



Experimental investigation for determining the strength of FRP Butt Joint and Welded Joints

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ABSTRACT

Fiber Reinforced Polymer (FRP) butt joints are increasingly used in aerospace, marine, automotive, and civil engineering applications due to their high strength-to-weight ratio and corrosion resistance. However, the structural performance of FRP butt joints is significantly influenced by bonding quality, surface preparation, adhesive properties, and loading conditions. This study presents an experimental investigation to determine the mechanical strength and failure characteristics of FRP butt joints under tensile loading.

FRP laminates were fabricated using [specify fiber type, e.g., glass/carbon fiber] and joined using a structural adhesive. Specimens were prepared according to standardized dimensions and tested under monotonic tensile loading using a universal testing machine. Key parameters such as ultimate tensile strength, joint efficiency, stiffness, and failure modes were evaluated. Surface treatments and adhesive thickness variations were also examined to assess their influence on joint performance.

Experimental results indicate that joint strength is primarily governed by adhesive properties and interfacial bonding quality. Failure modes observed included adhesive failure, cohesive failure within the adhesive layer, and delamination of the composite substrate. The findings provide insight into the load transfer mechanism and contribute to optimizing joint design for improved structural integrity and durability.

This investigation enhances the understanding of FRP butt joint behaviour and supports the development of reliable design guidelines for bonded composite structures.

Keywords:- Fiber Rein Force Polymer, Composite Material, Three Point Bend Test and Weld Joint.

1. INTRODUCTION

Fibre Reinforced Polymer (FRP) composites are increasingly used in aerospace, marine, automotive, and civil engineering applications due to their high strength-to-weight ratio, corrosion resistance, and design flexibility. However, the structural efficiency of FRP components is highly dependent on the performance of their joints. Among various joining techniques, adhesive butt joints are commonly employed where alignment continuity and minimal geometric modification are required. A butt joint in FRP structures consists of two composite adherends bonded end-to-end using an adhesive layer. Although simple in configuration, butt joints are generally subjected to high peel and shear stresses concentrated at the bond interface, making them prone to premature failure. The anisotropic nature of FRP materials further complicates stress distribution and failure mechanisms within the joint region. Understanding the strength and failure behaviour of FRP butt joints is essential for reliable structural design. Factors such as fibre orientation, adhesive thickness, surface preparation, curing conditions, and loading type significantly influence joint performance. Experimental characterization is therefore necessary to determine joint strength and validate analytical or numerical models. This study presents an experimental investigation to evaluate the ultimate strength and failure modes of FRP butt joints under tensile loading. Standardized test procedures are adopted for specimen preparation and mechanical testing to ensure repeatability and accuracy. Parameters such as load–displacement behaviour, ultimate tensile strength, and fracture characteristics are analysed. The outcomes of this investigation contribute to improved joint design methodologies and provide insight into optimizing adhesive bonding techniques for composite structures.

2. EXPERIMENTAL PROCEDURE

Sharp corner of pipes made rounded for better contact. To get good binding between FRP & pipe, bending area of the pipe roughed with help of emery paper then surface of pipe clean & degreased with acetone. For fabrication of joint, pipes are required to be aligned. To facilitate the alignment of pipes & wrapping of wetted glass around the joint, winding.

Machines used, two M.S. pipes of outside diameter $25^{+0.05}$ & thickness = $2^{-0.03}$ mm & L=175 for strengths & limitations. A fastening of structure is generally simple & effective for which little mechanical skill is required. The fastening works well in many applications, but it often gets loosened & weakness the components, because of holes made in the parts to be joined. Although welding between steel parts in simple & effective and is



widely used, it has some serious limitations like subjecting components to high temperature with associated problems such as distortion, scaling, crack in weldment or heat affected zone. Also the weld joints may not be suitable for high pressure leak proof due to various defects in the welding. In addition, the joining through welding is limited to similar materials (steel to steel, Aluminium to Aluminium, etc.) and components cannot be removed easily for reuse when life of product over. The adhesive bonding can join different materials, but most adhesives are poor in tension. Thus a special design of a joint is required to load the adhesive predominantly in shear. Recently, some investigators have started experimenting how to joints parts using a fibre reinforcement material. A roving or a fabric of high strength fibres (glass, carbon, & Kevlar) wetted in the thermo-set resin (Epoxy, unsaturated, polymer, etc.) is appropriately wrapped round the joint and is allowed to be cured. This kind of joint is known as FRP- joint. Welding of low alloy steel for better microstructure & mechanical properties were studied. The mechanical properties of multi pass welded joint were reported (Dutta C.K 2004). Comparative study of composite material and domestic material and getting higher strength with superior mechanical properties. (Stephen Lee 2010). Conduct experimental stress analysis to check the stresses in a unidirectional carbon/ Epoxy composite material (Dragen. D.K. 2008). Conduct test on different material in shearing to check the strength of material. However it is compared with composite material strength (Reham S.S. et al 2011). Single pipe place face to face and butt joint with glass fibre. Joint made by wetting glass fibre in Epoxy and winding it around the joint. Then prepared specimen evaluated for three point bend test. The universal testing machine of 20 tons capacity having least count of 0.01mm was used for finding the strength of FRP joint. The ratio of hardener and Resins are 1:10(gm.). The details of simple specimen is presented in Fig.1 (a).

Length of each pipe = 175 mm, FRP butt joint length = 110 mm.

