ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

IJESRT
INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

TESTING AND ANALYSIS OF COMPOSITE MATERIALS UNDER TENSILE LOADING WITH DIFFERENT LAP JOINTS

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DOI: 10.5281/zenodo.1002665

ABSTRACT
The composite structural members are highly used in the following applications such as aerospace, automobiles, marine, architecture etc., has attracted extensive attention in the past decades. A numerical and experimental study was carried out to identify the ultimate strength and failure modes of Bonded-single lap joints, Riveted-single lap joints and Hybrid-single lap joints at two different layers (3&4 Layer). In our project work, the effect of bonded, riveted, hybrid lap joints at different layer is analyzed in ANSYS and compared with the experimental test. ANSYA FEA tool has been utilized to investigate the stress distribution characteristics of a composite single lap joint under tensile loading. The experimental results are compared with FEA results using ANSYS. Our objective is to investigate the characteristics of failure modes and strength of composite single lap joints at two different layers with zero-degree fiber orientation using ANSYS.

KEYWORDS: Lap Joints, Composite, Glass Fibre

I. INTRODUCTION
These are three main types of synthetic fibers are used widely to reinforce plastic materials: glass, aramid, and carbon. Glass is by far the most widely used reinforcement fiber and is the lowest in cost. Aramid and carbon fibers have high strengths and low densities and so are used in many applications, particularly aerospace, in spite of their higher cost. Fiber reinforced plastic composites are superior to metals in terms of specific strength and stiffness, corrosion resistance, and formability. Composite materials, therefore, are used for primary structures of small or mid-sized nautical vessels, and aerospace structures. Although FRP is more expensive than major metals, glass fibers are relatively inexpensive compared with carbon and aramid fibers, so that glass fiber reinforced plastics are widely used for vessel structures. Common fiber reinforced composites are composed of fibers and a matrix. Fibers are the reinforcement and the main source of strength while the matrix 'glues' all the fibers together in shape and transfers stresses between the reinforcing fibers. Sometimes, fillers or modifiers might be added to smooth manufacturing process, impart special properties, and/or reduce product cost.

II. LITERATURE SURVEY
Bonded joints are widely used in many industries and accordingly much effort has been expended on understanding their mechanical behaviour. A significant amount of research has been dedicated to the study of adhesive bonded joints. Goland and Reissner (1944) accounts for the eccentricity that is present between the applied tensile loading in single lap joint. Hart-Smith (1973) formulated a model that basically has the same assumptions as Goland and Reissner"s but the deformations of the upper and lower adherends are considered separately.

Bigwood and Crocombe (1989) used the finite difference method to solve the differential equation that represents the peel and shear stresses in an adhesive layer. Oplinger (1991) included large deformations of the upper and lower adherends. Crocombe and Bigwood (1992) later developed an elasto-plastic analysis of adhesively bonded joints. Shi and Cheng (1993) used the principle of minimum complementary energy to derive an approximate solution for the stress distribution in adhesively bonded cylindrical lap joints for which the adherends are subjected

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to axial loads. Tsai and Morton (1994) analyzed the influence of large deflections of the overlap joint on the computation of the edge moments.

Mortensen and Thomsen (2002) presented a unified analytical approach to solve for the local fields in an array of common bonded joint configurations for more general loading conditions. Luo and Tong (2007) presented fully coupled and closed form nonlinear solutions of the edge moment factor and the adhesive stresses for single lap adhesive bonded joints with isotropic adherends under tensile loading.

Kohei Ichikawa, Yuichiro Shin, Toshiyuki Sawa (2008) analysed the stress distributions in stepped-lap adhesive joints subjected to static tensile loadings The performance of adhesive joints between pultruded FRP bridge decks and steel girders was investigated experimentally and numerically by Thomas Keller and Martin Schollmayer (2008). Khaled Shahin, Farid Taheri (2009) presented an analytical solution for the deformations in adhesively bonded joints on elastic foundations, with special attention to adhesive joints between the face sheets of sandwich beams.

III. MATERIALS AND METHODS

Materials and Tools

MAIN MATERIALS	HELPING TOOLS
• E-Glass fiber: **Unidirectional** • Epoxy Resin: **Softener – LY556 (90%)** **Hardener- HY951 (10%)** • Araldite Standard	• Wax • Brush • Cotton • Wooden frame • Blade • Thinner • Mylar sheet

Fabrication

Fabrication of glass fiber is done by hand layup process. The hand lay-up process provides for low costs for tooling, high fibre/resin ratios and offers precision throughout the entire component. Hand lay-up is used for mould production, complex shapes, and low volume production. A release agent, usually in either wax or liquid form, is applied to the chosen mould. This will allow the finished product to be removed cleanly from the mould. Resin polyester, vinyl or epoxy is mixed with its hardener and applied to the surface. Sheets of fibreglass matting are laid into the mould, then more resin mixture is added using a brush or roller. The material must conform to the mould, and air must not be trapped between the fiberglass and the mould Additional resin is applied and possibly additional sheets of fiberglass. Hand pressure, vacuum or rollers are used to make sure the resin saturates and fully wets all layers, and any air pockets are removed. The work must be done quickly enough to complete the job before the resin starts to cure. In some cases, the work is covered with plastic sheets and vacuum is drawn on the work to remove air bubbles and press the fiberglass to the shape of the mould.

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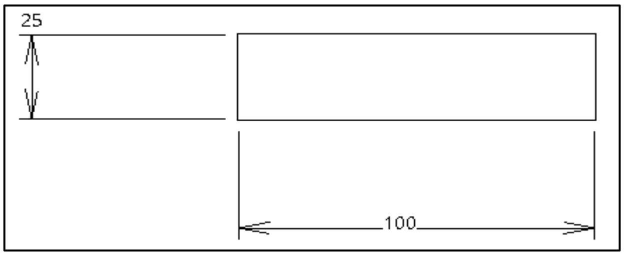
Specimen Dimension



Adhesive Bonding

Adhesively bonded structures are used to obtain lighter weight and efficient structures. In adhesive bonded aircraft, metals and composite structures such as stringers, ribs and sandwich skin panels, channel sections are bonded to the fuselage or wings to increase strength and rigidity as shown in the figure. Bonded structure has an advantage of cost saving and weight reduction. The structure consists of an assembly of sub-structures properly arranged and connected to form a load transmission path. Such load transmission path is achieved using joints. Joints constitute the weakest zones in the structure. Failure may occur due to various reasons such as stress concentrations, excessive deflections etc. Or a combination of these.

Property	Araldite® Standard resin	Araldite® Standard hardener	Araldite® Standard mixed
Colour	Neutral	Pale yellow	Pale yellow
Specific gravity	ca. 1.17	ca. 0.97	ca. 1.07
Viscosity at 25^0 C(Pas)	30-50	20-40	30-45
Pot life (100g at 25^0 C)	-	-	100-150 minutes

Adhesive bonding is a material joining process in which adhesive placed between the faying surfaces, solidifies to produce an adhesive bond. Adhesive bond often allows structures that are mechanically equivalent to or stronger than conventional assemblies, to be built at lower cost and weight. Adhesive bonding can also offer an improvement in quality, strength to weight ratio, fewer component parts and an increase in work productivity. As a means of joining materials, the use of adhesives offers many advantages when compared to other conventional methods such as brazing, welding, riveting, bolting etc.,

Failure Modes

The shear strength decreases considerably as the binding area expands, which could be the result of the fact that deformation resistance occurring in small areas was more than those large areas and two different failures at single lap joints was caused by the peel stress and shear stress. Adhesive failure, cohesive failure and thin-layer fiber failure are matrix failure. Failure-mode classification, relating to testing FRP bonded joints includes seven classes of failure modes identified as shown in figure:

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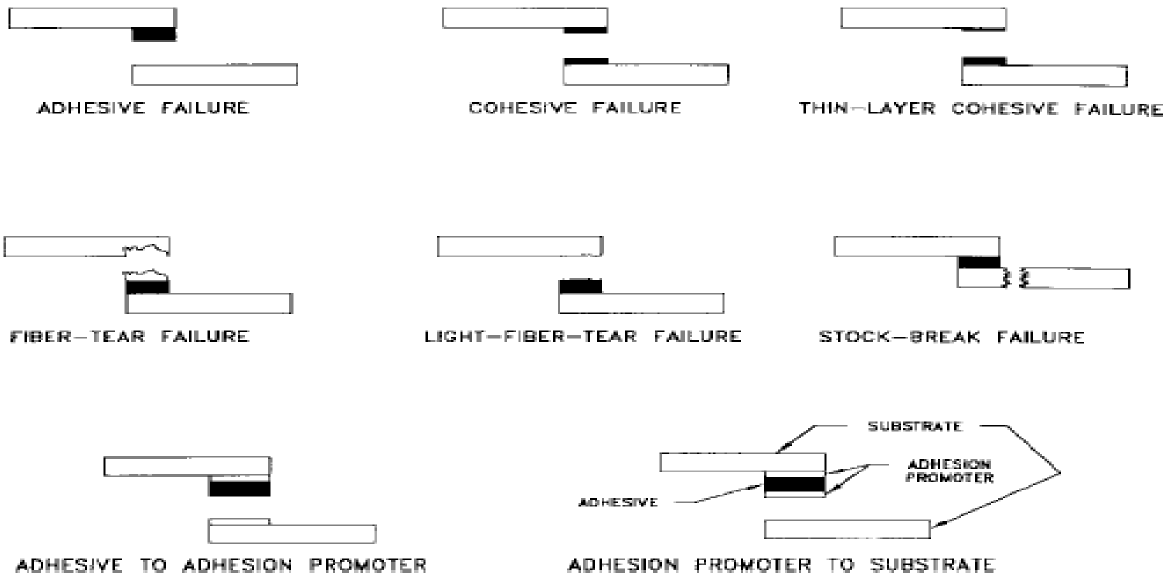
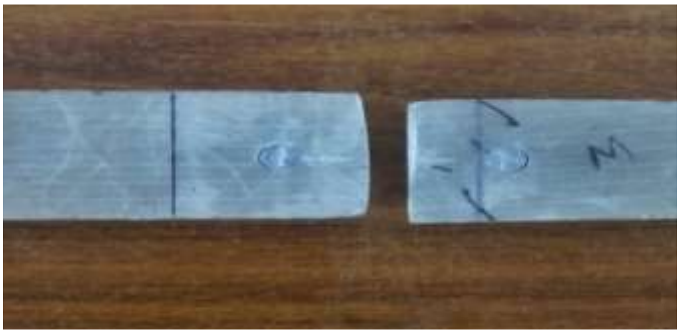
CODEN: IJESS7

Types of Failure modes



RIVETED SINGLE LAP JOINTS:

Rivets are considered to be permanent fasteners Riveted joints are therefore similar to welded and adhesive joints. Rivets have been used in many large scale applications including shipbuilding, boilers, pressure vessels, bridges and buildings etc. A riveted joint, in larger quantities is sometimes cheaper than the other options but it requires higher skill levels and more access to both sides of the joint A rivet is a cylindrical body called a shank with a head.



A hot rivet is inserted into a hole passing through two clamped plates to be attached and the heads supported whilst a head is formed on the other end of the shank using a hammer or a special shaped tool. The plates are thus permanently attached. Design of joints is as important as that of machine components because a weak joint may spoil the utility of a carefully designed machine part. Mechanical joints are broadly classified into two categories viz., non-permanent joints and permanent joints. Nonpermanent joints can be assembled and dissembled without damaging the components. Examples of such joints are threaded fasteners (like screw-joints), keys and couplings etc. Permanent joints cannot be dissembled without damaging the components. These joints can be of two kinds depending upon the nature of force that holds the two parts. The force can be of mechanical origin, for example, riveted joints, joints formed by press or interference fit etc, where two components are joined by applying mechanical force. The components can also be joined by molecular force, for example, welded joints, brazed joints, joints with adhesives etc.

