EMPD 5 (1) Mei 2026, 316-322 ISSN 2964-6987
Energy, Materials and Product Design
https://journal.unram.ac.id/index.php/empd

EFFECT OF OVERLAP LENGTH AND ADHESIVE THICKNESS ON THE SHEAR STRENGTH OF JUTE FIBRE COMPOSITE AND FIBREGLASS COMPOSITE JOINTS

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https://doi.org/10.29303/empd.v5n1.316-322
Received 10 April 2026; Received in revised form 5 May 2026; Accepted 11 May 2026

ABSTRACT

Adhesively bonded joints have attracted the attention of engineers for connecting different materials to develop lightweight structures. The materials that can be bonded include composite materials with different reinforcements, such as glass and natural fibres, but to achieve optimal strength, factors such as adhesive thickness and overlap length remain decisive. This study aims to determine the effect of overlap length and adhesive thickness on the shear strength of jute fibre-reinforced composite and glass fibre-reinforced composite joints. This study used single lap joints according to ASTM D1002. The overlap lengths varied by 15, 20, 25, and 30 mm, while the adhesive thicknesses varied by 0.2, 0.4, and 0.6 mm. This study found that joint strength decreases with increasing overlap length, whereas the effect of adhesive thickness depends on overlap length. At overlap lengths of 15 and 20 mm, joint strength increases with increasing adhesive thickness, whereas at 25 and 30 mm overlap lengths, it appears to remain constant. The optimal adhesive thickness is 0.4 mm. At an overlap length of 20 mm, the shear strength at adhesive thicknesses of 0.4 mm and 0.2 mm is 4.58 MPa and 3.71 MPa, respectively, or an increase of about 36% relative to the 0.2 mm thickness. The results imply that for hybrid jute and fibreglass composite joints, a short overlap length (i.e., 15 mm) and an adhesive thickness below 0.4 mm are recommended.

Keywords: *Natural fibre composites, Overlap length, Adhesive thickness, Adhesive joint, Shear strength*

1. Introduction

The use of adhesive joints is increasing and is used to join various structural materials, such as metals, composites, and ceramics, which are widely used in the automotive, aircraft, and electronics industries. Adhesive joints are increasingly attractive because they offer several advantages, such as the ability to join many different types of materials and a more homogeneous stress distribution than in rivets, spot welds, and pins. Adhesive joints produce good contour surfaces, are lightweight, and are able to dampen vibrations [1].

Natural fibre composites are increasingly used as structural components, such as in cars and ships, to develop lightweight, environmentally friendly structures [2]. However, the use of fibre composites alone is not enough to support high strength, as natural fibre composites have lower mechanical properties than synthetic fibre composites, such as fibreglass or carbon fibre composites. A combination of natural fibre composites and synthetic fibre composites is widely used in structural applications. The use of these two materials must be connected through splicing. An adhesive connection is the right solution because the two materials are different. Several researchers have conducted research on the adhesive bonding of natural fibre composites [3,4]. Honzalez-Murillo and Ansel [3] examined three joint configurations, including single lap joints (SLJ), intermingled fibre joints (IFJ) and laminated fibre joints (LFJ), which were tensile tested. The tensile strength of SLJ was very low compared to the composite (without joints), but IFJ and LFJ achieved a high proportion of the composite strength. The LFJ with an overlap length of 50 mm achieved an average strength of 92% of its composite strength. In IFJ, as the blended length increases, the fibre bundles become more misaligned, adversely affecting strength. Queiroz et al. [4] examined jute fibreglass fibre, jute fibre-jute fibre and glass fibre-reinforced polymer composite (GFRP) intralaminar hybrid reinforced polymer composite joints. They showed that GFRP-GFRP joints were the most efficient joints with BetamateTM 2096 and AR 260 epoxy adhesives. Joints with adherends of natural fibres (jute and sisal) were less efficient. However, the joint strength increased significantly when glass fibres were introduced to jute and the jute intralaminar. Jute-based natural fibre composite joints, both hybrid and purely natural, have superior strength compared to sisal-based natural composite joints. The improved composite-adhesive interface in jute-based composites can explain this. Furthermore, Queroz et al. [2] examined the interlaminar addition of glass fibre laminates to natural fibres in the outer layer and compared with no laminates on the strength of single overlap joints. It was found that adding glass fibre layers on the outside, up to 3 layers, increased the failure load.

