Journal of Material Science and Mechanical Engineering (JMSME)
p-ISSN: 2393-9095; e-ISSN: 2393-9109; Volume 6, Issue 3; April-June, 2019 pp. 156-159

http://www.krishisanskriti.org/Publication.html

STUDY OF JOINT STRENGTH AND FAILURE MODE OF ADHESIVELY BONDED DOUBLE STRAP AND SINGLE LAP GFRPJOINTS

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Abstract—*In the paper an attempt has been made successfully to evaluate the joint strength and failure mode of adhesively bonded double strap and single lap GFRP joints in which overlap length was the design parameter to compute the strength of the joint. The double strap and single lap GFRP joints were prepared from unidirectional glass fibre and epoxy resin by using hand layup method. The prepared specimens were subjected to tensile test in universal testing machine, the load displacement respond, load time respond and joint strength were recorded, investigated and data were compared. From this, it reveals that double strap joint has more joint strength as compared to supported single lap joint for same overlap length. It was also observed that the joint strength increases with increase in an overlap length in both the joints. The failure mode in the specimens was generally thin layer cohesive failure or light fiber tear failure.*

1. INTRODUCTION

Composite are the materials which generally have different physical or chemical properties than its individual components. Composite material are being used in bridge and builiding construction. FRP composite strip and sheets are used for many rehabilitation projects and construction project since, composite have many advantageous characteristics than traditional materials such as low weight, higher strength, non-corrosive nature, low maintaince and short time for marerial installation[4]. The FRP composite materials are use in combination with concrete as internal reinforcement that gives more strength to the column of building and column damaged by corrosion effects can be repair by the use of composite materials [6]. The adhesive bounded FRP has many applications in the field of aerospace, automobile, aircraft and marine industries. FRP composite are used in fabrication of structure and components used in propellers, components of manned and unmanned vehicles, components used in deep sea diving equipments, containers etc. In automobile, aircraft application the thickness of adhesive layer used for bounding joints is usually very thin as compared to structural application [8]. In aerospace and automobile field FRP component are generally join by bolted connection. However by the application of bolts the weight of component could increase and drilling holes may facilitate ingress of moisture[8].so, therefore adhesive bonding can be an better alternative to conventional bolting system by doing this various problem can be overcome [9]. The experiments had been performed to evaluate the mechanical properties of bounded, bolted and bounded-bolted composite-metal joints [1, 2, 7]. H.K.Lee et al [13] investigated the effect of overlap length, adhesive types and adhesive layer thickness on joint strength of adhesively bounded joints. Valle and Keller [9] performed experiments on adhesively bounded lap joints, compared the data with finite elements analysis and developed a design method for adhesively bounded lap joints.

In this study, the main objective is to investigate how design parameter such as overlap length influence joint strength and failure mode of adhesively bounded double strap and single lap joints GFRP joints.

2. MATERIAL USED

Unidirectional Glass fiber (SikaWrap 430GSM), two-phase epoxy-hardener resin (SikaDur 330IN) and adhesive (araldite) was purchased from local Sika India distributor. These were the material used to prepared double strap and single lap GFRP joints.

Table 1.a Properties of raw material

Material	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 1.b Property of adhesive (araldite)

Property	Araldite Resin	Araldite Hardener	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.

3. SPECIMEN PREPARATION

In this present study, 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 [12]. 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 [10] 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. The Unidirectional Glass fibers (SikaWrap 430GSM) was layered and oriented onto a one sided mold. Epoxy resin (SikaDur 330IN) was then poured onto fabric surface and rolled out using a hand roller. The epoxy resin was prepared by mixing one part of hardener in four part of epoxy by weight. This process was repeated until the required thickness of plates was obtained and the obtained material was cured for a week at the room temperature. Then they were cut into strip of required length and width and then they were stick together with help of adhesive (araldite) to form adhesively bounded double strap and single lap GFRP joints, which can be seen in fig. 1.

4. EXPERIMENTAL DETAILS

For testing and investigation of specimen the method and apparatus used were based on ASTM D3528 and ASTM D3165. The universal testing machine was used for tensile test with 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 ASTM D3528. The grip length of 50mm was given used to the specimen. Load-time response, load-displacement response and maximum load in kN were recorded. The failure of specimens was monitor by the sudden or major drop in load-time response and load-displacement response.

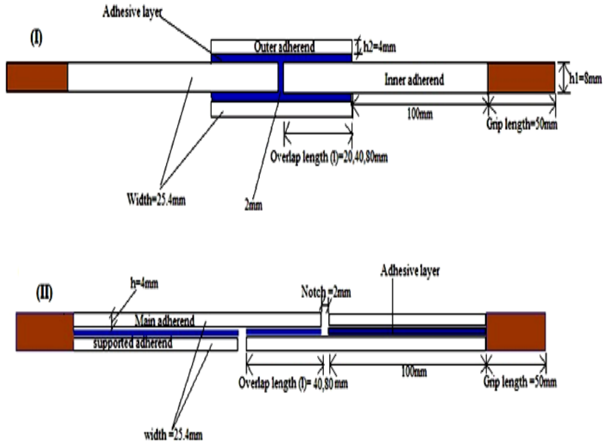

Fig. 1 Specimen details and pictorial representation of (I) double strap GFRP joint specimen (II) supported single lap GFRP joint specimen.

5. TEST PLAN

The main focus of the study is to investigate the influence of variation overlap length on joint strength and failure mode of double strap and single lap GFRP joints depending upon this the test plan was design and followed. According to standard three specimen were tested and load-displacement response, load- time response and various mechanical properties was recorded and analysis. In this manner, joint strength and failure mode were obtained depending up the variation overlap length. Summary of test result and average joints strength are shown in table 3.

Fig. 2 Double-strap joint and single lap joint specimen placed in UTM.

Table 3 Summary of test result

Specimen designation	Number of specimen	Overlap length(mm)	Joint strength (average)(kN)
(A) Double-strap GFRP joint specimens			
A-80	3	80	19.7

A-40	3	40	15.93
A-20	3	20	12.61
(B) single-lap GFRP joint specimens			
B-80	3	80	9.1
B-40	3	40	5.8

6. EXPERIMENTAL INVESTIGATIONS

6.1 Effect of overlap length

In the experiment variation of overlap length was done to investigate the influence of different overlap lengths l=80mm, 40mm and 20mm in double strap joints and l=40,80mm in single lap joints on joint strength. Moreover, its effect can be seen in fig.3 and fig. 4. Overlap of length l=80mm has 56% more joints strength with respect to l=20mm and overlap of length l=40mm has 27% more joint strength with respect to l=20mm overlap length in double strap joint. Were as, overlap length l=80mm has 56% more joints strength with respect to l=40mm in single lap joints.

6.2 Comparison of joint strength between double strap and single lap GFPP joints

Considering overlap lengths l=80 and 40mm in double strap and single lap GFRP joints. They were compared and it was found that single lap joints has 53% and 63% less joint strength with respect to double strap GFRP joints for overlap lengths l=80 and 40mm respectively. which can be seen in fig. 5 and fig. 6. From this, we can say that double strap GFRP joints is more superior to single lap GFRP joints for same overlap length.

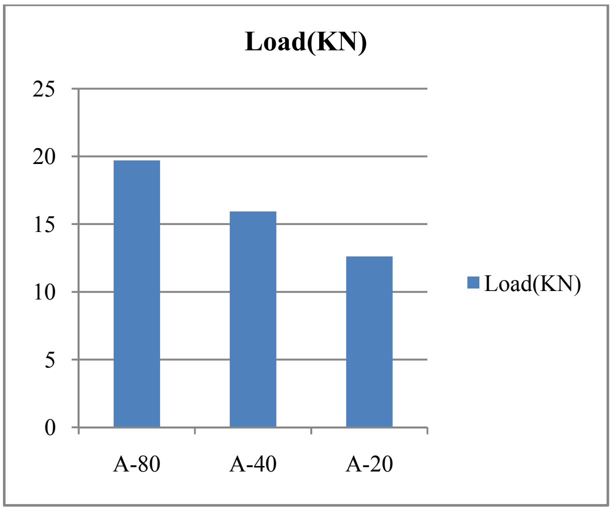

Fig. 3 Effect of variation overlap length on joint strength in double strap GFRP joint

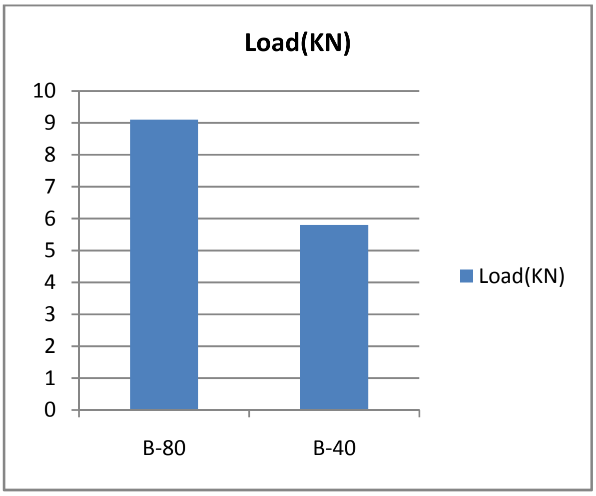

Fig. 4 Effect of variation overlap length on joint strength in single GFRP joint

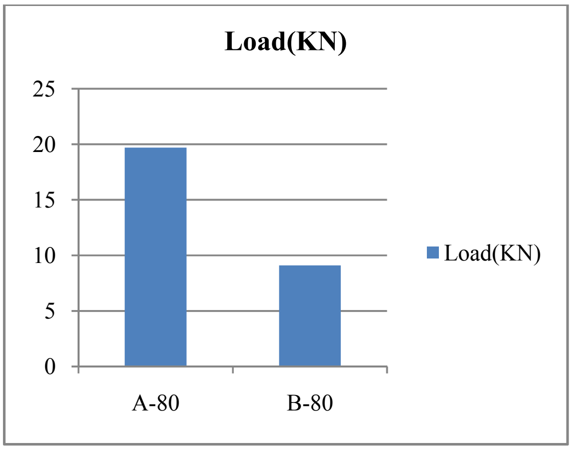

Fig. 5 Comparison of joint strength between double strap and single lap GFPP joints for overlap length l=80mm

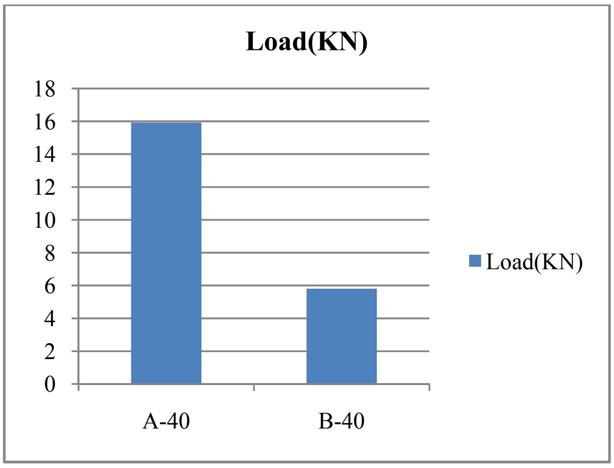

Fig. 6 Comparison of joint strength between double strap and single lap GFPP joints for overlap length l=40mm

6.3 Failure behavior of test specimens

Most of the specimens suddenly fracture with slightly burst sound, indicating brittle failure, catastrophic failure. According to ASTM D5573 [11] failure between adherend and adhesive are classified into two six categories. In these investigation most of the fracture in specimen can be classified as thin-layer cohesive (TLC) or the light-fiber-tear (LFT) failure pattern as based on ASTM D5573 as shown fig.7.

Fig. 7: The thin-layer cohesive (TLC) or light-fiber-tear (LFT) failure observed in test

7. CONCLUDING REMARKS

The double strap GFRP joints and single lap GFRP joints were prepared according to design parameter then joint strength and failure mode were investigated experimentally. Overlap length was the design parameter to compute joint strength and failure mode. The load-displacement response, load-time response and joint strength of double strap GFRP joints were compared with single lap GFRP joints to decide superior strength characteristics between double strap and single lap GFRP joints for same overlap length.

The following conclusions are made from experimental investigation:

1) The joint strength of double strap GFRP joints and single lap GFRP joints increase with increase in overlap length.

2) The joint strength of double strap GFRP joint is superior to single lap GFRP joints for the same overlap length it means that double strap has more load carrying capacity.

3) Most specimens are fracture suddenly with a slight bursting sound, indicating a brittle, catastrophic failure. Most failure behaviors of the joints show thin layer cohesive failure pattern or the light-fiber tear failure pattern. These failure patterns obtained can closely relate to the peel failure.

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