Technical Specification

Transport and Main Roads Specifications
MRTS59 Manufacture of Fibre Reinforced Polymer (FRP) Composite Girders

July 2017

Queensland Government

Copyright

Feedback: Please send your feedback regarding this document to: tmr.techdocs@tmr.qld.gov.au

Contents

1 Introduction 1

2 Definition of terms 1

3 Referenced documents 1

4 Quality system requirements 3

4.1 Hold Points, Witness Points and Milestones 3

5 Conditions for manufacture of FRP composite girders 4

5.1 Standard 4

5.2 Registered manufacturer 4

5.3 Design 5

5.3.1 General 5
5.3.2 Prototype testing 5
5.3.3 Acceptance criteria 5
5.3.4 Certified design 6

5.4 Manufacture of fibre composite girders 6

6 Materials 7

6.1 Fibre 7

6.2 Fabric 8

6.3 Resin 8

6.4 Adhesive resin 10

6.5 Core 10

7 Fabrication 11

7.1 General 11

7.2 Assembly of components 11

7.2.1 Continuous process – profile section from pultrusions 11
7.2.2 Panels 12
7.2.3 Fabrication of bridge girders 12

7.3 Fabrication process – Vacuum Assisted Resin Infusion (VARI) process 12

7.4 Tolerances 13

7.5 Provision for performance monitoring 13

8 Marking, handling, storage 14

8.1 Marking 14

8.2 Handling 14

8.3 Provision for lifting 14

8.4 Storing 14

9 Testing of girders 14

9.1 General 14

9.2 Acceptance testing 15

9.3 Acceptance criteria 15

9.4 Records 15

10 Inventory 16

Appendix A: Data sheets 17

1 Introduction

This Technical Specification applies to the manufacture of Fibre Reinforced Polymer (FRP) Composite Girders. The FRP girders are intended for two different applications:

- to replace timber girders in an existing timber bridge, or
- to use as superstructure in a new bridge.

This Technical Specification shall be read in conjunction with MRTS01 *Introduction to Technical Specifications,* MRTS50 *Specific Quality System Requirements* and other Technical Specifications as appropriate.

This Technical Specification forms part of the Transport and Main Roads Specifications Manual.

FRP composite girders shall be fabricated only by a manufacturer who is registered with the department.

Information regarding registration and registered manufacturers can be obtained via email request to the following address tmr.techdocs@tmr.qld.gov.au.

2 Definition of terms

The terms used in this Technical Specification shall be as defined in Clause 2 of *MRTS01 Introduction to Technical Specifications.* Further definitions are as defined in Table 2.

Table 2 – Definition of terms

Term	Definition
Fibre	A general term used to refer to filamentary materials. Often, “fibre” is uses synonymously with “filament’.
Yarn	Assemblage of twisted filaments and fibres formed into a continuous length that is suitable for use in weaving textile materials.
Resin	The polymeric material used to bind together the reinforcing fibres in FRP.
Laminate	A composite material consisting of one or more layers of fibres impregnated in a resin system and cured.
Core	Lightweight materials used for load bearing or formers for shaping FRP section.
Panels	A sandwich element where a core is held by two or three layers of tri-axial glass laminate.

3 Referenced documents

Table 3 lists documents referenced in this Technical Specification.

Table 3 – Referenced documents

Reference	Title
AS 5100.2	*Bridge Design –Part 2 Design Loads*
AS/NZS ISO 9001	*Quality Management Systems - Requirements*
ASTM C 273	*Standard Test Method for Shear Properties of Sandwich Core Materials*
ASTM D 1621	*Standard Test Method for Compressive Properties Of Rigid Cellular Plastics*

