RECENT APPLICATIONS OF GLASS REINFORCED PLASTICS

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Introduction

Traditional timbers and steels used for shipbuilding operate throughout their lives in an extremely hostile environment and it is not surprising, therefore, that considerable attention is being paid to the products of a fast-growing plastics industry. Glass-reinforced plastics (GRP) represent only a limited part of the potential field of interest which has been steadily eroding more conventional materials either by direct replacement or in the form of protective coatings.

The advantages and limitations of GRP may be broadly summarized as follows:

Advantages

(*i*) Non-corrosive and highly resistant to marine biological attack.
(*ii*) Low density (sg 1·4–1·6) with high specific strength (UTS/sg).
(*iii*) Capable of being formed into complex structures without the restrictions imposed by standard ranges of materials.
(*iv*) Mechanical properties can be varied locally to suit design requirements.
(*v*) Has low thermal conductivity (K value 1·6, steel 350, aluminium 850).
(*vi*) It is non-magnetic.
(*vii*) It is radar and acoustically transparent.
(*viii*) Requires little skill to fabricate.

Limitations

(*i*) Low Youngs Modulus which can result in unacceptably large deflections or the use of excess material.
(*ii*) Does not yield and has limited elastic range. Unlike steel, therefore, energy will not be absorbed by local yielding.
(*iii*) Is highly anisotropic due to the wide discrepancy between the glass and resin properties.
(*iv*) High cost of basic materials and labour intensive processing.
(*v*) Initial mould costs for small scale production.
(*vi*) Combustibility of the resins.
(*vii*) Quality control requirements.
(*viii*) Deterioration due to long term immersion.
(*ix*) Complex nature of high efficiency joints.
(*x*) Reduced strength of resins at above ambient temperature.

The above clearly indicates that proposals to displace conventional materials with GRP involve consideration of both the advantages and the limitations together with a detailed look at the design to assess the viability of the proposed change.

	Initially Assumed	*Currently Adopted*
Tensile Strength	35 000 p.s.i.	33 000 p.s.i.
Tensile Modulus	2·5 x 10^6 p.s.i.	2·0 x 10^6 p.s.i.
Compressive Strength	35 000 p.s.i.	27 000 p.s.i.
Compressive Modulus		2·0 x 10^6 p.s.i.
Shear Strength	17 500 p.s.i.	16 000 p.s.i.
Shear Modulus	0·5 x 10^6 p.s.i.	0·5 x 10^6 p.s.i.
Interlaminar Shear	2 000 p.s.i.	2 000 p.s.i.

FIG. 1—GRP DESIGN PROPERTIES—REINFORCEMENT WOVEN ROVING 25 OZ. RESIN BRP 2785 ISOPHTHALIC

Materials

The less initiated may be unfamiliar with the broad spectrum of materials and processes included under the GRP heading.

Broadly speaking, GRP products comprise a resin matrix containing glass fibres ranging in diameter from about 9 to 15 microns. Most reinforcement is produced from 'E' glass with less than 1 per cent alkali content. The filaments are produced by rapidly drawing molten glass through a multiple bushing, quenching and winding into handleable strands. The strands are used for chopping, milling, forming into rovings or twisting into yarns for weaving into fabric. Woven fabrics are produced to a wide range of weave patterns and thicknesses, woven rovings while somewhat similar produce coarser weaves to a more limited range of patterns, and the chopped fibres are formed with a resin-soluble binder into chopped strand mat.

The resins used in marine applications are usually unsaturated polyesters or epoxides, the former being most widely used for new construction due to lower cost and good curing properties at ambient temperature. The epoxide resins exhibit enhanced properties when cured at above ambient temperatures, have excellent adhesion characteristics and are frequently used for bonding metals or cured polyester laminates in repair applications. It is worth recording that the introduction of ambient temperature curing resins in the late 1930s virtually marks the birth of the modern GRP industry.

Processes

Although more sophisticated methods of production are widely used, contact moulding is the most common form for marine applications.

Essentially this method requires a male or female mould strong enough to support the laminate without unacceptable distortion. The mould surface is coated with a parting agent and this in turn is usually followed by a resin-rich gel coat to provide a good surface to the finished laminate. The glass reinforcement and resin in correct proportions are laid in the mould layer by layer until the required shape and thickness is formed. Each layer is consolidated by hand rolling which also removes undesirable air pockets, puckers in the glass, etc. After completion of lay-up the laminate is allowed to partially cure before removal from the mould.