In joint design, overlap length and adhesive layer thickness are important factors. Increasing the overlap length increases the joint's failure load until it reaches the optimum overlap length, after which it tends to be constant or decrease [5,6,7], whereas the adhesive thickness does the opposite. Increasing the adhesive thickness decreases the joint strength, but the decrease depends on whether the adhesive is brittle or ductile [8,9,10,11]. However, most of those studies were conducted on metal adherends. Little research has been reported on the connection between natural fibre composites and synthetic fibre composites. So this study aimed to investigate the effects of overlap length and adhesive thickness on jute fibre composite and glass fibre composite (fibreglass joint).

2. Materials and Method

2.1. Materials

The materials used were woven jute fibre and woven fibreglass (with an area density of 600 g/m^2) as reinforcement. Yukalac BQTN 157 unsaturated polyester resin and methyl ethyl ketone hardener were used for the composite matrix. Epoxy Union was formulated using a diglycidyl ether bisphenol-A resin and a polyamine hardener as the adhesive.

2.2. Alkali treatment

Alkali treatment was carried out before the jute fibre was used to make composites. Alkalisation of woven jute fibres was carried out by soaking the jute fibres in NaOH solution with a concentration of 0.5% for 24 hours. After that, the jute fibres were removed and rinsed with running water until the NaOH solution disappeared from the surface of the fibres. Then the fibres were dried in the open sun until dry.

2.3 Composite fabrication

To make a composite with a size of 200 × 150 mm^2, jute fibres were laid out in a mould in 3 layers. After that, the unsaturated polyester resin mixed with hardener was stirred until homogeneous, then poured into the mould. The resin-to-hardener weight ratio was 100:1. The composite thickness was kept at 3 mm. The composite was then allowed to harden at room temperature for 24 hours. The same method was used to make fibreglass composites with 6 layers of fibreglass. The thickness of the fibreglass composite was also 3 mm. During hardening, the composite was pressed at a pressure of 2 tonnes.

2.3. Single lap joint fabrication

The type of joint made was a single lap joint, as per ASTM D1002 [12] (see Figure 1). The joint materials (adherend) were jute fibre composite and fibreglass composite. The composites (jute fibre and fibreglass) were cut to a width of 25 mm and a length of 87.5 mm, plus the overlap length, with overlap lengths of 15, 20, 25, and 30 mm. The next stage was sanding the specimen on the surface that was connected, which was then cleaned with acetone until it was clean. The next step was to mix epoxy union glue with hardener at a 1:1 weight ratio. The mixture was stirred until evenly distributed, then vacuumed to allow trapped air bubbles to escape. Splicing of hemp and fibreglass composites was done by evenly applying adhesive to the parts to be joined. To maintain uniform adhesive thickness, 0.2, 0.4, and 0.6 mm-diameter copper wires were inserted parallel to the overlap length through the adhesive layer, corresponding to adhesive thicknesses of 0.2, 0.4, and 0.6 mm, respectively. Because the copper wire was embedded in the adhesive layer, the adhesive thickness was approximately equal to the copper wire diameter. The joints were placed in a jig to keep them in a fixed position during adhesive curing. The joints were heated in an oven for 1 hour at 70º C for adhesive curing. Afterwards, the joints were taken out and allowed to stand for 24 hours at room temperature. Tabs were applied at both ends of the joint to ensure force alignment during testing.