Reference	Title
ASTM D 1623	*Standard Test Method for Tensile and Tensile Adhesion Properties of Rigid Cellular Plastics*
ASTM D2196-99	*Standard Test Methods for Rheological Properties of Non-Newtonian Materials by Rotational (Brookfield type) Viscometer*
ASTM D3039	*Standard Test Method for Tensile Properties of Polymer Matrix Composite Materials*
ASTM D5379	*Standard Test Method for Shear Properties of Composite Materials by the V-Notched Beam Method*
ASTM E1640	*Standard Test Method for Assignment of the Glass Transition Temperature By Dynamic Mechanical Analysis*
DIN 53424	*Testing of Rigid Cellular Materials - Determination of Dimensional Stability at Elevated Temperatures with Flexural Load and with Compressive Load*
ISO 10364:2007(E)	*Structural adhesives - Determination of the pot life (working life) of multi-component adhesives*
ISO 11357-2 :2013(E)	*Plastics - Differential scanning calorimetry (DSC) - Part 2: Determination of glass transition temperature and glass transition step height*
ISO 11359-2 :1999(E)	*Plastics - Thermomechanical analysis (TMA) - Part 2: Determination of coefficient of linear thermal expansion and glass transition temperature*
ISO 12114:1997(E)	*Fibre-reinforced plastics - Thermosetting moulding compounds and prepregs - Determination of cure characteristics*
ISO 13934-1:2013(E)	*Textiles - Tensile properties of fabrics - Part 1: Determination of maximum force and elongation at maximum force using the strip method*
ISO 14125:1998(E)	*Fibre-reinforced plastic composites - Determination of flexural properties*
ISO 15040:1999(E)	*Composites - Prepregs - Determination of gel time*
ISO 1675:1985(E)	*Plastics - Liquid resins - Determination of density by the pyknometer method*
ISO 1889:2009(E)	*Reinforcement yarns - Determination of linear density*
ISO 2535:2001(E)	*Plastics - Unsaturated-polyester resins - Measurement of gel time at ambient temperature*
ISO 2555:1989 (E)	*Plastics - Resins in the liquid state or as emulsions or dispersions -- Determination of apparent viscosity by the Brookfield Test method*
ISO 2896:2001	*Rigid Cellular Plastic – Determination of Water Absorption*
ISO 3219:1993 (E)	*Plastics - Polymers/resins in the liquid state or as emulsions or dispersions - Determination of viscosity using a rotational viscometer with defined shear rate*
ISO 3374:2000(E)	*Reinforcement products - Mats and fabrics - Determination of mass per unit area*
ISO 4587:2003(E)	*Adhesives - Determination of tensile lap-shear strength of rigid-to-rigid bonded assemblies*
ISO 4602:2010(E)	*Reinforcements - Woven fabrics - Determination of number of yarns per unit length of warp and weft*
ISO 4606:1995 (E)(textile glass)	*Textile glass - Woven fabric - Determination of tensile breaking force and elongation at break by the strip method*

Reference	Title
ISO 527-2:2012(E)	*Plastics - Determination of tensile properties - Part 2: Test conditions for moulding and extrusion plastics*
ISO 527-4:1997(E)	*Plastics - Determination of tensile properties - Part 4: Test conditions for isotropic and orthotropic fibre-reinforced plastic composites*
ISO 845-2006(E)	*Cellular plastics and rubbers - Determination of apparent density*
ISO 9396:1997(E)	*Plastics - Phenolic resins - Determination of the gel time of resols under specific conditions using automatic apparatus*
ISO/IEC17025	*General requirements for the competence of testing and calibration laboratories*
MRTS01	*Introduction to Technical Specifications*
MRTS50	*Specific Quality System Requirements*

4 Quality system requirements

4.1 Hold Points, Witness Points and Milestones

General requirements for Hold Points, Witness Points and Milestones are specified in Clause 5.2 of MRTS01 *Introduction to Technical Specifications.*

The Hold Points, Witness Points and Milestones applicable to this Technical Specification are summarised in Table 4.1.

Table 4.1 – Hold Points, Witness Points and Milestones

Clause	Hold Point	Witness Point	Milestone
5.3.2	1. Prototype testing		
5.4	2. Manufacture of girders		Submission of information listed
6.1	3. Fibre compliance		
6.3	4. Compliance certificate from the resin supplier		
6.5	5. Core compliance		
7.2.2	6. Approval of FRP panels		Submit QA Forms for FRP composite panels (seven days)
7.3			Submit QA forms related to Vacuum Assisted Resin Infusion Process (seven days)
7.4		1. Measurement of girder dimensions	
9.1	7. Acceptance of girder test results	2. Testing of girders	Submission of test results (14 days)

5 Conditions for manufacture of FRP composite girders

5.1 Standard

All FRP composite girders shall be manufactured according to the details shown in the approved drawings designed according to Chapter 16 – Design of Fibre Reinforced Polymer Composite Girders, of the department's *Design Criteria for Bridges and Other Structures.*

5.2 Registered manufacturer

Fibre composite girders shall only be fabricated by a registered manufacturer. Registration as an approved manufacturer will be reviewed periodically or earlier if unsatisfactory performance is reported. Information regarding registration status can be obtained from the department, refer Clause 1 of this Technical Specification.

To be eligible for registration as a Registered Manufacturer, a manufacturer shall:

a) Demonstrate that the manufacturer is capable of supplying girders by completing a design that complies with Chapter 16: Design of Fibre Reinforced Polymer (FRP) Composite Girders, of the department's *Design Criteria for Bridges and Other Structures*. The design shall be certified by a Registered Professional Engineer Queensland (RPEQ). The girder shall be manufactured and satisfactorily tested according to the criteria stipulated in Chapter 16.

b) Operate a quality management system certified to a minimum of AS/NZS ISO 9001. The system will be audited by the department to ensure that fabricators are working as stated in their Quality Assurance system requirements and the system conforms to the requirements of Transport and Main Roads Contracts.

- The auditor will inspect the premises prior to incorporating into the register.

The auditor is a Transport and Main Roads officer or a panel consisting of Transport and Main Roads personnel, a person from an academic institution and an FRP consultant from the industry. The composition of the auditor panel shall be made in consultation with Transport and Main Roads Deputy Chief Engineer (Structures).

- After registering the manufacturer, the department's auditor will conduct surveillance audits – periodic and random. The department's auditor reserves the right to carry out inspections in production facilities without giving prior notice. The manufacturer shall grant inspectors access to all areas used for production, storage and testing and shall present all documentation concerning records and tests carried out.