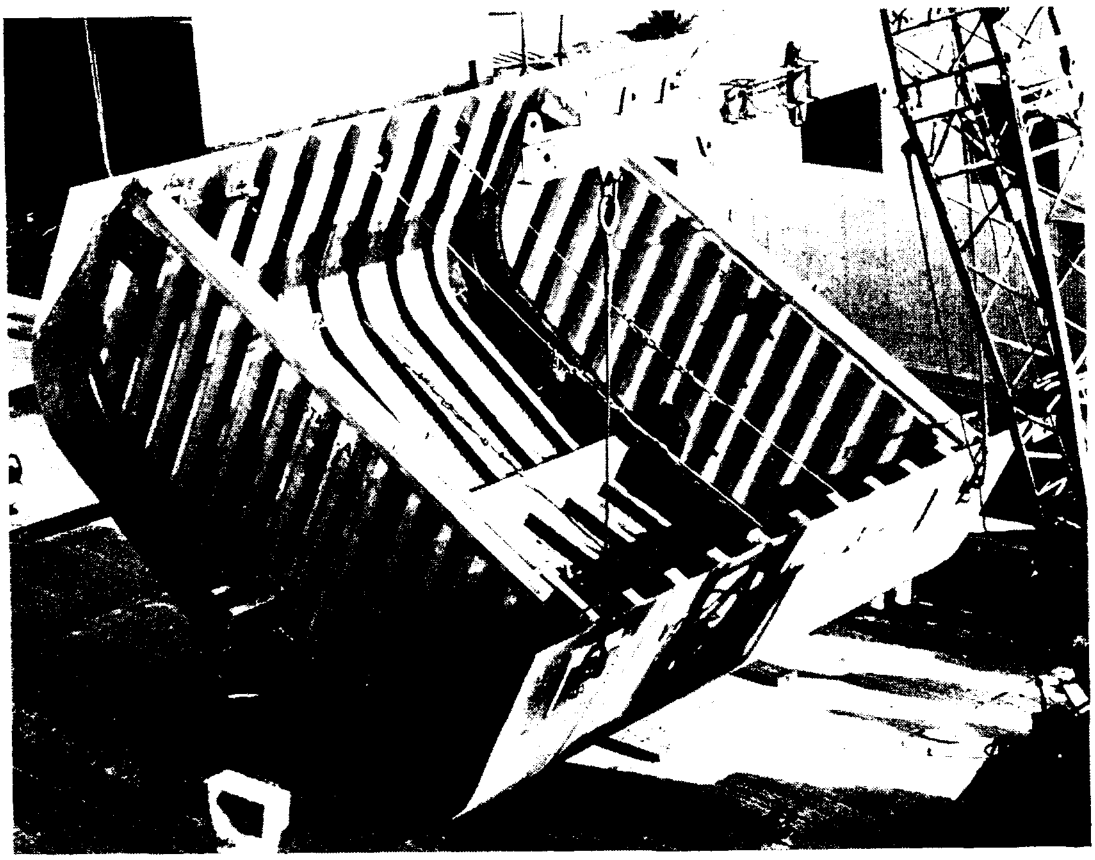

FIG. 2—GRP TEST SECTION

Applications

Boats

In common with pleasure craft, ships' boats in the Navy have been produced mainly in GRP since the mid-1950s. Here the GRP competes with traditional timber and the use of very high strength reinforcement is rarely justified, although there is an apparent trend towards the greater use of woven materials to reduce weight and improve impact properties.

Pipe Systems

The use of thermoplastic pipes in ships has been limited to systems operating at low pressure and near ambient temperature. Interest is growing in the use of GRP to externally reinforce the thermoplastic liner and form a system more acceptable for shipboard application. A parallel development of more attractive thermoplastics could well see wider applications in this area in the near future.

Filament wound glass-epoxide resin pipe has been available for a number of years and has shown excellent resistance to erosion at high flow rates. The limitations are in fittings, bends, junctions, etc., which make costs prohibitive for normal ship systems.

Protective Cladding

These applications include sea inlets and discharges, propeller shafts, 'A' brackets, rudders, etc., where local corrosion or erosion is delayed or prevented by a surface cladding of GRP. The cladding materials are usually chopped strand mats (CSM) or woven tapes in epoxide resins. On a larger scale, existing timber hulls are clad below the waterline to improve resistance to marine biological attack.

