection of the present invention does not have this problem and provides an accurate thickness and density to the scour protection. This allows to accurately defining the depth of the underwater bottom.

[0007] The foundation/leveling layer comprises rock with the claimed size distribution, whereby the wording rock may encompass any granular material such as rocks and/or stones, either natural and/or man-made.

[0008] The gap width between edges of the slabs may be chosen according to the selected size distribution of the rocks of the foundation/leveling layer. A particularly preferred embodiment of the invention provides a scour protection wherein the gap width ranges from 10-100 mm, more preferably from 20-90 mm, and most preferably from 30-60 mm. The preferred embodiments help preventing washing out of underwater bottom layers below the slabs, and add to the stability of the scour protection. The gaps between the concrete slabs should be present along one edge of each of at least two slabs, preferably along two edges of each of at least three slabs, more preferably along three edges of each of at least four slabs, and most preferably along four edges of each of at least five slabs. The gaps may be present along edges that extend substantially parallel to an alongside direction of the quay wall, and/or may be present along edges that extend substantially perpendicular to the alongside direction of the quay wall. The gap width between slabs is preferably a constant but may vary along an edge of two adjacently positioned slabs, preferably within 50% of the average gap width, more preferably within 20% of the average gap width, and most preferably within 10% of the average gap width.

[0009] The scour protection according to the invention advantageously allows maximizing the available water depth alongside the quay wall. It has turned out that the average thickness of the foundation/levelling layer and of in particular of the concrete slabs may be selected much smaller than with the known granular scour protection for instance. In an embodiment of the invention, a scour protection is provided wherein the slabs have a thickness ranging from 200-500 mm, more preferably from 275-425 mm, and most preferably from 325-375 mm. These preferred thicknesses provide the required protection against erosion, and further allow handling the slabs while positioning them on an underwater bottom.

[0010] An important advantage of the invented scour protection relates to an embodiment wherein concrete slabs are provided onto the foundation/leveling layer without requiring mutual connection of slabs. This facilitates replacement of a damaged slab by another slab.

[0011] The scour protection in accordance with the invention requires a gap between edges of the concrete slabs. To facilitate a correct positioning an embodiment relates to a scour protection wherein edges of the slabs are provided with distance holders or spacing lugs. The spacing lugs may be separate or may be integral to the slab, and can be made from concrete, wood, rubber or another polymer, metal, and other suitable materials. The spacing lugs or distance holders are instrumental in maintaining the required gap between slab edges.

[0012] The invented scour protection comprises a foundation/leveling layer of rocks with a size distribution conforming to $100 < D_{n50} < 225$ mm. With D_{n50} is meant the nominal rock size that is exceeded by 50 wt.-% of the rocks. Other useful embodiments of the invention provide a scour protection wherein the size distribution of the rocks conforms to $100 < D_{n50} < 185$ mm, more preferably to $100 < D_{n50} < 155$ mm, and most preferably to $110 < D_{n50} < 130$ mm.

[0013] In another embodiment of the invention, a scour protection is provided wherein the size distribution of the rocks is selected such that at most 10 wt.-% of the rocks has a size < 100 mm, and/or at most 10 wt.-% of the rocks has a size > 225 mm. In a particularly useful embodiment, at least 80 wt.-% of the rocks has a size between 100-225 mm.

[0014] The foundation/leveling layer serves to support the concrete slabs, and distributes the forces to the underlying soils. In a useful embodiment of the invention, a scour protection is provided wherein the foundation/levelling layer is level to within 200 mm, and more preferably to within 100 mm. The foundation/leveling layer may be horizontal but may also have a slope exhibiting an angle with the horizontal direction, whereby the angle may be between 0-40 degrees, more preferably between 0-30 degrees, and most preferably between 0-20 degrees.

[0015] The scour protection according to the invention may be provided at any depth under water. In a preferred embodiment of the invention, a scour protection is provided wherein at least some of the slabs are provided at a depth of at least 15 m, more preferably at least 20 m, and most preferably at least 25 m.

[0016] The concrete slabs of the scour protection may have any shape and may be curved or flat. An embodiment of the invention relates to a scour protection wherein the slabs are planar, and the edges of the slabs are straight and extend in a thickness direction perpendicular to the plane of the slabs. A practical embodiment of the invention provides a scour protection wherein the slabs have a lateral dimension of at least 3.5 m, more preferably at least 6 m, and most preferably at least 7 m. A preferred scour protection comprises at least some slabs having a size of 8 x 8 x 0.35 m, with a variation of at most 40% of each dimension, more preferably at most 30% of each dimension, and most preferably at most 20% of each dimension.

[0017] The scour protection may extend in a transverse distance perpendicular to the quay wall over 1-10 meters only, over at least 10 meters, or over more than 100 m. The scour protection may extend in a longitudinal direction parallel to (alongside) the quay wall over a few meters only, preferably over more than 100 m, and more preferably over more than 1 km.

