# User guide for the adoption of FRP (Fibre Reinforced Polymer) in Sydney Water

**Engineering and Environmental Services**
**Liveable City Solutions**

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## Appendices

# 1 Introduction

Fibre Reinforced Polymer (FRP) has been installed in some Sydney Water sites. The use is mainly driven by its better corrosion resistant properties in corrosive environment. While its use is often successful, there is anecdotal evidence of some unexpected early failure and durability problems.

There is a lack of available publication and knowledge on the design methodology, material properties and history of performance in service to both designers and constructors. This has consequently limited the adoption of the material.

The purpose of this User Guide is to outline the common issues associated with the use of FRP. This is not a technical document and appropriate advice should be sought.

# 2 FRP

## 2.1 Composite material

FRP is a composite material consisting of a thermosetting polymer resin reinforced with glass or other type of fibres that provide strength and stiffness. The type of resin and fibre together with the mix proportion and manufacturing process would determine the strength and chemical resistance properties of the composite.

## 2.2 Suitability

A suitability report (**Appendix** 1) was prepared by Engineering and Environmental Services in 2013. It outlined the general properties, market availability and some examples of use in Sydney Water. The most common applications are floor gratings, platforms, handrails and ladders. Some cases of structural use as support members were found, and quite extensively in a recently completed job at Penrith WWTP.

The report found:

1. FRP has good corrosion resistance to chemicals.
2. FRP is light weight and possesses higher strength-to-weight ratio than steel.
3. The durability under exposure to sunlight could be compromised.
4. FRP composites exhibit little or no ductile behaviour which means failure may be sudden without early warning.
5. There is a general lack of availability of published standards for materials properties and design methodology in Australia.
6. FRP could have a cheaper life cycle cost over conventional galvanised steel when used in corrosive environment.
7. There are local manufacturers but the market is generally supplied by imported materials mostly from China.

A wider adoption of FRP gratings in corrosive environment was supported by the report. It recommended further work to be done on the capability of the market in the supply of reliable FRP guardrails and ladders systems.

The report did not endorse the wider use of FRP structural sections unless severe corrosion is a critical issue and significant benefit can be derived. If used, the structure must be designed by a competent engineer and supplied/ fabricated by an experienced manufacturer.

Observation and validation of the long term performance of the existing FRP installations in Sydney Water were recommended.

## 2.3 Life cycle cost

The adoption of FRP to substitute the use of galvanised steel can be determined by carrying out a total life cycle cost comparison. The sectional size for both materials shall be selected to provide the same load carrying capacity. Up-to-date supply and installation prices should be obtained from suppliers.

There is no established data on the expected life span of FRP when used in our work site environment. FRP is expected to last typically twice as long as galvanised steel in corrosive environment. Some indicative life span expectancy is given in **Table 1** and may be used in the absence of better data.

However, the advantage of longer life in FRP could be offset by the cost of more frequent inspection. Repair cost of defects or replacement of damaged parts may also be higher. This must be taken into account in the life cycle cost comparison.

# Table 1 – Indicative life span

| *Environment* | FRP | Galvanised Steel |
|---|---|---|
| *A. Open or ventilated, not exposed to high corrosive elements* | 50 yrs | 75 yrs |
| *B. Closed but not exposed to high corrosive elements* | 50 yrs | 25 yrs |
| *C. Open or ventilated, but exposed to high corrosive elements* | 50 yrs | 25 yrs |
| *D. Closed and exposed to high corrosive elements* | 25 yrs | 10 yrs |

## 2.4 Location selection

The use of FRP should be based on consideration of the corrosion environment, safety risk, vandalism and life cycle costs. **Table 2** gives some guidance on its adoption in typical Sydney Water sites.

## Table 2 – Location selection for FRP

| Environment | Description | Location examples | Notes |
|---|---|---|---|
| A. Open or ventilated, not exposed to corrosive elements | Benign indoor and dry environment | • control room<br>• office<br>• water pumping station<br>• water treatment plant<br>• drinking water reservoir | • galvanised steel typically offers better life cycle cost than FRP.<br>• electrical insulation properties of FRP may be beneficial.<br>• check compliance with BCA code when used in fire emergency egress |
| B. Closed but not exposed to highly corrosive elements | Constantly immersed in or splashed by water or in the water vapor space | • inside drinking water reservoir | • FRP may offer better value in particular when access for maintenance is difficult.<br>• must comply with AS4020 when used in contact with drinking water. |
| C. Open or ventilated, but exposed to corrosive elements | Marine environment | • wharf and jetty<br>• outfall site | • vinylester resin only.<br>• consider vandalism and safety risks. |
| | Coastal environment subject to salt spray | • site within 1 km from coastline | • consider vandalism and safety risks in public areas |
| | Corrosive chemicals – chlorine, sodium hypochlorite #, alum, sodium hydroxide. | • chemical dosing plant | • vinylester resin only.<br>• check chemical resistance properties with supplier |
| | Corrosive chemicals – petrol, diesel and hydrocarbons | • emergency generator site | • vinylester resin only.<br>• check chemical resistance properties with supplier. |
| | Occasional splashes of sewage or contact with bio-solids | • sewage pumping station<br>• Wastewater treatment plant | • vinylester resin only. |
| D. Closed and exposed to corrosive elements | Continually immersed in septic sewage or in non-ventilated sewage atmosphere | • sewage inlet chambers<br>• settling tanks and digesters<br>• SPS wet wells<br>• sewage maintenance holes | • vinylester resin only. |

# See Section 2.5

## 2.5 Chemical resistance properties

Chemical resistance properties tables are available from FRP manufacturers. The incorrect specification of resin type and curing system may reduce the longevity of FRP composite installations.

