Evaluation of Adhesively Bonded Joint Strength of Glass Fibre Reinforced Composites

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Abstract: *Adhesively-bonded joints provide several benefits, such as more uniform stress distribution than conventional techniques such as fastening or riveting, high fatigue resistance and the possibility of joining different materials. Composite substrates in the form of fibre-reinforced plastics are not isotropic and several tests are necessary to determine all the mechanical properties of the material. In this study two types of joints were synthesis i.e. adhesively bonded double strap GFRP (glass fibre reinforced composites) joints and supported single lap GFRP joints. This study is mainly focused upon the synthesis of glass fibre reinforced composites joints order to determine effect of variation overlap length and surface roughness on the joints strength of adhesively bonded double strap GFRP joints and supported single lap GFRP joints. The design parameters investigated in this study were overlap length and surface roughness. The load–displacement response and joint strength of double-strap joints were compared with those of supported single-lap joints to address the superior strength characteristics of double-strap joints over supported single-lap joint.*

Key Words: GFRP, Lap joints, Strap Joints, Joint Strength , FRC

1. INTRODUCTION

Although mechanical joints including in automobile, aeronautical, maritime, sporting, and others all tend to be good choices for consumers in these sectors, adhesively bonded joints may possibly be a feasible alternative.[1-2] The conventional joints often provide advantages like the ones they provide, which is why bonded joints have gained prominence (i.e. more uniformly distributed stresses, design flexibility, reduced weight, lower cost, fatigue resistance, damage tolerance, good surface finish, strength to weight ratio, etc.). Additionally, fibre reinforced composites (FRC) are increasingly used in bonded systems owing to their ability to minimize structural weight and expense by removing metal adherends, whereas glass (GFRP) and carbon fiber (CFRP) reinforced composites be the trending area in FRCs.[3-4]

Steel reinforcement bars may be an alternative reinforcement for aggressive chloride rich conditions, where glass fiber-reinforced polymer (GFRP) reinforcement bars may be an alternative reinforcement choice. Any of these sites contain bridges, culverts, and parking garages. GFRP bars do not corrode, much like steel bars. Despite having a tensile strength that is more than 400% that of steel, GFRP is very fragile, exhibits linear elastic brittle behavior, and has low stiffness. When compared to other FRP products, GFRP offers a balanced level of both cost and efficiency, making it an appealing alternative for infrastructure projects.

It has been proven that tests on steel-reinforced knee-joints have been performed since the 1960s. The number of effective reinforcers faced in relation to the severity of risk of premature joint failure was directly proportional to the risk of brittle joint failure . The crack that emerged on the diagonal strut as a result of the increasing reinforcement ratio was confined by reducing the reinforcement ratio to a maximum, and this maximum reinforcement ratio had been surpassed when a splitting crack grew in the middle of the diagonal strut [5]. This observation was followed by the observations of Swann (1969), Luo et al. (1994), and Johansson (2001), who all conducted analysis using heavily hardened specimens. A limited reinforcing ratio produced steel with a tensile strength that was greater than the engineered strength, and the experimental strength of the specimens exceeded the design strength (strength of the members forming a joint). So, if you recall the formulas you saw in [6-8], you should be able to repeat those formulas back to me, if appropriate.

When we examined the change in composition between specimens that had not been detained and those that had been placed in a restricted position, Zou and Hane studied the impact of confinement in the joint on the various specimen positions by comparing unfettered and caged joint specimens. The confining container showed the specimen to have a large ductility as opposed to the large specimen which struggled in a brittle way [9]. Mayfield et al. (1971) tested one sample in the joint and observed that it showed higher average stiffness and a significantly reduced crack diameter [10].

Full-scale experiments on a two-story FRP-RC prototype. Additionally, FRP and shear reinforcement was used in all the frames; however, no joint reinforcement was added. The evaluations of the feasibility of FRP-RC models showed that the use of seismically active regions was feasible [for creating artificial attachments]." FRP reinforcement was used as longitudinal and shear reinforcement throughout the frames; however, no additional joint reinforcement was installed. Results from these tests indicated that the use of FRP-RC frames is a feasible option in seismic regions [11]. Said and Nehdi (2004) performed seismic tests comparing two exterior beam-column joints reinforced with GFRP and steel, respectively [12].

2. Materials and Methods

From the previous research it is found that work so far reported in literature has been mainly focused on the synthesis of GFRP composites in combination with natural fibres and the characterization of the mechanical properties. There are very less detailed studies on fabrication of GFRP composites joints in order to carry out the mechanical testing. Some of the following gaps in the previous research are:

- Very less work has been done to study the joint strength of GFRP joints.
- Most of the work has been done to study the tensile and flexural strength of GFRP material.

