PATENT SPECIFICATION

(11) 1 543 806

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(21) Application No. 25918/76 (22) Filed 22 June 1976
(31) Convention Application No. 590 730
(32) Filed 26 June 1975 in
(33) United States of America (US)
(44) Complete Specification published 4 April 1979
(51) INT CL² E02B 3/06
(52) Index at acceptance E1H 15

(19)

(54) IMPROVEMENTS IN OR RELATING TO QUAY STRUCTURES

(71) I, HENRI VIDAL, a French subject of 8 bis, Boulevard Maillot, 92 Neuilly, France, do hereby declare the invention, for which I pray that a patent may be granted to me, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to wharves, and more particularly to quays for conveniently loading and unloading ships.

There are several methods of constructing wharves. One method is to drive piles into the earth along or adjacent the shore of a navigable body of water. A platform is then constructed across the top of the piles. A channel is dredged along the wharf to allow a fully-loaded ship to tie up at the wharf without touching the bottom when the water is at its lowest level.

The wharf must be capable of supporting heavy loads of cargo and equipment encountered in loading and unloading a ship. The wharf also must resist the impacts of the vessels while berthing against the wharf. Consequently, the structural components of the wharf must be massive and sturdy. Piles individually are not massive and sturdy, but by adding bracing between piles, a reasonably rigid structure can be provided. This method of construction is slow and expensive.

Another disadvantage is that in cold climates, there is the danger of ice pressure and friction on the piles and bracing. This problem is aggravated when the water level rises and falls due to the effects of tide. In some areas of the Northern Hemisphere, the tide may rise and fall as much as 50 feet.

One alternative is to construct a solid quay structure adjacent the shore by sinking large reinforced concrete caissons in a row along the shore, and ballasting the caissons with fill. The area between the caissons and the shore is then back filled to the level of the top of the caisson. This method of wharf construction is a good one because of the large mass of the structure. However, the caissons must be partially precast in a dry area, and then floated and towed to the site where casting resumes up to completion. Furthermore, it is necessary to prepare a foundation under water and to sink the caissons at the proper place on the foundation. All of these operations are very expensive.

Other alternatives for wharf construction use steel sheet piling either to constitute a curtain with anchorages containing the backfill for the quay platform, or form a sequence of jointed cells to be filled in order to obtain a gravity wall at the back of which the platform is backfilled. These alternatives require large amounts of costly steel and are often subject to incidental rupture of the tie-rods and anchorages, or to unfastening of the steel sheet pile locks, particularly near the bottom imbedded in the foundation soil.

In view of these deficiencies of prior structures, it is an object of this invention to provide an improved quay structure which is capable of being constructed efficiently.

A further object of the invention is to provide a method of constructing a quay structure which is very stable even when the soil of the foundation is not sufficiently sound for other methods of construction.

According to the invention there is provided a method of constructing essentially in water a quay structure comprising a vertical facing wall obtained by the assembly of juxtaposed and superimposed panels to which are fixed reinforcements having tensile strength extending substantially horizontally inside a particulate material constituting a fill formed behind the facing wall, the superimposed panels forming vertical rows, with the panels either substantially fully immersed or having a substantial part immersed, including the steps of preparing construction elements, each construction element comprising the assembly of a facing panel, reinforcements in the form of girders fixed to the panel to extend substantially

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perpendicularly to the panel and a tower section secured to the girders and spaced from the panel, juxtaposing and superimposing essentially under the water panels of the construction elements so as to define at least partially a facing wall and simultaneously superimposing in mutual supporting relation the tower sections corresponding to each vertical row of superimposed panels so as to erect vertical tower supports, which are parallel to the facing wall and together with the facing wall and girders constitute an at least partially immersed framework and pouring particulate material into the water behind the immersed panels or the immersed part of the panels in the framework, so as to form a substantially immersed fill.

Preferably, the method further includes disposing further panels upon the facing wall to extend the wall upwardly above water level, and adding on top of the immersed fill a further mass of particulate material so as to embed reinforcements in the form of flat strips which are fixed to the non-immersed panels or to the non-immersed part of the panels.

A coping wall may be disposed and supported on the upper surface of the further particulate material so as to be substantially contiguous with said facing wall but not supported thereby. To this coping wall may be connected a plurality of further horizontal flat reinforcement strips and yet further particulate material may be added to embed said further strips. The coping wall may mount mooring bollards.

The wall panels are preferably hexagonal. At the base of the wall, base members may be provided with upright guide bars that extend to the height of the high water level. The guides are received in vertically aligned bores in the wall panels to position the panels properly during assembly. The hexagonal shape of the panels assists in guiding the panels to seat properly on the preceding course of panels. A tongue and groove joint and plastic material at the edges of the panels interlocks the panels and forms an effective seal.