[0018] The invention further provides an embodiment of a scour protection wherein the slabs are provided with a number of holes that extend from a front surface of the slabs to a back surface thereof. The holes interact with the gaps between the slabs in preventing uplifting forces that may destabilize the slabs. The holes are further instrumental in facilitating the placement of the slabs onto an underwater bottom.

[0019] The number of holes in the slabs may be chosen within a large range. In a preferred embodiment of the invented scour protection, the number of holes in one slab ranges from 10-100, more preferably from 20-90, and most preferably from 30-80. A preferred hole density ranges from 0,5 to 5 holes per m^2, more preferably from 0,8 to 3 holes per m^2, and most preferably from 0,9 to 2 holes per m^2. A cross-dimension of the holes (for instance the diameter in case of cylindrical holes) may be chosen within large ranges but is preferably selected between 20-200 mm, more preferably between 40-150 mm, and most preferably between 50-100 mm.

[0020] In order to increase the ease of installation, an embodiment of the scour protection according to the invention is characterized in that the slabs comprise lifting brackets. The lifting brackets may be integrated into the concrete slabs during casting thereof, and may for instance comprise steel brackets.

[0021] The concrete slabs of the invented scour protection are prefabricated, preferably at or close to the site where the scour protection has to be provided. The slabs comprise reinforcement in the form of a number of reinforcement bars (rebars), the number and properties of which are determined according to well known calculation principles. The rebars are instrumental in providing the slabs with the necessary strength when placed under water but also during lifting and positioning of the slabs onto the foundation/leveling layer.

[0022] An improvement of the scour protection is obtained in an embodiment that further comprises a geotextile layer, preferably provided below the foundation/leveling layer. The underwater bottom may first be provided with a ground filter layer that may partly extend underneath the quay wall. The underwater bottom is in the present embodiment covered with a geotextile layer. The geotextile layers are typically placed parallel to each other and with a certain overlap, and the foundation/levelling layer is preferably provided thereon.

[0023] The invention also relates to a method for providing an underwater bottom alongside a quay wall with scour protection. The invented method comprises providing a foundation/leveling layer of rocks with a size distribution conforming to $100 < D_{n50} < 225$ mm on the bottom, and adjacently positioning a plurality of prefabricated reinforced concrete slabs on top of the foundation/levelling layer such that a gap is left between edges of the slabs. The scour protection is particularly advantageous for placement under water at considerable depths of at least 15 m, more preferably at least 20 m, and most preferably at least 25 m.

[0024] The foundation/leveling layer may conveniently be provided onto an existing underwater bottom by dumping the rocks into the water from a vessel, preferably a vessel with a fall pipe, from a crane, or from any other suitable tool or device. The lifting of the slabs and subsequent positioning of the slabs onto the foundation/leveling layer may conveniently be carried out by a lifting device that is preferably provided with a lifting frame from which a slab may conveniently be suspended. The lifting frame and/or the slab itself may be provided with positioning and/or measuring tools, such as sonars, and the like.

[0025] Preferred embodiments of the invention relate to a method wherein the slabs are positioned such that the gap between edges of the slabs ranges from 20-100 mm, and more preferably from 30-90 mm; wherein the slabs have a thickness ranging from 200-500 mm, more preferably from 275-425 mm, and most preferably from 325-375 mm; wherein edges of the slabs are provided with distance holders or spacing lugs; wherein the size distribution of the rocks conforms to $110 < D_{n50} < 130$ mm; wherein the size distribution of the rocks is selected such that at most 10 wt.-% is < 100 mm, and/or at most 10 wt.-% is > 225 mm; wherein the foundation/levelling layer is level to within 200 mm; wherein at least some of the slabs are provided at a depth of at least 15 m, more preferably at least 20 m, and most preferably at least 25 m; wherein the slabs are planar, and the edges of the slabs are straight and extend in a thickness direction perpendicular to the plane of the slabs; wherein the slabs are provided with a number of holes that extend from a front surface of the slabs to a back surface thereof, wherein the number of holes ranges from 10-100, more preferably from 20-90, and most preferably from 30-80; wherein the slabs have a lateral dimension of at least 5 m, more preferably at least 6 m, and most preferably at least 7 m; wherein at least some slabs have a size of 8 x 8 x 0.35 m, with a variation of at most 40% of each dimension; wherein at least some slabs comprise lifting brackets and the slabs are lifted by cables attached to the brackets; and/or wherein a geotextile layer is provided, preferably below the foundation/leveling layer.

[0026] It is expressly stated that the embodiments of the invention disclosed in the present application may be combined in any possible combination of these embodiments, and that each embodiment separately may be the subject of a divisional application.

