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(54) FLOATING CAISSONS, METHODS AND APPARATUS FOR CONSTRUCTING FLOATING CAISSONS

SCHWIMMENDE CAISSONS, VERFAHREN UND VORRICHTUNG ZUM BAU VON SCHWIMMENDEN CAISSONS

CAISSONS FLOTTANTS, PROCÉDÉS ET APPAREILS DE CONSTRUCTION DE CAISSONS FLOTTANTS

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Description

[0001] The present application claims the benefit of European patent application nº EP 20 382 605.2 filed on July 7th, 2020.

[0002] The present disclosure relates to floating caissons, and to methods and apparatuses of constructing floating caissons. The present disclosure further relates to structures including caissons.

BACKGROUND

[0003] Infrastructure in ports and harbours make marine traffic possible, and may facilitate facilitating loading and unloading of vessels. Furthermore they have to offer protection from tides and waves action.

[0004] In structures in port and harbour areas, caissons may be used. The use of floating caissons is relatively popular because it allows rapid construction in marine environments. Caissons may be used in the construction of e.g. breakwaters, ports, wharves, dry docks, fishing ports, berths, marinas and other.

[0005] Floating caissons are box-like elements, made of (reinforced) concrete, and which typically have a square or rectangular cross-section and have a number of empty cylindrical cells. Inner walls extending between opposite side walls form a grid and a number of empty cylindrical cells (with a square or rectangular cross-section) is formed in the grid.

[0006] Caissons provide stability and rigidity, and may for this reason be used in different port infrastructures as mentioned before. After construction, the caissons may towed with suitable towboats or other towing systems to their destination. Once in place, the caisson may be ballasted, i.e. the cells may be filled with concrete or granular material. This operation may be performed by auxiliary floating platforms that carry both the material and a special crane to transfer the material. Tractors, dozers, loaders and trucks may help finish the filling operation on top of the caisson.

[0007] A known technique for forming floating caissons is as follows: a slab of concrete may be formed and the parts of the inner walls are formed by pouring concrete in formworks. Once the concrete has formed, the formworks are lifted to form additional portions of walls on top of the already formed walls. Steel meshes may be used to reinforce the walls.

[0008] The walls may be formed in increments of e.g. 1 meter. Due to this technique, the shapes that can be used for the caissons are limited: in principle, only straight walls can be used. Also, this technique requires for the caisson building floating dock to be at least as high as the height of the structure to be built. This makes the caisson building docks very expensive, which means that only a very limited number of them may be use in a country. Infrastructural works may suffer important delays, because caisson building docks are unavailable.

[0009] WO2018222553 A1 discloses an apparatus for constructing a floating caisson in accordance with the preamble of claim 7. It discloses furthermore a method of forming a wall of a floating caisson layer-by-layer, as with and/or by a 3D printer.

[0010] The present disclosure in various examples provides methods, systems, and devices for manufacturing floating caissons and floating caissons that at least partially resolve some of the aforementioned disadvantages.

SUMMARY

[0011] In a first aspect, a method of forming a wall of a floating caisson in accordance with claim 1 is provided.

[0012] In accordance with this aspect, a method of forming walls, portions of walls, and caissons are provided which allow more versatility in the shape of the caisson. Since no formwork is used, and concrete is sprayed on a support, the resulting wall may have any shape that can be given to the support. Also methods in accordance herewith require less complicated apparatus. Since the wall portion that has been formed is lowered, the surrounding apparatus does not need to be raised to construct subsequent wall portions.

[0013] The terms "spraying" or "shooting" concrete are used interchangeably throughout the present disclosure.

[0014] In some examples, the forming of one or more subsequent wall portions comprises providing one or more subsequent supports having first and second outer faces on top of the base supports and forming the subsequent wall portions by spraying or shooting concrete on the first and second outer faces of the subsequent supports. The terms subsequent supports and additional supports are used interchangeably throughout the present disclosure.

[0015] In some examples, lowering the platform may comprise reducing the buoyancy of the platform after the forming of each subsequent wall portion. The platform with already formed structure on top may be lowered by varying the buoyancy of the caisson and/or the platform. The caisson, to the extent that it has been constructed, may be filled with water as desired. The top of the formed structure may thus be lowered to be substantially level with the working decks, so that subsequent wall portions may be easily formed.

[0016] In some examples, reducing the buoyancy of the platform may include filling the platform with water. Particularly when the caisson has been constructed, the platform may be lowered and separated from the caisson to liberate the caisson from the apparatus used in making it. The caisson may then be towed and transported to its destination.

[0017] In some examples, the base supports and/or subsequent supports are made from a material that is relatively lightweight compared to concrete. Specifically, the base supports and/or subsequent supports may be made from polystyrene foam. Polystyrene foam is lightweight, is cheap and can be formed (by cutting, stacking

etc.) in almost any desired shape.

[0018] In some examples, through-holes may be made or provided in the (base) support or additional supports. Connectors for connecting the wall portions on the first and second faces of the supports may be provided. The connectors may be prefabricated, or may be made *in situ.* In order to make connectors *in situ,* armatures may be placed in the through-holes and concrete may be shot or sprayed in the through holes.

[0019] In some examples, the end portions of the armatures may be folded to be substantially parallel the wall portions on the first and second faces.

[0020] In a further aspect, an apparatus for constructing a floating caisson in accordance with claim 7 is provided.

[0021] In accordance with this aspect, an apparatus is provided which may be more cost effective than prior art solutions. Particularly, the apparatus may be lower than known floating caisson building docks. In particular, the position of the platform with respect to the floating pontoon can be varied to allow for the manufacture of subsequent parts of the floating caissons. I.e. instead of constructing continuously at a higher level until the structure is finished, the construction may take place at substantially the same height. The already formed structure is lowered to be able to keep on working at substantially the same height.

[0022] The overhead structure may comprise a plurality of vertical supports supporting transverse beams. The working decks may be suspended from the transverse beams. Also the shotcrete distribution system may be guided along the transverse beams.

[0023] In some examples, one or more of the working decks may be movable with respect to a fixed part of the overhead structure, and particularly one or more of the working decks may be movable horizontally along transverse beams. The transverse beams may include guides or rails along which vertical supports connected to the working platforms may be displaced. Working decks that can be displaced can be helpful to allow for curved walls of caissons.

[0024] In yet a further aspect, a floating caisson comprising a bottom slab and a plurality of vertical walls in accordance with claim 10 is provided.

[0025] A caisson in accordance with this aspect may be relatively lightweight, i.e. for the same strength and stiffness, the caisson may be lighter than in the prior art. The core in particular may be lightweight. The core may be formed by the supports, as defined in the other aspects, upon which concrete is sprayed to form the walls. Concrete is provided on its outer faces. Particularly bending strength and stiffness of the resulting structure may be improved by providing the material further away from the neutral axis and avoiding a massive solid structure. The geometrical distribution of the mass of the structures has a higher second moment of area and thereby greater stiffness and strength for a given mass can be achieved. An aspect of the double-wall reinforced concrete surfaces is to remove the concrete which has the smallest or no load bearing effect, i.e. the effect is to remove the material that is not carrying much load and concentrating it where the load is highest".

[0026] In some examples, one or more of the vertical walls, and specifically external vertical walls of the floating caisson, may include a convex or concave shape. In some examples, one or more of the vertical walls may be doubly curved.

BRIEF DESCRIPTION OF THE DRAWINGS

[0027] Non-limiting examples of the present disclosure will be described in the following, with reference to the appended drawings, in which:

Figures 1A - 1D schematically illustrate a method, and apparatus for constructing a floating caisson according to a first example;

Figures 2A - 2C schematically illustrate different stages in a method for constructing a floating caisson according to an example;

Figures 3A - 3B schematically illustrate an example of a caisson that may be used in structures along the shore;

Figures 4A - 4B schematically illustrate a further example of an apparatus for constructing a floating caisson;

Figures 5A - 5D schematically illustrates a further example a construction method of a caisson;

Figure 6 schematically illustrates a method for transporting a floating caisson once constructed; and

Figures 7A and 7B illustrate examples of working decks.

DETAILED DESCRIPTION OF EXAMPLES

[0028] Figures 1A - 1D schematically illustrate a method, and apparatus for constructing a floating caisson according to a first example. Figure 1A provides a cross-sectional view, whereas figures 1B - 1D provide top views of the same apparatus of figure 1A, each of the figures highlighting a different subsystem.

[0029] Figure 1A shows an apparatus 70 for constructing a floating caisson 100. The apparatus may be floating in a body of water, e.g. in a part of a sea close to a shore, port or harbor where a structure is to be built.

[0030] The apparatus 70 comprises a floating pontoon 10, and a submersible platform 20, which is connected to the floating pontoon 10. The connection is such that a vertical position (inside the water) of the platform 20 can be varied with respect to the floating pontoon 10. In this

particular example, the connection between the floating pontoon 10 and the platform 20 may include one or more cables or chains or mooring lines, which may be connected at anchoring points 12 and 14. The connection may include pulleys or winches as needed.