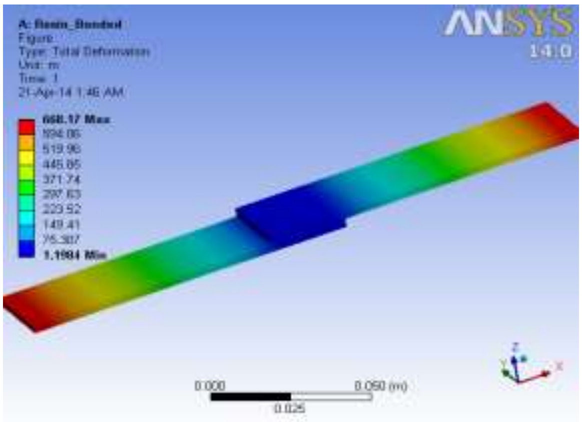
ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

Hybrid Lap Joint

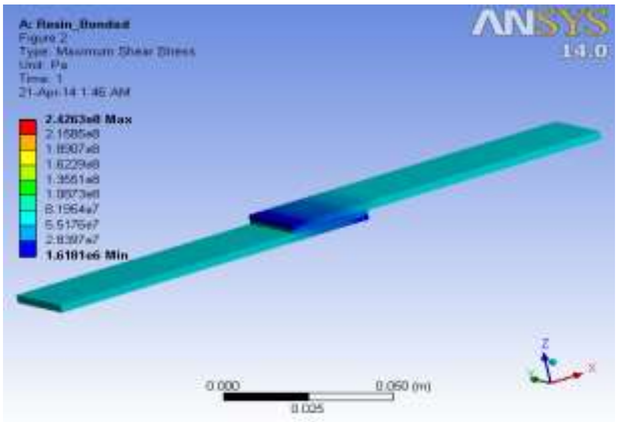
To overcome the potential weakness of adhesive bonding, bonded/riveted hybrid joints were proposed. In the hybrid joint, mechanical fastening is added to the bonded joints to improve the joining strength. The hybrid joints with lower modulus adhesives allowed for load sharing between the adhesive and the rivets, and were shown to have greater strength and fatigue life in comparison to adhesive bonded joints. The hybrid joining improves joint strength when the mechanical fastening is stronger than the bonding. However, fiber damage and delamination due to fabricating rivet holes are still problematic for the conventional bonded/riveted hybrid joints between FRP and metals.

