

PATENT SPECIFICATION

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(54) IMPROVEMENTS IN OR RELATING TO MARINE STRUCTURES

(71) I, ALFRED ALPHONSE YEE, a citizen of the United States of America, of 3169 Alika Avenue, Honolulu, Hawaii, United States of America, 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:—

The present invention relates to marine structures.

In the past, a variety of concrete type marine vessels have been proposed. However, such constructions, for the most part, have proven unsatisfactory since they did not meet the necessary strength and weight requirements capable of withstanding stresses due to wave action and the like. While a few concrete marine vessels, such as the prestressed types, have proven satisfactory from a structural standpoint, they have been too costly to manufacture and market on a competitive basis with conventional marine vessels.

According to the present invention a marine structure comprises a shell having a rigid peripheral side wall and rigid top and bottom walls connected to the side wall to define with the side wall an enclosure, the periphery defined by the side wall being closed by the bottom wall, and a plurality of further rigid walls each further wall being connected to and extending upwards between the bottom wall and the top wall, each further wall, when viewed in horizontal section having a closed periphery comprising a curved inner surface, each of the further walls being connected with the next adjacent further walls to provide a continuous interconnected support structure within all the enclosure, the side wall being connected to the further walls adjacent the side wall, the top wall, bottom wall, further walls and side wall being fabricated of non-metallic hardenable, mouldable material, the side wall comprising a plurality of straight sections.

The invention may be performed in various ways and two specific embodiments with possible modifications will now be described, by way of example, with reference to the accompanying drawing, in which:—

Fig. 1 is a perspective view of a marine structure with sections removed; 50

Fig. 2 is a plan sectional view of the structure illustrated in Fig. 1;

Fig. 3 is a sectional view taken along section 3—3 of Fig. 2; 55

Fig. 4 is a sectional view taken along section 4—4 of Fig. 2;

Fig. 5 is a plan sectional view of a second embodiment of the present invention;

Fig. 6 is a sectional view taken along section 6—6 of Fig. 5; 60

Fig. 7 is a sectional view taken along section 7—7 of Fig. 6; and

Fig. 8 is a partial perspective view illustrating vertical slip form equipment and a method which may be utilized for fabricating the marine structure. 65

Referring now, more particularly, to Fig. 1 of the drawings, a marine structure made according to the present invention is generally indicated by the numeral 10 and includes a plurality of cargo compartments 12 which are independent of each other and which extend vertically between top and bottom walls 14 and 16, respectively. These compartments may be utilized for the storage or transportation of petroleum products handled by way of conventional pump and pipe assemblies indicated by the numeral 18 communicating with each compartment. It will be appreciated that the structure may be utilized for the storage or transportation of dry products such as fertilizer, cement, grain or the like which may be loaded through hatchways such as those at 19. 70 75 80 85

It should also be noted that the construction is not limited to the exact shape and structure illustrated in Fig. 1. In plan, the structure may take the form of a circle, regular or random shape required for the functional purpose. Furthermore, the structures of the present invention may be utilized for both submerged and floating operations. For example, the marine structure may be used for submerged, underwater storage of petroleum products, the structure being located beneath the water in such a manner that it does not obstruct the passage of sea-going vessels and 90 95

is less affected by the forces of surface wave action.

It will also be appreciated that the construction associated with the present invention may be utilized to provide floating runway structures where land may not be available or where it is desirable to provide a runway facility remote from an urban area. Larger runway areas may be provided by coupling the floating structures together in alignment with each other to utilize the combined top surface areas for runway purposes.

Referring now, more particularly, to Figs. 2—4, the structure may be seen in more detail. Preferably, the structure is fabricated particularly from high strength concrete which may be prestressed or reinforced by conventional means, not illustrated. A plurality of side walls 22 surround the structure and, preferably, are integral with top and bottom walls 14 and 16 which extend substantially the entire length of the structure. The enclosed area between side walls 22 and top and bottom walls 14 and 16 is provided with a plurality of annular walls 24, preferably, but not necessarily, cylindrical in shape, each of which is tangentially connected at 25 and integral with the cylindrical walls immediately adjacent to it. In addition, the outermost cylindrical walls are tangentially integral at 27 with side walls 22, with support webs 29 providing additional strength. The cylindrical walls together define a continuous honeycomb-like network extending throughout the enclosure which provides a plurality of storage compartments, and also greatly enhances the overall strength of the structure.

Each annular wall serves as a vertical shear wall between top and bottom walls 14 and 16. Furthermore, the interconnection between the adjacent compartments provides a structure which is capable of handling large liquid or grain loads which normally exert pressure forces extending outwardly in a radial direction. Since the wall of one compartment is integral with the adjacent compartments, the effect of these radial forces is substantially neutralized. These radial forces are further neutralized by utilizing the generally diamond-shaped compartments at 30, defined between each group of annular walls, for storage purposes. By filling all compartments within the marine structure, the load capacity is approximately the same or greater than that of conventional barge or tanker of the same size, yet, the strength is greatly increased due to the vertical shear wall structure.

It will be appreciated that the annular walls serve as baffles which attenuate undesirable liquid flow within the structure. Since each annular wall defines a separate and independent compartment, different liquids or dry loads may be carried in each compartment while still providing the above mentioned neutralizing effect of the radial pressures

exerted upon the walls of the adjacent compartments.