[0031] The apparatus 70 further comprises an overhead structure 30 supported by the floating pontoon 10, wherein the overhead structure 30 comprises one or more working decks 40A, 40B and a shotcrete distribution system 50 for supplying shotcrete to workers on the working decks. The working decks are configured to support workers on the working decks. They may allow workers to move around on them.

[0032] Shotcrete, (sometimes called "gunite" or "sprayed concrete") is concrete or mortar conveyed through a hose and pneumatically projected at high velocity onto a surface, as a construction technique. The wall formed in this manner may be reinforced by conventional steel rods, steel mesh, or fibers. Shotcrete as used throughout the present disclosure may refer to both wet-mix and dry-mix versions.

[0033] In some examples, the submersible platform may have variable buoyancy to vary a position of the submersible platform 20 with respect to the pontoon and / or with respect the floating caisson 100. The platform 20 may have a system to control ingress and egress of water. Suitable (bilge) pumps and valve systems may be used.

[0034] In the top views of figures 1B - 1D, it may be seen that the floating pontoon 10 may have an open cross-section, and may be substantially U-shaped or C-shaped. With reference to figure 1C, it may be seen that several rows of inner working decks 40A may be arranged between the legs of the U-shape. In this particular example, four rows of inner working decks may be arranged. Each of the rows includes three inner working decks 40A. Additionally, an annular outer working deck 40B may be provided. The annular working deck may substantially surround all the inner working decks 40A.

[0035] With reference to figures 1A and 1B, it may be seen that the overhead structure 30 may include a plurality of vertical side supports 32 and a plurality of transverse beams 34. Each of the transverse beams 34 may extend between vertical side supports 32. The vertical side supports 32 may be directly positioned on top of floating pontoon 10 and carry the transverse beams 34.

[0036] As illustrated in figure 1A, the overhead structure may be formed or may comprise truss structures. The vertical supports 36 may extend between working decks 40A and 40B and a transverse beam 34. The vertical supports 36 may be suspended from the transverse beams 34.

[0037] In some examples, each of the inner working decks 40A may comprise an intermediate vertical support 36. In some examples, one transverse beam 34 may be arranged with each row of working decks 40 A.

[0038] With reference to figure 1D, it may be seen how a shotcrete distribution system 50 may include a central supply 54. From the central supply 54, several transverse distribution lines 56 may extend sideways. Each of the transverse distribution lines 56 may include one or more delivery hoses 58 (illustrated in figure 1A). The distribution lines may be supported by transverse beams 34. If the transverse beams 34 are formed as truss structures, the distribution lines may advantageously be arranged inside the truss structures.

[0039] The hoses 58 may be held by workers on the working decks 40A, 40B and may be used for spraying or "shooting" concrete. In some examples, the hoses may be arranged with the vertical supports 36. In some examples, a hose may be arranged with each of the vertical supports 36.

[0040] Shotcrete machines are available which can control the concrete spraying process and make it very fast and easy. Manual and mechanical methods may be used for the wet spraying process but wet sprayed concrete is traditionally applied by machine.

[0041] An apparatus according to the present disclosure may be relatively easily transported. I.e. it may be dismounted and transported by road (truck) or by sea to a construction site. The vertical supports 36, side supports 32 and transverse beams may be relatively easily disassembled from each other.

[0042] It may also be appreciated that the build-up of the apparatus illustrated herein is modular and may be easily scaled up as needed.

[0043] Using an apparatus such as the one shown in figure 1, a method of forming a wall 120 of a floating caisson 100 may comprise providing a slab 110 on a submersible platform 20. One or more supports 130 may be provided on top on top of the slab 20, the supports 130 having a first outer surface 132 and a second outer face 134. A wall portion may be formed by spraying or shooting concrete on the first and second outer faces 132, 134 of the supports 130.

[0044] Then, the platform 20 may be lowered. Subsequent wall portions may then be formed on top as needed.

[0045] The walls may thus be formed by spraying or shooting concrete on the supports. The supports 130 may be chosen to be lightweight. This shall be understood in the present disclosure as a support with a density that is lower than the density of the concrete sprayed on its face.

[0046] The supports 130 in examples may extend substantially perpendicular to the slab 110.

[0047] One example of a support is polystyrene foam. Polystyrene foam is lightweight, and may be cut, sized and shaped and arranged in a wide variety of ways. Thus any suitable support shape may be provided upon which concrete can be sprayed. The thickness of the concrete on either face of the support may be varied as needed. As a result, a wide variety of shapes and forms may be provided for the walls of the caisson. E.g. a wall of the caisson may be curved, e.g. be concave or convex. A wall of the caisson may have a double curvature, i.e. may be curved both in a vertical and a horizontal direction.

Even though any of the walls of the caisson may be curved in this manner. The curvature of the outer walls of the caisson may be particularly suitable, e.g. when they have to function as breakwater structure. The curvature of the outer walls of the caisson may be chosen such as to absorb impact of incoming waves and/or to divert incoming waves suitably.

[0048] Other materials may also be used for the support, e.g. wood or polymer structures. The supports may be partially hollow in some examples.

[0049] A process of constructing a wall or a plurality of walls of a floating caisson starts with the arrangement of base supports on slab 110 to form the bottom section of the walls. Once the bottom portion of the wall(s) has been formed, the platform 20 is lowered. Then, subsequent wall portions are formed until the desired height for the walls is reached. The forming of one or more subsequent wall portions comprises providing one or more subsequent supports having first and second outer faces on top of the base supports and forming the subsequent wall portions by spraying or shooting concrete on the first and second outer faces of the subsequent supports.

[0050] Wall 121 may be formed by a worker from the annular outer working deck 40B for one face of the wall and from an inner working deck 40A for the other face of the wall. The situation is similar for wall 124. For wall 122, spraying may be performed from two neighboring inner working decks 40A. The same applies to wall 123. It is noted that only a cross-section is shown in figure 1A. The floating caisson may have a plurality of walls that extend perpendicular to the walls 121, 122, 123 and 124.

[0051] In some examples, armatures may be positioned along the faces of the supports 130 prior to shooting concrete. The armatures may be steel meshes, or fiber reinforced composites (e.g. glass fibers, carbon fibers or Kevlar® fibers).

[0052] In some examples, the supports 130 may have through-holes extending from the first face 132 to the second face 134. In other examples, the through-holes may be made *in situ* (e.g. they may be driller or bored, or carved out or otherwise). In order to reinforce the resulting wall structure, connectors may be provided through such through holes.

[0053] The connectors may be prefabricated or may be made *in situ.* As the wall portions, concrete may be used for the connectors. In a particular example, a reinforcement, such as a steel mesh or steel bars may be positioned in the through-hole substantially extending from the first face 132 to the second face 134. When concrete is shot on the faces 132, 134, the spaces of the connectors may be filled with concrete at the same time.

[0054] In some examples, the steel meshes or steel bars of the connectors may be folded at both ends to be substantially parallel to the walls.

[0055] An aspect of examples of the methods disclosed herein is that the overhead structure including working decks may stay substantially at the same height throughout the entire construction process of a caisson. The floating caisson, to the extent that it has been constructed, is lowered. Subsequent wall portions may thus be formed from the same height. The operators (and working decks) thus stay in substantially the same position. In prior art solutions, the caisson building floating docks, need to be at least as high as the heights of the structure to be built, since formworks are used.

[0056] In some examples, the buoyancy of the platform may be reduced after the forming of each subsequent wall portion. In some examples, the platform may be filled with water as needed to vary its buoyancy. Once wall portions of the caissons have dried up, the caisson may be filled with water to a desired level WL_{in}. This water level does not need to be the same as the overall water level WL at sea, and in general will be different.

[0057] Figures 2A - 2C schematically illustrate different stages in a method for constructing a floating caisson according to an example. In figure 2A, the first step of spraying concrete is about to take place. It may be seen in figure 2A that a slab has been arranged on platform 20. Such a slab may be made as known in the art. The slab may be made of (steel) reinforced concrete. Steel bars may stick out upwards from the slab. Also the slab may contain stub(s) forming the beginning of the walls to be created. Then base supports 130 are may positioned. Reinforcement (steel) meshes may be arranged on either side of the supports 130.

[0058] Then, concrete is sprayed on the base supports 130. In some examples, the base supports 130 may be entirely covered in such a step. In other examples, the base supports 130 that are positioned may not be entirely covered. E.g. the base supports 130 may have a height of 1,5 or 2 meters, whereas in a single step 1 meter of concrete is sprayed and then left to dry. It should be clear that these dimensions are only examples, and that in practice they may be varied.

[0059] After the concrete has dried, the platform 20 with the caisson is lowered. As mentioned before, the caisson may be filled with water as need to lower the caisson structure to the level needed. Then, a next portion of wall may be made by repeating the same process. Additional supports may be positioned, reinforcements may be arranged along the first and second faces, and concrete may be shot. In some or all of these steps, connectors between the faces may be provided as explained in other parts of the present disclosure.