Unidirectional E-glass fibre (Sikawrap 430GSM) having fabric design thickness of 0.172 mm and fibre density of 2.56 g/cm3 manufactured by SIKAWRAP, two-phase epoxy-hardener resin(Sikadur 330IN) and adhesive (araldite) were used to prepare specimens. Both the materials i.e. glass fibres and epoxy resin were supplied by S N Associates, Delhi. The two-phase epoxy-hardener resin (Sikadur 330IN) used to prepare specimens were mixed in the ratio of 100:40 respectively.

Table 1 Properties of raw material

Materials	Major properties			
	Density (gm/cc)	Modulus (N/mm^2)	Failure strain (%)	Strength (N/mm^2)
Glass fiber	2.56	76000	2.8	3400
Epoxy	1.3	3500	0.9	30

Table 2 Property of adhesive (araldite)

Property	Araldite Resin	Araldite Hardener	Araldite Standard mixed
Colour	Neutral	pale yellow	pale yellow
Specific gravity	1.17	0.97	1.07
Viscosity at 25°C (Pas)	30 – 50	20 – 40	30 - 45
Pot Life (100 g at 25°C)	-	-	100 – 150 min.

For the experimentation unidirectional roll of woven glass fibre was purchased having 50 cm width. The sheets were initially cut from roll according to required length (Fig. 1).

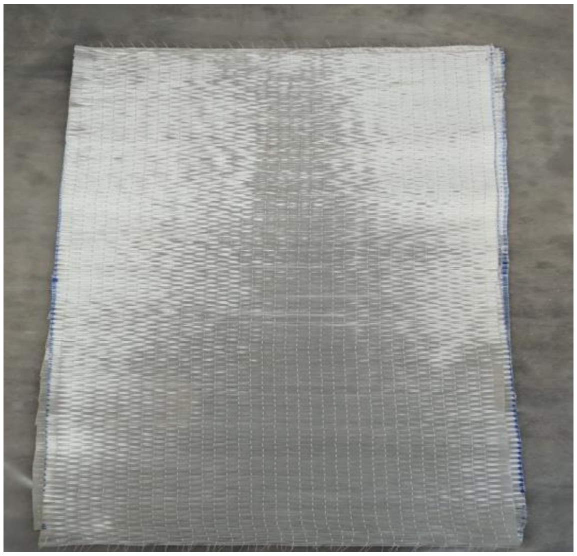

Fig. 1 Unidirectional E-glass fibre mat used for making specimen

Table 3 Compositions and properties of E glass fibres

Compositions (%)	**E-glass**
SiO2 (Silicon dioxide)	52.4
Al2O3 + Fe2O3	14.4
CaO	17.2

MgO	4.6
Na2O + K2O (sodium oxide + potassium oxide)	0.8
B2O3 (Boron trioxide)	10.6
Properties	
Density (gm/cm3)	2.60
Thermal Conductivity (W/mK)	13
Coefficient of Thermal Expansion (10-6 K-1)	4.9
Tensile Stress (GPa)	3.45
Elastic Modulus (GPa)	76

For the experiments two types of specimen were prepared and investigated one was single lap joint and double strap GFRP joint. The specimens were made by using guideline and methodology of ASTM D5868 [13]. ASTM D5868 standard gives the information regarding adhesive bonded joints between FRP to FRP or between FRP to metal and described the test methodology on lap shear joints. The specimens exactly made by ASTM D5868 may lead to eccentricity and may produce bending moments in specimens also many machine in laboratory such as UTM can only test uniaxial specimens without any eccentricity so supported single lap and double strap GFRP joints were made to overcome this problem. ASTM D3165 [14] and ASTM D3528 [15] provide guideline for determine tensile shear strength of adhesives in specimens. The specimens slightly larger than standard were made depending on designed parameter and for proper investigation of joints strength. The GFRP specimens where made by using hand layup technique. Dimension of specimen can be seen in fig. 2.

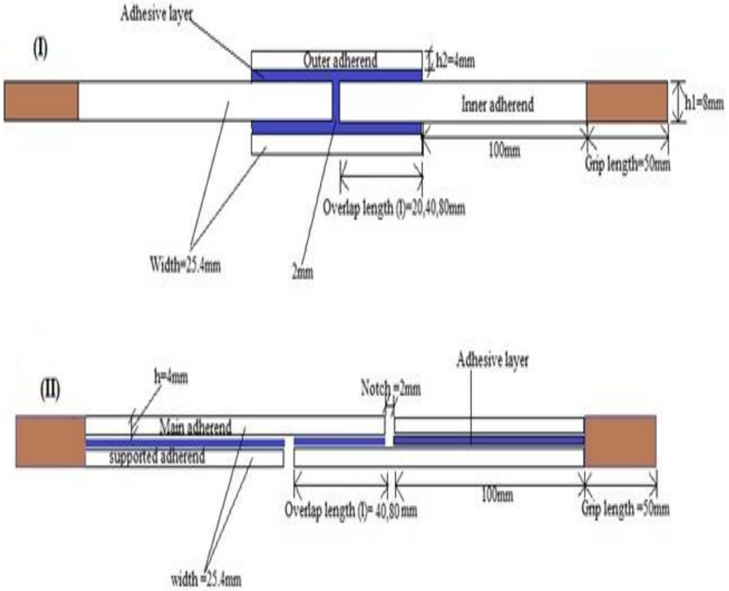

Fig. 2 Specimen details and pictorial representation of (I) double strap GFRP joint specimen (II) supported single lap GFRP joint specimen.

Preparation of double strap and single lap GFRP joints

After cutting strips according to required dimension, the surface of plates use for making double strap GFRP joints were rubbed with sand paper of grad 320 grad 150 grad and some were used as it is to determine the effect on joints strength due to the surface roughness. After these they were stick by the araldite adhesive to form double strap joints as shown in fig. 3

Fig. 3 Double strap GFRP joint test specimen

Fig. 4 Single lap GFRP joint test specimen

3. DISCUSSION: For testing and investigation of specimen the method and apparatus used are based on ASTMD 3528 and ASTMD 3165. The universal testing machine was used for tensile test of load capacity of 150KN and with the constant head-loading rate of 1.27mm/min until the failure of the specimen as based up on ASTMD 3528. The grip length of 50mm was given to the specimen. Load-time response, load-displacement response and maximum load in KN were recorded automatically.

There are many design parameter which can influence the failure mode and joints strength of adhesively bonded lap joints such as adhesive types, overlap length, adhesive layer thickness etc. but in this study we are only focused on the variation of overlap length and surface roughness depending upon this systematic test plan was made and load-displacement response, load- time response, joints strength and failure mode of adhesive bonded lap joints was investigated. To examine the influence of surface roughness the sand paper (320grade, 150grade) was used and also some specimens were used as it is without use of any sand paper or we can say that without surface roughness in this manner the influence of surface roughness was examine on double strap joints. To examine the effect of overlap length providing the highest joint strength three different specimens of overlap length l=20mm,40mm and 80mm of double strap joints were prepared and overlap length l=40mm,80mm for single lap joints were prepared. Finally, to compare the highest joints strength between single lap joints and double strap joints the specimens with l=40mm and l=80mm overlap length was compared. All results according to design parameter were summarized in Table 4.

Table 4 Summary of test plane and measured joints strength result

Specimen designation	Overlap length(mm)	Number of specimen	Joint strength (average)(kN)
(A) Double-strap joint specimens			
A-80-320G	80	3	19.86
A-80-150G	80	3	19.63
A-80-0G	80	3	15.60
A-40-320G	40	3	15.94
A-40-150G	40	3	15.91
A-40-0G	40	3	12.42
A-20-320G	20	3	12.62
A-20-150G	20	3	12.56
A-20-0G	20	3	10.15
(B) Supported single-lap joint specimens			
B-80-150G	80	3	9.10
	40	3	5.82

4. Conclusion: The load–displacement response and joint strength of adhesively bonded double-strap and supported single-lap GFRP joints were investigated experimentally. The design parameters investigated in this study were overlap length and surface roughness. The load–displacement response and joint strength of double-strap joints were compared with those of supported single-lap joints to address the superior strength characteristics of double-strap joints over supported single-lap joint. The joint strength of double strap and single lap joints increase with increase in overlap length. The load carrying capacity of double-strap joints is shown to be superior to that of supported single-lap joints.There was not much significant increased for specimen with surface roughness which was obtained by 320 grade of sand paper as compared to 150 grade they almost had same result. But there was 25% increased in the joint strength of specimen having surface roughness with respect to specimen without any surface roughness. Most specimens are fractured suddenly with a slight bursting sound, indicating a brittle, catastrophic failure. Most failure behaviors of the joints are the Thin Layer Cohesive (TLC) failure pattern or the Light-Fiber Tear (LFT) failure pattern. These failure patterns are closely related to the peel failure.

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