BRIEF DESCRIPTION OF THE DRAWINGS

[0027] The invention will now be elucidated in more detail with reference to the accompanying figures, without otherwise being limited thereto. In the figures:

Figure 1 schematically shows a cross section of a quay wall, the foot of which is provided with a scour protection in accordance with an embodiment of the invention;

Figure 2 schematically shows a cross section of a quay wall, the foot of which is provided with a scour protection in accordance with another embodiment of the invention;

Figure 3A schematically shows a side view of a part of the scour protection of figure 2;

Figure 3B schematically shows a top view of a part of the scour protection of figure 2;

Figure 3C schematically shows a side view of a concrete slab that is part of the scour protection of figure 2;

Figure 3D schematically shows a detailed top view of part A of the scour protection of figure 3B; and

Figure 4 schematically shows a perspective view of a lifting frame used for placing a concrete slab of an embodiment of the present invention on an underwater bottom alongside a quay wall.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0028] With reference to figure 1, a large vessel 1 is shown alongside a quay wall 2. The vessel 1 may be any vessel of considerable size, and comprises a Malaccamax container ship for illustrative purposes. A Malaccamax ship has the maximum dimensions that are still permissible to pass the most restrictive area of the Malacca Strait. A Malaccamax container ship typically has a draught of about 21 m, which is comparable to VLCC (Very Large Crude Carriers) vessels for instance. A Malaccamax container ship typically would have the following characteristics fully loaded:

Laden Draft - 21 m
Length over all (Loa) - 470 m
Beam (B) - 61.5 m
Freeboard (F) - 14 m
Length between perpendicular (Lbp) - 437.5 m
Displacement (Md) - 435000 tons
Deadweight (Dwt) - 370000 tons
Block coefficient 0.751
Windage Area - 18600 m^2

The propulsion particulars of the vessel 1 in fully loaded state may be summarized as follows:

Main Propeller (Twin) Diameter - 10 m
Power for Main Engine - propeller 90000 kW
Stern/ Bow Thrusters' Diameter - 3.5 m
3 Stern/ 3 Bow Power - propeller 3700 kW

which generates considerable flow velocities against the quay wall and the underwater bottom in front of the quay wall toe. Typical jet flow velocities at full power are about 14 m/s for the main propellers, and about 6 m/s for the combined thrusters. The scour protection in accordance with the invention adequately protects these parts against erosion.

[0029] The vessel 1 has a draught 11 of about 21 m, and extends above the water 10 over a distance 12 of about 14 m. The water level is at 0.3 m CD (chart datum). The toe of the quay wall 2 is at -23,5 CD, while the maximum depth of the water basin alongside the quay wall 2 is at -26.5 m CD. The vessel 1 is at its stern equipped with two main propellers 13. Stern thrusters are not shown.

[0030] As shown in figure 1, the quay wall itself comprises for illustrative purpose a number of caissons 20, filled with dredged material 21. The caissons 20 are provided with a steel top plate 22, and extend over several km in an alongside direction of the quay wall 2. The caissons 20 rest on a foundation layer of compacted sand key 23, provided with a top layer of rock mound 24. The sand key 23 is preferably compacted and has been provided in a dredged volume of bottom material 25. The caissons 20 are on top provided with a sand surcharge 26 that is retained by a retaining ridge member 27 that extends alongside the quay wall 1.

[0031] An embodiment of the scour protection 3 for the underwater bottom 25 alongside the quay wall 1 is shown in figure 2 and comprises a foundation/leveling layer 4 of rocks with a size distribution conforming to D_{n50} = 120 mm and at most 10 wt.-% is < 100 mm, and at most 10 wt.-% is > 225 mm, and a plurality of prefabricated reinforced concrete slabs 5, adjacently positioned on top of the foundation/levelling layer 4 and leaving a gap 50 between edges 51 of the slabs 5. The slabs 5 comprise a number of planar and square slabs 5a of 8 x 8 m wide and 0.35 m thick. At the toe of the quay wall 2 are provided a number of reinforced concrete slabs of rectangular size, being 4 m long, 8 m wide and 0.5 m thick. The other end of the scour protection 3 comprises a number of reinforced concrete slabs of rectangular size, being 3.5 m long, 8 m wide and 0.35 m thick. The thickness 40 of the foundation/leveling layer 4 is about 0.5 m and gradually increases in thickness towards the quay wall 2 to a thickness 41 close to the quay wall toe of about 1.5 m. The slope 42 of the foundation/leveling layer 4 is about 11 degrees.

[0032] The scour protection 3 shown in figure 2 further comprises a geotextile layer 6, provided between the foundation/leveling layer 4 and the bottom 25. The geotextile layer comprises a PP geotextile fabric and extends from the toe of the quay wall 2 to an opposite end of a deepened area 60 of the water basin 10.

[0033] As shown in figures 3A to 3D, the scour protection 3 according to an embodiment of the invention comprises a foundation/leveling layer 4 with a thickness 40 of about 0.5 m and a number of reinforced concrete slabs 5a having a thickness 50 of about 0.35 mm. The gap width 51 between slabs 5a ranges from 40-80 mm. As shown in the top view of figure 3B and in figure 3D, which shows detail A of the slabs 5 of figure 3B, the edges 58 of the slabs 5a are provided with spacing lugs 53 to provide the gap width 51. Reinforcing strips 53 are provided at the corners of each slab 5a.