[0060] In the situation of figure 2B, the total height of the walls has been constructed. As such, the floating caisson 100 is finished. It may be seen in figure 2B, how the top of the walls is substantially level with the working decks. In order to remove the caisson 100 from the apparatus, the caisson may be flooded with water to a desired level WL_{IN}. The submersible platform 20 may also be flooded with water as needed to separate it from the floating caisson, see figure 2C. The caisson may then be pulled out and transported to the site of construction.

[0061] In accordance with examples disclosed herein, a floating caisson is constructed that comprises a bottom

slab and a plurality of vertical walls. The vertical walls comprise a core of a first material, and a first shotcrete layer on a first face of the core and a second shotcrete layer on a second opposite face of the core. The resulting floating caisson may be lighter than similar caissons in the prior art. The strength and stiffness however may still be the same as in the prior art. Less concrete is needed to reach the same level of bending strength.

[0062] The core may be made from a lightweight material, optionally polystyrene foam. The first and second concrete layers may be made of reinforced concrete. The bottom slab may be made from concrete as well, optionally reinforced concrete. In some examples, one or more of the vertical walls, particularly the outer walls of the caisson may include a convex or concave shape. The core may be formed by the base support and additional supports mentioned before.

[0063] Figures 3A - 3B schematically illustrate an example of a caisson that may be used in structures along the shore. Figure 3A shows a side view of a caisson 200 that may be used in a structure such as a pier, seawall or jetty. Jetties may be used e.g. to delimit harbors. Sea side is indicated with reference sign 260, and lee side is indicated with reference sign 250. The sea side wall 230 may be substantially concave and may function as breakwater. The lee side wall 235 may also be curved, but have a different curvature than the sea side wall. Reference sign 280 indicates a top surface of the caisson 200. The top surface 280 of caisson 200 may be used by pedestrians and other traffic once the caisson has been constructed and is operational.

[0064] With examples of the methods disclosed herein, the upper portion 270 on the sea side wall 230 forming a barrier or wall may be formed integrally with the caisson and the sea side wall. In prior art solutions, such a wall would normally be added *in situ* after placement of the caisson.

[0065] Figure 3B illustrates how a caisson 200 may have been transported to the construction site to be placed. The caisson 200 may be ballasted and positioned on bedding 210.

[0066] Figures 4A - 4B schematically illustrate a further example of an apparatus for constructing a floating caisson. In the example of figure 4A, the apparatus 70 comprises a floating pontoon 10. Like the previous example, a superstructure of the apparatus 70 comprises vertical side supports 32 and transverse beams 34. The working decks 40C and 40D are coupled to vertical beams 36 suspended from the transverse beams 34. Similarly to the previous example, a shotcrete distribution system 50 for supplying shotcrete to workers 60 on the working decks.

[0067] Further, as in the previous example, a submersible platform 20 may be connected to the floating pontoon to vary the vertical position of the submersible platform. The position of the submersible platform may be changed without changing the vertical position of the floating pontoon. A connection between the pontoon 10 and platform 20 may include a plurality of chains, wire ropes, cables or similar. Anchoring points 12 and 14 may be provided as commented before.

[0068] The floating caisson 300 to be constructed in this example is slightly different from the example of figure 1. A middle wall of floating caisson 300 is a substantially vertical straight wall, whereas the front and rear walls are curved. Figure 4A illustrates how the supports 130, 131 upon which the shotcrete is shot may be different for the different walls.

[0069] One difference between the example of figure 4 and the example of figure 1, is that vertical guides 92 extend between the sea bed SB and the submersible platform 20. The guides 92 facilitate the platform 20 to move vertically and not drift.

[0070] A further difference between the example of figure 4 and the example of figure 1 is that one or more of the working decks may be movable, and in particular one or more the vertical supports 36 carrying working decks 40C may be displaced along transverse beams 34. The transverse beam may comprise rails or guides, along which the vertical supports 36 may be slid. Also the outer working deck 40D may be displaced in a similar manner.

[0071] The floating pontoon 10 may have a closed perimeter as may be seen in the top view of figure 4B. In a horizontal cross-section, the floating pontoon 10 may have a square ring-shaped form, or gates are provided to close the C-shape or U-shape of the pontoon.

[0072] The platform 20 may have a system to control ingress and egress of water. Suitable (bilge) pumps and valve systems may be used. Water lines 21 may be used to selectively fill the platform 20. One or more water lines 21 in some examples may lead from pontoon 21 to submersible platform 20.

[0073] Figures 5A - 5D schematically illustrates a further example a construction method of a caisson. Figure 5A illustrates a first step (or one of the first steps) for constructing wall portions with base supports 130, 131. At the stage of figure 5, a slab of concrete has been provided, with relatively small stubs where the walls are to be formed.

[0074] The outer walls of the floating caisson in this example are curved. The working decks 40C and 40D may be horizontally moveable to allow workers to shoot concrete on the supports, even as the walls are curved. Between the steps of figure 5B and 5C, the working decks are horizontally moved. The last construction step may be seen in figure 5C. A curved support 131 is placed to form the last portion of a sea side wall of the floating caisson.

[0075] When the floating caisson has been finished, figure 5D, the submersible platform 20 may be filled with water to sink the platform 20. The floating caisson may then be towed away.

[0076] Figure 6 schematically illustrates a method for transporting a floating caisson once constructed. It was noted before that the pontoon 10 of the apparatus 70 may form a closed cross-section. In order to tow a floating

caisson 300 to a construction site where it may be filled to sink it, a towing vessel 160 using cables 165 or similar may tow the floating caisson 300 away. One side 13 of the floating pontoon may be closed off with gates 13A and 13B which may be opened after construction is finished.

[0077] Figures 7A and 7B illustrate examples of working decks 40C and 40D. The working decks 40C may include a female receiving portion to mate with a bottom portion of the vertical supports 36, such that the vertical support 36 can fit inside and the working deck may thereby be attached to the vertical support. The working surface 45 of the working deck may be substantially flat so that workers may move around comfortably and safely. Several ribs 43 may be seen that reinforce the working decks 40C, 40D.

[0078] While the use of shotcrete has generally been described in the illustrated examples, and walls of floating caissons are formed generally by shooting or projecting concrete on a support, in other examples, classic formworks may be used. Substantially the same apparatus including pontoon, submersible platform and a similar overhead structure including working decks may be used in these cases. Instead of shotcrete, concrete for formworks may be supplied through a suitable distribution system.

[0079] Thus, the scope of the present disclosure should not be limited by particular examples, but should be determined only by a fair reading of the claims that follow.

Claims

1. A method of forming a wall (121, 122, 123, 124) of a floating caisson (100, 200, 300) comprising:

   providing a slab (110) on a submersible platform (20);
   providing one or more base supports (130, 131) on top of the slab (110), the base supports (130, 131) having a first outer face (132) and a second outer face (134);
   forming a first wall portion by spraying concrete on the first (132) and the second (134) outer faces;
   lowering the platform (20) below a water level; and
   forming one or more subsequent wall portions on the first wall portion.

2. The method of claim 1, wherein the forming one or more subsequent wall portions comprises providing one or more subsequent supports having first and second outer faces on top of the base supports (130, 131) and forming the subsequent wall portions by spraying or shooting concrete on the first and second outer faces of the subsequent supports.

3. The method of claim 1 or 2, further comprising lowering the platform (20) by reducing the buoyancy of the platform (20) after the forming of each subsequent wall portion.

4. The method of claim 3, wherein reducing the buoyancy of the platform (20) includes filling the platform (20) with water.

5. The method of any of claims 1 - 4, wherein the base supports (130, 131) and/or subsequent supports are made from a material that is relatively lightweight compared to concrete.

6. The method of any of claims 1 - 5, wherein the base supports (130, 131) and/or subsequent supports are made from polystyrene foam.

7. An apparatus (70) for constructing a floating caisson (100, 200, 300), the apparatus (70) comprising:

   a floating pontoon (10),
   a submersible platform (20), which is connected to the floating pontoon (10) in such a way that a vertical position of the platform (20) with respect to the floating pontoon (10) can be varied, and
   an overhead structure (30) supported by the floating pontoon (10), **characterised in that**
   the overhead structure (30) comprises one or more working decks (40A, 40B, 40C, 40D) configured to support workers on the working decks (40A, 40B, 40C, 40D) and a shotcrete distribution system (50) for supplying shotcrete to workers on the working decks (40A, 40B, 40C, 40D).

8. The apparatus according to claim 7, wherein one or more of the working decks (40A, 40B, 40C, 40D) are movable substantially horizontally.

9. The apparatus according to claim 7 or 8, wherein the submersible platform (20) is connected to the floating pontoon (10) with one or more cables, optionally guided by pulleys.

10. A floating caisson (100, 200, 300) obtainable by a method according to any of claims 1 -6 comprising a bottom slab (110) and a plurality of vertical walls (121, 122, 123, 124), wherein

    the vertical walls (121, 122, 123, 124) comprise a core (130, 131) of a first material, and
    a first shotcrete layer on a first face of the core (132) and a second shotcrete layer on a second opposite face of the core (134).