The following application of approval forms from industry recognised agencies to be used during the auditing process:

1. Application of approval – For the production or processing of non-metallic materials.
2. Application of approval – For the manufacturing of components made of fibre-reinforced reaction resin (FRP).
3. Application of approval – Workshop Inspection Fibre Reinforced Plastic (FRP).

c) Establish procedures for manufacture of fibre composite girders, and

d) Have an inspection and test plan including Hold Points acceptable to the department for manufacturing fibre composite girders which demonstrates compliance with this specification. The inspection and test plan shall address supply of materials.

Registration as a registered manufacturer of FRP composite elements / girders shall be reviewed at intervals from six months to three years depending on registration level, or earlier if unsatisfactory performance is reported.

5.3 Design

5.3.1 General

Design of FRP girders shall comply with Chapter 16: Design of Fibre Reinforced Polymer (FRP) Composite Girders of the Transport and Main Roads *Design Criteria for Bridges and Other Structures.* The Contractor shall submit full design calculations to demonstrate compliance with Chapter 16.

The Contractor shall allow adequate time for the design process including 28 days for assessment of the design, time for prototype testing and time for feedback and redesign. No additional payment will be made for time taken for redesign and reassessment.

Alternatively the Contractor may submit a design that has been approved by the department.

5.3.2 Prototype testing

Where the manufacturer has successfully tested a girder with a span within one metre of the new design using the same materials and design processes, the manufacturer does not need to prove the design by testing a prototype. Otherwise the design shall be proven by undertaking a full scale test after the design has been assessed by the Administrator.

Testing shall not be undertaken unless the Administrator is present. **Hold Point 1**

The full scale testing shall consist of the following:

- serviceability bending and shear tests
- ultimate bending and shear tests

Serviceability bending moment capacity, stiffness, ultimate bending and shear capacities are critical properties and to be verified against the design calculations.

- fatigue tests - for new bridges, Clause 6.9 of AS 5100.2 shall apply
- FRP girders destined for timber bridges shall be tested for one million cycles with 70% and 20% of service load and 100% spike loads at every 200,000 cycles
- drill tests, and
- end crushing tests, if required.

Load deflection characteristics shall be recorded.

5.3.3 Acceptance criteria

A prototype test will be accepted provided it meets all of the following criteria:

1. Deflection versus applied load plot shall be linear in the SLS region and behaviour shall be ductile before reaching the ultimate capacity as shown in the load deflection curve in

Chapter 16: Design of Fibre Reinforced Polymer (FRP) composite girders, of the Transport and Main Roads *Design Criteria for Bridges and Other Structures*.

2. Residual deflection when load is removed shall be less than 1.5 mm after allowing for "bedding in".
3. "Creep" at maximum load (load at target proof moment, five minutes duration) shall not exceed 1 mm. If excessive creep occurs the source shall be determined and the issue resolved.
4. If deflection is larger than the calculated value, the test shall be rejected. If deflection is smaller than the calculated value, the test may be accepted subject to ascertaining that the reason for the difference does not compromise the performance of the beam, and
5. Beams shall show no sign of distress during testing.

5.3.4 Certified design

The Contractor shall submit RPEQ certified drawings showing profile dimensions, cross section and materials to be used.

5.4 Manufacture of fibre composite girders

At least seven days before manufacture is due to commence, the Contractor shall provide the following information to the Administrator: **Milestone**

a) RPEQ certified drawings showing profile dimensions, cross section and materials to be used. A copy of the Transport and Main Roads design approval shall also be submitted.

b) The fabrication program.

c) The place of manufacture.

d) An outline of the method of manufacture.

e) Quality Assurance Plan covering:

- fibres
- resin components: the manufacturer shall provide the mix design of the resin consisting of resin, catalyst (initiators), promoters, inhibitors, additives, fillers, pigments, UV agents, chemical and fire resistant additives
- core components and the constituents including mechanical test results
- fixings and inserts
- adhesion of fibres and resin
- mixing of resin
- layup of fibres
- wet out of fibres
- consolidation/compaction of laminates
- curing schedule
- defects detection, and

- final product QA testing.

f) Traceability of a FRP girder all the way back to the raw materials used, and

g) Details of the methods for UV protection.

Manufacture of fibre composite girders shall not commence until the above details have been accepted and Hold Point 1 has been released by the Administrator. **Hold Point 2**

6 Materials

6.1 Fibre

Fibrous reinforcement includes continuous fibres, discontinuous fibres, whiskers and carbon nano tubes. The most common types of fibrous reinforcement are glass, carbon and aramid fibres – other types of fibres include boron, silicon carbide (SiC), alumina, and sapphire, all of which are used in special applications. The choice of fibre for a specific application depends on the desired mechanical and environmental properties.

Only the following glass fibre types are permitted to be used for manufacture of FRP composite girders. Minimum properties of fibre before processing shall be as specified in Table 6.1:

- E-glass
- ECR-glass, and
- S-glass.