Numerical Simulation

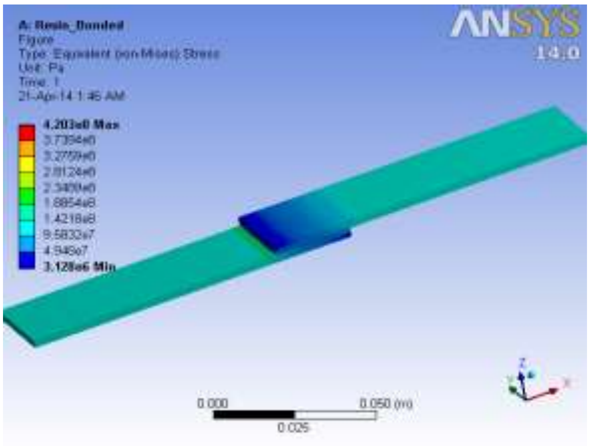
Bonded Joint



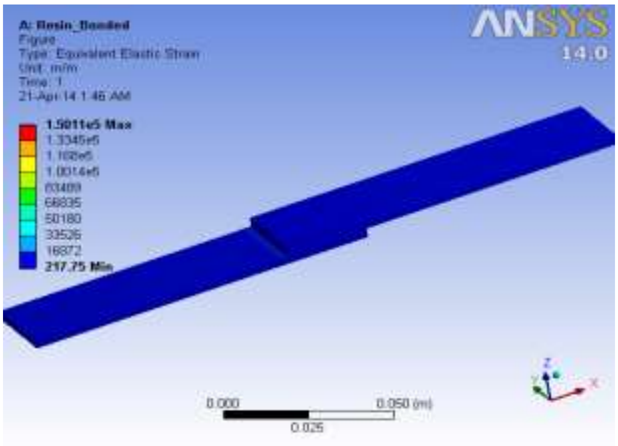
TOTAL DEFORMATION



SHEAR STRESS



VON-MISES STRESS



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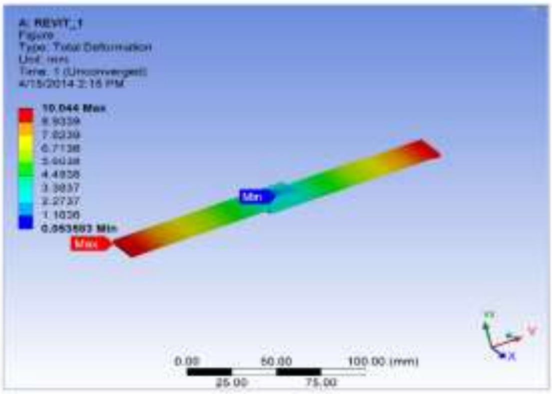
Riveted Joint



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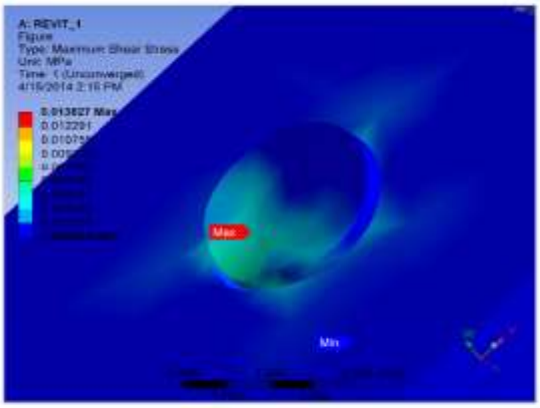

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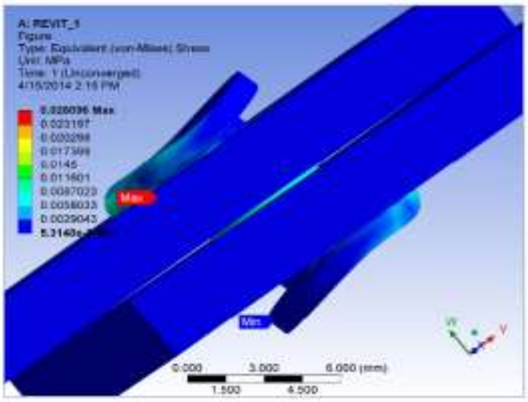

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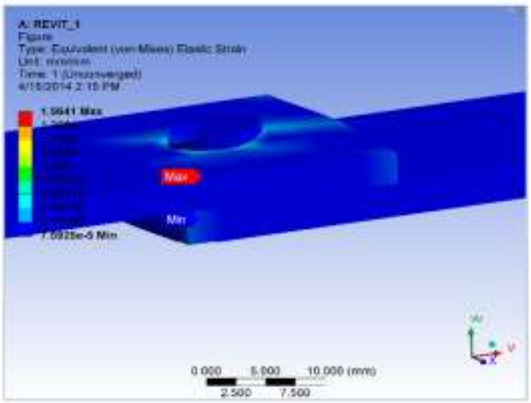

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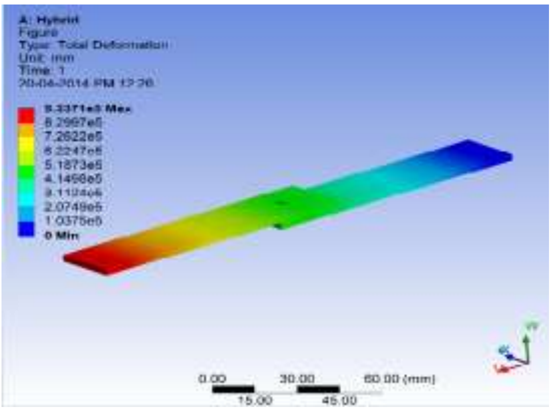
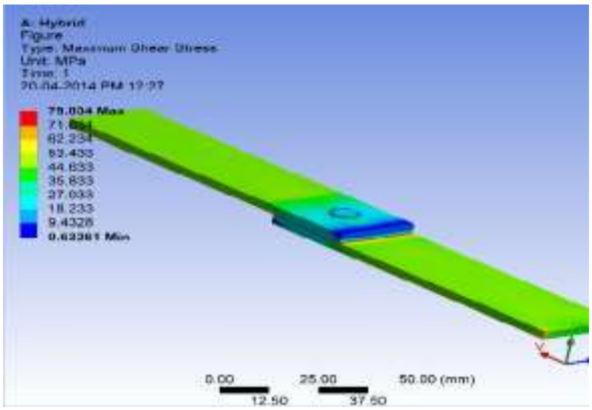
Hybrid Joint



TOTAL DEFORMATION



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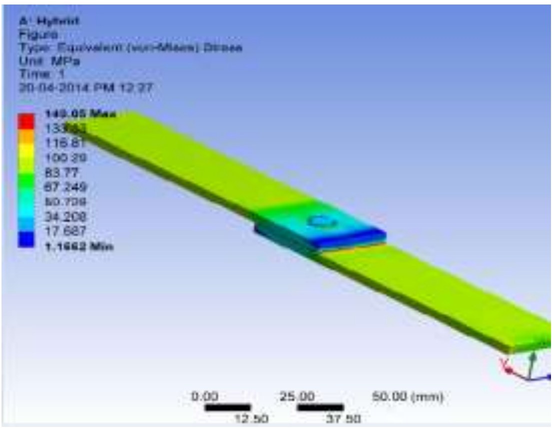

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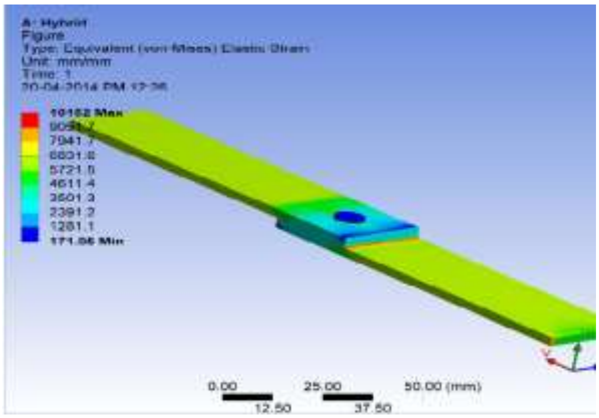

VON-MISES STRAIN

MATERIAL DATA:

Types of Joint	Maximum deflection	Minimum shear stress (MPa)	Maximum shear stress (MPa)
Bonded	668.17 m	1.6181e6	2.4263e8
Riveted	10.044 mm	3.0066e-6	0.013827
Hybrid	9.3371e5	0.63261	79.034

IV. CONCLUSION

In our project, the response of single lap joints with composite adherent, riveted and hybrid subjected to tensile load was investigated for two different layers (3&4 layers).

i) The load –displacement data obtained from the experiments were in good agreement with analysis results. Experimental and numerical data showed that the maximum stress occurred at the corner sections of the joint, whereas minimum stress occurred at 3 layer. Increasing the overlap additional layer results in significant reduction in the stress distribution throughout the joint.

ii) The precisely composite single-lap (Bonded, Riveted and Hybrid) joint analysis method must be able to predict failure modes in GFRP composite.

iii) The suitable strength prediction of the single lap joints is essential to decrease the amount of expensive testing at the design stage. Usually designers use Hybrid single lap joints for maximum strength.

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K. S. Sajikumar (Senior Lecturer, Department of Mechanical Engineering College of Engineering, Thiruvananthapuram, Kerala)
Dr .N. Asok Kumar (Asst. prof., Department of Mechanical Engineering College of Engineering, Thiruvananthapuram, Kerala)

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The manuscript was received on 5May 2008 and was accepted after revision for publication on 16 September 2008.

CITE AN ARTICLE

E, H., Mr. (2017). TESTING AND ANALYSIS OF COMPOSITE MATERIALS UNDER TENSILE LOADING WITH DIFFERENT LAP JOINTS. *INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY, 6*(10), 126-133.