United States Patent

Duff

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[45] **May 23, 1972**

[54] REINFORCED CONCRETE BOAT HULL AND METHOD OF CONSTRUCTION

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[52] **U.S. Cl.** .....**114/65 A,** 52/309

[51] **Int. Cl.**.....**B63b 5/14**

[58] **Field of Search** .....114/65 A; 9/6; 52/309

[56] **References Cited**

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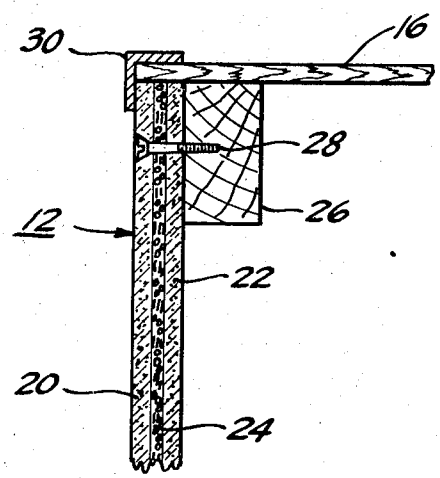
[57] **ABSTRACT**

A boat having a concrete hull formed of a plurality of alternate, integrally bonded layers of concrete and fiber-reinforced epoxy resin, and a method of constructing a concrete and fiber-reinforced epoxy resin boat hull. The hull is a unitary structure comprised of a plurality of layers of concrete having an integrally bonded layer of fiber-reinforced epoxy resin interspaced between adjacent layers of concrete. The strength of the structure can be even further increased by the addition of a minor proportion of epoxy resin to the concrete.

16 Claims, 7 Drawing Figures



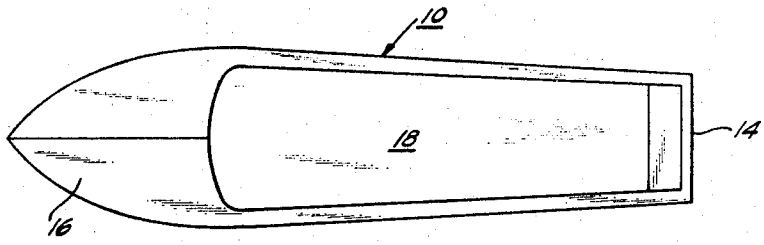


Fig 1

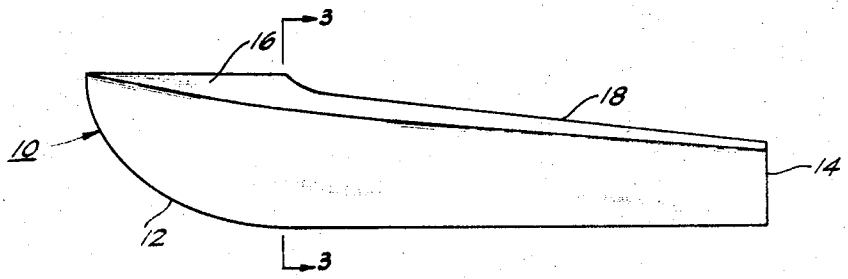


Fig 2

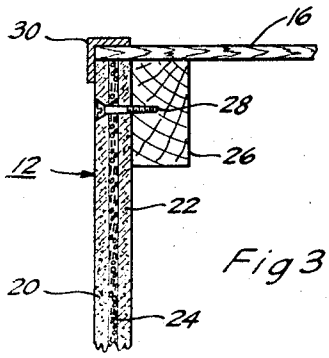


Fig 3

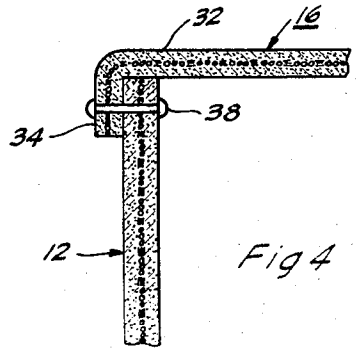


Fig 4

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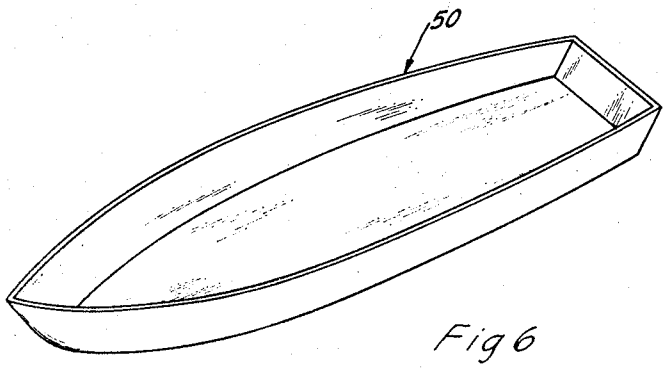