11. The floating caisson according to claim 10, wherein the core (130, 131) is made from a lightweight material, optionally polystyrene foam.

12. The floating caisson according to claim 10 or 11, wherein the first and second shotcrete layer are made of reinforced concrete.

13. The floating caisson according to any of claims 10 - 12, wherein the bottom slab (110) is made from concrete, optionally reinforced concrete.

14. The floating caisson according to any of claims 10 - 13, wherein one or more of the vertical walls (121, 122, 123, 124) includes a convex or concave shape.

15. A breakwater structure including one or more floating caissons (100, 200, 300) according to any of claims 10 - 14.

Patentansprüche

1. Verfahren zum Formen einer Wand (121, 122, 123, 124) eines schwimmenden Senkkastens (100, 200, 300), das Folgendes umfasst:

Bereitstellung einer Platte (110) auf einer versenkbaren Plattform (20);
Bereitstellen einer oder mehrerer Basisstützen (130, 131) auf der Oberseite der Platte (110), wobei die Basisstützen (130, 131) eine erste Außenfläche (132) und eine zweite Außenfläche (134) aufweisen;
Bildung eines ersten Wandabschnitts durch Aufspritzen von Beton auf die erste (132) und die zweite (134) Außenfläche;
Absenken der Plattform (20) unter einen Wasserspiegel; und
Ausbilden eines oder mehrerer nachfolgender Wandabschnitte an dem ersten Wandabschnitt.

2. Verfahren nach Anspruch 1, wobei das Ausbilden eines oder mehrerer nachfolgender Wandabschnitte das Bereitstellen einer oder mehrerer nachfolgender Stützen mit ersten und zweiten Außenflächen auf der Oberseite der Basisstützen (130, 131) und das Ausbilden der nachfolgenden Wandabschnitte durch Sprühen oder Spritzen von Beton auf die ersten und zweiten Außenflächen der nachfolgenden Stützen umfasst.

3. Verfahren nach Anspruch 1 oder 2, das ferner das Absenken der Plattform (20) durch Verringern des Auftriebs der Plattform (20) nach der Bildung jedes nachfolgenden Wandabschnitts umfasst.

4. Verfahren nach Anspruch 3, wobei die Verringerung des Auftriebs der Plattform (20) das Füllen der Plattform (20) mit Wasser umfasst.

5. Verfahren nach einem der Ansprüche 1 bis 4, bei dem die Basisstützen (130, 131) und/oder die nachfolgenden Stützen aus einem Material hergestellt sind, das im Vergleich zu Beton relativ leicht ist.

6. Verfahren nach einem der Ansprüche 1 bis 5, wobei die Basisstützen(130, 131) und/oder die nachfolgenden Stützen aus Polystyrolschaum hergestellt sind.

7. Eine Vorrichtung (70) zum Bau eines schwimmenden Senkkastens (100, 200, 300), wobei die Vorrichtung (70) umfasst:

einen Schwimmponton (10),
eine versenkbare Plattform (20), die mit dem Schwimmponton (10) so verbunden ist, dass eine vertikale Position der Plattform (20) in Bezug auf den Schwimmponton (10) verändert werden kann, und
eine von dem Schwimmponton (10) getragene Überkopfstruktur (30), wobei
die Überkopfstruktur (30) ein oder mehrere Arbeitsdecke (40A, 40B, 40C, 40D) , die so konfiguriert sind, dass sie Arbeiter auf die Arbeitsdecke (40A, 40B, 40C, 40D) tragen, und ein Spritzbetonverteilungssystem (50) zur Versorgung der Arbeiter auf die Arbeitsdecke (40A, 40B, 40C, 40D) mit Spritzbeton umfasst.

8. Vorrichtung nach Anspruch 7, wobei eines oder mehrere der Arbeitsdecks (40A, 40B, 40C, 40D) im Wesentlichen horizontal beweglich sind.

9. Vorrichtung nach Anspruch 7 oder 8, wobei die versenkbare Plattform (20) mit dem Schwimmponton (10) mit einem oder mehreren Seilen verbunden ist, die gegebenenfalls über Umlenkrollen geführt werden.

10. Schwimmender Senkkasten (100, 200, 300), der durch ein Verfahren nach einem der Ansprüche 1 bis 6 erhältlich ist und eine Bodenplatte (110) und eine Vielzahl von vertikalen Wänden (121, 122, 123, 124) umfasst, wobei

die vertikalen Wände (121, 122, 123, 124) einen Kern (130, 131) aus einem ersten Material umfassen und
eine erste Spritzbetonschicht auf einer ersten Seite des Kerns (132) und eine zweite Spritzbetonschicht auf einer zweiten gegenüberliegenden Seite des Kerns (134).

11. Schwimmender Senkkasten nach Anspruch 10, wobei der Kern (130, 131) aus einem leichten Material, gegebenenfalls Polystyrolschaum, hergestellt ist.

12. Schwimmender Senkkasten nach Anspruch 9 oder 10, wobei die erste und die zweite Spritzbetonschicht

aus Stahlbeton hergestellt sind.

13. Schwimmender Senkkasten nach einem der Ansprüche 10 bis 12, wobei die Bodenplatte (110) aus Beton, wahlweise aus Stahlbeton, hergestellt ist.

14. Schwimmender Senkkasten nach einem der Ansprüche 10 bis 13, wobei eine oder mehrere der vertikalen Wände (121, 122, 123, 124) eine konvexe oder konkave Form aufweisen.

15. Eine Wellenbrecherstruktur mit einem oder mehreren schwimmenden Senkkästen (100, 200, 300) nach einem der Ansprüche 10 bis 14.

Revendications

1. Méthode de formation d'une paroi (121, 122, 123, 124) d'un caisson flottant (100, 200, 300) comprenant :

fournir une dalle (110) sur une plate-forme submersible (20) ;
fournir un ou plusieurs supports de base (130, 131) sur la dalle (110), les supports de base (130, 131) ayant une première face extérieure (132) et une deuxième face extérieure (134) ;
former une première portion de paroi en projetant du béton sur la première (132) et la deuxième (134) faces externes ;
abaisser la plate-forme (20) en dessous du niveau de l'eau ; et
la formation d'une ou de plusieurs parties de paroi ultérieures sur la première partie de paroi.

2. Méthode de la revendication 1, dans laquelle la formation d'une ou de plusieurs parties de paroi ultérieures comprend la fourniture d'un ou de plusieurs supports ultérieurs ayant une première et une deuxième face extérieure sur les supports de base (130, 131) et la formation des parties de paroi ultérieures par pulvérisation ou projection de béton sur la première et la deuxième face extérieure des supports ultérieurs.

3. Méthode de la revendication 1 ou 2, comprenant en outre l'abaissement de la plate-forme (20) en réduisant la flottabilité de la plate-forme (20) après la formation de chaque portion de paroi ultérieure.

4. Méthode de la revendication 3, dans laquelle la réduction de la flottabilité de la plate-forme (20) comprend le remplissage de la plate-forme (20) avec de l'eau.

5. Méthode de l'une des revendications 1 à 4, dans laquelle les supports de base (130, 131) et/ou les supports ultérieurs sont fabriqués à partir d'un matériau relativement léger par rapport au béton.

6. Méthode de l'une des revendications 1 à 5, dans laquelle les supports de base (130, 131) et/ou les supports ultérieurs sont en mousse de polystyrène.

7. Appareil (70) pour la construction d'un caisson flottant (100, 200, 300), l'appareil (70) comprenant :

un ponton flottant (10),
une plate-forme submersible (20), qui est reliée au ponton flottant (10) de manière à ce que la position verticale de la plate-forme (20) par rapport au ponton flottant (10) puisse être modifiée, et
une structure aérienne (30) supportée par le ponton flottant (10), dans laquelle
la structure aérienne (30) comprend un ou plusieurs ponts de travail (40A, 40B, 40C, 40D) configurés pour soutenir les travailleurs sur les ponts de travail (40A, 40B, 40C, 40D) et un système de distribution de béton projeté (50) pour fournir du béton projeté aux travailleurs sur les ponts de travail (40A, 40B, 40C, 40D).

8. L'appareil selon la revendication 7, dans lequel un ou plusieurs des ponts de travail (40A, 40B, 40C, 40D) sont déplaçables sensiblement horizontalement.

9. L'appareil selon la revendication 7 ou 8, dans lequel la plate-forme submersible (20) est reliée au ponton flottant (10) par un ou plusieurs câbles, éventuellement guidés par des poulies.

10. Un caisson flottant (100, 200, 300) obtenu par un procédé selon l'une quelconque des revendications 1 à 6, comprenant une dalle de fond (110) et plusieurs parois verticales (121, 122, 123, 124), dans lequel

les parois verticales (121, 122, 123, 124) comprennent une âme (130, 131) d'un premier matériau, et
une première couche de béton projeté sur une première face du noyau (132) et une seconde couche de béton projeté sur une seconde face opposée du noyau (134).