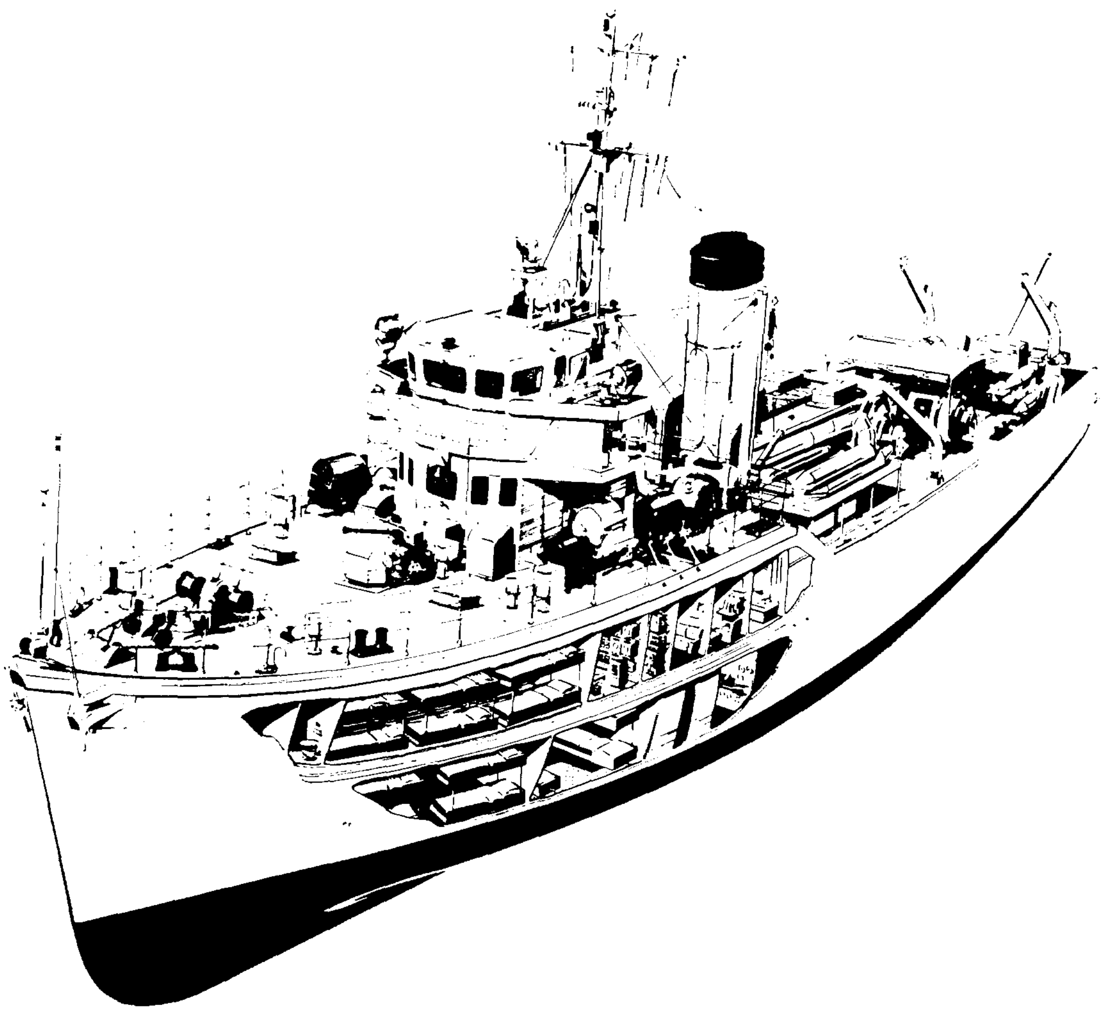

FIG. 3—ARTIST'S IMPRESSION OF THE GRP MINEHUNTER

Submarine Casings

This refers to the non-pressurized working platform above the pressure hull and represents a large structural application successfully introduced some ten years ago. Fabrication was originally in CSM but was later changed to woven rovings to increase strength and reduce weight. Although GRP shows significant weight advantages, particularly when submerged, resistance to corrosion was the principal consideration for the departure from steel and, later, aluminium.

Radomes and Sonar Domes

These components take advantage of the acoustic and radar transparency of GRP and involve laying up mostly CSM laminates with extremely low void content.

The above activities cover a fairly wide range and have been proved over a number of years in service. It will be apparent, however, that the applications have been limited to moderately stressed laminates where failure would not be catastrophic. The most recent application indicates the growth of confidence resulting from these earlier and somewhat tentative steps.