Fig 6

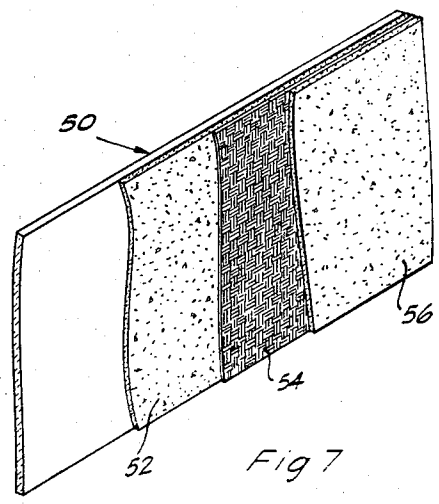

Fig 7

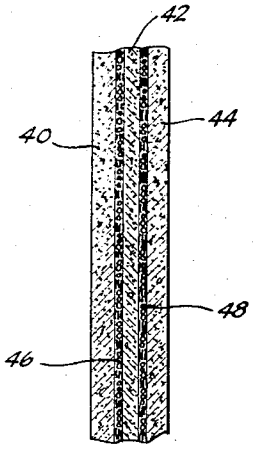

Fig 5

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REINFORCED CONCRETE BOAT HULL AND METHOD OF CONSTRUCTION

This invention relates to the construction of boats, and particularly to the construction of boats having reinforced concrete hulls and to methods of constructing reinforced concrete boat hulls.

Because of its relatively low cost, durability and availability, it has long been proposed that reinforced concrete be employed as a material of construction for boat hulls. However, because of the difficulty of attaining sufficient tensile and flexural strength, the difficulty of forming specially shaped parts, the high weight and large bulk of the formed structures, and the susceptibility of many concretes to attack by sea water, concrete has not gained wide acceptance as a material of construction for boat hulls, and particularly has not gained acceptance in the construction of small boats and pleasure craft.

Accordingly, a principal object of this invention is to provide a boat having a hull of relatively light weight, inexpensive construction.

Another object of this invention is to provide a boat having a reinforced concrete hull of superior strength and durability.

Still another object of this invention is to provide a boat having a relatively thin reinforced concrete hull of high strength and durability.

A further object of this invention is to provide a boat having a reinforced concrete hull of unitary construction.

A still further object of this invention is to provide a method for constructing a relatively light weight, inexpensive boat hull having superior strength and durability.

A yet further object of this invention is to provide a method for constructing a boat having a hull of relatively thin unitary construction that exhibits superior strength and durability.

The manner in which the foregoing and other objects of this invention are realized will be apparent to those skilled in the art from the specification and claims considered together with the accompanying drawings, wherein like numerals refer to like parts throughout, and in which:

FIG. 1 is a top view of a boat constructed with the reinforced concrete hull of this invention;

FIG. 2 is a side view of the boat illustrated in FIG. 1;

FIG. 3 is an enlarged partial cross-sectional view of the hull and deck construction of the boat illustrated in FIG. 1;

FIG. 4 is an enlarged partial cross-sectional view of another embodiment of hull and deck construction;

FIG. 5 is a partial cross-sectional view of another embodiment of reinforced concrete construction employing a plurality of layers of concrete and fiber-reinforced epoxy resin;

FIG. 6 is a perspective view of the mold employed in the construction of the reinforced hulls of this invention; and

FIG. 7 is a perspective view illustrating the method of constructing the reinforced concrete hulls of this invention.

Briefly, this invention contemplates a boat having a concrete hull formed of a plurality of alternate, integrally bonded layers of concrete and fiber-reinforced epoxy resin, and a method of constructing a concrete and fiber-reinforced epoxy resin boat hull. The hull is a unitary structure comprised of a plurality of layers of concrete having an integrally bonded layer of fiber-reinforced epoxy resin between adjacent layers of concrete. Also, the strength of the structure can be further increased by adding a minor proportion of epoxy resin to the concrete.

Referring now more specifically to the drawings, the numeral **10** generally designates a boat which can be seen in its completed form illustrated in FIGS. **1** and **2**; and which includes a hull **12** having a rear transom section **14** and a deck **16** partially enclosing the hull **12** to provide a covered forward section and an open cockpit **18**. For purposes of illustration, the drawings depict a boat of the runabout class adapted to be powered by an outboard motor, not shown, mounted on rear transom **14**. However, it is to be realized that boats of all classes, such as rowboats, skiffs, whaleboats, lifeboats, launches, speedboats, sailboats, houseboats and larger powered launches can be constructed in accordance with this invention, and that the power driven boats can be adapted to be powered by outboard motors, inboard-outboard motors, and by inboard motors.