E-glass shall not be used in the following applications:

- members in salt-rich arid areas
- sea water – tidal or splash zone, and
- soft or running water.

The manufacturer shall ensure that the sizing applied for fibres are compatible with the resin used in the production of FRP girders.

Glass fibres are typically used in low-cost applications of polymer matrix composites. The primary advantages of glass fibres are their low cost and high strength, along with typical glass properties such as hardness, corrosion resistance, and chemical inertness. However, glass fibres also possess some disadvantages, including low modulus of elasticity, poor abrasion resistance and poor adhesion to polymer matrix resins, especially in the presence of moisture. The poor adhesion requires the use of chemical coupling agents such as silane.

Table 6.1 – Minimum properties of fibres before processing

Fibre Properties	E-glass	ECR-glass	S -glass
Specific Gravity	2.54	2.71	2.47
Tensile Strength MPa (22°C)	3400	3300	4600
Tensile Modulus GPa (22°C)	72	72	88

Fibre Properties	E-glass	ECR-glass	S -glass
Elongation %	4.8	4.8	3.0
Coefficient of Thermal Expansion 10^{-6}/°C	5.0	5.9	2.9

The manufacturer shall nominate the type of fibre and provide test results from a NATA certified laboratory or an equivalent departmental approved third party verifier to demonstrate compliance with Clause 6.1. **Hold Point 3**

A minimum of five fibre samples for every girder shall be taken for testing at regular intervals during the manufacturing process.

6.2 Fabric

Fibres are woven into a fabric. Fibres can be aligned in any direction with 0˚, 45˚ and 90˚ being the most common.

The manufacturer shall nominate the commercial name of the fabric and include the type of weave (plain, twill, satin, and so on), type of yarn (weft and wrap), characteristics other than weft and warp (finishing, veil, wrapping, and so on) and any other information deemed necessary.

The manufacturer shall provide the properties and data by completing Data Sheet 1 shown in Appendix A.

The manufacturer shall supply test certificates from a NATA certified laboratory or an equivalent departmental approved third party verifier to the Administrator.

In the absence of a departmental approved third party verified approval certificate, a minimum of five fabric samples for every girder shall be taken for testing at regular intervals during the manufacturing process.

6.3 Resin

A polymer which may exist in solid, semi-solid or liquid state. A resin matrix is used to impregnate the fibres and bind filaments, fibres and layers of fibre together.

Only the following thermosetting resin binders shall be used in the manufacture of FRP composite girders; thermoplastic resins shall not be used. The resins given below form the matrix of FRP composites only. Adhesive resins are covered in Clause 6.4.

Thermosets are cross-linked polymers that have undergone an irreversible chemical reaction to permanently connect all molecular chains with covalent bonds. This material sets (or cures) into shape by adding a catalyst (or by heating). As the polymer gels, it undergoes an irreversible chemical reaction to form a 3-D network of cross-links, gaining a higher degree of rigidity and transforms permanently.

Thermoplastic are linear or branched polymers, with molecular chains that are connected or formed by weak intermolecular bonds (van der Waals bonds). Unlike thermosets, thermoplastics do not cure or set when heated; in fact they become more fluid as the temperature increases.

There is no chemical reaction or cross linking as with thermosets; the material changes are entirely physical. Because the changes are reversible, thermoplastics can be recycled and repossessed.

- polyester resin
- epoxy resin
- vinyl ester resin, or
- phenolic resin.

The allowable material properties of the cured resin shall be as shown in Table 6.3.

Table 6.3 - Allowable properties of resin

Property	Units	Polyester Resin	Epoxy Resin	Vinyl Ester Resin	Phenolic Resin
Tensile Strength (min)	MPa	70	70	70	40
Young's Modulus (Range)	GPa	2-3	2-4	3-4	1.5-2.5
Flexural Elongation at Failure (min)	%	4	4	4	1.5
Density (Range)	g/cm^2	1.2-1.3	1.2-1.3	1.12	1.24
Heat Distortion Temperature (min)	°C	90	90	90	90
Shrinkage (max)	%	5	2.5	5	5

The manufacturer shall provide the commercial name of all components used including, mono or bi / tri-component, paste or fluid consistency, use, type of accelerators, catalysts, hardeners, promotors, additives, inhibitors, fire retardants and fillers and any other necessary information.

The manufacturer shall provide the properties of the unmixed resin components by completing Data Sheet 2A shown in Appendix A.

The manufacturer shall supply test certificates for unmixed resin from a NATA certified laboratory or an equivalent Transport and Main Roads approved third party verifier to the Administrator.

The manufacturer shall provide the characteristics of the mixed resin by completing Data Sheet 2B shown in Appendix A.

The manufacturer shall supply test certificates for mixed resin from a NATA certified laboratory or an equivalent third party verifier to the Administrator.

The manufacturer shall provide the properties of the cured resin by completing Data Sheet 2C shown in Appendix A. The cured resin properties shall comply with Table 6.3. The additional properties shall be reported.

The manufacturer shall supply test certificates for cured resin from a NATA certified laboratory or an equivalent departmental approved third party verifier to the Administrator.