The GRP Minehunter

Following several years intensive research and development an order was recently placed for a GRP ship which when completed will be the largest marine

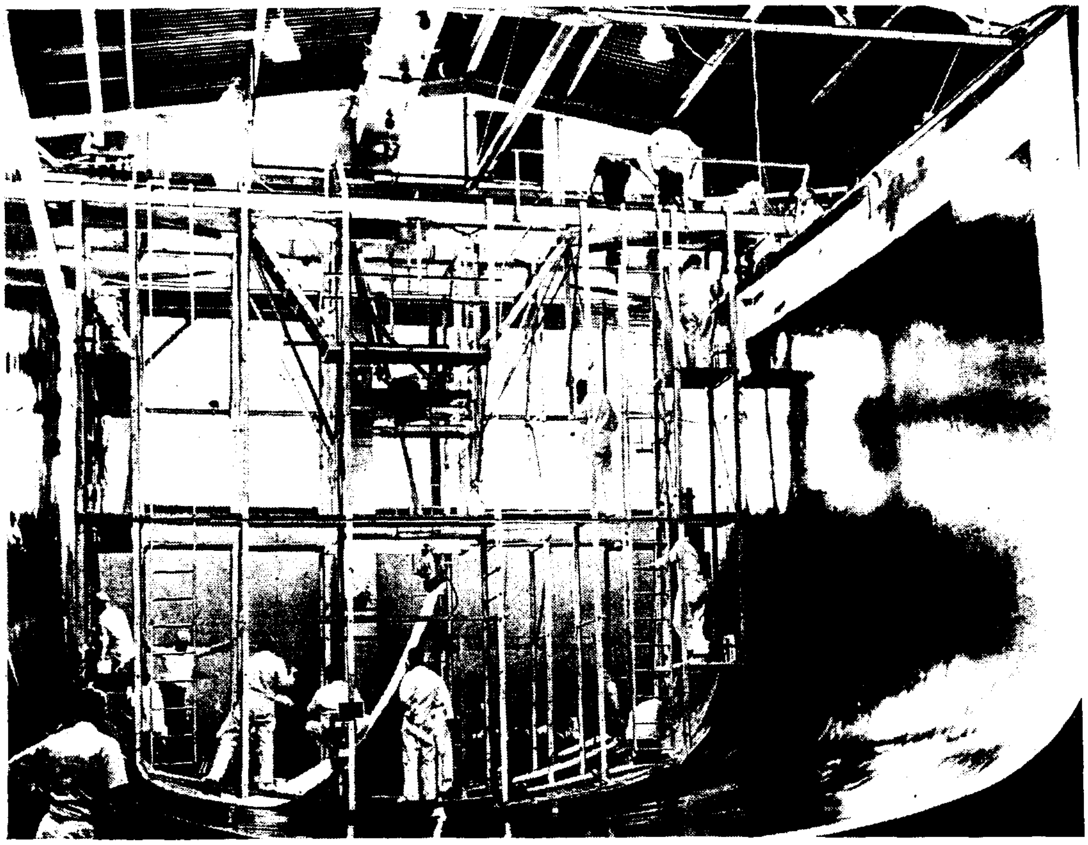

FIG. 4—TYPICAL LAYING OF SHELL PLATING

structure yet attempted. To date, GRP hulls have not exceeded 100 ft in length whereas the minehunter will be 150 ft long and involve a hull laminate weighing approximately 120 tons.

The first stage of this exercise involved detailed feasibility and design studies to assess the overall effects of the material properties particularly in relation to compression, fatigue, creep, overall and local buckling of the hull girder. Structural design data was necessarily confirmed experimentally for both sandwich and single-skin constructions, the latter being chosen for the first ship. Although considerable data regarding material properties appears in the Technical Press, little useful data was available for the design of large structures subjected to pulsating compressive loads in which the laminate performance is likely to be somewhat inferior to the widely-published tensile behaviour.

The production of the ship has involved the construction of a steel female mould in which the skin or 'shell plating' is formed from heavy weightwoven rovings in a low reactivity isophthalic polyester resin. In parallel with the work in the hull mould, bulkheads, decks and miscellaneous components will be moulded and stored for installation at the appropriate time. The GRP effort will extend over a period of about six months and although basically a contact moulding process, the sheer scale effect has involved a great deal of research and development effort in areas not immediately obvious to anyone unassociated with the programme.

Laminating is continuous throughout the construction period and bond integrity and strength must be maintained both in the basic laminates and for all main structural attachments such as frames, machinery seats, decks, bulkheads, etc. Even using a low reactivity resin the gel time (and pot life governing working periods) is about four hours. The laminates are formed from woven rovings 4 ft wide and the junctions are necessarily dispersed to give a minimum loss of

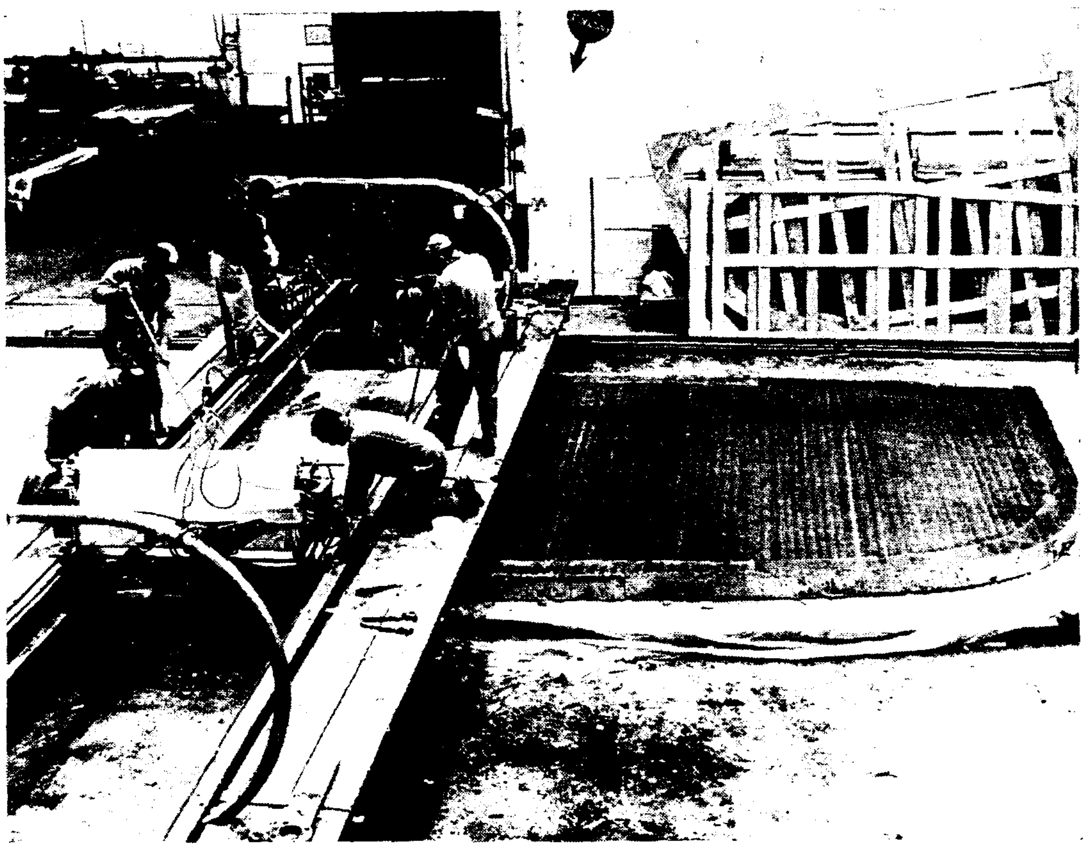

FIG. 5—BULKHEAD IN COURSE OF CONSTRUCTION

strength. Also, cured resin surfaces require preparation to obtain high bond strengths when further laminating takes place and a large experimental programme has been essential to measure the effects on bond strength of various delay periods and methods of surface preparation. Detailed programming has then been necessary within the parameters determined by experiment.

One of the obviously important factors contributing to laminate properties is the glass content and it was quickly realized that the conventional 'bucket and brush' approach would be completely inadequate for the bulk of the lay-up. Machinery was therefore developed to regulate the proportion of resin applied to the glass and at the same time pay out the impregnated fabric into the appropriate mould for consolidation.

Other programmes have been necessary to establish the behaviour of GRP structures in the tropics where temperatures on exposed decks may closely approach the heat distortion temperature of ambient cured resin, the effects of combustion in terms of structural degradation, fume toxicity and smoke emission, the assessment of long term properties of immersed laminates, etc.

Another important facet requiring investigation was that of producing high efficiency joints in the structure. In plain laminates prepared from CSM repairs are relatively straightforward but as higher strength materials are introduced repairs become more complex; also the investigation necessarily included the static and fatigue behaviour of interconnections between the various parts of the structure.

It will be realised that to detail the many various aspects covered in several years of intensive research is quite impossible in a short presentation. Suffice it to say that every stage in the programme has been essential and is typical of the pioneering represented by the size of the ship involved. The data now available should materially assist industry and further developments aimed at improving economics could lead to substantial production of ships up to 200 ft long in the next ten years.

Conclusion

GRP is an important new material offering advantages over traditional materials in a marine environment. Its choice for load-bearing structures requires careful study and steady growth in application seems the more likely trend than the spectacular increases so frequently experienced in the field of thermoplastics.

As data accumulates and production methods progress, the future challenge will lie with the designer and the extent to which he can take advantage of the many attractions of this material.

Acknowledgments

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