Referring now, more particularly, to Figs. 5—7, a second embodiment of the marine structure of the present invention is illustrated and is generally indicated by the numeral 34 and includes a plurality of side walls 36, similar to those illustrated in Fig. 2. It should be noted, that the second embodiment, as well as the first embodiment, may take several forms, such as rectangles, circles, squares, or the like. Basically the second embodiment utilizes the same concepts as the first, however, a substantial cost saving is realized by interconnecting the annular, or cylindrical, walls indicated at 38 with radial walls 40 which lie along a line between the axes of the adjacent cylinders and which extends between the top and bottom walls 42 and 44, respectively. Thus, the radial load forces exerted outwardly upon each cylindrical wall is transmitted to the adjacent cylindrical compartment by way of the radial walls, rather than a direct inter-tangential connection as utilized with the first embodiment. By utilizing the radial walls of the second embodiment, a significant reduction in the volume of concrete per unit of volume of storage space may be realized. This is readily apparent from the volume equation for each embodiment. For example, the volume of concrete for a single cylindrical wall of the first embodiment may be expressed as follows:

$$V_1 = \pi h (R_1^2 - R_2^2) \\ = 2\pi R_m t h.$$

Where R_m = mean radius, h = height, and t = wall thickness.

The volume of concrete required to produce substantially the same storage area with the structure of the second embodiment may be expressed as follows:

$$V_2 = \pi h (r_1^2 - r_2^2) + 2lht \\ = 2\pi r_m t h + 2lht$$

Where r_m = mean radius, t = wall thickness, h = height of the cylinder, and l = radial wall length.

Since the cylinder wall volume increases by a factor of π as the radius increases, it is apparent that the total wall volume is less when the radial walls are utilized and a significant cost saving may be realized.

It will be appreciated that the vertical shear walls of both the first and second embodiments resist shear in the longitudinal and transverse directions. The flat top and bottom walls, in turn, act as flanges which resist bending moment in both the longitudinal and transverse directions.

Referring to Fig. 8, the preferred method of fabrication is illustrated. It has been found that the structure may be most economically produced by the method of vertical slip forming a concrete structure. This is done by providing vertically movable forms including an outer form 26 to shape exterior walls 22 and a plurality of cylindrical forms 28 which are jacked or otherwise moved upwardly in unison as the lower layers of concrete reach a hardened condition. The forms are continuously filled with concrete supplied by way of a crane assembly 32.

Several techniques and methods of vertical slip forming and the drying procedures related thereto are well known. It will be appreciated, however, that due to the particular shear wall construction, the structure may be economically fabricated by vertical slip techniques, while conventional marine structures of comparable strength had to be fabricated from steel or similar materials requiring high material and labor costs. Minor changes may be made in the relative positions or number of vertical shear walls or the shell configuration.

There has thus been described a marine structure for storage, support or transport operations, said structure comprising a plurality of vertically extending cylindrical walls formed from concrete and intertangentially connected to each other to define a plurality of compartments and being connected to top and bottom hull walls such that the cylindrical walls serve as vertical shear walls strengthening the structure to withstand stresses caused by wave action and the like in both longitudinal and transverse directions.

The structure is preferably formed from concrete or similar materials and which may be utilized for storage or transportation of liquid or dry cargo, such as a barge or tanker, or as a support vessel for heavy equipment or the landing of aircraft.

WHAT I CLAIM IS:—

1. A marine structure comprising a shell having a rigid peripheral side wall and rigid top and bottom walls connected to the side wall to define with the side wall an enclosure, the periphery defined by the side wall being closed by the bottom wall, and a plurality of further rigid walls each further wall being connected to and extending upwards between the bottom wall and the top wall each further wall, when viewed in horizontal section having a closed periphery comprising a curved inner surface, each of the further walls being connected with the next adjacent further walls to provide a continuous interconnected support structure within all the enclosure, the side wall being connected to the further walls

adjacent the side wall, the top wall, bottom wall, further walls and side wall being fabricated of non-metallic hardenable, mouldable material, the side wall comprising a plurality of straight sections.

2. A marine structure as claimed in Claim 1, in which the further walls are annular.

3. A marine structure as claimed in Claim 1 or Claim 2 in which the further walls are connected to each other by intermediate walls extending between and connected to the top and bottom walls, the intermediate walls and the further walls serving as vertical shear walls between the top and bottom walls.

4. A marine structure as claimed in any one of the preceding claims, wherein the outermost ones of the connected further walls are connected directly to the adjacent parts of the side walls.

5. A marine structure as claimed in Claim 1 or Claim 2, in which the further walls serve as vertical shear walls between the top and bottom walls to define a rigid structure capable of resisting longitudinal wave actions in shear and bending moments, and the further walls are circular in horizontal section and are connected together by substantially radial walls extending between the top and bottom walls.

6. A marine structure as claimed in Claim 5, wherein the radial walls are integrally formed with the further walls.

7. A marine structure as claimed in Claim 5 or Claim 6, wherein outer ones of the rigid further walls are connected to the immediately adjacent parts of the side wall.

8. A marine structure as claimed in any one of Claims 1 to 3, in which each of the further walls is a rigid cylindrical wall connected to and extending axially upwards from the bottom wall so that the further walls define a plurality of compartments separate from each other, the rigid cylindrical walls, side wall, top and bottom walls being of integral concrete construction with the cylindrical walls being rigidly and tangentially connected with each other.

9. A marine structure as claimed in any one of the preceding claims, wherein the hardenable, mouldable wall material comprises high strength concrete.

10. A marine structure substantially as hereinbefore described with reference to Figs. 2 to 4, or Figs. 5 to 7, of the accompanying drawings.

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