A minimum of five resin samples for every girder shall be taken for testing of Barcol / Shore D hardness and the Glass transition temperature (Tg) at regular intervals during the manufacturing process.

In the absence of a departmental approved third party verified approval certificate, a minimum of five resin samples for every girder shall be taken for testing of all the parameters shown in Data Sheet 2C at regular intervals during the manufacturing process.

The girders shall be protected from degradation due to UV exposure. As a minimum, a UV stabiliser shall be added to the resin mix. A suitable pigment shall be added to the exterior layer to protect from damage by sunlight. The manufacturer shall detail the process proposed and shall obtain approval. **[Refer to Hold Point 1]**

The fire protection coating shall be applied evenly around all faces of the FRP girders and diaphragms.

The complete resin mix (ingredients, quantities, and procedure for mixing, applying and curing) shall be submitted to the Administrator (commercial in confidence). The mix design and mixing methodology shall be approved by the resin supplier. The Contractor shall present a compliance certificate from the resin supplier stating that the mix is in accordance with their recommendations. **Hold Point 4**

The manufacturer shall demonstrate that compliance with the matrix mix design is maintained at all times.

6.4 Adhesive resin

Adhesive is a polymeric material capable of bonding two materials together. The adhesive shall be capable of producing strong and durable bonding which maintains the bond integrity throughout the intended lifetime of the structure.

Only epoxy adhesive resin shall be used in bonding structural elements. The manufacturer shall provide the commercial name, mono or bi-component, pasty or fluid consistency, use and any other information deemed useful.

The manufacturer shall provide the bonding properties of the adhesives by completing Data Sheet 4 shown in Appendix A.

The manufacturer shall nominate the surface preparation method for the adhesive testing.

The manufacturer shall use the substrates representative of the elements used in the girder fabrication in carrying out the shear test.

The manufacturer shall supply test certificates from a NATA certified laboratory or an equivalent departmental approved third party verifier to the Administrator.

A minimum of five adhesive resin samples for every girder shall be taken for testing of Barcol / Shore D hardness and the Glass transition temperature (Tg) at regular intervals during the manufacturing process.

In the absence of a departmental approved third party verified approval certificate, a minimum of five shear tests shall be carried out as in Data Sheet 4.

6.5 Core

Core material shall be compatible with the resin used and the manufacturing system. Core material shall be non-friable, closed cell and have low water absorption. The manufacturer shall supply to the

Administrator the Data Sheet 3 shown in Appendix A. The manufacturer shall specify a Manufacturer's Specified Minimum Value" (msmv) for the properties shown in Data Sheet 3 and shall provide the test results from a NATA accredited testing facility to the Administrator. Non confirming core material shall be rejected by the Administrator. **Hold Point 5**

The manufacturer shall supply test certificates for core materials from a NATA certified laboratory or an equivalent departmental approved third party verifier to the Administrator.

In the absence of a departmental approved third party verified approval certificate, a minimum of five core samples for every girder shall be taken for testing of all the parameters shown in Data Sheet 3 at regular intervals during the manufacturing process.

7 Fabrication

7.1 General

The manufacturer shall identify the methods of FRP girder construction in the following four key areas:

- assembly of only FRP components - profiles and panels
- casting process involving vacuum assisted resin infusion process
- hybrid - steel and FRP components, and
- hybrid - steel, concrete and FRP components.

7.2 Assembly of components

7.2.1 Continuous process – profile section from pultrusions

The pultrusion technique is a fully automated closed mould continuous process in which continuous fibre, rovings, or mats are passed through a resin bath, drawn through a preforming die to form the composite into a strip, and cured in a heated die.

FRP profiles shall have a minimum 60% of fibre content by weight.

Minimum properties of FRP profiles shall be as shown in Table 7.2.1.

The manufacturer shall supply to the Administrator the data sheet of the FRP profile used in composite girders.

A Quality Assurance process shall be used in the fabrication of the profiles.

Table 7.2.1 – Minimum properties of FRP profiles

Property	Units	Test method	Minimum properties
Tensile Strength - axial	MPa	EN ISO 527-4/ASTM D3039	300
Tensile Strength - transverse	MPa	EN ISO 527-4/ASTM D3039	55
Tensile Modulus - axial	GPa	EN ISO 527-4/ASTM D3039	30
Tensile Modulus - transverse	GPa	EN ISO 527-4/ASTM D3039	7
Flexural Strength - axial	MPa	EN ISO 14125	240
Flexural Strength - transverse	MPa	EN ISO 14125	100

Property	Units	Test method	Minimum properties
Shear Strength – in plane	MPa	ASTM D5379	50
Shear modulus – in plane	GPa	ASTM D5379	3
Interlaminar Shear Strength	MPa	ASTM D5379	25

7.2.2 Panels

Panels shall be produced by an automated and controlled process in a controlled environment with full temperature, humidity and dust control.

Resins shall be cured at elevated temperatures in accordance with the resin manufacturer's specification.

A Quality Assurance process shall be used in the fabrication of the panels.