The wall panels and coping wall may be shaped and equipped to receive ladders and all other necessary devices as required by berthing and handling operations on the wharf.

This invention incorporates the general principles of construction as disclosed in U.S. Patents No. 3,421,326 and No. 3,686,873.

In order that the invention may be readily understood a preferred embodiment thereof will now be described by way of example with reference to the accompanying drawings in which:—

FIG. 1 is an elevational view of a quay structure viewed from the water side constructed in accordance with the invention;

FIG. 2 is an enlarged cross-sectional view of the quay structure along the line 2—2 in FIG. 1;

FIG. 3 is a detail elevational view of the quay structure during an intermediate stage of construction;

FIG. 4 is a cross-sectional view of the quay structure along the line 4—4 in FIG. 3.

FIG. 5 is a cross-sectional view of the wall panels along the line 5—5 in FIG. 3, and showing the joint detail;

FIG. 6 is a cross-sectional view of the structure along the line 6—6 in FIG. 2;

FIG. 7 is a perspective view of a wall panel with associated horizontal truss members and vertical truss members;

FIG. 8 is a detailed perspective view showing the attachment between the wall panel and a horizontal truss member;

FIG. 9 is a detailed cross-sectional view of the cope structure and the bollard along the line 9—9 in FIG. 1;

FIG 10 is a top plan view of the cope and bollard assembly, as shown in FIG. 9, but with portions of the fill removed for the purpose of illustration; and

FIG. 11 is a cross-sectional view of the structure along the line 11—11 in FIG. 9.

A quay structure 2 constructed in accordance with this invention is illustrated in FIGS. 1 and 2. Typically, a quay structure extends along the bank or shore of a body of water. The average water level 4 is shown with respect to the structure, although in tidal waters, the water level may rise and fall appreciably. Beneath the water, the bottom 6 is dredged and filled with rock or similar material to provide a foundation 8 on which a quay wall 10 is constructed.

The wall 10 includes a plurality of full wall panels 12, and partial panels 14 along the top of the wall. At the foot of the wall, a plurality of base members 16 are supported on the foundation 8. For optimum economy and better quality, the panels 12, partial panels 14, and base members 16 are precast in concrete at or near the construction site.

The base members 16 are elongate and are arranged in end-to-end relation, as shown in FIGS. 1, 3 and 4. The central portion 17 of the base member 16 has substantially the same size and shape as the upper half of one of the panels 12. At each end, the base member 16 has a lateral extension 19 to support the lower edge of one of the panels 12. Each of the base members 16 also includes a pair of upright guides 18 which are fixed at the lower end in the base member 16. Each of the panels 12 and 14 have vertical bores 20 arranged to receive the guides 18.

As shown in FIGS. 3—6, each panel 12

has a hexagonal shape and is symmetrical about vertical and horizontal axes. The upper and lower edges of the panels are substantially parallel to the horizontal axis. At the end of each panel, the upper inclined edges and the lower edges slope at approximately 60° from the horizontal axis. In order to facilitate the assembly of the wall panels, the panels are arranged in vertical rows and adjacent vertical rows of panels are offset by the height of one-half of a panel. This arrangement positions the upper inclined edges of the panels adjacent the top edge of the panel in the next row, as shown in FIG. 3. When a panel 12 or 14 is placed between the preceding panels, these upper edges cooperate to guide the subsequent panel into position. The upper inclined edges and the horizontal top edge of each panel are provided with a tongue or rib 22, and the lower edges are provided with a corresponding groove 24. Preferably, a deformable seal 26 (FIG. 5) is placed between the tongue 22 and the groove 24 to prevent the leakage of backfill through the wall while keeping the wall pervious to the water. The central portion 17 of the base member 16 has the shape corresponding to the upper portion of the panels 12, and the half panels 14 have a shape corresponding to the lower portion described for the panels 12.

Referring to FIGS. 2—7, each of the panels 12 has a plurality of horizontal girders or truss members 26 secured to the land side of the panel. Similarly, the base members 16 also have truss members 26 secured thereto. As shown in FIG. 8, the truss members 26 are preferably constructed of steel bars welded together in a rigid framework. The truss members 26 are designed to support tensile stresses, and to avoid significant deflection horizontally and vertically while the wall is being constructed. The truss members 26 are secured to the panels 12 by anchors 28 embedded in the panels.

As shown in FIG. 2, a vertical truss or tower structure 30 is spaced from the land side of the wall 10 and supports the horizontal truss members 26 in a substantially horizontal position. The tower 30 includes a footing 32 supported on a foundation 34 of crushed rock, or other suitable materials.

