

## Study of the Strength of Single Lap Adhesive Joints Through Three Point Flexural Loading Method

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### Abstract

Now-a-days adhesive joints are gaining popularity in joining the load-bearing components for aerospace and automobile industries. This technique helps in joining dissimilar metals together. Spot-welds are used in the automotive industry. It requires huge investment as well as most advanced automated machinery. Also they must reach both sides of the metals. They can't join aluminium metal effectively. So adhesives are used to join the metals. Many problems faced in adhesive bonding have now been overcome. Bonding of oily surfaces, high speed applications in robotics and adhesives which can withstand high impact strength have been developed. A study of the strength of a lap adhesive joint using three point bending test on a standard specimen made of glass-epoxy composite lap joint as per the standards of ASTM is done. The purpose of this study is to understand the overlapping length, alumina nano particle addition to the epoxy matrix for the single lap joint adhesive strength of the glass fiber reinforced polymer test coupons at room temperature.

**Keywords** — Three point bending test, flexural test, automotive, glass-epoxy composite.

### 1. INTRODUCTION

The aerospace industry has influenced the automotive industry in recent days<sup>[1]</sup>. The customer's expectations are increasing and they are seeking better quality and efficient technology in products. Several aerospace companies use their aerospace technology in their automotive divisions to manufacture and sell advanced class automobiles. Automobile engineers and design engineers are constantly striving to produce lighter and cheaper products. Welding is considered a versatile method to join two similar or

dissimilar metals. Generally, spot-welding is used to join the metals in automotive industry. This technology is a high cost complex and difficult to automate process. Other major disadvantages of this process are: (i) the spot weld fails to reach both the ends of the metal, (ii) spot welding has some movement constraints, (iii) they induce thermal stresses. Besides these, fatigue failure may occur at the ends of the spots and tendency to corrode increases in spot welds. So, adhesive joints are gaining popularity in joining two machines/structural members. There are several advantages of adhesives over spot-welds. Adhesives can be used in high speed production lines with help of the robotics technology. Adhesives have better impact strength. The objective of this research is to provide the information regarding safety of “adhesive” joints to a design engineer. As single lap joints are widely used in the automotive industry a single lap adhesive joint is considered for a 3-point bending test in this Study.

## 2. LITERATURE REVIEW:

Many tension, flexural and bending experiments have been done on single-lap joints to know their behavior. Volkersen et al. <sup>[2]</sup> worked on adhesive plasticity, free stress present at the end of the overlap, composite adherend and the fillet. Finite element will be useful when complex geometry such as adhesive fillets and adhesive shaping are considered. Andreassi et al. <sup>[3]</sup> and have dealt with the study of adhesive fillet. Fessel et al. <sup>[4]</sup> used finite element to study the wavy adherends for automobile application. Adams et al. <sup>[5]</sup> reported that failure load can be predicted by calculating the initial yield of the adherend. Also there is a case that the strength decreases with the increase in the bondline thickness. Liu et al. <sup>[6]</sup> gave a full experimental and theoretical address on the four point bending test. Ozel et al. <sup>[7]</sup> used high strength steel to perform a four-point bending test.

## 3. EXPERIMENTAL PROCEDURE:

This work deals with 6 single lap joints with variations. They are as follows.

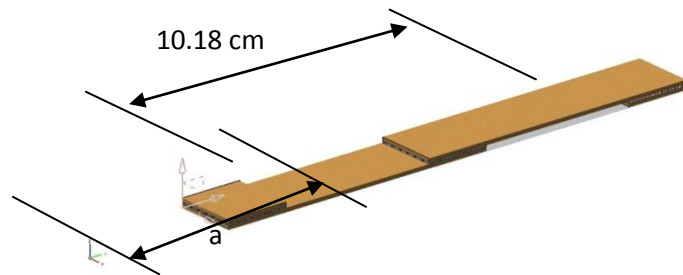
**Table I : Specimen overview**

S.No	Overlapping length (mm)	Adhesive bond type	Spew-fillet
1	15	Epoxy with 2% alumina	No
2	25	Epoxy with 2% alumina	No
3	30	Epoxy with 2% alumina	No
4	45	Epoxy with 2% alumina	No
5	60	Epoxy with 2% alumina	No
6	15	Epoxy	No
7	30	Epoxy	No
8	45	Epoxy	No

These single lap joints were manufactured under normal atmospheric condition and heat treated at 80 deg Celsius.