11. Le caisson flottant selon la revendication 10, dans lequel le noyau (130, 131) est fabriqué à partir d'un matériau léger, éventuellement de la mousse de polystyrène.

12. Le caisson flottant selon la revendication 9 ou 10, dans lequel la première et la deuxième couche de béton projeté sont en béton armé.

13. Le caisson flottant selon l'une des revendications 10 à 12, dans lequel la dalle de fond (110) est en béton, éventuellement en béton armé.

14. Le caisson flottant selon l'une des revendications 10 à 13, dans lequel une ou plusieurs des parois verticales (121, 122, 123, 124) ont une forme convexe ou concave.

15. Structure de brise-lames comprenant un ou plusieurs caissons flottants (100, 200, 300) selon l'une des revendications 10 à 14.

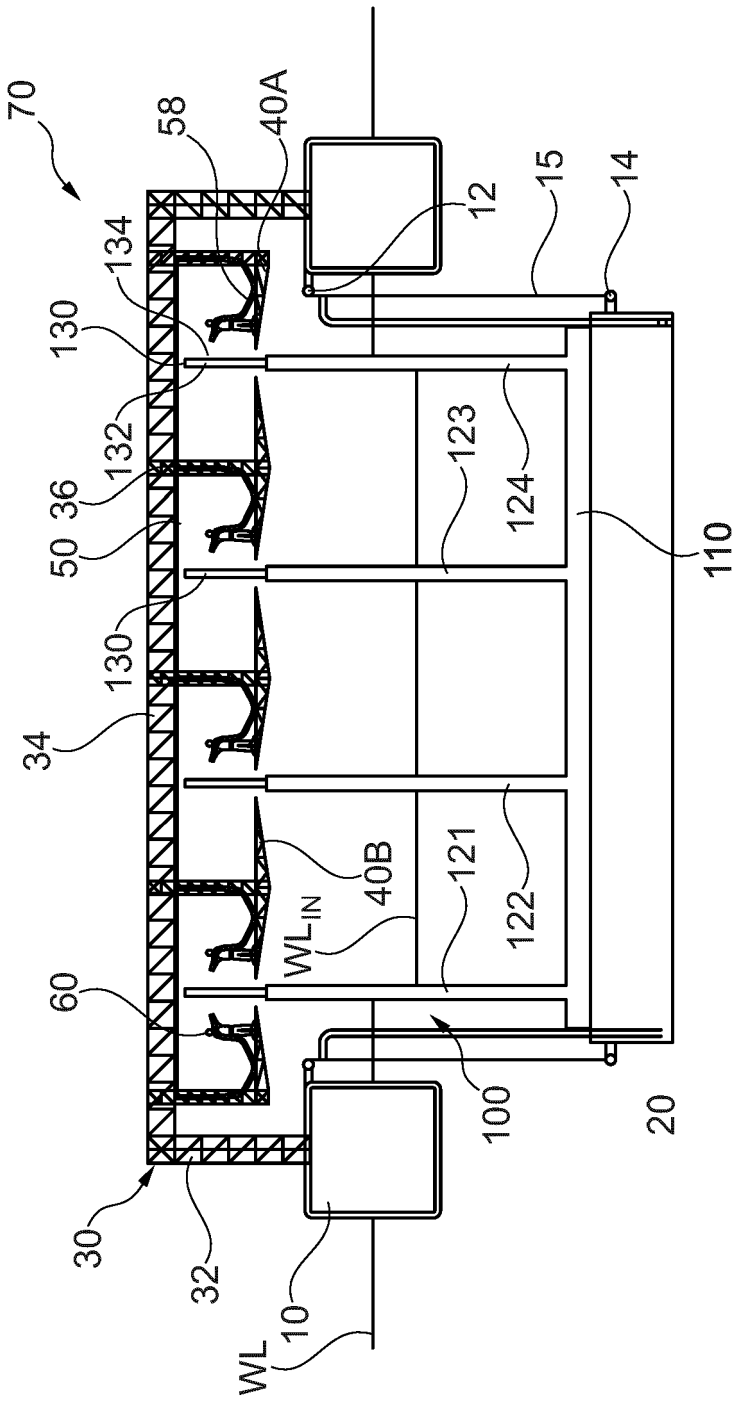
70
58
40A
12
15
14
134
130
132
36
50
130
34
123
124
110
40B
WL_{IN}
121
122
60
100
20
30
32
10
WL