The tower 30 is constructed in separate sections 31 corresponding to each of the panels 12 and base members 16. Each tower section for a full panel 12 is provided at the top with a pair of horizontal channels 36 (FIG. 7) which extend approximately parallel to the face of the panels. The channels 36 are supported by steel bars 38 which extend generally vertically between the truss members 26 and which join the truss members together to form a rigid framework. At the lower end of the tower section, a pair of runners 40 are welded or otherwise secured to the bars 38 in alignment with the channels 36, so that the runners 40 are received in the channels 36 and supported thereby, when the tower sections are stacked on one another, as shown in FIG. 2.

At the top of the wall, the half panels 14 and the uppermost full panels 12 project above the level of the water 4. Instead of the truss members 26, reinforcement strips 42 are secured to the upper portion of each of the uppermost panels 12. The reinforcing elements 42 are substantially the same as those described in U.S. patent No. 3,686,873. The reinforcing elements 42 are attached to anchors 44 which are embedded in the panels 12. The lower portion of the uppermost panels 12 is provided with truss members 26 and the lower half of a tower section, as shown in FIG. 2. The half panels 14 are also provided with reinforcing elements 42 that are secured to the panels by anchors 45 corresponding to the anchors 44.

The space on the land side of the wall 10 from the bottom 6 to a level above the water level 4 is filled with coarse fill material 46, such as crushed rock or gravel. Above the fill 46, fill material 48 compatible with the reinforcing elements 42 fills the space behind the panels 12 and 14 and around the reinforcing elements 42. Suitable fill material 48 includes earth, sand, small size gravel, or other particle material e.g. as described in U.S. patent No. 3,421,326. At the foot of the wall 10, a protective berm 50 (FIG. 2) extends throughout the length of the wall.

A coping wall 52 hereinafter referred to as a cope wall is superimposed on the fill 48 and is supported on the fill independently of the wall 10. A gap 54 is preferably provided between the panels 12 and 14 and the cope wall 52 to ensure that the cope wall does not engage the wall 10.

Preferably, the cope wall 52 is a monolithic structure of concrete which is cast in situ. Spaced at intervals along the top of the cope wall are bollards 56 for tying up ships. The bollards 56 are secured in the cope wall 52 by anchor bolts 58 (see Figure 9). A ship tied to the bollards 56 exerts a large force tending to pull the cope wall 52 in the direction of the ship, due to wave action, water current, or wind, for example. To resist this tendency, a plurality of reinforcing elements 60 extend outwardly from the rearward side of the cope wall 52 as shown in FIGS. 9—11. The reinforcing elements 60 of thin flexible material, but having high tensile strength, as described in U.S. patent No. 3,686,873, are secured to the

cope wall by anchors 62 embedded in the wall. A suitable fill 64 is placed over the fill 48 and between the reinforcing elements 60. The fill 64 is a particulate material, as described in U.S. patent No. 3,421,326. The base 66 of the cope wall extends a sufficient distance from the face of the wall to provide sufficient support for the monolithic structure 52. The frictional engagement between the base 66 and the surrounding fill 64 and 48 resists displacement of the structure relative to the fill 48 and 64.

The quay structure may be readily constructed even in deep water by providing first a level foundation 8 for the wall 10 and a foundation 32 for the tower 30. The base members 16 are placed on the foundation 8 and levelled. The first course of panels 12 is then lowered, with the guides 18 passing through the slots 20 until the downwardly inclined edges of the panels engage the corresponding edges of the base members 16. At the same time, the truss members 26, which were previously attached to the panels 12, are positioned horizontally by stacking the runners 40 of the tower section 31 on the channels 36 that extend along the upper surface of the base 32. Each successive panel is installed in sequence in the same manner. When the uppermost course of truss members 26 has been installed, fill 46 is deposited in the space on the land side of the wall 10 to substantially fill the space to a height above the level of the water 4.

The reinforcing members 42 are then arranged on successive layers of fill 48, so that the space around the reinforcing elements 42 is substantially filled, and the surface is levelled to receive the cope wall 52.

The cope wall 52 may be cast in situ and rest on the upper surface of the fill 48. The frictional engagement between the base 66 and the fill material 48 prevents displacement of the cope wall 52.

The reinforcing strips 60 are arranged in successive layers in the fill 64 adjacent each of the bollards 56, and the fill 64 is leveled.

The quay structure of this invention has many advantage over prior structures: economy, flexibility, stability and massiveness. the wall 10 can be constructed under water. the panels may be relatively large in size to obtain maximum economy, and for faster and more accurate construction. For example, the panels may be of the order of 40 feet in length and 20 feet in height, and of precast concrete.

While this invention has been illustrated and described with reference to a preferred embodiment, it is recognized that variations and changes may be made therein, without departing from the invention as set forth in the claims. For example, this invention may be utilized in constructing retaining walls on an underwater foundation.