**4. SPECIMEN GEOMETRY:**

ASTM D 1002 standard is followed to manufacture the single lap joint (Fig. 1). The overlapping length varies as 15 mm, 25 mm, 30 mm, 45 mm and 60 mm. The thickness is between 0.1 mm to 0.5 mm.

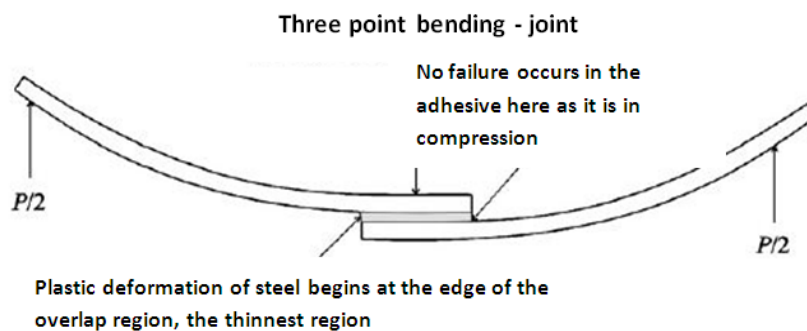


**Figure.1 Lap joint specimen**

**5. TESTING PROCEDURE:**

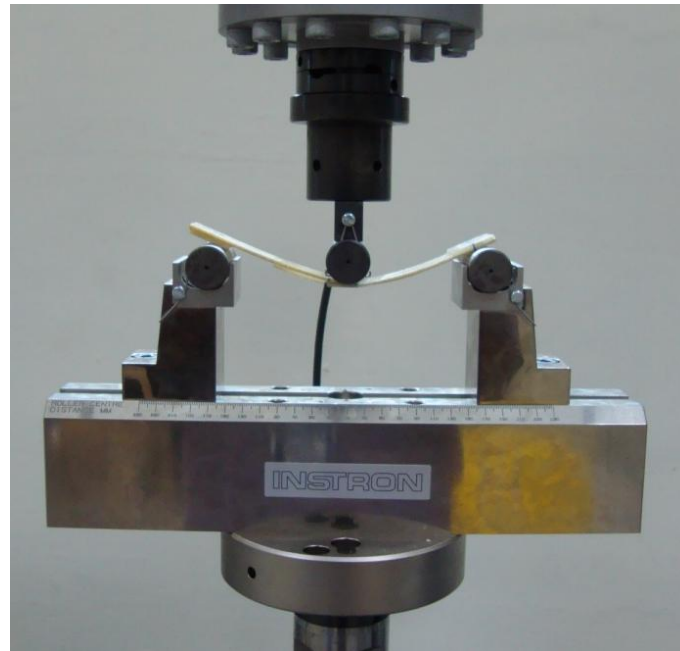
The lap joints are tested under the cross-head speed of 1 mm/min. The bondline thickness is maintained at 0.1 mm. This is considered because the increase in the bondline thickness may decrease the strength of the single-lap joint and there may be some crack propagation due to the increase in bondline thickness. The extent of the overlapping thickness may influence the peak load that can be applied to the single-lap joint. Failure at the edge of the overlap can be overcome by increasing the overlapping length. The distance between the loading points varies with each specimen. The loading point is always in the middle of the span. The bending moment of the lap joint can be determined by the geometry and the overlapping length.

**6. THREE POINT BENDING TEST:**



**Figure.2 Three point bending test <sup>[8]</sup>**

The three point bending test is carried out in the Instron 8800 testing machine as shown in Fig. 3.



**Figure.3 15mm overlap (2% alumina)**

The bond line thickness is maintained at 25mm. The width varies from 15 mm to 60 mm. In the three-point bending, the bending moment is maximum at the middle. So the variation in the overlap length will affect the bending moment of the lap joint.

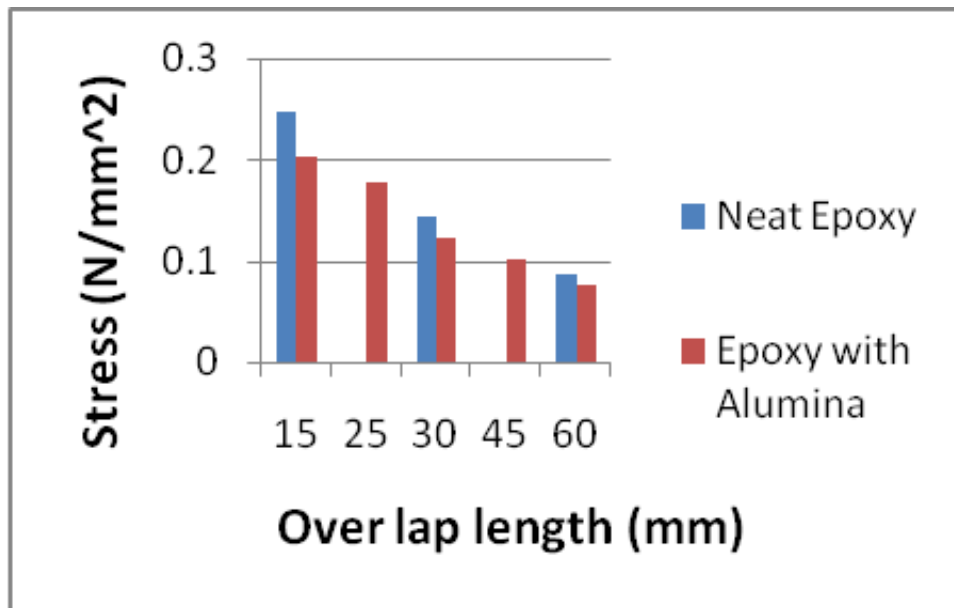
**Table II (a): Peak load**

Distance between loading points (a) (mm)	Overlap length (mm)	Adhesive bond type	Peak load (N)
165	15	Epoxy with 2% alumina	146.65
153	25	Epoxy with 2% alumina	155.76
149	30	Epoxy with 2% alumina	182.6
134	45	Epoxy with 2% alumina	276.54
119	60	Epoxy with 2% alumina	289.56
165	15	Epoxy	91.66
149	30	Epoxy	114.36
134	45	Epoxy	176.10



### 7. STRESS DISTRIBUTION:

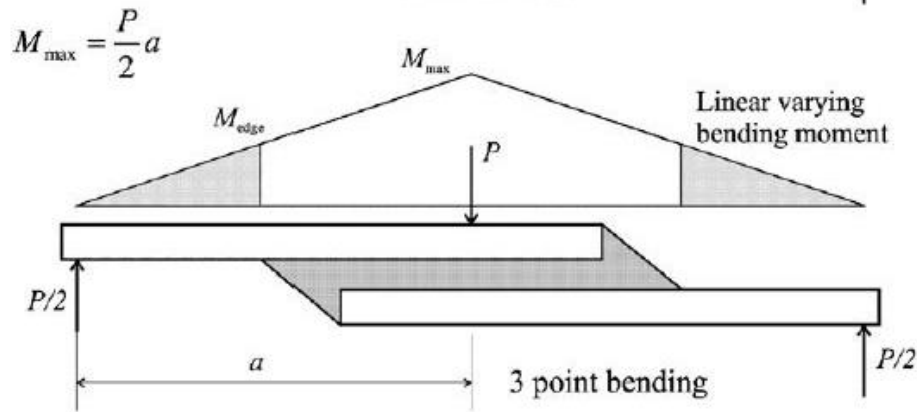
The stress distribution in the various overlapping length is discussed below. Generally the industry has a consideration that addition of the alumina to neat epoxy will increase the strength of the joint. From the above results we can conclude that the addition of alumina has the highest stress carrying capacity. The stress carrying capacity is less in neat epoxy. The epoxy which is added with the alumina particles has influenced the strength of the lap. So the addition of alumina is recommended since addition increases the strength of the lap.