Copies of forms completed for this process shall be submitted to the Administrator within seven days of the panels being produced. **Milestone**

The panels shall not be accepted into the works until the Quality Assurance forms are accepted by the Administrator. **Hold Point 6**

The tolerance for the thickness of the panels shall be +/- 1 mm. Glass shall be laminated without visible wrinkling or distortion of the fabric.

7.2.3 Fabrication of bridge girders

FRP composite girders and diaphragms shall be fabricated inside a factory under controlled conditions.

The manufacturer shall describe the surface preparation (including sanding and priming) required for good adhesion between critical elements.

Girders shall be dry fitted prior to applying adhesive to ensure proper fit of all components and compliance with finished dimensions.

Finished girders and diaphragms shall be cured at elevated temperatures in accordance with the adhesive manufacturer's specification.

7.3 Fabrication process – Vacuum Assisted Resin Infusion (VARI) process

VARI process involves impregnation of a dry reinforcement by liquid thermoset resin driven under vacuum. In this process dry preform fabrics are placed in an open mould and a plastic vacuum bag is placed on the top of the mould. The one sided mould is connected with a resin source and a vacuum pump. Curing and de-moulding steps follow the impregnation process to finish the product.

The manufacturer shall take adequate measures in fabricating wrinkle free and void free end products in the VARI process.

The manufacturer shall ensure a vacuum drop test is carried out prior to resin infusion.

The manufacturer shall ensure vacuum bags are correctly fitted and no bridging is accepted.

The manufacturer shall ensure that there are no resin rich areas in tight radii curves.

Operate a quality management system certified to a minimum of AS/NZS ISO 9001 shall be adopted in the fabrication of girders.

Copies of forms completed for this process shall be submitted to the Administrator within seven days of the girder being produced. **Milestone**

7.4 Tolerances

Completed FRP girders and diaphragms shall comply with the tolerances set out in Table 7.4.

Measurement of dimensions for acceptance of each beam including any diaphragms shall be a: **Witness Point 1**

Table 7.4 – Dimensional tolerances

Measurement	Tolerance
Overall depth	+/- 2 mm
Overall width	+/- 2 mm
Overall Length of Beam	+/- 5 mm
Lateral Bow	5 mm over length of girder
Squareness	Not greater than 1 degree out of square on any cross-section
Twist	With one end cross-section taken as a reference, any cross section shall not exceed 1 degree
Position of holes in beams	+/- 1 mm
Position of Hybrid Units in elevation	+/- 2 mm

7.5 Provision for performance monitoring

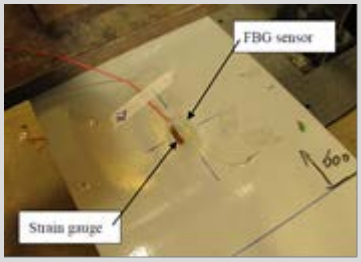
Provisions shall be in place during the manufacturing process to accommodate the installation of fibre optic sensors or the strain gauges on selected girders as directed by the Administrator.

Electrical connections to strain gauges/fibre optic sensors shall be durable and vandal resistant.

The manufacturer's information on gauges shall be supplied to the Administrator.

The location of sensors and gauges shall be recorded on the "as constructed" drawing of the girder.

Strain gauges/fibre optic sensors shall be fitted to the inside face of the web panel of the nominated girder. Gauges shall cover the + 45° and - 45° directions. Strain gauges / fibre optic sensors shall be provided at mid span and at each end of the girder - top and bottom. Two gauges shall be provided at each location and each direction to provide redundancy.

Surface mounting of a Fibre Optics Sensor (FBG) and a Strain Gauge. The best practice is to embed these sensors in the material during the fabrication process.	 Fibre optic sensor and strain gauge

8 Marking, handling, storage

8.1 Marking

On each fibre composite girder, the following information shall be clearly and permanently marked on a surface which shall not be on public display when erected:

a) the date of manufacture

b) the girder identification number

c) the manufacturer's name or registration mark

d) the maximum mass of the girder

e) areas permissible to cut and drill

f) areas designated to support, and

g) the maximum service temperature the girder is designed for.

8.2 Handling

FRP composite girders shall be handled with adequate care to eliminate the potential for fracture by impact, undesirable bending, twisting and whipping.

8.3 Provision for lifting

FRP composite girders shall only be lifted using soft slings and a spreader beam. The soft slings shall be perpendicular to the beam centreline.

8.4 Storing

Fibre composite girders shall be stored clear of the ground on adequate supports (timber bearers) placed on a plane surface in a manner that avoids damage, twisting or warping. The ground shall not be liable to subsidence under the weight of the elements.

The girders shall not rest on any location between the specified support points.

9 Testing of girders

9.1 General

The manufacturer shall provide mechanical test results of fibre, fabric and laminates and coupon tests of the composite section in the longitudinal and transverse direction. The number of samples shall not be less than five for any given property.

The tests shall be carried out at a laboratory accredited by:

- NATA
- NATA Mutual Recognition Agreement (MRA) Network Laboratory, or
- other internationally recognised accreditation body (that is, signatory to ILAC or APLAC).