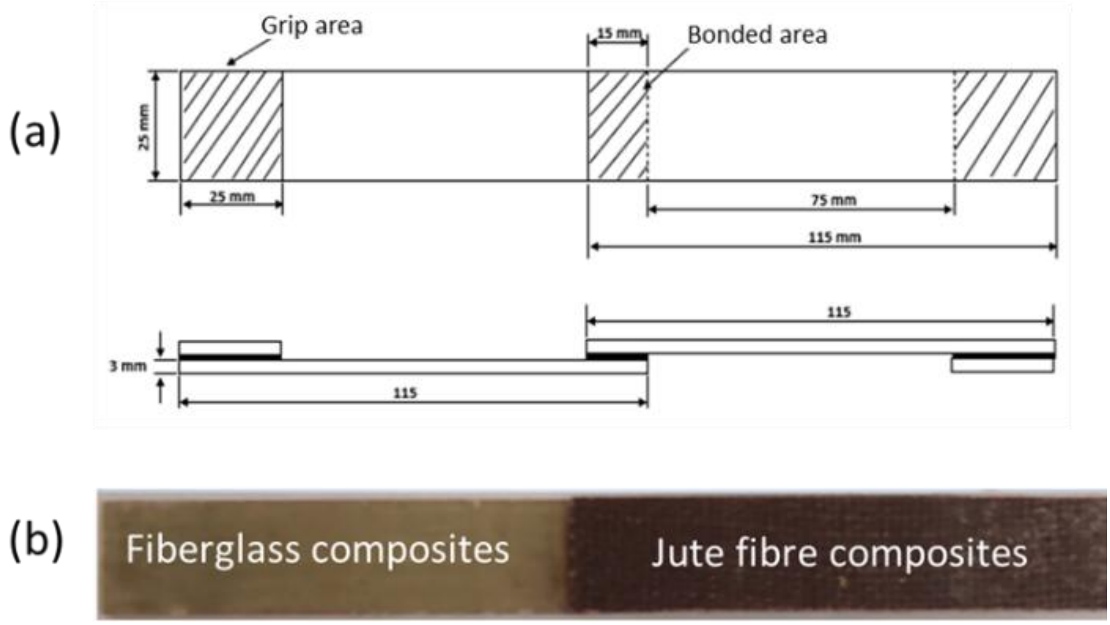

Figure 1 (a) Dimensions of single lap joint specimen, (b) Photograph of joint specimen

2.4. Mechanical testing

Shear testing of the joints was performed using a universal tensile tester at a displacement rate of 2 mm/min. After testing, the failure surface of the specimen was photographed with a digital camera to determine the failure mode. At least three specimens were tested for each variation.

3. Results and Discussion

3.1. Shear strength

Based on the research results, the shear strength data for the jute composite and fibreglass composite joints are shown in Figures 2 and 3, respectively. Based on Figures 2 and 3, at adhesive thicknesses of 0.2 and 0.6 mm, the joint shear strength decreases with increasing overlap length. Meanwhile, at an adhesive thickness of 0.4 mm, the shear strength increases at an overlap length of 20 mm. Then it tends to decrease compared to an overlap length of 15 mm. Increasing the overlap length tends to increase the joint's failure load due to the larger glueing area (before reaching the critical overlap length) (see Figure 2). However, the shear strength of the joint is the opposite (see Figure 3). The joint shear strength tends to decrease with increasing overlap length, and several researchers have experimentally demonstrated it [5,7]. Increasing the overlap length beyond a certain value caused plastic deformation of the adhesive, which did not increase the joint's capacity to sustain additional load [1].

The high shear strength at an overlap length of 20 mm and an adhesive thickness of 0.4 mm is an optimal condition resulting from the adhesive's optimal deformation.

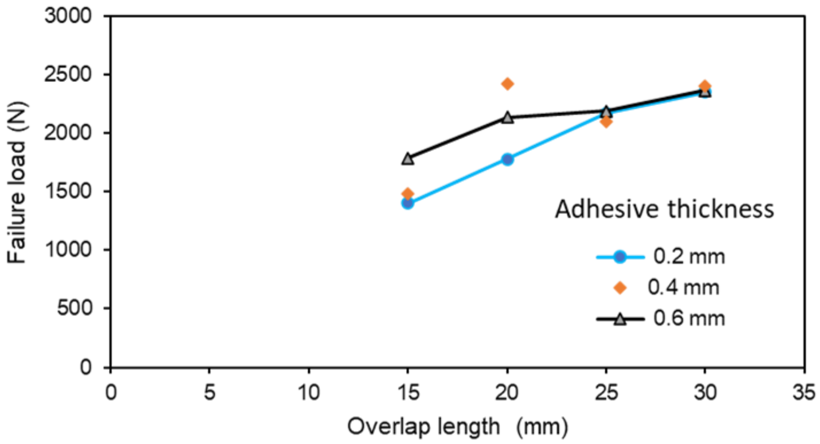

Figure 2 Relationship of variation in overlap length with specimen failure load at various adhesive thicknesses