As particularly indicated in FIG. **3**, hull **12** is a laminated structure comprised of two outer layers of concrete **20** and **22** and an inner layer **24** of fiber-reinforced epoxy resin bonding the concrete into an integral unitary structure having high strength and durability. The finished hull can vary from about ⅛-inch to about 1-inch in thickness; however, an overall thickness of about ¼-inch to about ½-inch is preferred in most applications.

FIG. **3** also illustrates the construction wherein a wood stringer **26** is attached along the upper inner edge of hull **12**. Stringer **26** can be attached by any convenient means, such as by drilling and countersinking a hole through the concrete and attaching the stringer with flathead screws **28**. The screw holes can then be filled with cement or epoxy resin-cement mixture to cover the screw heads so as to provide a smoothly finished surface. Deck **16** can be constructed of wood, plastic, fiber glass, or laminated concrete and fiber-reinforced epoxy resin similar to hull **12**, and is secured to stringer **26**, and the joint finished with metal or plastic molding **30**.

FIG. **4** illustrates an alternative mode of construction in which both hull **12** and deck **16** are constructed of laminated concrete and fiber-reinforced epoxy resin. In this embodiment, deck **16** is formed of a generally flat section **32** and an integral downturned lip **34** adapted to fit snugly on the exterior of hull **12**. Deck **16** can be attached to hull **12** by any convenient means, such as by drilling a hole through both lip **34** and hull **12**, and joining these sections by bolts, or, as illustrated, by rivets **38**. Also, the joint can be sealed and further joined by coating the mating surfaces of the hull and deck with epoxy resin prior to adjoining them so as to form a tight bond therebetween.

FIG. **5** illustrates a mode of construction wherein the hull, deck, transom, bulkhead, or other relatively thick section is constructed of a plurality of layers of concrete with intermediate layers of fiber-reinforced epoxy resin integrally bonded therebetween to provide a unitary structure. In the illustrated embodiment, the integral structure is formed of three layers of concrete **40**, **42** and **44**, with a layer of fiber-reinforced epoxy resin **46** and **48** interposed between adjacent layers of concrete. With this mode of construction, a member can be formed with as many alternate layers of concrete and fiber-reinforced epoxy resin as desired.

The concrete employed in the constructions of this invention is a hardened mixture of hydraulic cement, aggregate, and sufficient water to harden the cement. The hydraulic cement can be any of the commercial hydraulic cements such as ASTM Type I or normal Portland cement, ASTM Type II or modified Portland cement, ASTM Type III or high-early-strength Portland cement, ASTM Type IV or low-heat Portland cement, ASTM Type V or sulphate resistance Portland cement, ASTM Type IP or Portland-pozzolana cement, plastic cement, or gun plastic cement. Also, the cement can optionally contain additives to improve various properties, such as workability, aggregate segregation, air entrainment, and to accelerate or slow setting time. The aggregate is sand, although fine pea gravel and crushed aggregate can be used in part, particularly in thicker constructions.

Typical concrete compositions employed in the practice of this invention are admixtures of about 125 to 175 pounds of aggregate per 94 pound sack of cement and sufficient water to harden the cement. Water in the amount of 4½ to 5 gallons per sack of cement is usually sufficient to obtain maximum strength on curing. However, in any case, the water content is adjusted to obtain a wet cement mix of the proper consistency. Thus, a typical cement composition useful in the constructions of this invention is as follows:

hydraulic cement	94 pounds
aggregate	125 to 175 pounds
water	4½ to 5 gallons

Also, the strength of the ultimate structure can be increased by admixing a minor proportion of epoxy resin into the wet cement mix. Usually, from about ¼ to 3 gallons of epoxy resin per sack of cement is employed, and preferably from about 2 to 3 gallons per sack.

The fiber-reinforcing material for the epoxy resin layer can be metal, plastic, cloth, or glass fiber in the form of matting, woven material, or short lengths of chopped fibers. Other fibers that can be employed are sisal, hemp, cotton, nylon, rayon, polyethylene terephthalate (Dacron), acrylic fibers (Orlon), and other synthetic and natural fibers. Included within the woven materials are metal, plastic, cloth or glass screen or mesh. A Particularly preferred fiber-reinforcing material that imparts superior strength to the ultimate structure is woven glass fiber roving. Glass fiber roving is a woven-type material in which bundles of glass fibers are woven in a basket-like weave.