Fig. 1(a) Photographic View of FRP-Butt Joint



2.1 Process

Two thin M.S. pipes outside diameter 25.29⁺_{0.05} and $t = 2^{+0.03}$ and length 175 mm of each pipe placed face to face and butt joined with glass fiber of width equal to 25 mm joint made by wetting glass fiber in epoxy system and winding it around the joint. For winding two M.S. pipes are tightened over the central rod of winding axle. Glass fiber coming out passes through a tension central assembly. Then glass fiber passes through resin bath to get all fiber wetted. Then wetted glass fiber wound on M.S. pipe at an angle 90⁰ to pipe axis.

E-Glass ¾ good tensile strength (3450 MPa), low tensile modulus (70 GPa), lowest cost fiber, available in many forms, widely used in commercial and industrial products, most-used in filament winding.

Epoxy ¾ wide range of resins available, best strength properties, curing at elevated temperature, good chemical resistance, higher viscosity systems, higher material cost, applications across broad market segment range.

Resins: The resin matrix that holds everything together, provides the load transfer mechanism between the fibers that are wound onto the structure. In addition to binding the composite structure together, the resin matrix serves to provide the corrosion resistance, protects the fibers from external damage, and contributes to the overall composite toughness from surface impacts, cuts, abrasion, and rough handling. Resin systems come in a variety of chemical families, each designed to provide certain structural performance, cost, environmental, and/or environmental resistance. (Note: Only the thermo set family is covered in this article.) A few major resin matrix families of interest to filament winders are:

Resin and Hardener

Resin - Dobecker 5022, Hardener – Beck 758,

Ratio of resin and hardener = 10:1 by weight, Glass fiber density = 600 g/m²



(b) Three-Point Bent Test Fig. 2 Universal Testing Machine

3. JOINING METHODS

There are two types of joining methods:

- 1) Butt
- 2) Strap

The butt and strap joining method (also known as the butt and wrap, the butt weld, and the reinforced overlay joint; and sometimes referred to as an adhesive) is the oldest and most reliable joining method in the industry today. The butt and strap is made as it is described - two pieces of pipe are butted together and layers of chopped strand mat and woven roving are wrapped around the pipe in a resin matrix. The weld is applied to the exterior of the pipe and, if accessible, the interior as well (usually on pipe larger than 18" nominal I.D.). Refer to Figure 1 for a typical butt weld joint. By using the same materials as the pipe, the butt weld joint can be designed with axial and bending strength properties equal to or superior than the pipe. Sometimes the butt and strap joint is referred to as an adhesive, as it is a mechanical, not a chemical, bond. However, the butt and strap should not be confused with the adhesive bonded joints described next.

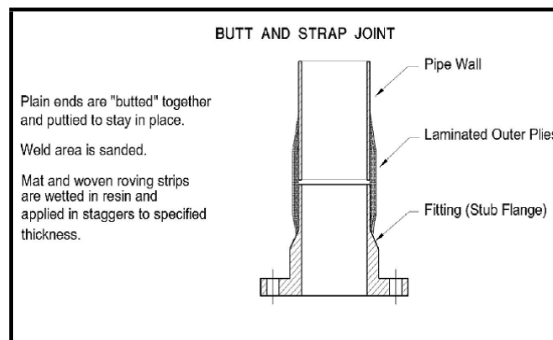


Fig. 3 Butt and Strap Joint

Fig.4 Woven Fabric



4. RESULTS AND DISCUSSION

Table 1.1: Details of Three Points Bend Test of Specimen Prepared from 25 mm Width Woven Glass Fiber

Job No.	Pile No.	Length of FRP Sleeve (mm)	Length of FRP (mm)	Bending Stress (N/mm ²)	Displacement at Max load (mm)	Total Tapered length of sleeve	Bending stress (N/mm ²)
1	7 (Without	110	80	2.20	90	53.5	223.79



	Mat)						
2	11	125	80	7.25	95	54.8	507.80
3	7 (Without Mat)	125	90	4.40	93	50.1	330.50
4	5	110	65	3.10	95	49/2	485.58
5	8	110	80	3.60	85	50.2	298.70
6	7	110	75	3.60	87	48.7	360.30
7	9	110	75	5.6	93	51.3	435.20

5. CONCLUSION

The FRP butt joint is prepared by winding glass fiber wetted in epoxy over a two steel pipes forming FRP sleeve. Winding machine is developed to wind 110 mm wide coarsely woven glass fabric having 600 gsm densities. To make a FRP joint, the fabric is cut into an appropriate trapezoidal shape, is wetted in epoxy and wound over steel pipe. The FRP sleeve thus obtained is of uniform thickness in its central position. Tests are performed on different piles on pipes. In some specimen the failure occurs at the joint plain. On the compression side deboning of fiber takes place and on tensile side fibers are ruptured.

FRP joint made with coarsely woven glass fabric are found to be quite satisfactory when tested under bending test. Butt joint is made with joining two pipes of outside diameter 25 mm and thickness 2 mm by arc welding. Specimen is test under point loading on universal testing machine and maximum load or critical load at which the joint is failed is noted. The comparison between two methods is made and it is found that strength of FRP butt joint is more than welded joint.

6. FUTURE SCOPE

Adhesive strength between fabric and joint can be improved to use the stuff fiber like a carbon fiber. Tensile strength of the FRP-joint can be improved using hump. HUMP developed pressure between the fabric winding and pipes so that is FRP joint taken tensile load. When applied tensile load on the specimen then hump pressure the fiber and developed the resistance force against the tensile load.

7. REFERENCES

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