Fig. 1A

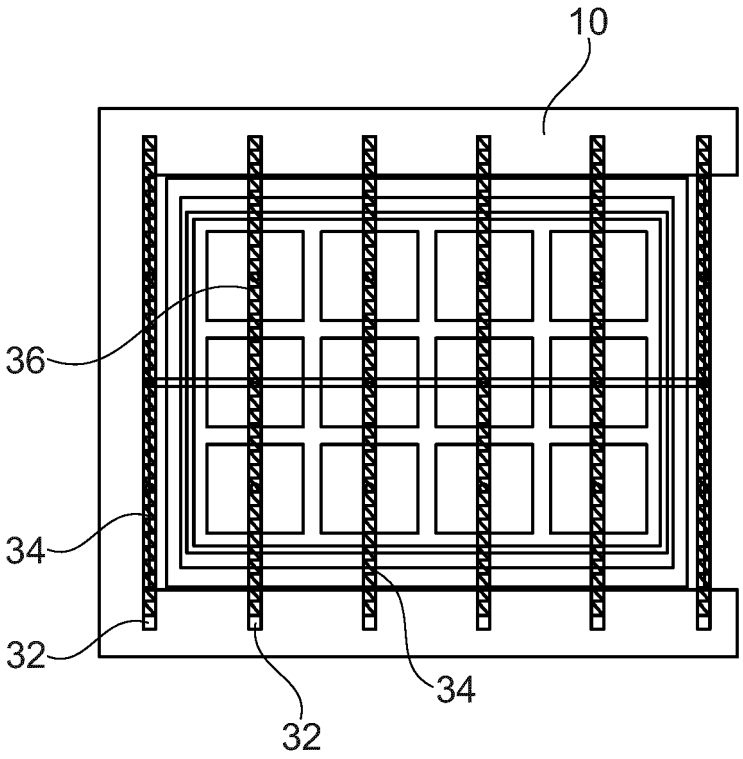

Fig. 1B

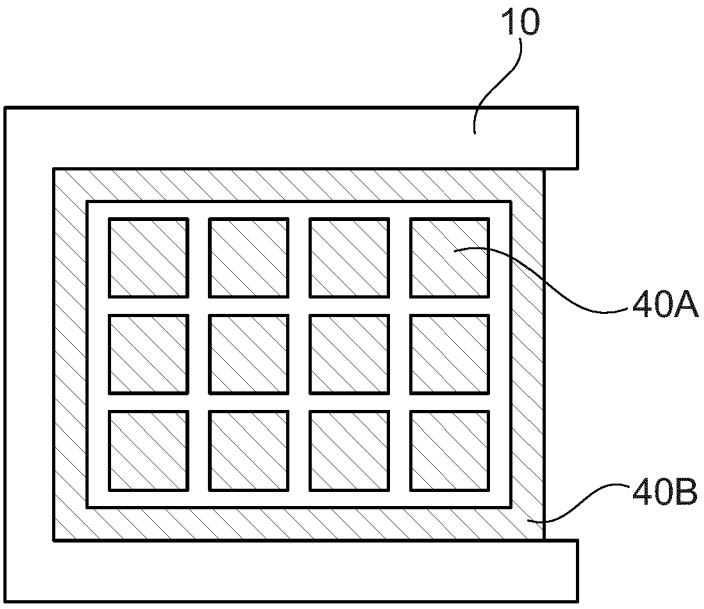

Fig. 1C

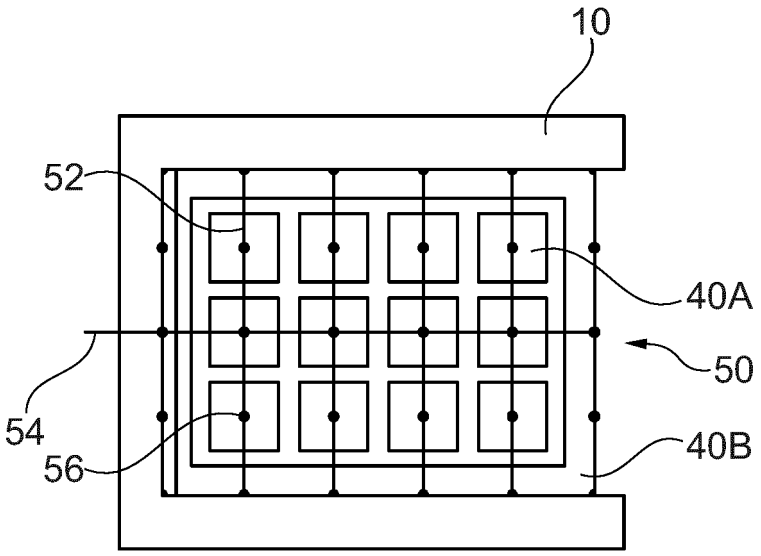

Fig. 1D

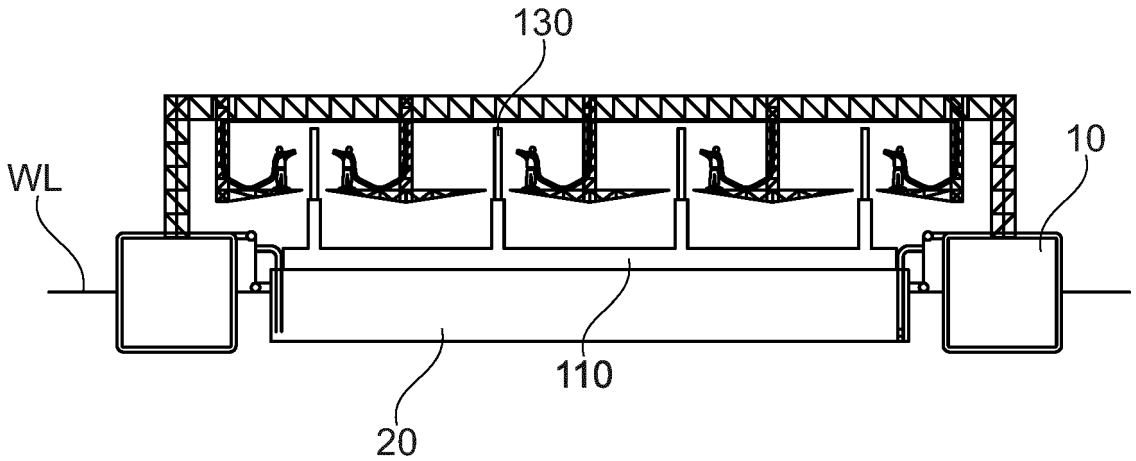

Fig. 2A

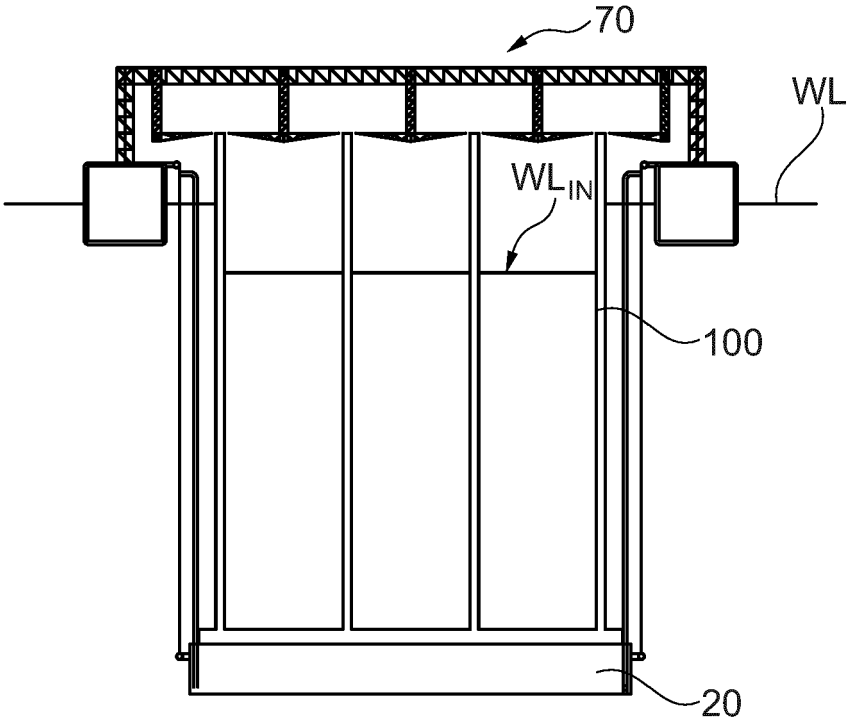

Fig. 2B

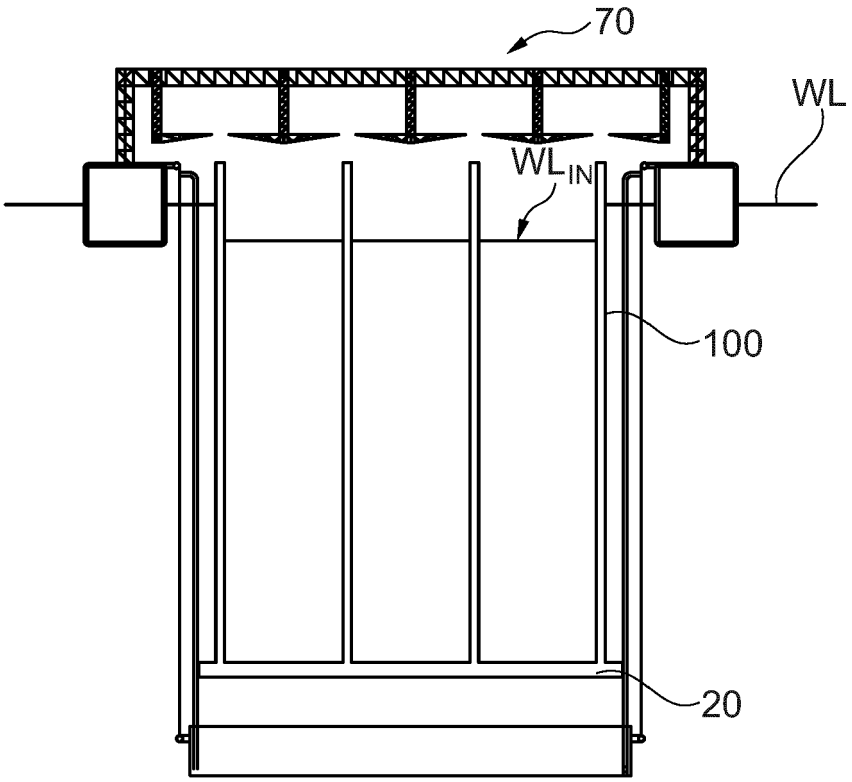

Fig. 2C