[0034] The slabs 5a are further provided with a number of holes 54 that extend from a front surface 55a of the slabs 5 to a back surface 55b thereof. About 64 holes are regularly distributed over the surfaces (55a, 55b). The slabs 5 also comprise lifting brackets 56, as shown in the side view of figure 3C.

[0035] With reference to figure 4, an embodiment of a method for providing an underwater bottom 25 alongside a quay wall 2 with scour protection 3 is shown. The method comprises providing a foundation/leveling layer 4 of rocks with a size distribution conforming to 100 < D_{n50} < 225 mm on the bottom 25, and adjacently positioning a plurality of prefabricated reinforced concrete slabs 5 on top of the foundation/levelling layer 4 such that a gap 51 is left between edges 58 of the slabs 5. The slabs 5 are conveniently placed on top of the foundation/leveling layer 4 by a suitable lifting device, such as a crane (not shown) operated from the shore or from a vessel or pontoon. A lifting frame 7 is suspended by wires 71 from a hook of the crane. To the four corners of the lifting frame 7 are attached suspending wires 72 which may be paid out or retracted by a suitable mechanism 73 provided on the frame 7. A slab 5 is attached to the wires 72 and brought under water by lowering a crane boom and/or paying out the wires (71, 72). The spacing lugs 52 allow to position the slabs 5 onto the foundation/leveling layer 4 such that a suitable gap width is maintained between edges 58 of adjacently positioned slabs 5. The frame 7 further may be provided with sonar or other positioning systems for accurate positioning of the slabs 5. The holes 54 in the slabs 5 allow to let the water escape from underneath the slab 5 while lowering it into the water, which further helps in accurate placement of the slabs 5.

Claims

1. Scour protection for an underwater bottom alongside a quay wall, comprising a foundation/leveling layer of rocks with a size distribution conforming to 100 < D_{n50} < 225 mm, and a plurality of prefabricated reinforced concrete slabs, adjacently positioned on top of the foundation/levelling layer and leaving a gap

between edges of the slabs.

2. Scour protection according to claim 1, wherein the gap width ranges from 10-100 mm, more preferably from 20-90 mm, and most preferably from 30-60 mm.

3. Scour protection according to claim 1 or 2, wherein the slabs have a thickness ranging from 200-500 mm, more preferably from 275-425 mm, and most preferably from 325-375 mm.

4. Scour protection according to any one of the preceding claims, wherein edges of the slabs are provided with distance holders or spacing lugs.

5. Scour protection according to any one of the preceding claims, wherein the size distribution of the rocks conforms to 110 < D_{n50} < 130 mm.

6. Scour protection according to any one of the preceding claims, wherein the size distribution of the rocks is selected such that at most 10 wt.-% of the rocks has a size < 100 mm, and/or at most 10 wt.-% of the rocks has a size > 225 mm.

7. Scour protection according to any one of the preceding claims, wherein the foundation/levelling layer is level to within 200 mm.

8. Scour protection according to any one of the preceding claims, wherein at least some of the slabs are provided at a depth of at least 15 m, more preferably at least 20 m, and most preferably at least 25 m.

9. Scour protection according to any one of the preceding claims, wherein the slabs are planar, and the edges of the slabs are straight and extend in a thickness direction perpendicular to the plane of the slabs.

10. Scour protection according to any one of the preceding claims, wherein the slabs are provided with a number of holes that extend from a front surface of the slabs to a back surface thereof.

11. Scour protection according to claim 10, wherein the number of holes ranges from 10-100, more preferably from 20-90, and most preferably from 30-80.

12. Scour protection according to any one of the preceding claims, wherein the slabs have a lateral dimension of at least 5 m, more preferably at least 6 m, and most preferably at least 7 m.

13. Scour protection according to any one of the preceding claims, wherein at least some slabs have a size of 8 x 8 x 0.35 m, with a variation of at most 20% of each dimension.

14. Scour protection according to any one of the preceding claims, wherein the slabs comprise lifting brackets.

15. Scour protection according to any one of the preceding claims, further comprising a geotextile layer, preferably provided below the foundation/leveling layer.

16. Method for providing an underwater bottom alongside a quay wall with scour protection, the method comprising providing a foundation/leveling layer of rocks with a size distribution conforming to 100 < D_{n50} < 225 mm on the bottom, and adjacently positioning a plurality of prefabricated reinforced concrete slabs on top of the foundation/levelling layer such that a gap is left between edges of the slabs.