When used in contact with or within splash zone of sodium hypochlorite, special caution should be taken. For long term contact, vinylester resin with a BPO/DMA curing system must be used.

Additional requirements such as an enhanced corrosion barrier may also be required. In most other applications in the splash zone, adequate washdown will eliminate significant durability issues. Where timely washdown is unlikely to occur, the use of FRP composites may not be appropriate.

# 3 Inspection and maintenance

## 3.1 Preventive inspection

The objective of preventive maintenance inspection is to mitigate the threat to safety caused by unexpected failure. Repair cost may also be reduced if defects are detected early. It will also provide a record of the long term performance of the asset over time.

Owing to the brittle nature of FRP and the potential issues with performance under UV light exposure, more frequent preventive inspection is required. This inspection may be carried out by competent staff using the inspection form in **Appendix 2**. When the extent of any defect is of concern, specialist assessment by a competent FRP inspector should be undertaken.

The frequency of inspection would depend on the environment to which the installation is exposed. **Table 3** provides a guide for the frequency. This may be varied and is dictated by site condition and age of the asset.

## Table 3 – Recommended FRP preventive maintenance inspection frequency

| Environment | Interval |
|---|---|
| A and B: Not exposed to corrosive elements | 12 months |
| C and D: Exposed to corrosive elements | 6 months |

## 3.2 Repair and maintenance

The repair and maintenance of FRP composites are specialized in nature. They should be undertaken by FRP suppliers with the necessary skill and experience. They may include re-coating, restoring finishes, reinstating clips and replacement of parts.

# 4 FRP gratings

Moulded FRP gratings are most common. Pultruded gratings are also available in the market. The gratings must comply with the requirements of AS 1657 – Fixed Platforms, walkways, stairways and ladders – Design, construction and installation.  The gratings must be provided with a non-slip surface and not used for surfaces with a slope more than $10^0$.

The capability and expertise of grating suppliers in the market is varied. There are trading firms who might simply import overseas products without informed quality control and are prepared to produce unreliable test certification.

To facilitate the purchase of gratings, a specification is available from Sydney Water. A market product assessment process will be implemented to encourage their wider adoption.

# Appendix 1 – Suitability Report FRP for platforms, walkways, safety grilles and structural members at facility installations

Sydney WATER

# SUITABILITY REPORT

## FIBRE REINFORCED POLYMERS (FRP) FOR PLATFORMS, WALKWAYS, SAFETY GRILLES AND STRUCTURAL MEMBERS AT FACILITY INSTALLATIONS

# CONTROL COPY SHEET

| Issue | Date | Description | Issued By |
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| DRAFT 1 | 30.09.13 | For comments | J. COOK |
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# 1. BACKGROUND

Engineering and Environmental Services have been commissioned by Service Delivery to review and compare the suitability of FRP products (grating and structural members) with current acceptable materials for walkways, platforms, safety grilles and supporting structures, under all probable environmental conditions experienced at various facility installations, i.e. pumping stations, treatments plants, reservoirs etc.

FRP is currently used within Sydney Water's field of operation, but not extensively. Most walkways and platforms are either steel or aluminium. Safety grilles and supporting members are usually stainless steel or steel.

# 2. INTRODUCTION

FRP stands for Fibre Reinforced Polymers, a composite material consisting of a thermosetting polymer resin (polymer that irreversibly becomes rigid when heated) reinforced with glass or other fibres that provide strength and stiffness.

There are three different types of resins used for manufacturing FRP. These are Isophthalic, Vinylester and Phenolic. The type of resin used depends on the required properties of FRP, such as chemical resistance, temperature resistance and mechanical properties.

UV stabilisers are also incorporated into the resin to reduce the effect of ultraviolet radiation and colour pigments are added for aesthetic appearance. However, some loss of colour occurs over long exposure to elements.

## Moulded gratings

Moulded ('waffle') grating panels are manufactured in an open, heated mould that resembles a large waffle iron. Continuous glass fibres are placed in the mould in alternating layers and thoroughly wetted out with resin. This process produces an integral, one-piece construction, which offers excellent corrosion resistance as well as bi-directional strength. When the weaving process is completed, the mould is heated to cure the product.

After curing, the panel is extracted from the mould. The standard panel would have a meniscus (concave) top surface for slip resistance. Grit can be bonded to the top of the completed grating panel as a secondary operation where superior non-slip properties are specified. See Figure 1

## Pultruded gratings and structural members

Grating can also be manufactured using a pultrusion process for applications that call for high strength and large spans. This is usually called an "I" beam grating as opposed to "waffle" grating. See Figure 2

Structural members are also made using the pultrusion process.

The Pultrusion process is a continuous moulding process using fibre reinforcement with thermosetting resin matrices. Pre-selected reinforcement materials, such as fiberglass roving, mat, woven fabrics or stitched fabric, are drawn through a resin bath in which all material is thoroughly impregnated with a liquid thermosetting resin.

The wet-out fibre is formed to the desired geometric shape and pulled into a heated steel die. Once inside the die, the resin cure is initiated by controlling precise elevated temperatures. The laminate solidifies in the exact cavity shape of the die, as it is continuously pulled by the pultrusion machine. Almost any constant cross-section can be pultruded.

Pultrusion allows customization, by the selection of the resin system, the type and form of fibreglass reinforcements, and the placement of the reinforcements within the composite profile. See Figure 3

Refer to section 6 for material specification.