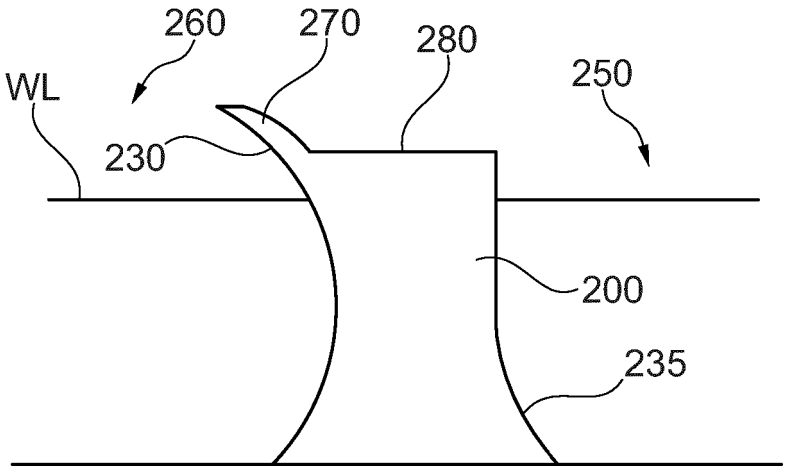

Fig. 3A

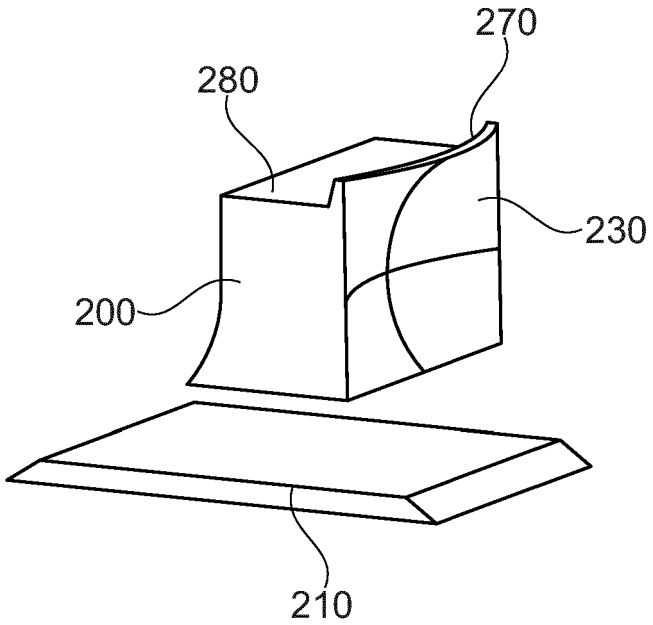

Fig. 3B

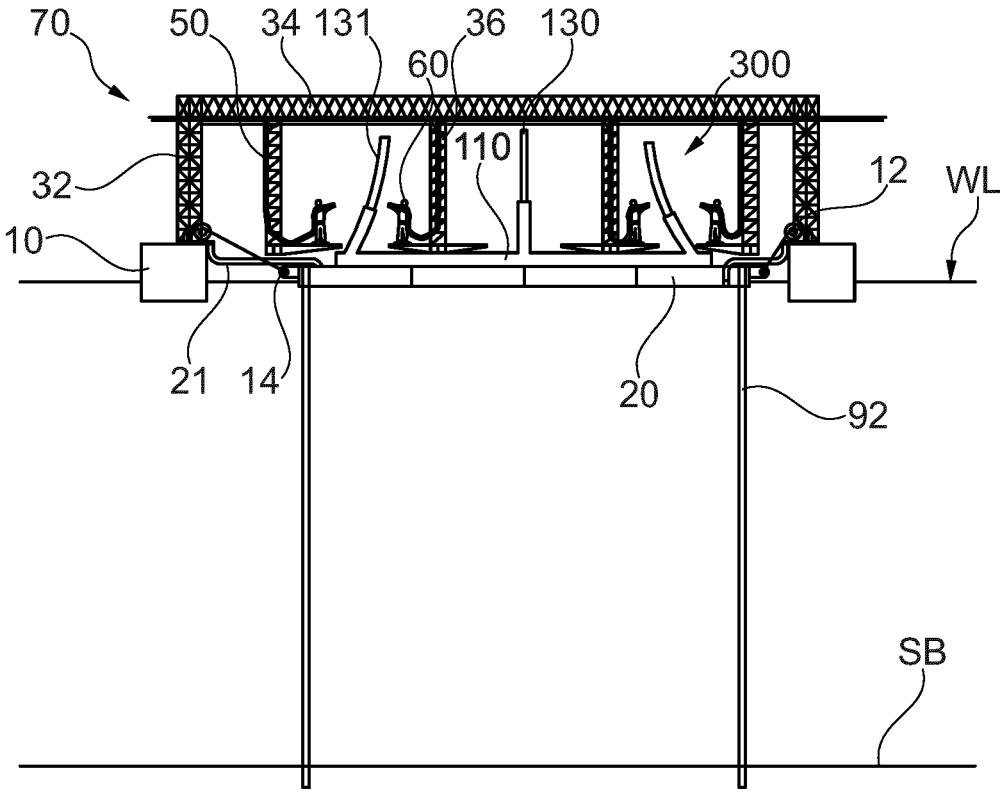

Fig. 4A

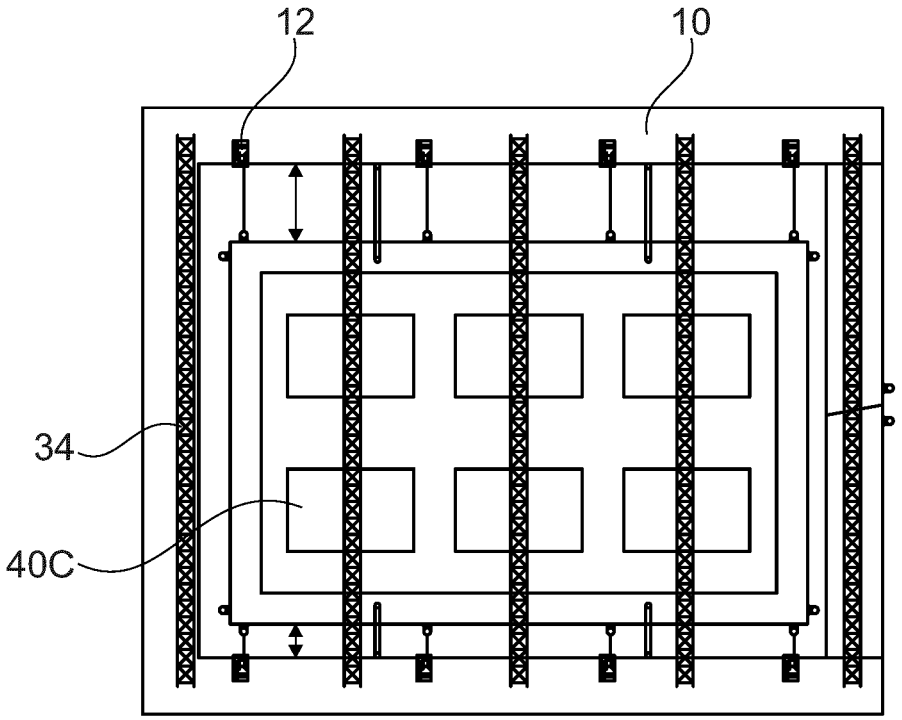

Fig. 4B

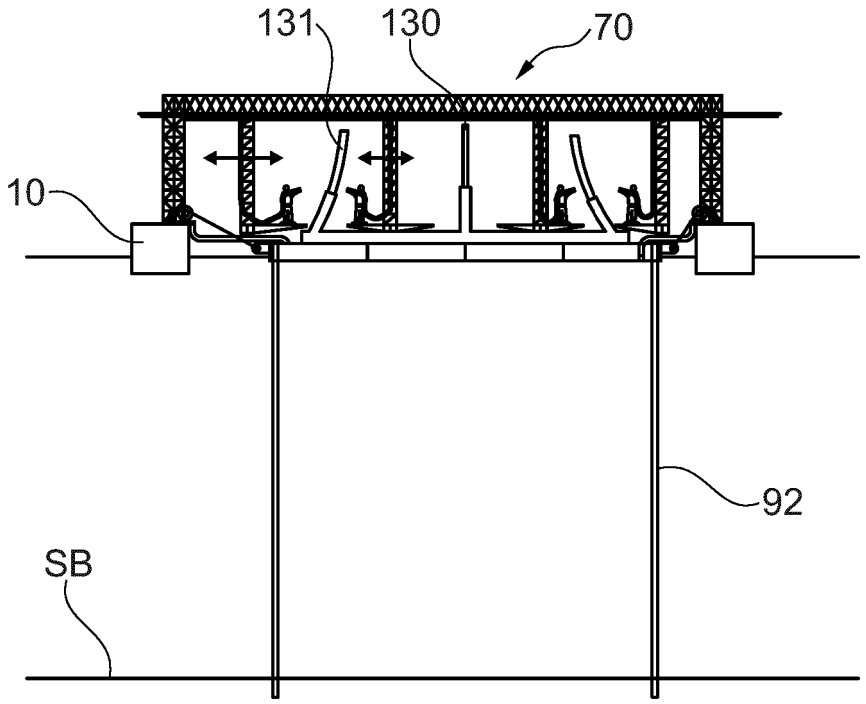

Fig. 5A

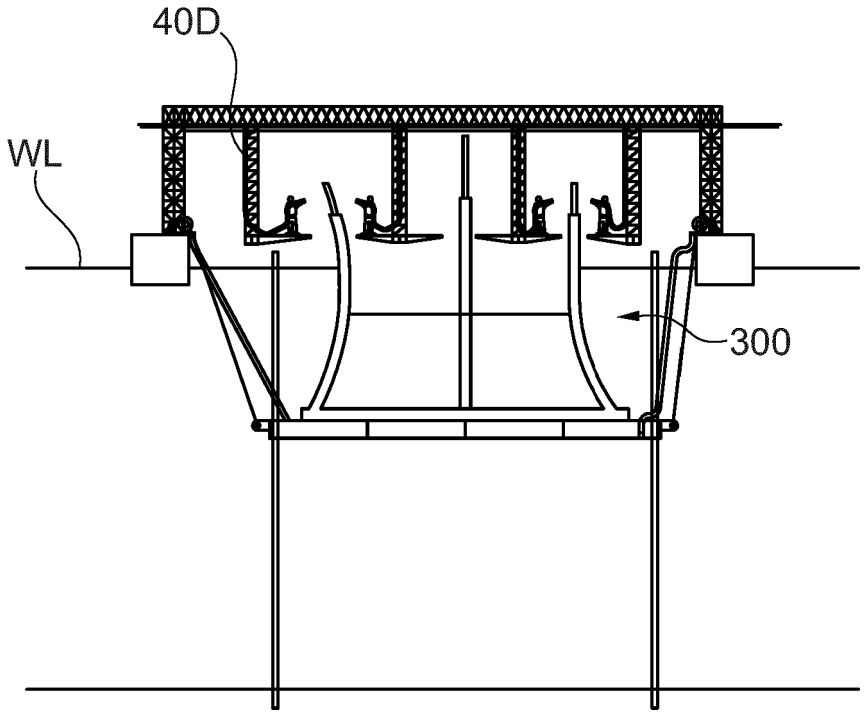

Fig. 5B

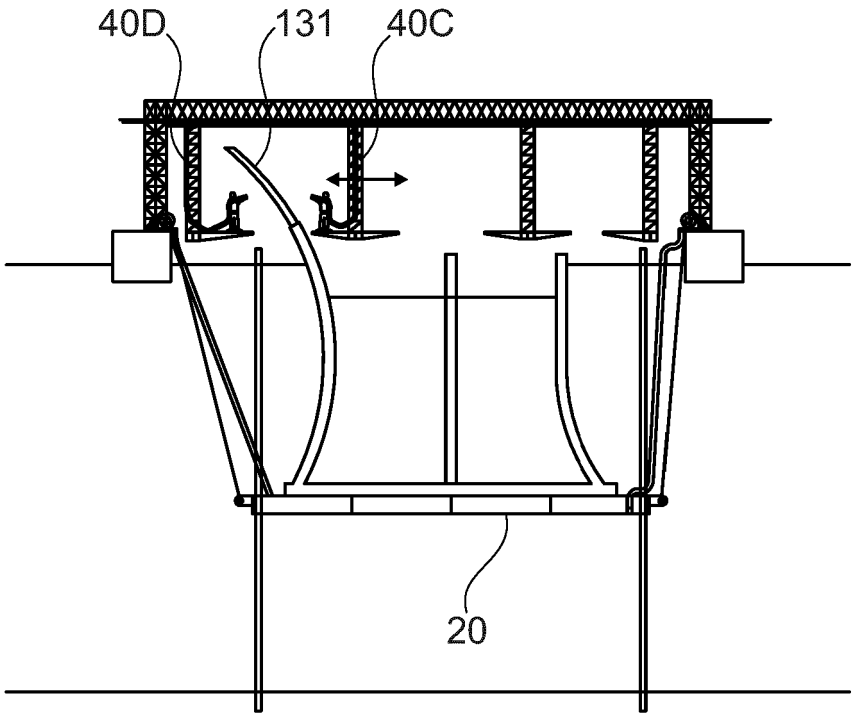

