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RESEARCH ARTICLE

Studies of FRP butt joint and welded joint by using Universal testing machine

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ABSTRACT : Structural material finds application in various industries, such as shipbuilding pressure vessel, bridge construction industries etc. The joining of two components together is an important and essential aspect of fabrication and erection. Every structure includes assemble materials into more complex shape. Often joint of a pipeline is the weakest link, as strength of joint is lower than strength of parent material, for example, joint of structural application with the welding, the failure occurs in most of the cases at the welded region. In critical applications, the assembly team is responsible for avoiding its failure; however, there is need to check the welded joint on a regular time interval. Many different kind of techniques are available to join the pipelines of various industries. These are broadly classified as bolting, welding, brazing and soldering, adhesive bonding etc. The winding machine is developed to wind coarsely woven fabric (600 g s m) found to be quite satisfactory, when tested under three point bending test on universal testing machine (UTM). To make a fiber reinforcement polymer (FRP) joint, the E-glass fibre is cut into an appropriate trapezoidal shape, which is wetted in epoxy and wound over steel pipe. The FRP sleeve thus obtained is of uniform thickness in its central position. Experiments are performed on different piles on pipes. In this study, a butt-joint between two mild steel pipes of $25.29^{+0.05}_{-}$ mm outside diameter and $2.00^{+0.05}_{-}$ mm thickness wall thickness was made by wrapping a glass fiber fabric. The fabric was wetted in epoxy before it wrapped around the joint. The joint was tested under different load condition, three point bend test, four point bend test, and tensile test. The strength of the FRP-joint was compared with the strength of welded joints.

Key words : FRP, Composite material, Three point bend test, Weld joint

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INTRODUCTION

Fiber reinforced polymer (FRP) composites is defined as a combination of fiber glass or carbon and a polymer matrix, which provides reinforcement in one or more direction. FRP composites differ from the traditional structural materials, such as steel or aluminum. FRP composites have an isotropic properties, *i.e.* properties apparent only in the direction of the fibers, while other traditional materials have isotropic properties *i.e.* uniform properties in all directions. The industrial application of composite material is specific to the need of operation and/ or environment, in which that operation takes place. Fiber reinforced composites are widely used in aircrafts, rockets and automotive structures, for their better advantage of lower weight, high strength and stiffness. Composite materials, such as fiberglass reinforced thermoset plastics have been used in piping systems over 40 years. Most of the composite pipes of conventional circular cross-section are manufactured by filament winding. Filament winding is the process by which fibers are layered onto a rotating mandrel, building the wall of the pipe layer-by-layer. This is an effective means to produce a pipe with good mechanical properties because the fibers are in tension, as they are layered onto the pipe and the operator is able to control the angle that they are layered and can, therefore, optimize the final product. However, current methods of filament winding are not conducive to manufacturing a pipe with a non-circular cross-section, such as rectangular, triangular and semi-circular etc. Components produced by the hand lay-up method, in which sheets of fabric are wetted with resin and wrapped by

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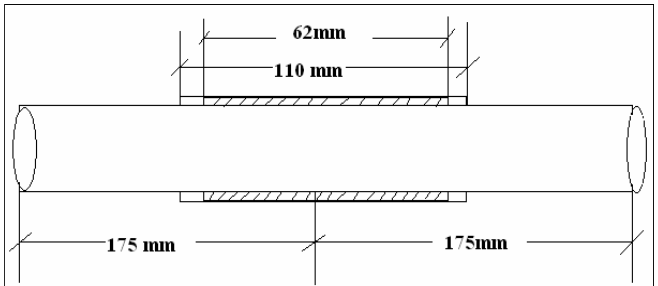
hand, layer-by-layer. This method is time consuming, labor intensive, and does not produce an end-product with the same quality as done in filament winding machine. Filament winding can produce components of unconventional shape, but the process requires specialized equipment and is typically reserved for high-cost aerospace components. In this research, new methods have been developed to construct composite pipes of unconventional shape (rectangular and triangular cross-sections only), which can adequately support design loads and remain cost effective for industrial use. Each joining process has its strengths and limitations. A fastening of structure is generally simple and effective for which little mechanical skill is required. The fastening works well in many applications, but it often gets loosened and weakens the components, because of holes made in the parts to be joined. Although welding between steel parts is simple and 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 effected 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, aluminum to aluminum, 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 fiber reinforcement material. A roving or a fabric of high strength fibers (glass, carbon, and Kevlar) wetted in thermo-set resin (epoxy, unsaturated, polymer,etc.), is appropriately wrapped around the joint and is allowed to be cured. This kind of joint is known as FRP- joint. Kolhe and Datta (2003) studied welding low alloy steel for better microstructure and mechanical properties. The better mechanical properties of multi pass welded joint were reported. Stephen Lee (2010) conduct comparative study of composite material for getting higher strength than domestic material with superior mechanical properties. Dragen (2008) conduct experimental stress analysis to check the stresses in a unidirectional carbon/ Epoxy composite material. Reham *et al.* (2011) conduct test on different material in shearing to check the strength of material. However, it is compared with composite material strength.

EXPERIMENTAL PROCEDURE

Sharp corner of pipes made rounded for better contact. To get good bending between FRP and pipe, bending area of the pipe roughed with help of emery paper then surface of pipe through cleaned and degreased with Acetone. For fabrication of joint, pipes are required to be aligned. The facilitate the alignment of pipes and wrapping of wetted glass like around the joint, winding machines used. Two M.S. pipes of outside diameter $25^{+0.05}_{-}$. and Thickness = $2^{+0.03}_{-}$ mm and L= 175 for single pipe place face to face and butt joint with glass fiber. Joint made by wetting glass fiber in epoxy and winding it around the joint. Then prepared specimen evaluated for three point bend test. The universal testing machine of 20 tonns capacirty having Least count of 0.01 mm. was used for finding the strength of FRP joint. The details of sample speciman are presented in Fig.1 (a,b).



(a) : Detail of sample of FRP-butt join
Length of each pipe = 175 mm, FRP butt joint length = 110 mm

(b) : Photo view of FRP-butt joint

Fig. A : Experimental setup for FRP-butt joint

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.

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 fibres 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 thermoset family is covered in this article) A few major resin matrix families of interest to filament winders are:

Resin and hardener:

Resin – Dobecter 5022, Hardener – Beck 758, ratio of resin and hardener = 10:1 by weight, Glass fiber density = 600 gsm.

(a) Universal testing machine (b) Three-point bent test

Fig. B : Universal testing machine

Joining methds:

There are two types of joining methods:

– Butt
– 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 Fig. A 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.

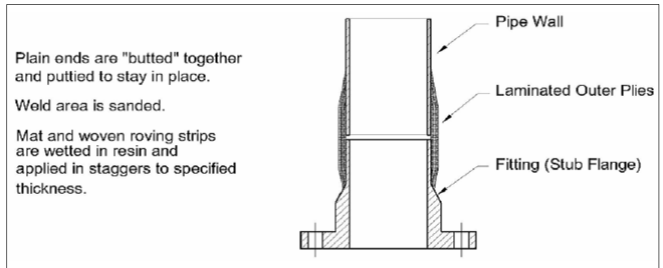


Fig. : Butt and strap joint

EXPERIMENTAL FINDINGS AND ANALYSIS

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.

Fig. 1 : Of woven fabric

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

Table 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	Length of FRP	Max load (KN)	Displacement at max load (mm)	Total tapered length of sleeve (mm)	Bending stress (N/mm^2) σ_b
1.	7 (without mat)	110	80	2.16	86	51.5	223.79
2.	11	125	80	7.36	92	52.8	505.69
3.	9 (without mat)	125	90	4.45	89	49.3	326.52
4.	5	110	65	2.95	92	48.1	480.44
5.	8	110	80	3.45	81	49.2	297.66
6.	7	110	75	3.45	82	48.6	356.04
7.	9	110	75	5.40	90	50.1	431.11

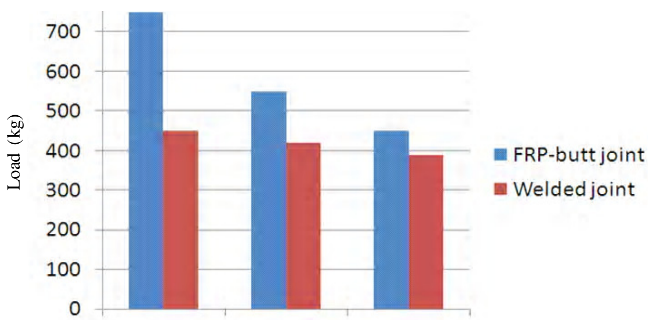


Fig. 2 : Comparative study of FRP butt joint and welded joint

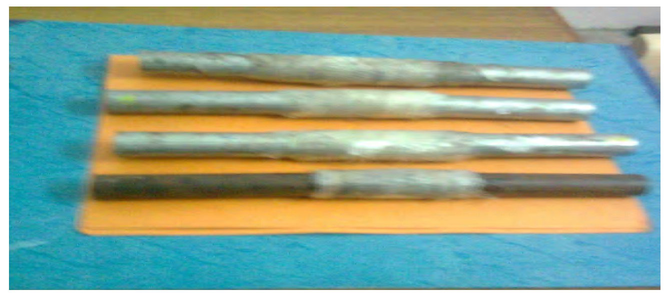


Fig. 3 : Trapezoidal glass fiber fabrics

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.

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 the tensile load on the specimen then hump presses the fiber and developed the resistance force against the tensile load (Fig. 3).

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