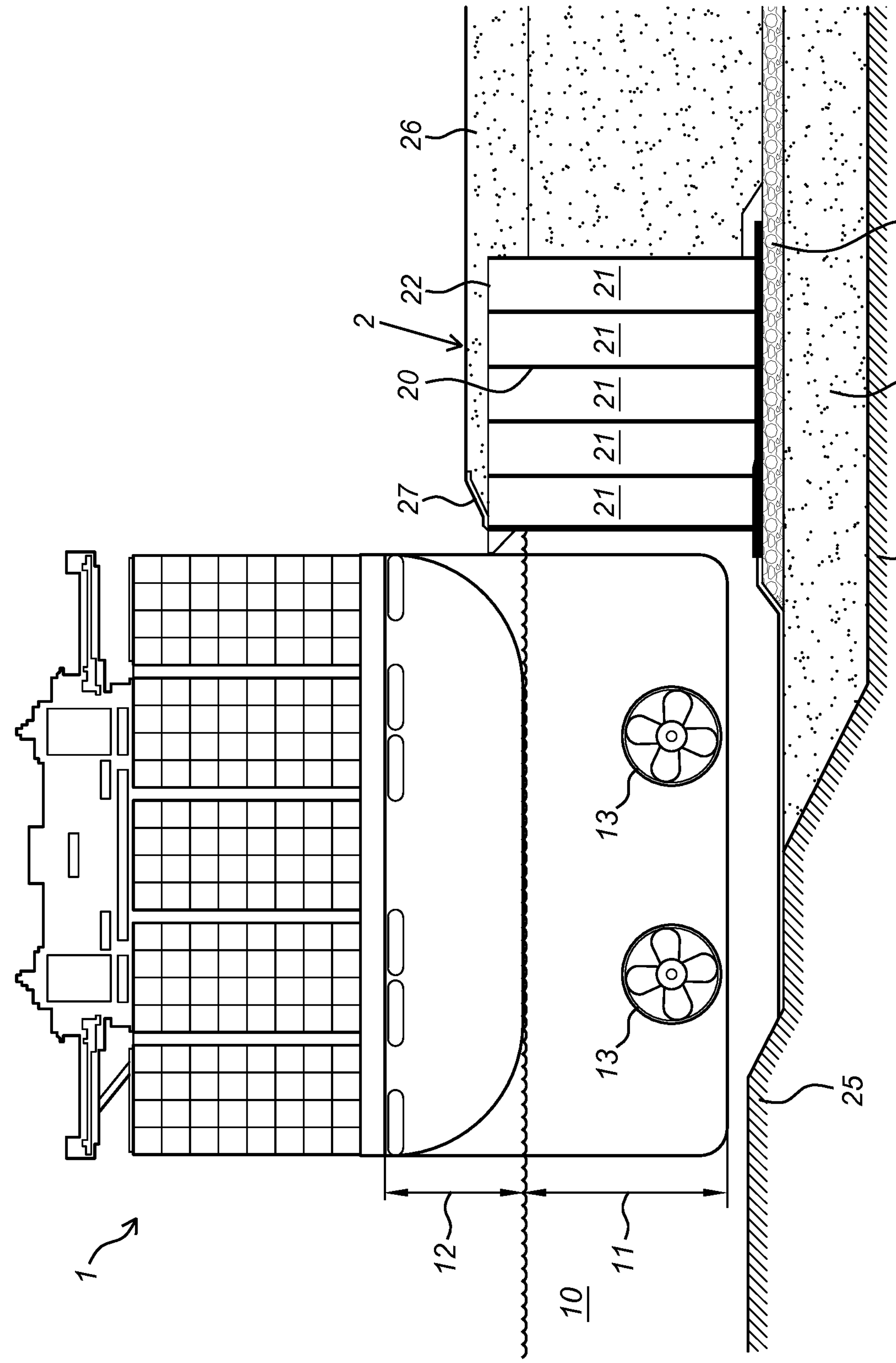

Fig. 1

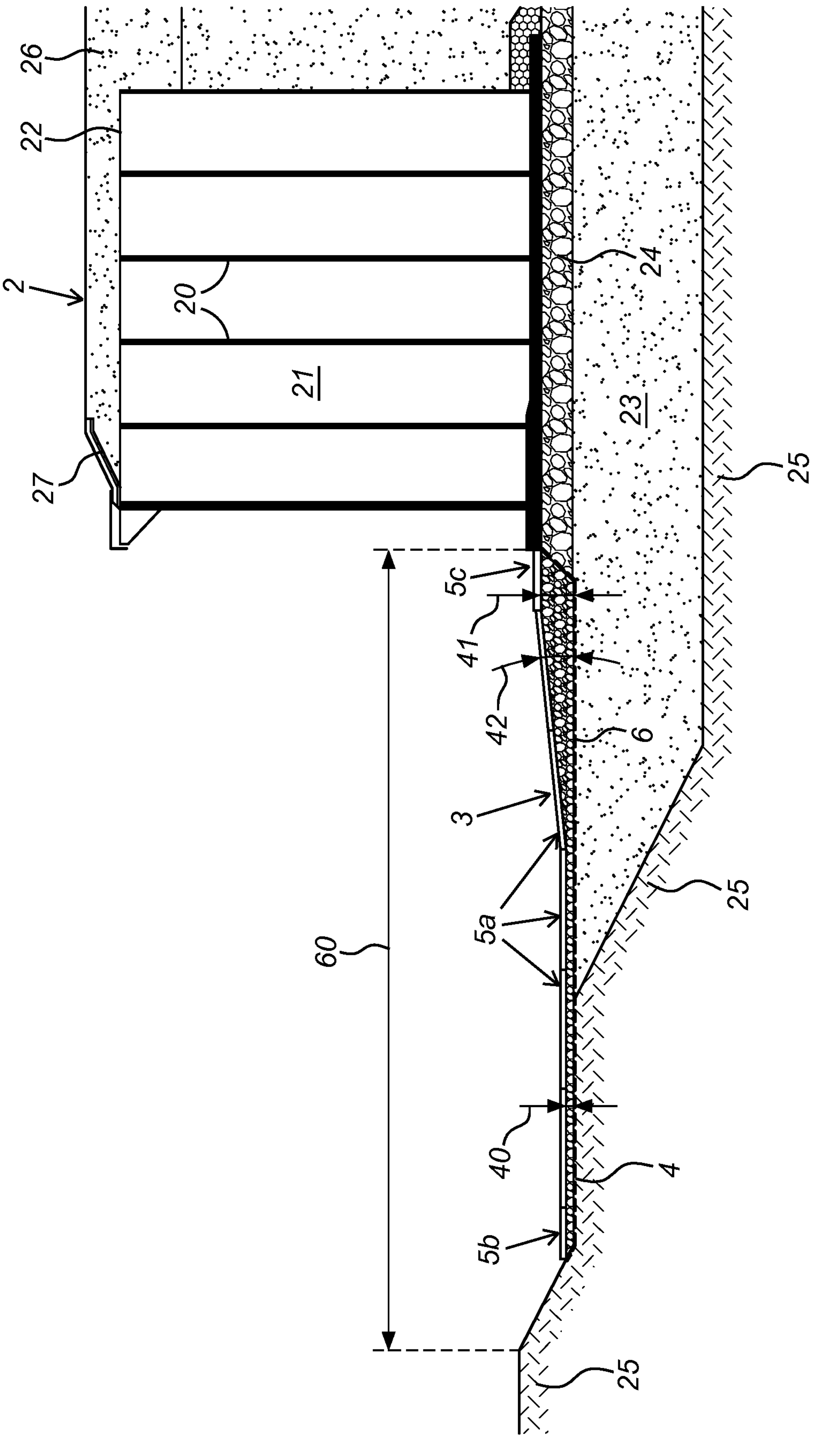

Fig. 2

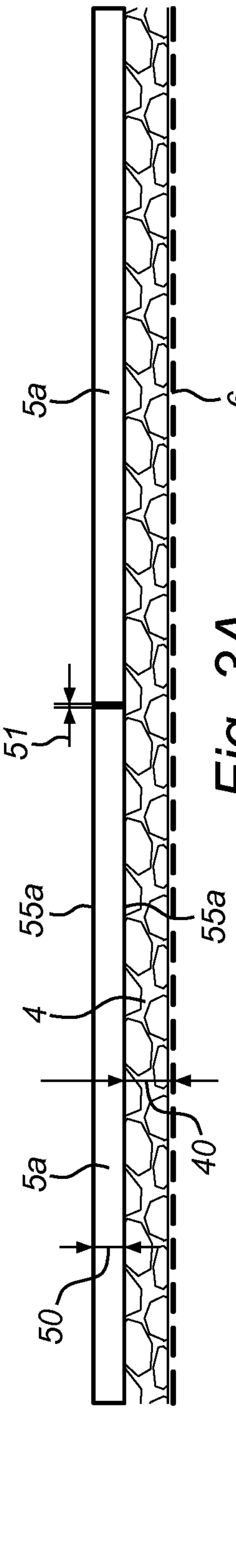

Fig. 3A

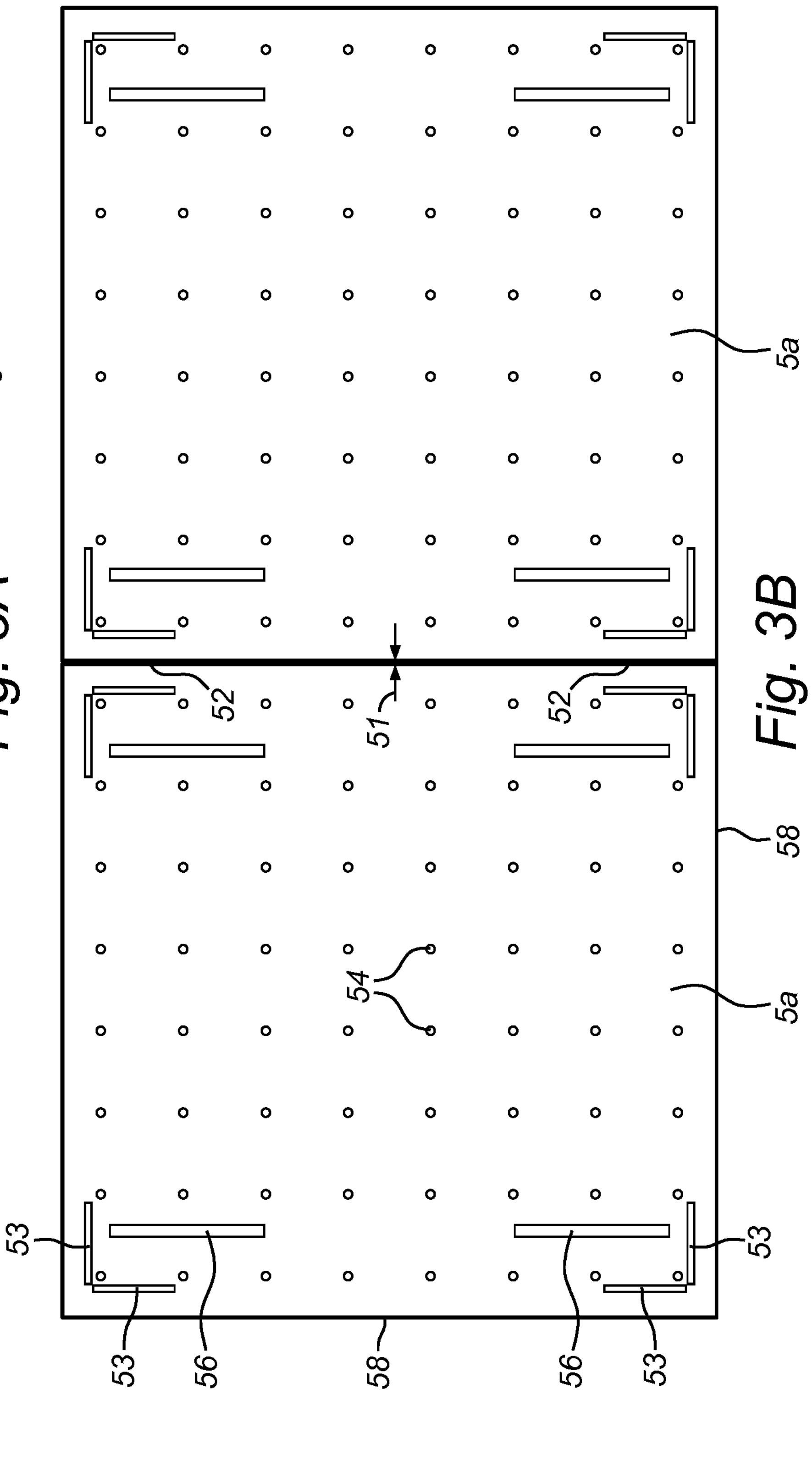

Fig. 3B

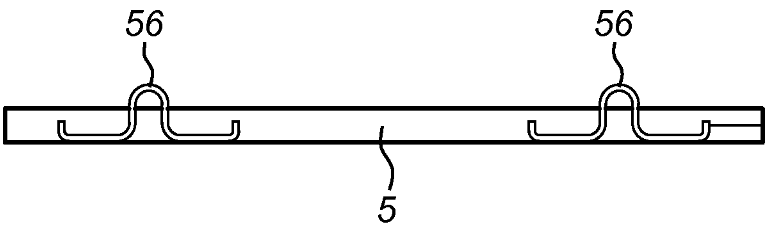

Fig. 3C

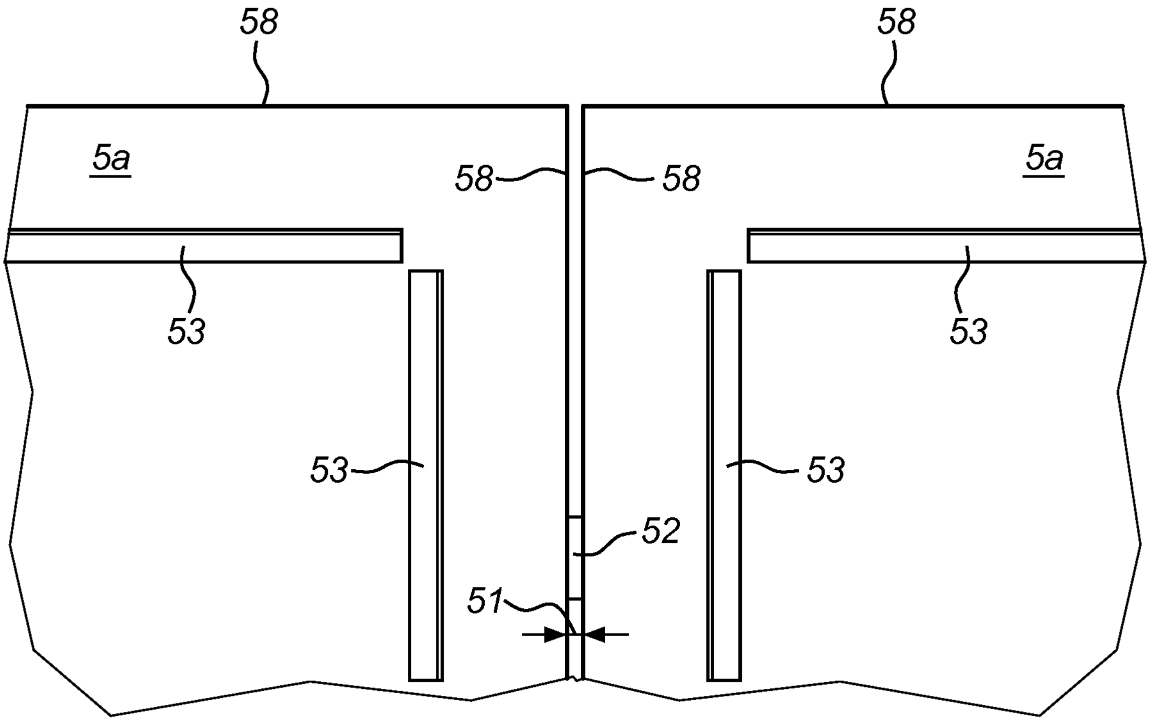

Fig. 3D

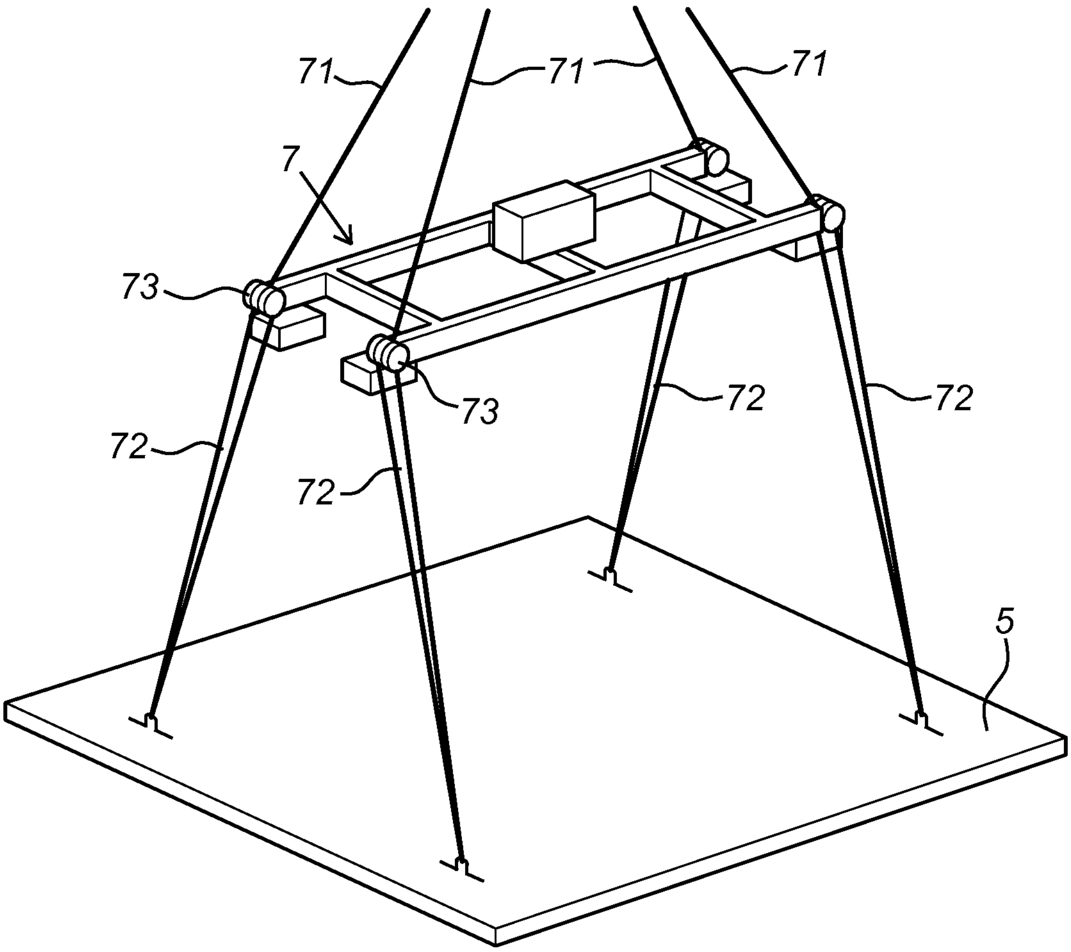

Fig. 4

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EUROPEAN SEARCH REPORT

Application Number
EP 15 16 5792

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	FR 2 125 826 A5 (NAUE KG E A H) 29 September 1972 (1972-09-29) * page 1 - page 5; figures * -----	1-16	INV. E02B3/06 E02B3/12
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A	FR 1 006 559 A (FREYSSINET M. EUGÈNE) 24 April 1952 (1952-04-24) * page 2, column 2, line 3 - line 6; figure 1 * -----	1,16	
A	FR 1 437 602 A (NEYRPIC ETS) 6 May 1966 (1966-05-06) * the whole document * -----	1,16	TECHNICAL FIELDS SEARCHED (IPC) E02B E02D E02F

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	21 October 2015	Van Bost, Sonia

CATEGORY OF CITED DOCUMENTS

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