Fig. 5C

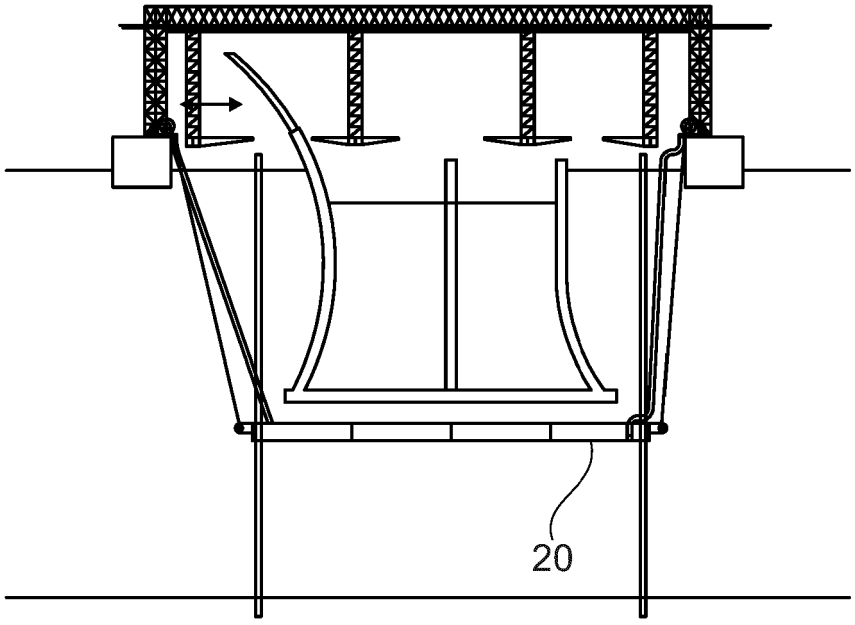

Fig. 5D

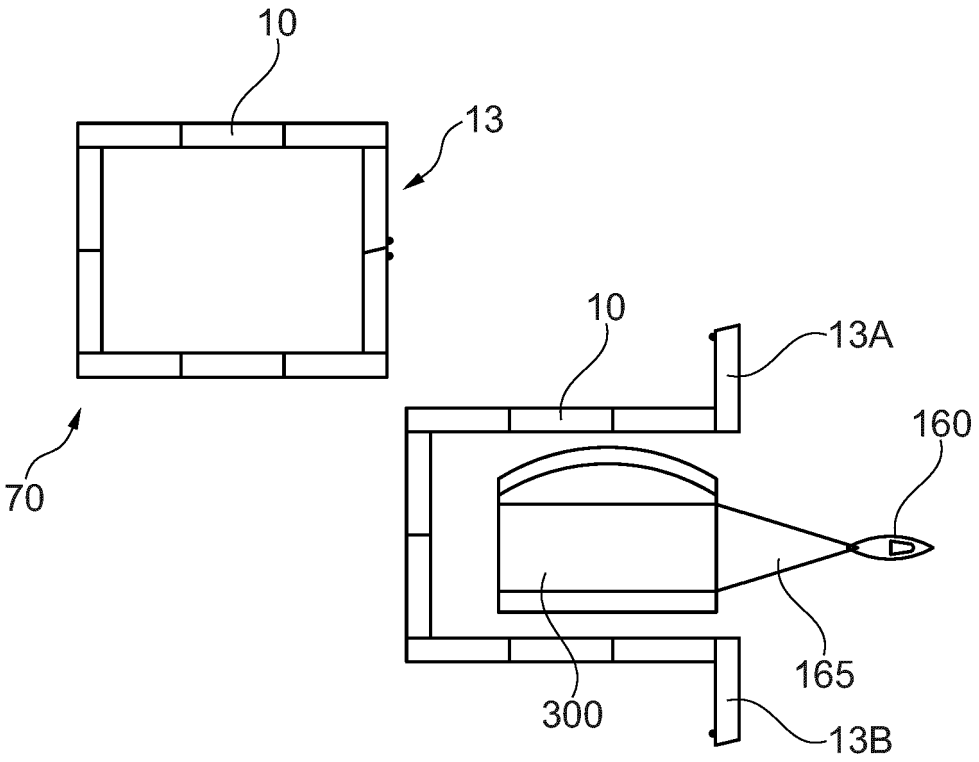

Fig. 6

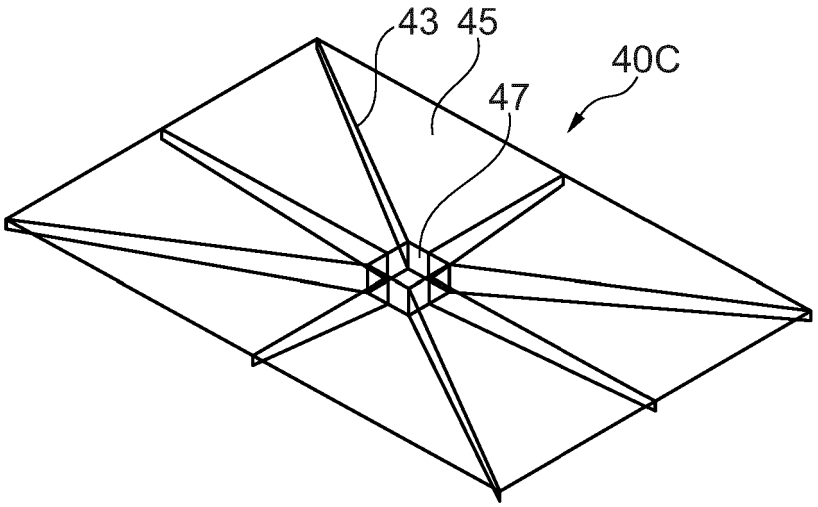

Fig. 7A

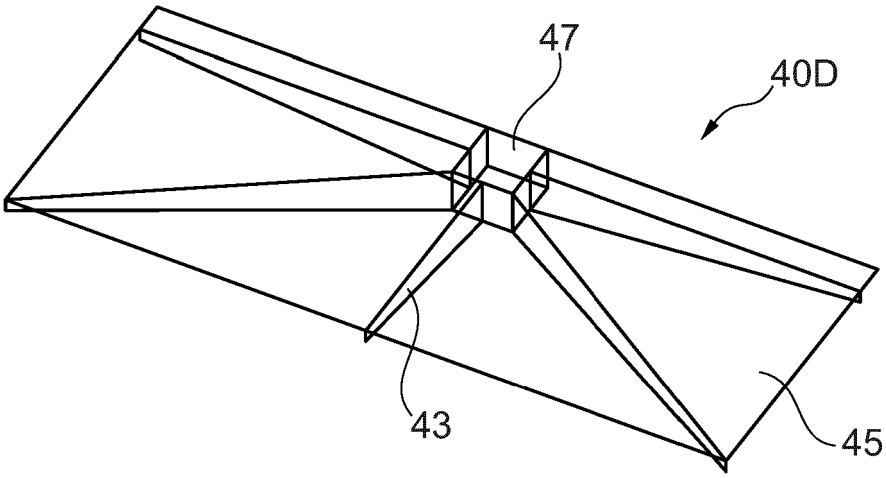

Fig. 7B

REFERENCES CITED IN THE DESCRIPTION

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- WO 2018222553 A1 **[0009]**