Various commercial epoxy resin compositions can be employed in the practice of this invention. These are typically undiluted low viscosity liquids or more viscous resins diluted with a solvent, and are conventionally employed in a two component system, i.e., the resin and catalyst are separately packaged and admixed only at the time of use. The epoxy resins preferred in the practice of this invention are low viscosity, undiluted liquids that exhibit the following properties after curing for 7 days:

Tensile strength	8,000 psi minimum
Tensile elongation	10 percent maximum
Flexural strength	15,000 psi minimum
Compressive yield	12,000 psi minimum
Hardness	above 60 shore D

A commercial epoxy resin exhibiting the foregoing properties and which is particularly useful in the practice of this invention is a two component epoxy resin marketed by the Adhesive Engineering Company under the trademark Concresive No. 1170, and identified as Part A and Part B. This material is admixed in the ratio of about 2 parts of Part A to 3 parts of Part B to about 3 parts of Part A to 2 parts of Part B, and is preferably employed in the proportion of about equal parts of Part A and Part B. Preferably, the two epoxy resin components are admixed prior to adding them to wet cement mixture.

The hulls, decks and other concrete parts of the boats of this invention are constructed by applying the materials wet, or in their uncured form, to suitably shaped molds. The concrete and epoxy resin are then hardened by curing, and the hardened member removed from the mold and assembled into the completed boat.

FIG. **6** illustrates a typical concave mold **50** that can be employed in the construction of the reinforced concrete hulls of this invention. Optionally, the mold is coated with a suitable concrete form release, mold release or separating compound to facilitate removal of the completed structure from the mold. As illustrated in FIG. **7**, a first relatively thin layer **52** of wet cement mixture is applied to the mold **50**. The wet cement mixture can be readily applied by trowelling, or with a low pressure plaster gun. Next, the layer **54** of epoxy resin saturated fibers is applied, and immediately thereafter, the layer **56** of wet cement mixture is applied. If desired, additional layers of epoxy saturated fibers and wet cement mixture can be applied to obtain a structure having the desired number of laminations. The final layer of wet cement mixture can be finished in any conventional manner to provide the desired finish, such as by trowelling, floating, rubber floating, brooming, etc.

The fiber-reinforced epoxy resin layer can be formed by presaturating the fibers with epoxy resin, and applying the epoxy resin saturated fibers to the previously applied layer of wet cement mixture. Alternatively, fiber-reinforcing material can be applied to the previously applied layer of wet cement, and the epoxy resin then applied by brushing or spraying. Where chopped fibers are employed, it is convenient to apply the fibers with a chopper gun that simultaneously blows the chopped fibers and sprays the epoxy resin onto the surface.

In a preferred method of constructing the reinforced concrete structures of this invention, a first layer of wet cement mixture is applied to the mold, and epoxy resin applied directly to the surface of this layer of cement. Next, a layer of epoxy resin-soaked, woven glass fiber roving is applied, and additional epoxy resin applied to this layer to obtain a layer of fiber-reinforcing material heavily saturated with the resin. Next, an additional layer of wet cement mixture is applied. As before, additional layers of epoxy resin-saturated fibers and wet cement mixture can be applied, if desired. In a preferred embodiment of the invention, the wet cement mixture contains a minor proportion of epoxy resin.

After the wet cement mixture and epoxy resin has set sufficiently that the structure has sufficient strength to be handled, the structure can be removed from the mold. Larger structures, such as the molded hull sections, can be effectively removed from the mold by injecting water, under pressure, between the concrete structure and the mold. The water breaks the concrete away from the mold and floats the structure in the mold. Water can be conveniently injected between the structure and the mold by connecting a water hose to a suitable hose connection in the bottom of the mold.

The performed hull and deck sections are assembled into the completed boat. The exterior surfaces of the concrete hull and deck sections can be left unfinished, or they can be provided with one or more coats of a suitable paint. A particularly durable finish is provided by coating the exterior surfaces of the concrete with epoxy paint. The boat can be fitted with marine hardware and accessory equipment in conventional manner.

While various embodiments of the invention have been described, it will be obvious to those skilled in the art that it is not so limited, but is susceptible of various changes and modifications, which are considered within the spirit and scope of the invention as defined by the attached claims.

Having now described my invention, I claim:

1. A boat hull comprising a unitary, generally hollow-form, relatively thin-walled, floatable structure comprised of alternate, integrally bonded layers of epoxy resin-containing concrete and fiber-reinforced epoxy resin, said epoxy resin-containing concrete comprising a hardened mixture of hydraulic cement, aggregate, water in an amount sufficient to harden the cement, and a minor proportion of epoxy resin.