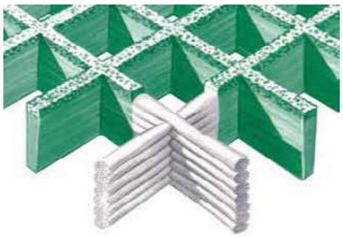

FIGURE 1 – MOULDED GRATING WITH GRIT SURFACE

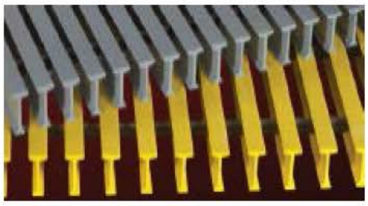

FIGURE 2 – PULTRUDED GRATING

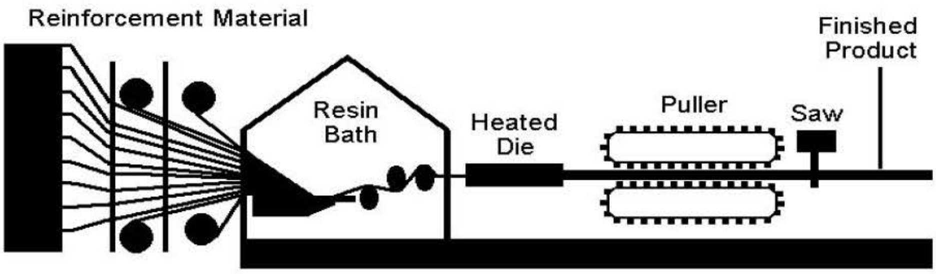


FIGURE 3 – THE PULTRUSION PROCESS

## 3. MARKET AVAILABILITY

FRP grating and structural members were developed in the United States of America. Virtually all FRP grating and associated products used in Australia are imported, with only a few major local distributors.

Most Australian distributors source their products from China. There are numerous suppliers in China and Australian distributors usually have agreements with one or more of these companies.

Examples of these arrangements are:

- The Suzhou Grating Company, located in Jiangsu, China. This company supplies to Webforge Pty Ltd and have done so for several years.
- The Nan Tong Super Composite Company, located in Nan Tong, China. This company supplies to Weldlok Pty Ltd, and have done so for several years.

Other companies contacted in Australia, such as Grating FRP Australia and Nextep, report similar arrangements.

All distributors keep some grating and a limited amount of structural members on hand for use ex-stock. However, if items are not available a 6-8 week lead time is to be expected. Quality control is paramount. Refer to section 6 for material specification.

## 4. ANECDOTAL USE OF FRP

### Within Sydney Water

a) **SWSOOS – Access Chambers**
Some access chambers on the SWSOOS had FRP grating on platforms with FRP support angles and beams. After a number of years, a report found that all had reached such a stage of deterioration that they were considered not adequate for further use. All supporting members were replaced with stainless steel and the FRP grating was replaced with new FRP grating.

**b) Quakers Hill WRP**

The inlet works was covered with steel grating until recently. It was decided to replace all the grating due to heavy corrosion. The grating was replaced in 2012 with FRP grating (composite with top plates to eliminate odours). See Figures 4 and 5

FIGURE 4 – INLET WORKS COVERS

FIGURE 5 – INLET COVER PANEL

**c) Penrith WRP**

A similar situation to Quakers Hill. The grating & supporting members were replaced in 2011 with FRP grating (composite with top & bottom plates to eliminate odours) & fibreglass supports. See Figures 6 and 7

FIGURE 6 – INLET WORKS COVERS

FIGURE 7 – INLET COVER PANEL

d) **Orchard Hills Reservoir**

The reservoir internal staircase and platform (including supports), normally fabricated from steel, was fully fabricated using FRP & installed around 2007. See Figures 8 and 9

FIGURE 8 – LADDERS

FIGURE 9 – PLATFORM / SUPPORTS

e) **Wahroonga Reservoir**

This reservoir is another example of what can be achieved with FRP. This internal staircase and platform (including supports), normally fabricated from steel, was fully fabricated using FRP & installed around 2010. See Figures 10 and 11

FIGURE 10 – SUPPORTS

FIGURE 11 – LADDERS

f) **General**

The picture below shows a Sydney Water valve chamber using FRP grating and support members, installed in 2002. The other picture shows FRP being used as supporting members. See Figures 12 and 13

FIGURE 12 – VC COVER and SUPPORTS FIGURE 13 – SUPPORTS

## External to Sydney Water

a) **Bathurst Sewage Treatment Plant, Bathurst**

FRP grating has been installed over open sewage channels in the Treatment Plant. It has been in place for at least 6 years. Supporting members for the grating are stainless steel. Bathurst Regional Council staff are very satisfied with the installation. See Figures 14 and 15

FIGURE 14 – CHANNEL GRATING FIGURE 15 – CHANNEL GRATING

b) **Great Barrier Reef Aquarium, Townsville**
A raised fibreglass floor system was installed at the aquarium in 2009. The sub-frame is all FRP structural members and the floor is solid top floor grating. The Great Barrier Reef Marine Park Authority are very satisfied with the installation. See Figures 16 and 17

FIGURE 16 – SUB FRAME

FIGURE 17 – SOLID TOP FLOOR

c. **Erie County (USA) Treatment Plant**
FRP Grating has been installed over sedimentation tanks in the STP. This grating has been installed for over 11 years. See Figure 18

FIGURE 18 - SEDIMENTATION TANKS GRATING

c) **Wessex Water, United Kingdom**

Wessex Water use FRP grating where:

- There is a high risk of corrosion
- A good "non-slip" finish is required

Wessex Water also tried FRP handrailing, but found it unsuitable due to high deflection and splintering problems.

## 5. COMPLIANCE WITH AS1657

This Australian Standard covers fixed platforms, walkways, stairways and ladders (design, construction and installation).

Whilst this standard does not apply to FRP in relation to materials, it is necessary that ladders, fixed platforms and walkways conform to the physical elements of the code ie. clearances, widths, loading requirements (which are transposed from AS/NZS 1170.1) etc.

FRP grating is available in spans varying from 300mm to 1500mm, with loadings and deflections measured accordingly. FRP grating can be cut to any width or length required to meet compliance with AS1657.

## 6. MATERIAL PROPERTIES AND QUALITY CONTROL

There are no Australian or international standards for the material properties of fibreglass strands or resins or glass fibre reinforced polymer composites used in structural applications except for pipes. AS1145 parts 4 & 5 (References 1 & 2) only specify the requirements for determining the strength properties of FRP samples in the form of flat pieces.

For adequate quality control of products, the strength grades of resins and glass fibres and also the strength of FRP products for varying mix proportion of glass fibre and the resin need to be standardised for the products to be used for structural purposes with good degree of confidence. Lack of this information could be attributed to the fact that fibreglass reinforced polymer products are used largely for their good chemical resistance to corrosion in chemical environments.

It would appear that this is not much better in other parts of the world. However, in the USA and perhaps in few other countries there are documented ranges of strength properties for resins, glass fibres and FRP composites. Therefore, the products available in these countries are likely to conform to the material properties expected by the local industry.

Floor gratings available in Australia are largely imported mainly from Asian countries without any details of the basic strength properties of glass fibres or resins or the polymer composite. Major distributors of the floor grating in their brochures provide safe load tables for varying cross sections and spans without any information relating to the margin of safety associated with the load rating for the short term or long term usage.

It is to be noted that there is limited information available on the long term performance of the FRP products, particularly in the prolonged exposure to UV environment even when the resins in FRP products include UV stabilisers.

While overseas suppliers of the floor gratings to the Australian market are likely to follow the established industry practices, it is difficult to ensure the quality of the products in the absence of standards or codes of practices. Therefore, the element of risk associated in the structural applications cannot be ignored.

The only comfort is that the load carrying capacities of these products are controlled by the deflection criteria rather than the material strength because of relatively low modulus of elasticity. Several local distributors claim to visit their suppliers overseas annually to ensure standards are being maintained. They also claim to do random testing in Australia to ensure that:

- Load requirements are met as per distributor's design manual
- Fire requirements are met to the American standards (References 3 & 4)

The use of structural sections in Australia such as angles, channels, beams etc are not as extensive as floor grating. One of the very few suppliers of structural sections Exel Composites, based in Melbourne, produce these members locally by the pultrusion method. The normally available range of structural sections are suitable for applications such as platforms. Most importantly, Exel Composites produce two grades of structural sections with material properties complying with American Society for Testing of Materials (ASTM). Another Sydney based company RPC Technologies produce locally made structural sections. Their method of production is contact mould casting in a similar manner to moulded grating casting. RPC Technologies claim that the strength properties of their structural sections are available.

## 7. DURABILITY

The major advantage of the FRP composites is the light weight, high resistance to acids, alkalis, solvents and corrosion in general.

Prolong exposure to outdoor ultraviolet radiation can cause chalking of the outside layer of composites and degrade composites given sufficient time. While gel coats are used in the marine and automotive industries, this expense is usually spared in industrial applications. Gelcoat is a thick fiberglass paint used as a protective coating over fibreglass, as well as for cosmetic reasons.

The major suppliers of floor grating in Australia confirmed that pigment is incorporated into the final layer of resin to add colour & prevent UV degradation (by including UV stabilisers or additives). As the addition of pigment makes the outer layer opaque, it limits the ability to visually inspect the components. No deterioration may be apparent. The only visual signs of deterioration will probably be delamination, particularly on the ends, or hairline cracks within the grating.

One of the major supplier's conference notes states that "up to 45% loss of strength in 6 years occurs in specimens with no UV treatment". This confirms the effectiveness of a UV blocker. It is therefore vital that UV protection is provided (either within the resin or by application of a gelcoat as well). However, its effectiveness over the long term is not proven.

Some companies provide a 12 month warranty on all products, which is well short of what would be recommended to promote the product. This required warranty period for Sydney Water would need to be specified within a technical specification.

Test certificates from NATA accredited companies are available from most suppliers, however these certificates appear to be for general material composition, not for UV resistance, lifecycle etc.

## 8. FABRICATION

FRP composite cannot be welded by traditional methods but can be bonded with adhesives. Traditional grinders, saws and drills can be used to trim composites to size and drill holes for bolts. All cut edges should be sealed with resins to prevent moisture penetration into the composite & to provide UV protection.

Therefore, the fabrication and treatment of the cut edges should be limited to the distributors or their authorised contractors to ensure the integrity of the product for the long term.

## 9. STRUCTURAL DESIGN

There are no current Australian standards for the structural design of FRP structural sections.

There was only one Australian Standard (Ref 9) which covered FRP sections produced by contact mould casting, but it has been withdrawn.

The only current document is the Eurocomp Design Code (Ref.8). The design guidelines presented in the Queensland Main Road's department (Ref 6) are based on Eurocomp Design Code.

It is not clear with accessible information on the website whether the structural design to Ref 8 is based on the material properties alone or also on the production method, as the glass fibres in the pultrusion method are continuous and in the contact mould casting the fibres are in the form of chopped strands, woven rovings etc.

In general, FRP composites exhibit little or no ductile behaviour beyond a point of linear stress strain behaviour of the material. It means failure is sudden without the warning of disproportionate increase in deflection with increase in load unlike steel. This aspect is covered well in Ref 8 and any competent designer should be able to address it adequately with known material properties.

Therefore, the design of structural sections produced locally such as by Exel Compostites and RPC Technologies with known material properties can be carried out with good degree of confidence.

For the floor grating which are manufactured overseas, the local distributors provide only load ratings for standard profiles versus spans without the material properties. Design checks can be carried out for a range of material properties to check the sensitiveness of the factors of safety with regard to strength. As mentioned previously, the deflection criteria generally controls the design and therefore nominal variations between assumed and actual properties are unlikely to be catastrophic.

Ref 10 highlights the ten major issues engineers face when developing bolted joint designs in FRP composite structures unlike in steel structures (these include fastener hole preparation, bearing strength, ply orientation, not over tightening the fasteners etc). This reference also includes adequate guidelines for the design of bolted connections. Therefore, the design needs to be carried out by competent engineers with adequate knowledge in FRP composite designs.

The factor of safety adopted for the structural design FRP products are considerably large than for concrete or steel structures. This is because of the brittle failure nature of the material, the additional safety margin is needed. In addition, the material properties are less unified than in the case of steel or concrete. Therefore, larger factors of safety adopted in the design should not be misconstrued as providing greater safety assurance than the traditional materials such as steel and concrete.

There is not much information available on the long term structural performance of FRP products when exposed to UV radiation and the designer should be mindful of this aspect when comparing the cost of other material such as aluminium and stainless steel in an environment exposed to UV radiation.

## 10. ADVANTAGES AND DISADVANTAGES

In addition to the high chemical resistance to acids, alkalis etc, FRP has the strength for limited structural applications, but some concern has been shown with unexpected failure, particularly if delamination has occurred. It would appear that this is as a result of inadequate attention paid to connection details and / or not adequately sealing the cut edges. A fibreglass ladder in the SWSOOS had a rung snap when being climbed.

The advantage that fibreglass has over steel is in the area of corrosion, provided cut edges are treated correctly, prior to installation.

The advantages of FRP is:

- Corrosion resistant properties – excellent resistance to corrosive and aggressive environment, salt water, acids, chlorinated water and other chemical compounds.
- Low maintenance requirements – requires no protective coating (except for cut edges after fabrication) hence eliminating the need for painting.
- High strength-to-weight ratio – less than one-half the weight of steel grating, allowing easy removal for access and installation.
- Low life cycle cost in comparison to steel products when is not exposed to UV radiation.

The disadvantages of FRP are:

- There are no Australian or international standards for the material properties of fibreglass strands or resins or glass fibre reinforced polymer composites used in structural applications.
- There are no current Australian standards for the structural design of FRP structural sections.
- Floor gratings available in Australia are largely imported without any details of the basic strength properties of glass fibres or resins or the polymer composite.
- There is limited information available on the long term performance of the FRP products, particularly in the prolonged exposure to UV environment even when the resins in FRP products include UV stabilisers.
- FRP composites exhibit little or no ductile behaviour beyond a point of linear stress strain behaviour of the material, which means that its failure is sudden without the warning of disproportionate increase in deflection with increase in load unlike steel.
- Because of the brittle failure nature of the material, the additional safety margin is needed.
- The design of FRP structures needs to be carried out by competent engineers with specialist knowledge in FRP composite designs.
- Special treatment required for the cutting face of FRP material to prevent delamination and deterioration. Therefore, the fabrication and treatment of the cut edges should be limited to the distributors or their authorised contractors to ensure the integrity of the product for the long term.

- When pigment is added to resin for UV protection, it is difficult to visually examine the products for any signs defects.
- Due to the above, the element of risk associated in the structural applications cannot be ignored

## 11. COST EFFECTIVENESS

Table 1 shows the supply only cost of some galvanised steel, aluminium, stainless steel and FRP products:

| TABLE 1 – COST OF SUPPLY ONLY | | | |
|---|---|---|---|
| **ITEM** | **GALV STEEL** | **STAINLESS STEEL** | **FRP** |
| 75 x 75 x 10 L | $ 17 / m | $ 89 / m | $ 36 / m |
| 100 x 100 x 10 L | $ 23 / m | $ 120 / m | $ 54 / m |
| 250 x 125 I-beam | $ 42 / m | - | $ 136 / m |
| 200 x 100 I-beam | $ 30 / m | - | $ 109 / m |
| 100 x 50 channel | $ 16 / m | $ 100 / m | $ 26 / m |
| 75 x 40 channel | $ 11 / m | $ 71 / m | $ 23 / m |
| | **GALV STEEL** | **ALUMINIUM** | **FRP** |
| Grating panels # | $125 ~ 220 /$m^2$ | $300 ~ 360 /$m^2$ | $100 ~ 170 /$m^2$ |

# Note: Price varies for grating depending on grid spacing & depth of section. The size required is determined based on span & deflection criteria.

The supply cost of FRP structural sections is considerably more than galvanised steel even for identical sections. Taking into account the higher strength of steel, FRP structural sections are unlikely to be competitive unless they are used in very corrosive environment in which savings would be gained in maintenance costs.

In the case of floor grating panels, the cost of FRP compares favourably with galvanised steel, both of which are less expensive than aluminium. The cost effectiveness would be determined by the expected life span of the materials. Table 2 presents the expected life spans under various environmental conditions.

| TABLE 2 – EXPECTED LIFE SPAN | | | |
|---|---|---|---|
| Environment | GALV STEEL | ALUMINIUM | FRP |
| | $125~220 /m$^2$ | $300~360 /m$^2$ | $100~170 /m$^2$ |
| A. Open or ventilated, not exposed to high corrosive elements<br>e.g. water pumping station | 75 yrs | 75 yrs | 50 yrs |
| B. Closed but not exposed to high corrosive elements<br>e.g. inside service reservoirs | 25 yrs | 50 yrs | 50 yrs |
| C. Open or ventilated, but exposed to high corrosive elements<br>e.g. sewage pumping station | 25 yrs | 50 yrs | 50 yrs |
| D. Closed and exposed to high corrosive elements<br>e.g. SPS wet well, STP inlet structures. | 10 yrs | 50 yrs | 25 yrs |

In open and ventilated locations not subject to corrosive gas or away from the coastline (A), galvanised steel floor gratings remain as the preferred material.

FRP floor gratings are potentially good choices for closed environment (B), and for locations exposed to high corrosive element such as sewage gases, chlorine and the like, or close to the coastline (C and D). The selection of material would very much depend on specific site conditions and the total life cycle cost.

## 12. RECOMMENDATIONS

FRP structural sections

FRP structural sections are generally not recommended unless severe corrosion is a critical issue. If it is used, the following issues must be thoroughly addressed:

- UV treatment and the long term effectiveness of pigmentation and/or gel coating
- The design is carried out and certified by competent specialist engineers with knowledge of composite polymer design

- Fabrication must be carried out by competent constructors with special attention to cut ends and site joints.

FRP hand-railing

There are examples of FRP hand-railing used in Sydney Water and other overseas water authorities such as Wessex Water. At the Penrith WRP, FRP handrails were installed at the inlet works area in 2011. The installation is robust and appears to wear well. However, the long term performance under UV exposure remains to be proven in time.

FRP is not recommended for general use as hand-railing until further long term performance observation of the Penrith project is made.

FRP safety grilles

A safety grill could have significant impact loading and any subsequent failure would lead to serious injuries. FRP is brittle and deterioration may not be detected by visual inspection.

A safety consideration is for the grilles to be hinged. Connection of FRP grilles to metal hinges poses potential installation flaws.

In Sydney Water installations, cut-outs in safety grilles are often made for particular purposes, such as level controls or flushing. These ad-hoc cut-outs inherently mitigate the strength of the grille.

FRP is therefore not recommended for safety grilles.

FRP floor grating

It is recommended that FRP can generally be considered for use as floor grating in closed humid environments, for locations exposed to high corrosive elements such as sewage gases, chlorine and the like, or close to the coastline where salt spray is prevalent. This floor grating is sometimes supplied in the form of composite floor plates, or in 'mini-mesh' format. The 'mini-mesh' configuration has small 12mm openings to prevent objects falling through.

There are a number of reputable firms in the market supplying quality FRP floor grating. It is suggested to procure these quality products through a 'product approval' process either in the form of product appraisal or expression of interest. A material specification and technical data schedules can be drawn up for this purpose.

## 13. REFERENCES


1. AS 1145.4-2001: Determination of Tensile Properties of Plastic Materials – Test Condition for Isotrophic and Orthotropic Fibre Reinforced Plastic Composites
2. AS 1145.5-2001: Determination of Tensile Properties of Plastic Materials- Test Conditions for Fibre Reinforced Plastic Composites.
3. ASTM D 635: Rate of Burning and/or Extent and Time of Burning of self – supporting plastics in a horizontal position
4. ASTM E 84: Safe Burning Characteristics of Burning Materials
5. Composites in Industrial Plants – Queensland Government
6. Design of Fibre Reinforced Polymer Composite Girders MRTS 69A (Main Rods, Queensland)
7. Design Manual-Fibre Grating and Structural Products, Delta Composites LLC, Texas
8. EUROCOMP Design Code
9. AS 2634 -1983 (withdrawn): Chemical Plant Equipment, Made from glass fibre reinforced plastics (GRP) based on thermosetting resins
10. Mechanically Fastened Joints in Composite Structures Parts 1 to 8, Composite Engineer's Viewpoint by Rick Heslehurst, Composites Australia
11. BS EN 13121: GRP Tanks and Vessels for use above ground. Design and Workmanship


This report has been produced with known information at this time.
In the future if more standardisation & quality control occurs, the recommendations of this report may be re-visited & different recommendations may eventuate.

## APPENDIX 'A'

### FRP Suitability Report – Client Comments on Draft Report

| Section /Reference | Comment | Reply | Action |
|---|---|---|---|
| 4. Anecdotal use of FRP | Have there been any recent inspections of the FRP installations (at Sydney Water sites) listed in this section to determine their condition/performance in corrosive environments and/or exposure to UV? | Quakers Hill WRP was visited to look at FRP grating installation at various points around the plant. It is not used extensively, but due to steelwork corrosion in the past, it was installed over the inlet works in 2012. Also, Penrith WRP was visited to examine a similar installation. FRP grating covers & supports were installed over the inlet works in 2011.<br><br>As these installations are only a few years old, it is too early to draw any conclusions on the performance of the product.<br><br>It is unlikely that many installations in Sydney Water are more than 6 years old. Where known, the year of construction will be added to the examples.<br><br>A more extensive observation survey could be undertaken, but this was not part of the scope. | Report modified in accordance with the reply.<br><br>Refer to Section 4 |
| 7. Durability | Is there any evidence of degradation due to UV? More information on this would help the reader understand the related concerns.<br>Where suppliers claim UV stability is addressed by the addition of pigments, can these suppliers back their claims up with any evidence? Will they provide a warranty? | UV degradation can occur on all FRP materials. Most grating supplied has UV inhibitors mixed in with the resin. This is usually sufficient, however further protection can be provided by applying a surface coating, such as a gelcoat or flowcoat.<br>Gelcoat is a thick fiberglass paint used as a protective coating over fibreglass, as well as for cosmetic reasons.<br><br>Some companies provide a 12 month warranty on all products, which is well short of what would be recommended to promote the product. This would need to be checked when purchasing.<br><br>Test certificates from NATA accredited companies are available from most suppliers, however these certificates appear to be for general material composition, not for UV resistance, lifecycle etc. | Report modified in accordance with the reply.<br><br>Refer to Section 7 |

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| Section /Reference | Comment | Reply | Action |
|---|---|---|---|
| 7. Durability | There is no mention of expected design life? Are there any guidelines on predicted design life in different corrosive environments? Is there anything that can be done as part of a routine condition assessment process that can predict YESL or at least identify degradation?<br>Are there any maintenance requirements? | A life expectancy, according to some suppliers can be at least 25 years (with full UV blocker protection), This will obviously vary depending on the type of resins and coatings selected.<br><br>Visual assessment is not sufficient to predict the YES, as no deterioration may be apparent. The only visual signs of deterioration will probably be delamination, particularly on the ends, or hairline cracks within the grating.<br><br>Testing would need to be carried out in at least 5 year intervals with testing to destruction.<br><br>One of the major supplier's conference notes states that "up to 45% loss of strength in 6 years occurs in specimens with no UV treatment". This confirms the effectiveness of a UV blocker.<br><br>It is therefore vital that UV protection is provided (either within the resin or by application of a gelcoat as well). However, its effectiveness over the long term is not proven. | Report modified in accordance with the reply.<br><br>Refer to Section 7 |
| 10. Safety and Cost Comparison | Can a comparative life cycle cost be calculated in addition to the unit rates for the different materials? Can an expected design life of FRP be assumed so as to compare with other materials such as stainless steel and aluminium? | Normally galvanised steel grating is used. It will depend on the environment as to the life cycle cost. | Refer to Tables 1 & 2 |
| 11. Recommendations | Can a recommendation be made on the use of FRP for handrails? | Wessex Water (England) installed a significant amount of handrailing in the past. Based on anecdotal evidence from them, it is suggested that it has high deflection & risks of splintering. However, within Sydney Water, there are some examples of FRP handrailing being used.<br><br>For instance, at Penrith WRP, it is used in the inlet works area. Examination has found that it appears to be wearing well & is solid, but once again, the installation is only a few years old.<br><br>More investigation (not part of this report) would be required & comparisons with other handrail systems made before it can be recommended for use. | Report modified in accordance with the reply.<br><br>Refer to Section 12 |

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| | | | |
|---|---|---|---|
| 11. Recommendations | FRP Grating (as safety grilles) - It is stated these are not suitable due to "significant impact loading". How is this different to the potential impact loads expected on walkways, platforms and supporting structural members. | The openings within the FRP grating are too small & with the likelihood of cut outs etc in these safety grilles for level controls & other equipment, the structural integrity will be compromised. As well as this, due to the fact that they must be hinged, this will also affect the performance of the grating<br><br>Also, larger sections would be required to cater for the impact loading & ensuring structural integrity | Report modified in accordance with the reply.<br><br>Refer to Section 12 |

**Suggested further work (by the client)**

| Item | Recommendation | Reply | Action |
|---|---|---|---|
| 1. EOI | Send out an EOI to suppliers/manufacturers for further information regarding tests, warranties etc. (This could be done formally through long term supplier/procurement group) | A full specification should be produced and attached with any request for further information | To be carried out in the next stage of the process (not part of this report) |
| 2. Inspections / Case Studies | Visit installations at Sydney Water sites that are exposed to UV and/or corrosive environments to assess condition. | Another further site visit to be undertaken (this time to Penrith WRP) to discuss UV exposure in corrosive environments. Also, a visit to the factory of a supplier to be undertaken to examine their product & discuss all stages of production | These visits carried out on 18.11.13 report updated accordingly |
| 3. UV stability | Further research to understand design life implications when exposed to UV | ---- | To be carried out in the next stage of the process (not part of this report) |
| 4. Standards & Technical Specifications | Incorporate recommendations (when agreed) to relevant standards and specifications. | ---- | To be carried out in the next stage of the process (not part of this report) |
| 5. Approved products list | Develop product specification and Sydney Water approved list (if use is accepted). | ---- | To be carried out in the next stage of the process (not part of this report) |

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# Appendix 2 – FRP inspection Form

## FRP Asset Preventive Maintenance Inspection Form

| | | | |
|---|---|---|---|
| Site: | | | |
| Asset Location: | | | |
| Date: | | Inspected by: | |
| Asset Description: | | | |
| Asset Type | ☐ Grating | ☐ Guardrail | ☐ Ladder |
| | ☐ Platform | ☐ Stairway | ☐ Pipework |
| | ☐ Tank | ☐ Structural | ☐ |

Record of Defects

| Location Identifier | Defect Description | Photograph No. | Notes |
|---|---|---|---|
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## Recommended FRP Preventive Maintenance Inspection Frequency

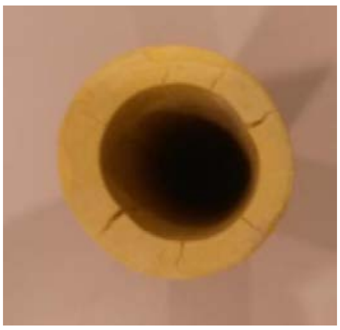
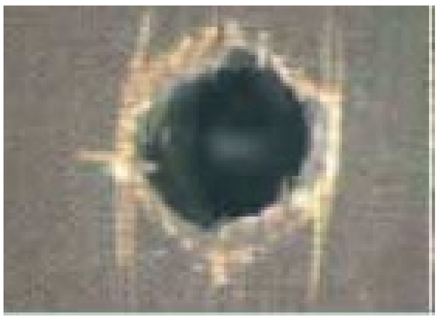
| Environment | Interval |
| --- | --- |
| A and B: Not exposed to corrosive elements | 12 months |
| C and D: Exposed to corrosive elements | 6 months |

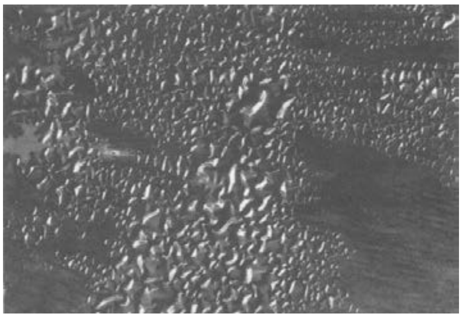
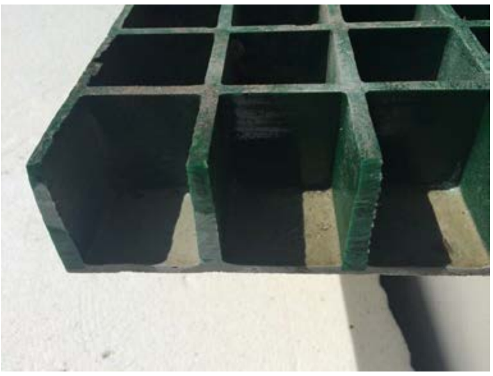
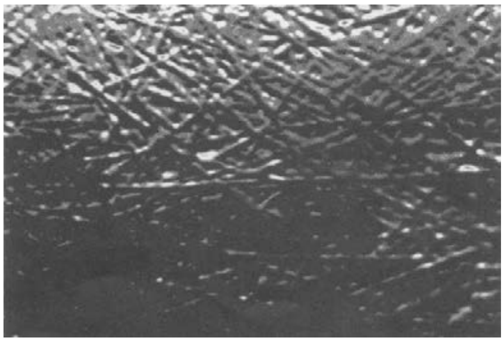
*Note: May be varied as dictated by site condition and age of asset*

## Defect description:

| Defect | Description | Corrective Action |
| --- | --- | --- |
| Surface discoloration | Result of chemical reaction, heat or erosion. | Monitor a control area and record rate of degradation. Typically no immediate repair is required. Obtain specialist advice if degradation continues. |
| Powdery surface | Film or barrier that is product of reaction between resin and process fluid. Barrier may inhibit ongoing rate of attack. | |
| Softening, voids | Small crater or pits on the surface. | |
| Surface crazing | A pattern of fine interconnected cracks. Shallow and slow growing. | |
| Shrinkage crack | A pattern of shallow parallel cracks caused by thermal shrinkage. | |
| Blistering | Permeation of water or chemicals into the laminate matrix thus causing the formation of pressure-filled pockets. Blisters tend to stop to grow in time. Not considered a problem unless result in breakup of structural laminate. | |
| Resin loss | Surface stripped of resin. If stripped surface is polished, it is probably caused by erosion. If surface is fuzzy, resin may have been attacked by process fluid. | Replacement may be required. Obtain FRP specialist advice. |
| Exposed fibre | Loose fibre remaining due to resin loss, insufficient resin cover or mechanical damage. | |
| Delamination | Separation of layers in the laminate caused by disbanding between resin and reinforcement. | |
| Surface wearing | Loss of surface slip resistance layer, UV surface veil, or mechanical wear on bearing surface. | |
| Structural crack | Crack is usually deep and bundles of fibres are severed. | Seek structural engineer's advice. |
| Deformation | Deflection, buckling or rolling of members. | |
| Mechanical damage | Chips, scratches, breaks or cuts caused by improper handling or external impact. | |
| Unsafe fasteners | Missing, loose, dislodged, deformed, unsecured clips, bolts, nuts and pins. | Rectify immediately. |

## Photo Guides

| | |
|---|---|
| *Delamination of a flange*<br> | *Delamination of a pultruded channel*<br> |
| *Delamination of a pultruded I-beam flange*<br> | *Discoloration*<br> |
| *Blister and delamination of pipe flange*<br> | *Fractured laminate*<br> |
| *Radial fracture of pultruded tube*<br> | *Flaking after drilling*<br> |

| | |
|---|---|
| *Incorrect pipe penetration to tank wall without stiffener*<br> | *Surface voids*<br> |
| *Gelcoat wrinkling*<br> | *Surface crazing*<br> |
| *Incomplete edge sealing*<br> | *Exposed fibre pattern*<br> |
| *Gelcoat blister with oozing fluid*<br> | *Plate detachment*<br> |