Testing facilities used shall have accreditation to ISO/IEC17025, unless otherwise agreed by the Deputy Chief Engineer (Structures).

Testing of FRP composite girders shall comply with Clause 9. **Witness Point 2** Notice shall be given 10 days prior to the tests. The Test Report for the girder shall be submitted to the Administrator for

approval at least 14 days prior to the girder being transported to the site. **Milestone** Girders shall not be transported to site until the test report has been accepted by the Administrator. **Hold Point 7**

9.2 Acceptance testing

Ten per cent of girders with a minimum of one girder shall be tested. The following tests are to be carried out.

- Serviceability Limit State (SLS) Bending, and
- Serviceability Limit State (SLS) Shear.

Loading arrangements as well the test load requirements shall be as established in the design.

Deflection and Stiffness for serviceability conditions from the proof test shall satisfy the criteria outlined in Chapter 16: Design of Fibre Reinforced Polymer (FRP) Composite Girders of the department's *Design Criteria for Bridges and Other Structures*.

9.3 Acceptance criteria

The tested beam will be accepted provided it meets all of the following Criteria at Serviceability Limit State loading **[Refer to Hold Point 4]**:

1. Deflection versus applied load plot shall be linear in the SLS region as shown in the load deflection curve in Chapter 16: Design of Fibre Reinforced Polymer (FRP) Composite Girders, of the department's *Design Criteria for Bridges and Other Structures.*
2. Beams with deflection larger than specified shall be rejected. Beams with deflection smaller than specified value may be accepted subject to ascertaining that the reason for the difference does not compromise the performance of the beam, and
3. Beams shall show no sign of distress during testing.

Fibre composite girders shall remain available for inspection for a minimum of seven days.

The acceptability of a fibre composite girder shall be determined by inspection on the basis of visual inspection and geometric measurements or by non-destructive testing (NDT) such as ultrasonic testing.

Fibre composite girders shall be rejected if they fail to meet any of the requirements of this specification.

If a girder fails the acceptance criteria, all of the relevant girders represented by the girder tested shall be rejected. The Contractor may submit an extended test program for consideration.

9.4 Records

The following shall be recorded:

- test location
- list of all witness personnel to the test
- date and time of test
- details of test girder
- photographs taken of the test setup and during testing
- details of the test setup

- equipment calibration data, and
- test results including time, load cell readings, strain gauge readings and deflection for each load increment.

The test report shall incorporate all of the above data.

10 Inventory

The manufacturer shall provide the following inventory to the Administrator, upon acceptance of the FRP girders by the Administrator:

- permanent ID mark for each girder giving type and location of the girder
- dimensions including length
- limitation on drilling
- limitation on cutting including cutting at an angle
- permissible cutting device
- lifting restrictions
- non-conformance report, and
- loading facility at the location.

Appendix A: Data sheets

Data Sheet 1: Technical data sheet: Non-Impregnated fabric

The manufacturer shall report the statistical values needed to evaluate the strength characteristics (for example, sample mean, sample standard deviation, population, percentile, confidence interval).

Fabric description

[Detail the type of weave (plain, twill, satin, and so on), type of yarn (weft and wrap), characteristics other than weft and warp (finishing, veil, wrapping, and so on) and any other information deemed necessary].

Frequency of testing

The manufacturer shall supply test certificates from a NATA certified laboratory or an equivalent departmental approved third party verifier to the Administrator

In the absence of a departmental approved third party verified approval certificate, a minimum of five fabric samples for every girder shall be taken for testing at regular intervals during the manufacturing process.

Fabric characteristics

[Complete the fabric properties]

Properties	Direction of yarn	Measurement unit	Test Method Reference Standard	Measurement Value
Yarn count	warp	Tex	ISO 1889: 2009(E)	
	weft	Tex		
Yarn density		g/cm³		
No. of yarns/cm	warp	no/cm	ISO 4602:2010(E)	
	weft	no/cm		
Mass (weight)	total	g/m²	ISO 3374:2000(E)	
	warp	g/m²		
	weft	g/m²		
Young modulus of elasticity for tensile stress	warp	MPa		
	weft	MPa		
Tensile strength (mean and characteristic value)	warp	N	ISO 4606:1995 (E)(textile glass) ISO 13934-1:2013(E)	
	weft	N		
Failure strain	warp	%	ISO 4606:1995 (E)(textile glass) ISO 13934-1:2013(E)	
	weft	%		

Storage condition

[Detail the storage requirements including temperature, humidity and environmental conditions].

Safety and handling

[Detail the safety and handling requirements].

Data Sheet 2A - Properties of unmixed resin

Resin description

[Detail the commercial name, whether mono or bi-component, paste or fluid consistency, use, type of accelerators, catalysts, hardeners and promotors, additives, inhibitors, fire retardants , fillers and any other necessary information].

Testing frequency

The manufacturer shall supply test certificates for unmixed resin from a NATA certified laboratory or an equivalent departmental approved third party verifier to the Administrator.

