

Australian Standard[®]

**Boat and ship design and
construction**

**Part 3: Fibre-reinforced plastics
construction**

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- American Bureau of Shipping
- Australian Chamber of Shipping
- Australian Maritime Safety Authority
- Australian National Maritime Association
- Australian Shipbuilders Association
- Bureau Veritas
- Department of Defence
- Department of Transport, Qld
- Det Norske Veritas
- Institute of Marine Engineers
- Lloyds Register of Shipping
- Royal Institution of Naval Architects
- University of New South Wales

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- Department of Marine and Harbors, S.A.
- Department of Marine and Harbours, W.A.
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Boat and ship design and construction

Part 3: Fibre-reinforced plastics construction

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PREFACE

This Standard was prepared by the Standards Australia Committee on Shipbuilding following a request by the Ship Standards Advisory Committee of the Australian Transport Advisory Council to replace the corresponding requirements in the *Uniform Shipping Laws Code*.

It is Part 3 of a series of Standards on boat and ship design and construction, the other Parts being—

Part 1: Design loadings; and

Part 2: Aluminium construction.

The Ship Standards Advisory Committee was of the view that the requirements for the design and construction of fibre-reinforced plastics vessels given in the *Uniform Shipping Laws Code* were difficult to use, did not cater sufficiently for the application of emerging technologies and in some cases did not reflect accurately the engineering principles underlying boat and ship design and construction.

Safety levels reflected in this Standard have been assessed to be closely similar to those of the corresponding rules published by the major international classification societies.

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CONTENTS

	<i>Page</i>
SECTION 1 SCOPE AND GENERAL	
1.1 SCOPE	5
1.2 APPLICATION	5
1.3 REFERENCED DOCUMENTS	5
1.4 DEFINITIONS	5
SECTION 2 MATERIALS	
2.1 GENERAL	7
2.2 MANUFACTURER'S RECOMMENDATIONS	7
2.3 PROPOSED LAMINATE	7
2.4 BASIC LAMINATE MATERIALS	7
2.5 OTHER ISOTROPIC MATERIALS	7
2.6 DETERMINATION OF LAMINATE PROPERTIES	8
2.7 ORTHOTROPIC REINFORCEMENT LAMINATES	8
SECTION 3 DESIGN	
3.1 PRINCIPLES	11
3.2 SHELL SCANTLINGS	11
3.3 SINGLE SKIN CONSTRUCTION	12
3.4 SANDWICH CONSTRUCTION	13
3.5 ADDITIONAL REINFORCEMENT	17
3.6 TRANSOM	17
3.7 STRUCTURAL MEMBERS AND FRAMING	18
3.8 BULKHEADS	20
3.9 PILLARS	20
3.10 DECKS AND DECKHOUSES	21
3.11 TANKS	21
3.12 STRUCTURES CONNECTING HULLS OF CATAMARANS	21
SECTION 4 PRODUCTION FACILITIES	
4.1 STORAGE OF MATERIALS	22
4.2 ENVIRONMENT FOR LAMINATING	22
SECTION 5 CONSTRUCTION	
5.1 PREPARATION	23
5.2 LAMINATING	23
5.3 DETAIL	23
5.4 THICKNESS CONTROL	24
5.5 CONFIRMATION OF REINFORCEMENT	24
5.6 FASTENINGS	25

SECTION 6 DETERMINATION OF PROPERTIES OF LAMINATES

6.1 FLEXURAL PROPERTIES	26
6.2 MASS OF REINFORCEMENT	26
6.3 IMPACT RESISTANCE	26
6.4 TEST PIECES	26

SECTION 7 MARKING

7.1 MARKING	26
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APPENDICES

A GUIDANCE ON THE AVOIDANCE OF OSMOSIS	27
B EXAMPLES AND GUIDANCE ON STRUCTURAL DETAILS	28
C IMPACT TEST PROCEDURE	36

STANDARDS AUSTRALIA

Australian Standard

Boat and ship design and construction

Part 3: Fibre-reinforced plastics construction

SECTION 1 SCOPE AND GENERAL

1.1 SCOPE This Standard specifies the structural requirements for fibre-reinforced plastics (FRP) vessels not exceeding 35 m in length. It includes multi-hull vessels but excludes novel types of vessels such as hovercraft, hydrofoils and small-waterplane-area twin hull (SWATH) vessels.

1.2 APPLICATION This Standard is intended for use by manufacturers building fibre-reinforced plastics vessels in accordance with the Uniform Shipping Laws Code.

1.3 REFERENCED DOCUMENTS The following documents are referred to in this Standard:

AS

1720 SAA Timber Structures Code

1720.1 Part 1: Design methods

2272 Marine plywood

2634 Chemical plant equipment made from glass-fibre reinforced plastics (GRP) based on thermosetting resins

4132 Boat and ship design and construction

4132.1 Part 1: Design loadings

ISO

178 Plastics—Determination of flexural properties of rigid plastics

1172 Textile glass reinforced plastics—Determination of loss on ignition

BS

3496 Specification for E glass fibre chopped strand mat for reinforcement of polyester resin and other liquid laminating systems

3532 Method of specifying unsaturated polyester resin systems

3749 Specification for E glass fibre woven roving fabrics for the reinforcement of polyester and epoxy resin systems

Australian Transport Advisory Council Uniform Shipping Laws Code

1.4 DEFINITIONS For the purpose of this Standard, the definitions given in AS 4132.1 and those below apply.

1.4.1 Basic laminate—a resin reinforced with chopped-strand mat or chopped rovings.

1.4.2 Chopped-strand mat—chopped strands of reinforcing material bonded together in a random manner with a resinous binder.

1.4.3 Curing—the process by which resins, which are normally unstable fluids, harden to form solids.

1.4.4 Curing time—the time taken to convert completely liquid resin into a solid.

1.4.5 Gelcoat—a thin layer of unreinforced resin on the outside (water side) of a panel of reinforced plastics laminate.

NOTE: The gelcoat hides the fibre pattern of the reinforcement, protects the bond between the resin and the reinforcement, and can provide special surface properties. It is often pigmented.

1.4.6 Fibre-reinforced plastics (FRP)—cured plastics material that has been reinforced with fibre.

1.4.7 Isotropic—in relation to reinforcement, means the properties in the weakest direction are 80 percent or greater of the properties in the strongest direction.

1.4.8 Orthotropic—reinforcements other than isotropic reinforcement.

1.4.9 Resin—a thermosetting liquid capable of being cured and intended to be used in conjunction with a reinforcing fibre to form a laminate.

1.4.10 Sandwich construction—construction in which a core material is sandwiched between two laminates.

1.4.11 Secondary bond—a mechanical bond between separate mouldings other than by mechanical fastenings.

1.4.12 Spray moulding—the simultaneous deposition of resin and reinforcing fibres by spraying.

1.4.13 Woven roving—bundled strands of reinforcing fibre loosely woven into a heavy fabric.

1.4.14 Shall—indicates that a statement is mandatory.

1.4.15 Should—indicates a recommendation.

1.4.16 May—indicates the existence of an option.

S E C T I O N 2 M A T E R I A L S

2.1 GENERAL Reinforcement is not considered to be structurally effective where applied in layers of less than 30 g/m² of basic laminate reinforcement or equivalent.

Care must be taken with all composite materials to ensure compatibility of components within one layer and between adjacent layers. Examples of the problems that can occur are—

- (a) bond problems between epoxy and polyester resins. In general, epoxy systems will bond to fully cured and sanded polyester surfaces, but polyester bond and cure properties onto epoxy surfaces are often poor; and
- (b) the inability of epoxy resins to wet out emulsion-bound chopped-strand mat. Powder-bound mat should be used with epoxy systems.

Where there is any doubt, material suppliers should be consulted and, if necessary, tests carried out.

NOTE: It is recommended that reinforcements and resins which have been approved by recognized classification societies are used.

2.2 MANUFACTURER'S RECOMMENDATIONS Notwithstanding the requirements stated by this Standard, the recommendations of the material manufacturer in regard to the materials and their application are to be complied with. Where the requirements stated in this Standard are in conflict with the material manufacturer's recommendations, the latter shall be followed.

NOTE: Guidance on suitable materials may be sought from a marine authority or classification society.

2.3 PROPOSED LAMINATE The properties of laminates proposed for use shall meet or exceed the properties of the basic laminate described in Clause 2.4. This shall be verified by analysis or testing as required by Clause 2.5.

2.4 BASIC LAMINATE MATERIALS

2.4.1 Gelcoat Any gelcoat should comply with the requirements of BS 3532.

NOTE: Gelcoat does not provide additional strength. It reduces the ability of water to permeate the reinforcement layers and protects the structural layers from exposure to ultra-violet light. It is often also used to aid the surface finish (see Clause 5.3 and Appendix A).

2.4.2 Resin The resin shall be an unsaturated polyester resin complying with the requirements of BS 3532 Type B.

2.4.3 Reinforcement The reinforcement in the basic laminate shall be chopped-strand mat or chopped rovings (see Clause 2.5 for basic laminate properties).

Chopped-strand mat shall be manufactured from 'E' glass complying with BS 3496.

Chopped rovings shall be manufactured from 'E' glass complying with BS 3749.

The fibre length shall not be less than 25 mm.

2.5 OTHER ISOTROPIC MATERIALS

2.5.1 General Resins, reinforcements and other materials used in construction shall be compatible with each other and with the marine environment. They shall be suitable for prolonged immersion in any oils or solvents used in the vessel's construction or operation, e.g. marine diesel or petrol (see Clause 3.11).

NOTE: Manufacturers' recommendations should be sought on the selection of resins and reinforcements.

2.5.2 Structural core materials Foam core materials shall be of the closed-cell type. Polyurethane shall not be used as a structural core material, but it may be used as a non-structural former for stiffening. Timber shall not be used as a core material for hull shell or decks at or below weather-deck level unless it complies with not less than one of the following:

- (a) it is marine plywood complying with AS 2272;
- (b) it is used in end-grain orientation;
- (c) it is of strip plank construction employing epoxy resin adhesives; or
- (d) the inner and outer shell laminates both exceed the requirements of this Standard by 600 g/m² of chopped-strand mat.

2.5.3 Adhesives The ultimate shear stress of both adhesives and their bonds with core and skin materials shall be not less than that of the core material.

2.6 DETERMINATION OF LAMINATE PROPERTIES

2.6.1 Basic laminate and combinations of basic laminate and woven roving The relationship between laminate thickness and glass reinforcement by weight for some glass laminates using typical polyester resins is shown in Figure 2.1, and the flexural properties of such laminates are shown in Figure 2.2.

The attainment of these flexural properties need not be confirmed by testing provided that appropriate steps are taken to ensure that the required thickness and glass content are achieved. Clause 6.2 specifies methods which may be used for checking mass of reinforcement.

NOTE: It is not feasible to produce basic properties for aramid fibres (such as Kevlar), carbon fibre or mixed laminates due to the complexity of design calculation and the wide variation of laminate properties according to the weaves employed.

2.6.2 Laminates using isotropic reinforcement The flexural properties of isotropic laminates not covered by Clause 2.6.1 shall be determined by testing in accordance with Clause 6.1.

Where test laminates are not symmetrical through their thickness, two sets of test pieces shall be used to determine the flexural properties. One set shall have the moulded surface in tension and the other shall have the moulded surface in compression. The lesser of these two flexural properties shall be used for the determination of scantlings.

Where a sandwich laminate is to be used, the flexure test piece shall consist of the two skins bonded together.

2.6.3 Laminates incorporating orthotropic reinforcement Where orthotropic laminates are used, laminate properties shall be determined by multi-layered and directional analysis and testing in accordance with the following and with Section 6.

Where a laminate consists of directional reinforcements at relative angles other than 0° and 90° to each other or to the panel axis, determination of properties in accordance with Clause 6.1 is not valid. The properties of such laminates shall be determined by testing equivalent individual elements of the multi-layered laminate in accordance with Clause 6.1 and by analysis.

2.7 ORTHOTROPIC REINFORCEMENT LAMINATES Where orthotropic laminates are used, laminate properties shall be determined by multi-layered and directional analysis and testing in accordance with Clause 2.6 and Section 6.

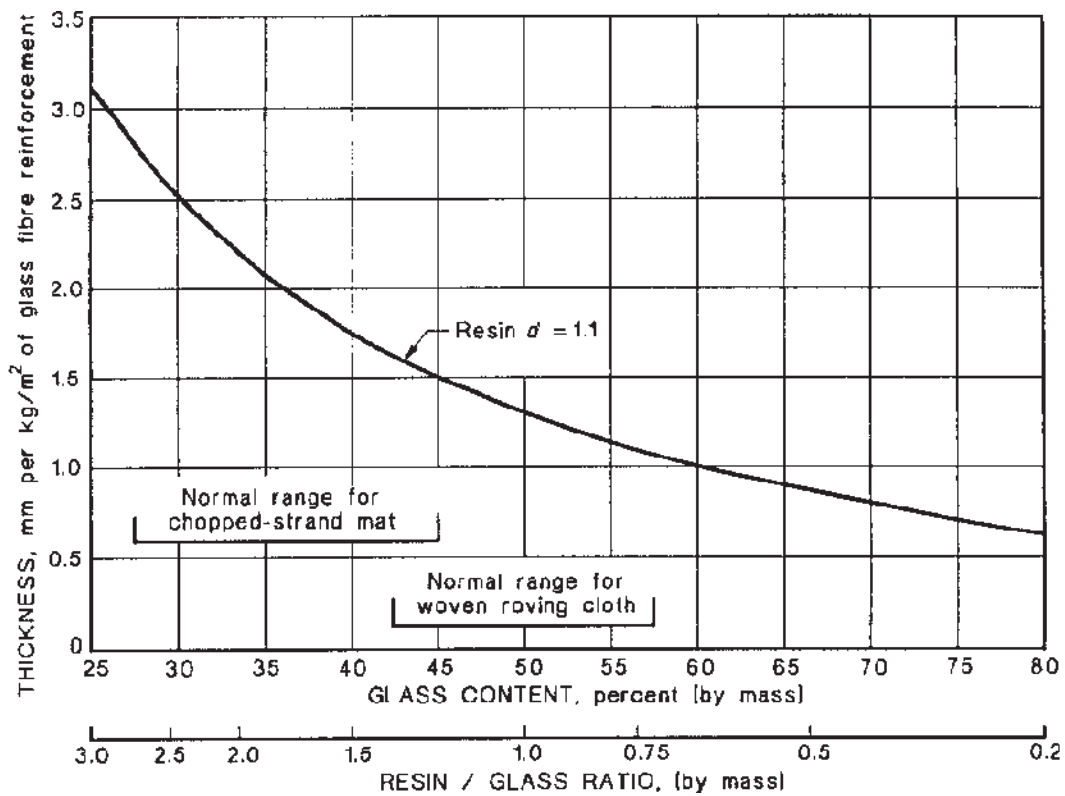
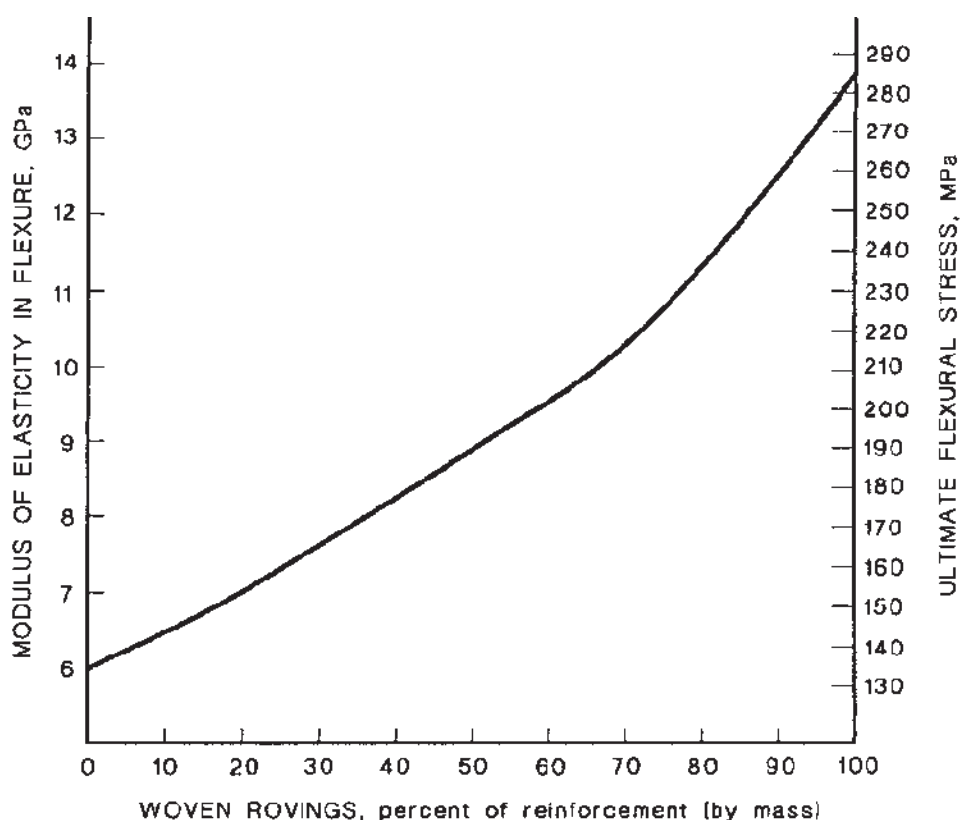


FIGURE 2.1 APPROXIMATE RELATIONSHIP BETWEEN LAMINATE THICKNESS AND GLASS-FIBRE CONTENT FOR RESINS WITH RELATIVE DENSITY OF 1.1



NOTES:

1 The properties are for the following resin to glass ratios by mass:

- (a) Chopped-strand mat 2.5:1.
- (b) Woven rovings 1:1.

2 Flexural properties assume an even distribution of woven rovings through the thickness.

FIGURE 2.2 FLEXURAL PROPERTIES FOR CHOPPED-STRAND MAT
AND WOVEN ROVING GLASS-FIBRE LAMINATES

SECTION 3 DESIGN

3.1 PRINCIPLES

3.1.1 Loadings The predominant loading on vessels covered by this Standard are hydrodynamic loadings from the water surrounding the hull.

This Standard uses equivalent static loadings given in AS 4132.1 to approximate this dynamic loading situation enabling design to proceed along normal static engineering principles.

NOTE: The design principles cover vessels operated in a seamanlike manner under adverse weather and sea conditions.

3.1.2 Equations The design equations in this Standard are based upon static design principles, isotropic materials, and longitudinal and transverse stiffening. Notwithstanding these equations, structures which are shown by more rigorous analysis to withstand the design loadings by the factors of safety specified in this Standard are to be accepted as complying with the Standard.

3.1.3 Safety factor Unless stated otherwise, the factor of safety applied in this Standard is 3.5 on ultimate stress.

3.2 SHELL SCANTLINGS

NOTE: Examples and guidance on structural details are given in Appendix B.

3.2.1 General The shell plating is designed as a grid of rectangular flat plates fixed and supported by stiffeners. The design pressure acts as a uniformly distributed load over the entire area of the plating considered.

The scantlings required for a vessel's hull are specified from the perspective of strength for satisfactory operation in normal service afloat. These scantlings may need to be increased to ensure satisfactory operation from other aspects such as vibration. For example, propeller-induced vibration may be reduced by either an increase in scantlings or an increase in propeller clearances.

The bottom area shall be determined in accordance with AS 4132.1.

Rigging loads and ballasted keel on yachts and the like are not considered and additional structure shall be designed and built into the vessel to withstand these loads with a factor of safety applied in accordance with Clause 3.1.3.

3.2.2 Curvature correction Where curvature is significant, the curvature correction factor (f) used in the equations given in Clauses 3.3 and 3.4, will reduce the required laminate thickness. Where curvature is not significant, f is equal to 1.

The curvature correction factor (f) is determined from the greater of—

(a) $f = 0.8$, or ... 3.2.2 (1)

(b) $f = 1 - \frac{x}{a}$... 3.2.2 (2)

where

f = curvature correction factor

x = distance between hull and chord between stiffeners, in millimetres (see Figure 3.1)

a = distance between centres of stiffening elements, measured along hull as shown in Figure 3.1, in millimetres.