WHAT I CLAIM IS:—

1. A method of constructing essentially in water a quay structure comprising a vertical facing wall obtained by the assembly of juxtaposed and superimposed panels to which are fixed reinforcements having tensile strength extending substantially horizontally inside a particulate material constituting a fill formed behind the facing wall, the superimposed panels forming vertical rows, with the panels either substantially fully immersed or having a substantial part immersed, including the steps of preparing construction elements, each construction element comprising the assembly of a facing panel, reinforcements in the form of girders fixed to the panel to extend substantially perpendicularly to the panel and a tower section secured to the girders and spaced from the panel, juxtaposing and superimposing essentially under the water panels of the construction elements so as to define at least partially a facing wall and simultaneously superimposing in mutual supporting relation the tower sections corresponding to each vertical row of superimposed panels so as to erect vertical tower supports, which are parallel to the facing wall and together with the facing wall and girders constitute an at least partially immersed framework and pouring particulate material into the water behind the immersed panels or the immersed part of the panels in the framework, so as to form a substantially immersed fill.

2. A method according to claim 1 including disposing further panels upon the facing wall to extend the wall upwardly above water level, and adding on top of the immersed fill a further mass of particulate material so as to embed reinforcements in the form of flat strips which are fixed to the non-immersed panels or to the non-immersed part of the panels.

3. A method according to claim 2 including disposing and supporting a coping wall on the upper surface of the further particulate material so as to be substantially contiguous with said facing wall but not supported thereby.

4. A method according to claim 3 including connecting to said coping wall a plurality of further horizontal flat reinforcement strips and adding yet further particulate material to embed said further strips.

5. A method according to claim 3 or 4 in which said coping wall is provided with an inwardly extending base portion resting on said further particulate material.

6. A method according to claim 3, 4 or 5,

cope wall by anchors 62 embedded in the wall. A suitable fill 64 is placed over the fill 48 and between the reinforcing elements 60. The fill 64 is a particulate material, as described in U.S. patent No. 3,421,326. The base 66 of the cope wall extends a sufficient distance from the face of the wall to provide sufficient support for the monolithic structure 52. The frictional engagement between the base 66 and the surrounding fill 64 and 48 resists displacement of the structure relative to the fill 48 and 64.

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The cope wall 52 may be cast in situ and rest on the upper surface of the fill 48. The frictional engagement between the base 66 and the fill material 48 prevents displacement of the cope wall 52.

The reinforcing strips 60 are arranged in successive layers in the fill 64 adjacent each of the bollards 56, and the fill 64 is leveled.

The quay structure of this invention has many advantage over prior structures: economy, flexibility, stability and massiveness. the wall 10 can be constructed under water. the panels may be relatively large in size to obtain maximum economy, and for faster and more accurate construction. For example, the panels may be of the order of 40 feet in length and 20 feet in height, and of precast concrete.

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2. A method according to claim 1 including disposing further panels upon the facing wall to extend the wall upwardly above water level, and adding on top of the immersed fill a further mass of particulate material so as to embed reinforcements in the form of flat strips which are fixed to the non-immersed panels or to the non-immersed part of the panels.

3. A method according to claim 2 including disposing and supporting a coping wall on the upper surface of the further particulate material so as to be substantially contiguous with said facing wall but not supported thereby.

4. A method according to claim 3 including connecting to said coping wall a plurality of further horizontal flat reinforcement strips and adding yet further particulate material to embed said further strips.

5. A method according to claim 3 or 4 in which said coping wall is provided with an inwardly extending base portion resting on said further particulate material.

6. A method according to claim 3, 4 or 5,

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in which said coping wall mounts mooring bollards.

7. A method according to any of claims 2 to 6, in which said reinforcement strips extend from the facing wall or coping wall in splayed fashion.

8. A method according to any of the preceding claims in whcih said facing panels are provided with vertically aligned bores in which are received vertically disposed guide bars.

9. A method according to any of the preceding claims in which the length of each tower section is substantially the same as the vertical extent of each panel.

10. A method according to any of the preceding claims in which the tower sections are provided at each end with cooperating connection members whereby adjacent sections may be interconnected.

11. A method according to claim 10 in which said connection members consist respectively of flat runners adapted to be received in U-section elements.

12. A method according to any of the preceding claims in which the free ends of the girders extend beyond the tower sections.

13. A method of constructing a quay structure substantially as hereinbefore described with reference to the accompanying drawings.

14. A quay structure constructed by a method according to any of the preceding claims.

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Printed for Her Majesty's Stationery Office by the Courier Press, Leamington Spa, 1979.
Published by the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.

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