Properties of unmixed resin

Property		Unit	Component A	Component B	Component C	Test Method Reference Standard	Notes
Colour							
Viscosity at 25ºC		Pa.s				ISO 2555:1989 (E) ISO 3219:1993 (E)	(1)
Thyxotropy index						ASTM D2196-99	(1)
Density		g/cm³				ISO 1675:1985(E)	
Mixing ratio	Volume	%					
	Weight						
Storage condition (sealed container)	Time	Month ºC					
	Temperature						

(1) For non thyxotropic resins the Garner viscosimeter can be used; for thyxotropic resins the Brookfield viscosimeter shall be used.

Data Sheet 2B – Characteristics of mixed resin

Mixing conditions:

[Description including inhibitors or hardeners/catalyst used].

Testing frequency

The manufacturer shall supply test certificates for mixed resin from a NATA certified laboratory or an equivalent departmental approved third party verifier to the Administrator.

Mixing restrictions:

[Description of the limitations to be observed for the mixed resin].

Property		Measurement unit	Test method reference standard	Notes	Value
Pot life (at 35ºC)			ISO 10364:2007(E)	(2)	
Gel time	At 20°C	min	ISO 9396:1997(E) ISO 2535:2001(E) ISO 15040:1999(E)	(3)	
	At 35°C				
Minimum application temperature		°C			
Exothermic peak	Time	min	ISO 12114:1997(E)		
	temperature	°C			
Full cure time	At 20°C	min	ISO 12114:1997(E)		
	At 35°C				

(2) Pot life (working life) = maximum working time after mixing all components

(3) Gel time = time needed from fluid to gel appearance at predefined temperature conditions

Data Sheet 2C - Properties of cured resin

Testing frequency

The manufacturer shall supply test certificates for cured resin from a NATA certified laboratory or an equivalent departmental approved third party verifier to the Administrator.

A minimum of five resin samples for every girder shall be taken for testing of Barcol / Shore D hardness and the Glass transition temperature (Tg) at regular intervals during the manufacturing process.

In the absence of a departmental approved third party verified approval certificate, a minimum of five resin samples for every girder shall be taken for testing of all the parameters shown in Data Sheet 2C at regular intervals during the manufacturing process.

Property	Measurement unit	Temperature	Value		Test Method Reference standard
			Cured at 5 days at 22°C	Cured 1 hr at 70°C	
Tensile strength	MPa				ISO 527-2:2012(E)
Young's modulus of elasticity for tensile stress	GPa				ISO 527-2:2012(E)
Flexural Elongation at Failure	%				ISO 527-2:2012(E)
Density	g/cm³				
Heat Distortion Temperature	°C	.....			
Shrinkage	%	.....			
Coefficient of thermal expansion	10^{-6} °C^{-1}	.....			ISO 11359-2:999(E)
Glass transition temperature	°C	.....			ISO 11357-2:2013(E) (DSC) ISO 11359-2:1999(E) ASTM E1640 (DMA)
Barcol Hardness					
Flexural Strength	MPa				
Flexural modulus	MPa				

Data Sheet 3 - Properties of core

Testing frequency

The manufacturer shall supply test certificates for core materials from a NATA certified laboratory or an equivalent departmental approved third party verifier to the Administrator.

In the absence of a Transport and Main Roads approved third party verified approval certificate, a minimum of five core samples for every girder shall be taken for testing as shown in Data Sheet 3 at regular intervals during the manufacturing process.

Property	Measurement unit	Value		Test method
		msmv	Test value	Reference standard
Density	Kg/m^3			ISO 845-2006
Tensile Strength	MPa			ASTM D 1623
Tensile Modulus	MPa			ASTM D 1623
Compressive Strength	MPa			ASTM D 1621
Compressive Modulus	MPa			ASTM D 1621
Shear Strength	MPa			ASTM C 273
Shear Modulus	MPa			ASTM C 273
Heat Distortion Temperature	°C			DIN 53424
Water Absorption	Kg/m^2			ISO 2896:2001

Data Sheet 4 - Properties of adhesive resin

Adhesive description

Commercial name, mono or bi-component, pasty or fluid consistency, use and any other information deemed useful.

The manufacturer shall supply test certificates for adhesive resin from a NATA certified laboratory or an equivalent departmental approved third party verifier to the Administrator.

A minimum of five resin samples for every girder shall be taken for testing of Barcol / Shore D hardness and the Glass transition temperature (Tg) at regular intervals during the manufacturing process.

In the absence of a departmental approved third party verified approval certificate, a minimum of five resin samples for every girder shall be taken for testing of all the parameters shown in Data Sheet 2C at regular intervals during the manufacturing process.

Bonding properties of resin

Property	Measurement unit	Temperature	Value		Test method reference standard
			Cured 5 days at 22°C	Cured 1 hours at 70°C	
Shear strength (average and characteristic value)	MPa				*Single lap shear* ISO 4587:2003(E)
Peeling strength (average and characteristic value)	kN/m				*Floating-roller method* ISO 4587:2003(E)

Storage conditions

Descriptions

Safety and handling

Description