2. The article defined in claim **1** wherein said concrete is a hardened mixture in the proportion of 94 pounds of hydraulic cement, about 125 to 175 pounds of aggregate, about 4½ to 5 gallons of water, and about ¼ to 3 gallons of epoxy resin.

3. The article defined in claim **1** wherein said fibers reinforced epoxy resin is epoxy resin reinforced with metal, plastic, cloth or glass mesh or screen; cloth, plastic or glass fiber matting; chopped cloth, plastic or glass fiber; or woven plastic or glass fiber roving.

4. The article defined in claim **1** wherein said structure is comprised of a plurality of layers of epoxy resin-containing concrete having an integrally bonded layer of fiber-reinforced epoxy resin interspaced between adjacent layers of said epoxy resin-containing concrete.

5. The article defined in claim **1** wherein said structure is comprised of two layers of epoxy resin-containing concrete and a layer of fiber-reinforced epoxy resin therebetween.

6. The article defined in claim **1** wherein the exterior surface of said hull is coated with epoxy paint.

7. A boat comprising a unitary, generally hollow-form, relatively thin-walled, floatable hull and a deck at least partially covering said hull, said hull and deck being constructed of a plurality of layers of epoxy resin-containing concrete having an integrally bonded layer of fiber-reinforced epoxy resin interspaced between adjacent layers of said epoxy resin-containing concrete, said epoxy resin-containing concrete comprising a hardened mixture of hydraulic cement, aggregate, water in

an amount sufficient to harden the cement, and a minor proportion of epoxy resin.

8. The article defined in claim 7, wherein said fiber-reinforced epoxy resin is epoxy resin reinforced with metal, plastic, cloth or glass mesh or screen, plastic or glass fiber matting, chipped cloth, plastic or glass fiber, or woven plastic or glass fiber roving.

9. The article defined in claim 7, wherein the exterior surfaces of the boat are coated with epoxy paint.

10. A boat hull comprising a unitary, generally hollow-form, relatively thin-walled, floatable structure comprised of a plurality of alternate layers of a hardened mixture of hydraulic cement, aggregate, water in an amount sufficient to harden the cement, and a minor proportion of epoxy resin, adjacent layers of said hardened mixture being interspaced with a layer of glass fiber-reinforced epoxy resin integrally bonded therewith.

11. The article defined in claim 12 including a deck at least partially covering said hull, said deck comprising a relatively thin-walled, molded structure comprised of a plurality of alternate layers of said hardened mixture interspaced with a layer of glass fiber-reinforced epoxy resin integrally bonded therewith.

12. The article defined in claim 11, wherein said glass fiber reinforcing is woven glass fiber roving.

13. The article defined in claim 11, wherein said glass fiber reinforcing is chopped glass fiber.

14. A hollow-form, relatively thin-walled, floatable structure comprised of a plurality of alternate layers of a hardened mixture in the proportion of 94 pounds of hydraulic cement, about 125 to 175 pounds of aggregate, sufficient water to harden the cement, and about ½ to 3 gallons of epoxy resin, adjacent layers of said hardened mixture being interspaced with a layer of chopped glass fiber-reinforced epoxy resin integrally bonded therewith.

15. The article defined in claim 14, including a deck at least partially covering said hull, said deck comprising a relatively thin-walled, molded structure comprised of a plurality of alternate layers of said hardened mixture interspaced with a layer of chopped glass fiber-reinforced epoxy resin integrally bonded therewith.

16. The article defined in claim 14, wherein said structure is comprised of two layers of said hardened mixture and a layer of chopped glass fiber-reinforced epoxy resin therebetween.

* * * * *

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,664,287 Dated May 23, 1972

Inventor(s) RAYMOND A. DUFF

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Claim 3, line 1, "fibers reinforced" should be --- fiber-reinforced ---.

Claim 8, line 1, delete the coma (,); and line 4, "chipped should be --- chopped ---.

Claim 9, line 1, delete the coma.

Claim 11, line 1, "12" should be --- 10 ---.

Claim 12, line 1, delete the coma (,).

Claim 13, line 1, delete the coma (,).

Claim 14, line 1, after "A" insert --- boat hull comprising a unitary, generally ---; and line 5, "½" should be --- 1/4 ---.

Claim 15, line 1, delete the comma (,).

Claim 16, line 1, delete the comma (,).

Signed and sealed this 2nd day of January 1973.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents