

CONSTRUCTION GUIDELINES

FOR FRP STRUCTURES

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■ Introduction

This Fabrication Guide serves as a comprehensive resource for both fabricators and contractors involved in pultruded FRP structures. It outlines recommended best practices for construction contract documents, fabrication techniques, and installation processes, while acknowledging that specific project instructions may supersede these guidelines.





■ Safety

Absolutely prioritize safety when working with FRP!

Following these guidelines and using caution during cutting and drilling minimizes risks associated with FRP grating and pultruded materials.

1. Personal Protective Equipment (PPE):

- Protect your eyes from flying debris, dust, and fragments by wearing safety glasses or goggles.
- Safeguard your hands against sharp edges and potential chemical exposure with gloves made of appropriate materials like nitrile or rubber.
- Prevent inhalation generated during cutting and drilling by wearing a dust mask or respirator.
- Use hearing protection, such as earplugs or earmuffs, especially when operating noisy equipment.

2. Ventilation:

- Ensure optimal ventilation in the work area to minimize the concentration of dust, fumes, or vapors.
- Indoors, utilize exhaust fans, open windows, or a local exhaust ventilation system to eliminate airborne contaminants.
- When working outdoors, be mindful of wind direction and position yourself upwind of any potential fumes or dust clouds.

3. Tool and Equipment Safety:

- Utilize tools and equipment specifically designed for cutting and drilling FRP materials.
- Before use, inspect all tools and equipment to ensure they are in good working condition and free from defects or damage.
- Adhere to the manufacturer's instructions for the proper use, maintenance, and storage of tools and equipment.

4. Work Area:

- Maintain a clean and clutter-free work area to prevent accidents or tripping hazards.
- Securely clamp or fasten the FRP grating or pultrusion product before cutting or drilling to prevent movement or slipping during the process.
- Ensure a clear and unobstructed workspace to allow for safe movement and operation of tools.

5. Cutting and Drilling Techniques:

- Follow proper cutting and drilling techniques as recommended by the manufacturer.
- Avoid applying excessive force or pressure to prevent tool or material damage and minimize the risk of accidents.
- Exercise caution regarding the rotation direction of the blade or drill bit and ensure it is suitable for the specific task at hand.
- Enhance cutting performance and reduce heat generation by using cutting fluids or lubricants designed for FRP materials.

6. Emergency Preparedness:

- Familiarize yourself with the location and operation of safety equipment, such as fire extinguishers and first aid kits, in case of emergencies.
- Have a clear understanding of emergency procedures and evacuation routes in your workspace.

7. Training and Knowledge:

- Ensure you have received proper training and guidance on working with FRP materials, including cutting and drilling techniques.
- Stay informed about the specific properties, hazards, and safe handling practices associated with the particular FRP grating and pultrusion products you are working with.



■ Fabrication Tolerance

Fabrication tolerances represent predefined allowable deviations from work lines for cutting, drilling, and machining processes applied to pultruded FRP structures. These tolerances are crucial for maintaining precise alignment and fit-up, particularly when employing bolted fasteners with hole diameters slightly larger than the bolt diameter.

Adherence to specified fabrication tolerances is paramount for accurate alignment and effective fit-up. These tolerances must not surpass allowable limits, as stipulated in relevant guidelines. Ensuring compliance with these tolerances guarantees the proper construction and functionality of pultruded FRP structures, facilitating seamless assembly and reliable performance.

Criteria	Tolerances
Cut Lengths	± 3 mm
Squareness of Cuts	± 1 degree
Hole Diameters up to 13 mm (0.5 in)	± 0.5 mm
Hole Diameters 13mm to 25 mm (1 in)	± 1 mm
Hole Diameters greater than 25 mm (1 in)	± 1.6 mm
Slots any dimensions	± 1.6 mm

- In applications such as load-bearing columns and critical connections, attaining tighter tolerances for the squareness of cuts is imperative. In these instances, it is essential to incorporate specific condition notes within the shop drawings to outline these precise requirements.



Sawing and cutting tools

- Sawing and cutting operations on pultruded FRP composites demand careful attention to achieve optimal outcomes. It is advisable to utilize a carbide or diamond grit edged blade for saw cutting. For high volume production cutting, a 30-40 or 60-80 grit diamond blade is recommended, while for smaller scale tasks, a disposable blade hacksaw with 24-32 teeth per inch or a masonry blade suffices.
- During sawing and cutting, providing adequate support for the workpiece is crucial to prevent shifting, which could result in chipping and splitting of FRP components. Apply gentle, consistent pressure to prevent blade clogging with residue and prolong blade lifespan. Regulating cutting speed is vital to prevent heat build-up that may discolor or fray the edges of the workpiece. Water cooling can enhance cutting speeds and eliminate dust for high volume or thick cross-section cutting, though proper disposal of contaminated cutting water is necessary. For high production operations using water jet cutting, consulting a manufacturer of water jet equipment is recommended.
- For cutting curves and circles, routers equipped with carbide (recommended RPM) or diamond (15,000-24,000 RPM) gritted rotary bits can be employed. Similar considerations regarding saw cutting apply to this method.
- It is essential to be mindful of dust generation during sawing, cutting, sanding, or abrading operations. Dust from carbon fiber is electrically conductive, necessitating additional precautions and considerations. Treat as nuisance Dust.
- By adhering to these guidelines and best practices, sawing and cutting of pultruded FRP composites can be executed effectively, ensuring accurate results and maintaining the quality of the finished components.



■ Drilling

It is recommended to employ carbide-tipped counter-bore fluted or diamond grit core drill bits for drilling operations. To avoid clogging of the cutting tip with residue and minimize heat build-up in the workpiece, it is essential to apply low pressure on the drill tip and maintain appropriate drill speeds. By adhering to these guidelines, the drilling process can proceed smoothly and efficiently, guaranteeing clean and precise holes without compromising the integrity of the pultruded FRP materials.



■ Surface Finishing and Preparation Techniques for Pultruded FRP Composites

To remove surface finishes and surfacing veils from pultruded FRP composites, sanding or abrasion techniques are commonly employed. For optimal results, it is recommended to utilize a high-speed sanding wheel with open grit sandpaper ranging from 40 to 80. Applying very light pressure during sanding yields the best outcomes, while excessive pressure should be avoided to prevent heat build-up in the FRP material.

Grinding pultruded FRP composites is generally discouraged unless water coolant is utilized to control heat. When grinding is necessary, it is advised to use a coarse grit wheel. By adhering to these guidelines, the sanding and grinding processes can be executed effectively, resulting in the removal of surface finishes and surfacing veils while preserving the integrity of the pultruded FRP composites.

■ Fabrication Tolerance

Bolted connections are integral in joining components of pultruded FRP structures, requiring adherence to the following guidelines for secure and reliable connections:

1. Hole Diameter:

Drill connection holes with a diameter 2 mm larger than the bolt size for M12 bolts and larger, and 1 mm larger for bolts smaller than 12 mm. Employ washers with a minimum thickness of 2.4 mm under the head and nut of bolted connections.

2. Counter Sunk and Counter Bore Bolts:

Utilize counter sunk and counter bore bolts as needed, ensuring sufficient component thickness and eliminating the risk of fastener pull-through.

3. Tightening and Torque:

For bearing-type FRP connections, tighten bolts to the snug-tight condition, ensuring full bearing contact between Fraying surfaces and all plies/components. Apply torque values suitable for the fastener type, diameter, and application, while avoiding “crushing” of pultruded FRP laminate, particularly with structural bolts of 12 mm or larger. Ensure washers evenly distribute the load and fully contact FRP surfaces. Consult the project’s Registered Design Professional for specific fastener tightening details.

4. Use of Anti-crush or Bush for Hollow Sections

■ Additional Considerations:

- **Clean Bolts:** Ensure bolts are free from burrs or foreign debris.
- **Oversized Flat Washers:** Implement oversized flat washers for effective stress distribution during bolting.
- **Alignment:** Verify proper alignment of the connection before inserting and tightening fasteners.
- **Anti-Seize Lubricants:** Use anti-seize lubricants to prevent galvanic corrosion in metallic bolts.
- **Uniform Tightening:** Tighten and torque bolts uniformly, following a cross bolting pattern to prevent partial loosening due to elastic interaction.
- **Fraying Surfaces:** Confirm firm contact of Fraying surfaces while avoiding over-tightening that may crush FRP material.
- **Locking Mechanisms:** Incorporate lock washers, nylon locking nuts, or thread locker adhesives to prevent bolt loosening and ensure long-term fastener security.

■ Structural Adhesive Bonding

Structural adhesive bonding is pivotal for ensuring the integrity and performance of pultruded FRP structures. To achieve successful bonding, adhere to the following guidelines:

1. Adhesive Types:

Structural adhesives commonly used for bonding pultruded FRP structures include epoxy-based, polyurethane, or methacrylate adhesives. The effectiveness of these adhesives depends on factors such as joint design, adhesive system selection, formulation, intended service conditions (thermal and chemical), substrate surface preparation, and proper application and curing.

2. Adhesive System Properties:

An ideal adhesive system should thoroughly wet out the substrate surface, exhibit minimal shrinkage, deliver high lap shear strength, develop compressive and tensile capacities surpassing those of the substrate, and remain resilient against potential distortions throughout the bonded joint's service life.

3. Tailoring the Adhesive:

Adhesive requirements may vary depending on the application. Adjusting the base resin and incorporating additives like diluents, modifiers, and fillers might be necessary to meet specific performance criteria. Consult the adhesive system manufacturer and supplier for expert guidance in the selection and formulation process.

4. Joint Design and Surface Preparation:

Proper joint design is essential for maximizing adhesive bond strength. Adequate substrate surface preparation, including cleaning and roughening, is crucial to ensure optimal adhesion. Adhesive application should adhere to the manufacturer's instructions and consider factors such as temperature, humidity, and open time.

5. Curing and Service Conditions:

Adhesives should undergo curing according to the manufacturer's recommendations, taking into account variables like temperature and curing time. The selected adhesive system should withstand the expected thermal and chemical conditions during the structure's service life.

The meticulous selection, formulation, and application of the adhesive system will significantly contribute to the overall performance and longevity of the structure.

■ Preparation and Assembly of Adhesive Joints:

To ensure optimal performance of adhesive joints in pultruded FRP structures, meticulous steps should be followed during preparation, bonding, and curing:

1. Surface Preparation:

- Remove surface contaminants on the parts to be joined using a clean cloth dampened with a solvent recommended by the adhesive manufacturer. Avoid immersing or soaking the FRP parts in the solvent.
- Sand both mating surfaces of the pultruded FRP structures with 80 grit sandpaper or a sanding disc to eliminate the surface veil. Continue sanding until the surfacing veil is removed, exposing the material substrate.
- After sanding, clear dust from the surfaces using a clean, dry rag or a fine-bristled brush. Do not wipe the surfaces with a solvent-dampened cloth after sanding or allow the parts to contact solvents again. If re-contamination occurs, repeat the cleaning steps, including a light sanding to remove any film.

2. Adhesive Preparation:

- Prepare the adhesive according to the specifications and instructions provided by the adhesive manufacturer.

3. Adhesive Application:

- Apply the adhesive to both parts to be joined following the adhesive manufacturer's specifications and instructions. Ensure adequate coverage of all faying surfaces, including any exposed glass fibers, with the adhesive.

4. Assembly and Clamping:

- Mate the parts to be joined and secure the assembly appropriately using clamps, bolts, or other suitable methods while the adhesive cures.
- Adhere to the adhesive manufacturer's instructions for recommended cure times. For epoxy-based and polyurethane adhesives, it is generally advisable to maintain bonding pressure for a total of 20-24 hours and leave clamps in position. Subject the connection to its full design load only after the joint has cured for a minimum of 48 hours, considering cure temperatures.
- If the adhesive manufacturer's instructions differ from the recommendations provided, prioritize the adhesive manufacturer's instructions.