**Figure.5 Stress vs Overlap length**

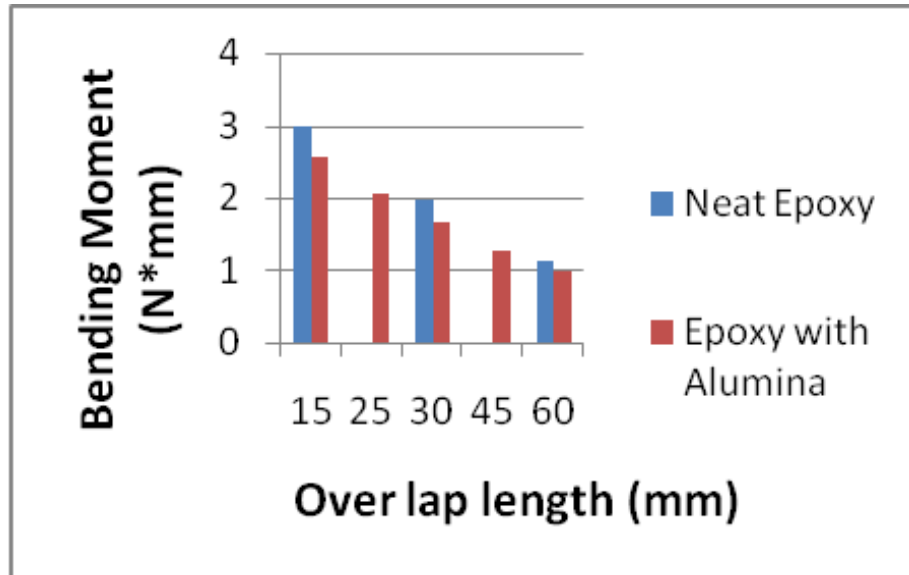
For the 15 mm overlap specimen, the stress in the bondline thickness is more because the total load acts on a small area. When the overlap length increases, the stress also decreases as the load acts on a larger bondline thickness. It is seen that the stress carrying capacity of the lap joint is high in the case of less overlap length and low in case of larger overlap length. The stress value for the 60 mm overlap joint is less but the load carrying capacity is more. Thus it is seen that increasing the overlapping length of the lap joint has better strength than the other.

**8. BENDING MOMENT OF THE FAILURE:**



**Figure.6 Bending moment diagram [8]**

The bending moment of the various specimens are discussed below. The bending moment of the lap is more in the middle region in the case of the three point bending test [Fig 6]. The bending moment is more in the case of 15 mm overlap and decreases to the 60 mm overlap [Fig 7].



**Figure.7 Bending Moment Vs overlap length**

The three point bending affects the adhesive bonding. So the failure occurs at the bond and the actual failure prediction is possible in the case of three point bending test. So, the result is determined by the failure load and extension failure.

**9. CONCLUSIONS:**

Generally the lap joint is tested under tension and flexure. The three point bending test is carried out. The main conclusions are as follows.

1. The load carrying capacity is high if the overlap length is more.
2. The addition of alumina nano particle has influenced the bond strength.
3. The increase in adhesive thickness will make the joint stiff.

Hence, it can be concluded that, designers can have more overlap length if the structure is subjected to more static loading.

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