Proper surface preparation, precise adhesive application, and adherence to curing guidelines will enhance the overall strength and longevity of the bonded assembly.



■ **CLEANING AND SEALING:**

Maintaining pultruded FRP structures requires precise cleaning and sealing practices. The following refined guidelines are recommended

Solvent Wipe Cleaning:

- Use a non-abrasive cloth dampened with a compatible solvent or cleaning solution to wipe the surface of the pultruded FRP structure.
- Ensure the cloth is clean and free of contaminants, avoiding prolonged immersion in solvent as it may cause damage.
- Surfaces solvent wiped and requiring adhesive bonding will need further preparation (see “Preparation and Making of an Adhesive Joint”).

Steam Cleaning:

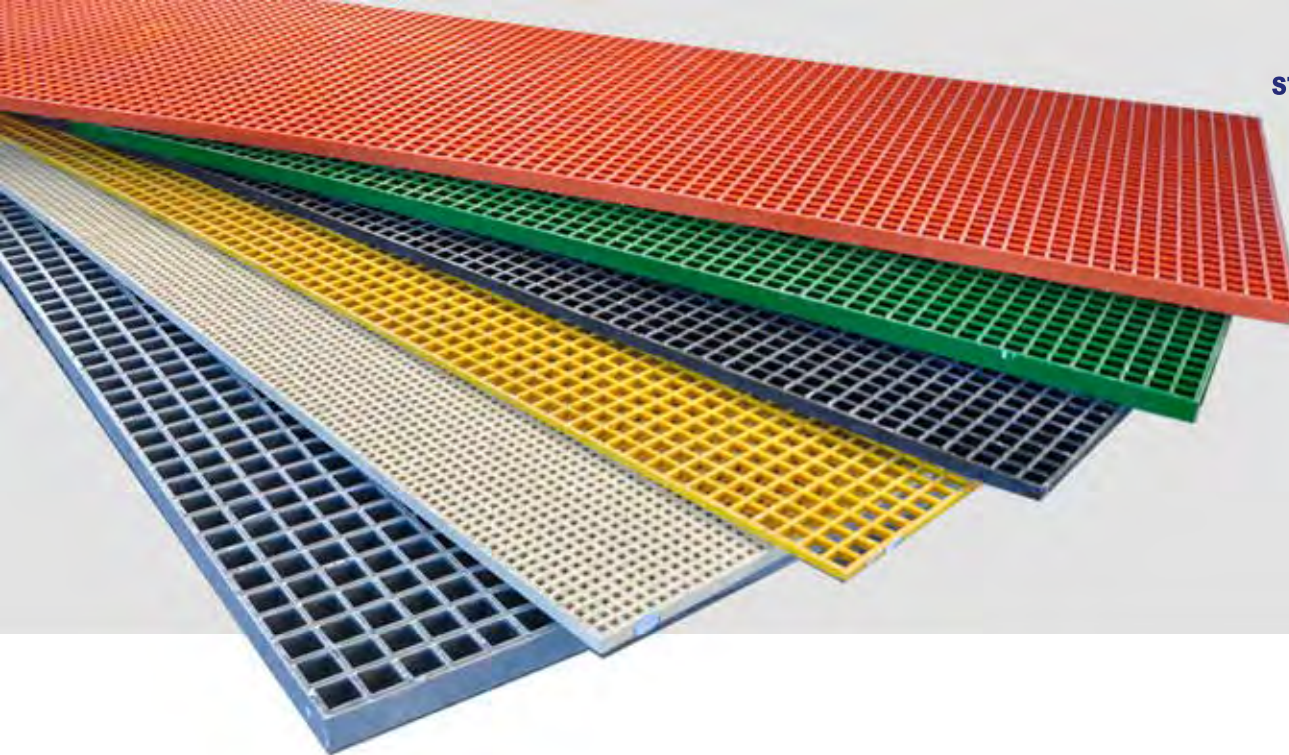
- Employ steam cleaning as a routine method for cleaning pultruded FRP structures.
- Limit steam heat temperature to a maximum of 120°C and 50 psi based on steam tables.

Steam Cleaning:

- Employ steam cleaning as a routine method for cleaning pultruded FRP structures.
- Limit steam heat temperature to a maximum of 120°C and 50 psi based on steam tables.
- Sweep the steam back and forth over the structure, avoiding prolonged exposure in one spot.
- Refrain from directing steam directly at adhesive bonded joints.
- Allow the structure to dry for 24 hours if sealing or coating is required after steam cleaning

Pressure Washing with Water:

- Utilize pressure washing with ambient temperature water and a water hose equipped with a high-pressure nozzle (maximum pressure limit: 50 psi).
- Sweep the water back and forth over the structure, avoiding prolonged exposure in one spot.
- Avoid directing the water blast directly at adhesive bonded joints.
- Permit the structure to dry for 24 hours if sealing or coating is necessary after water cleaning.



Resin Sealing:

- Apply resin sealing to drilled, cut, sanded, or broken surfaces of pultruded FRP structures for aesthetic enhancement and surface protection.
- Use catalyzed resins, acrylic lacquers, oil-based paints, or polyester, epoxy, or urethane paints compatible with the resin system used in the pultruded structure.
- Before sealing, remove shards or larger particles by deburring or sanding the areas to be sealed.
- Clear dust from the surfaces using a clean dry rag or fine bristled brush.
- Ensure the area is free of solvents or moisture for proper sealant adhesion.
- Mix, apply, and cure the sealant according to the instructions provided by the sealant manufacturer.

Grating cut and drilling

- Adjusting the size of gratings through cutting may become necessary. Sawing, preferably with diamond tools, ensures optimal results. For straight cuts, a circular saw is recommended, while bandsaws or compass saws are suitable for curved cuts. Drilling round holes with a diameter of up to approximately Ø20 mm is feasible. Larger holes require a spoon bit or a compass saw. Note that cutting large holes may remove reinforcing rods strengthening the grating; if concerned, reinforce with a flat profile before cutting.
- Various fittings and clips designed for bolts ensure stable and reliable grating installation. Applying a coat of thin lacquer protects cut surfaces, enhancing durability and preventing moisture penetration.
- Adhere to all safety precautions and manufacturer guidelines when working with FRP gratings, including wearing appropriate PPE and ensuring proper ventilation. Consult the manufacturer's instructions for specific details and recommendations regarding cutting, drilling, and installation.



FRP pultruded beam cut and drilling.

1. Marking and Measuring

- Use a measuring tape and a pencil or marker to measure and mark the desired length for the beam. Double-check measurements for accuracy.

2. Cutting the FRP Pultruded Beam

- Securely clamp the beam to prevent movement during cutting.
- For straight cuts, employ a circular saw with a fine-toothed blade suitable for FRP materials. Follow manufacturer's instructions for blade selection and operation.
- Guide the saw along the marked line steadily, applying light pressure. Let the saw do the cutting without forcing it.
- For curved or intricate cuts, utilize a jigsaw with a fine-toothed blade designed for FRP materials. Follow manufacturer's instructions for blade selection and operation.
- Carefully guide the jigsaw along the marked line, maintaining steady and controlled movement.

3. Drilling Holes in the FRP Pultruded Beam

- Measure and mark desired hole locations on the beam.
- Select an appropriate drill bit for FRP materials and secure it in the drill chuck.
- Apply steady pressure while drilling, using a low to medium speed setting to prevent overheating and potential damage to the FRP.
- Periodically withdraw the drill bit to clear accumulated debris for smooth drilling.

4. Deburring and Finishing



- Inspect cut edges and drilled holes for rough edges or burrs.
- Use a deburring tool or sandpaper to remove any sharp edges or rough surfaces, ensuring a clean finish.
- Clean the beam, removing any debris or dust generated during cutting and drilling.

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