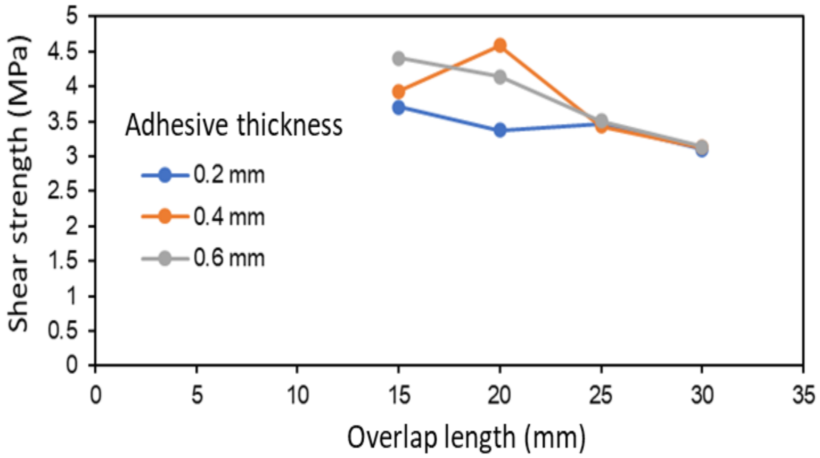

Figure 3 Relationship between variation in overlap length and shear strength

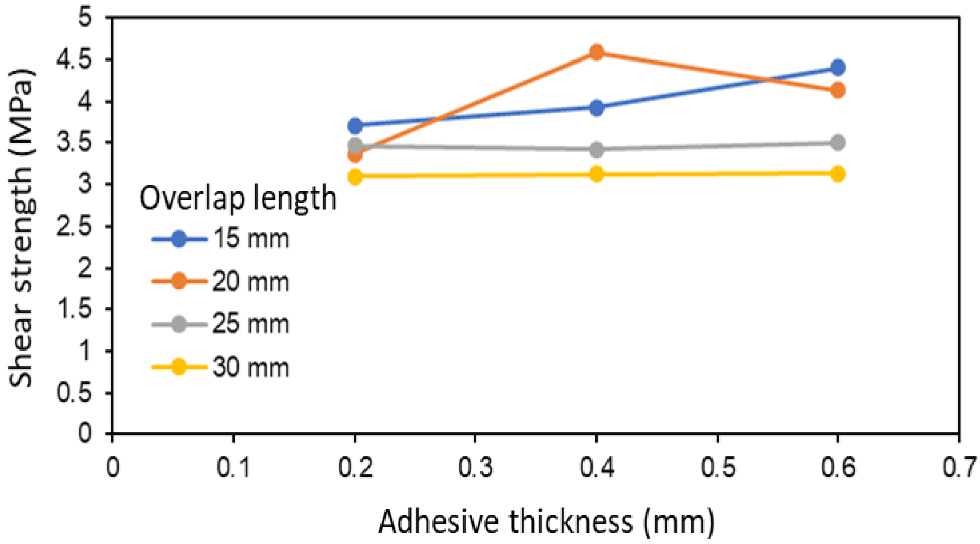

Figure 4 Relationship between thickness variation and shear strength of specimens

As shown in Figure 4, the effect of adhesive thickness on shear strength varies with overlap length. For overlap lengths of 15 and 20 mm, the shear strength increases with increasing thickness. Meanwhile, for overlap lengths of 25 and 30 mm, the shear strength tends to flatten with increasing thickness, so thickness does not significantly affect it. As reported experimentally and by the finite element method, the shear strength of the adhesive increases to a certain thickness, then decreases, because thicker adhesive is more prone to defects and voids [13,14]. However, stress analysis at the interface also shows that the development of plasticity in the adhesive accelerates as the adhesive layer thickens, leading to early failure [15]. However, there is an optimal adhesive thickness for maximum shear strength, which depends on the adhesive type. For brittle adhesives (epoxy and acrylic), 0.2-0.3 mm is the optimum thickness [16,17], while for ductile adhesives (polyurethane), the optimum thickness can reach 1 mm [13].

3.2. Mode of failure

Based on Figure 5, the average failure mode across all specimens is cohesive failure within the adhesive. This indicates that the adhesive has a strong bond with the substrate, but the failure occurs because the adhesive is not strong enough to withstand the applied load, making it the weakest part of the joint. At a thickness of 0.2 mm for all overlap lengths, failure is dominated by interfacial failure, and the failure load is the lowest compared to thicknesses of 0.4 mm and 0.6 mm, where failure is dominated by cohesive failure within the adhesive. The failure mode shown for the 0.4 mm thickness is dominated by cohesive failure for all overlap lengths. This indicates that an adhesive thickness of 0.4 mm is the optimum condition for this adhesive, as shown at an overlap length of 20 mm. As for the 0.6 mm thickness, although cohesive failure still dominates, interface failure also occurs, especially at the 30 mm overlap length.

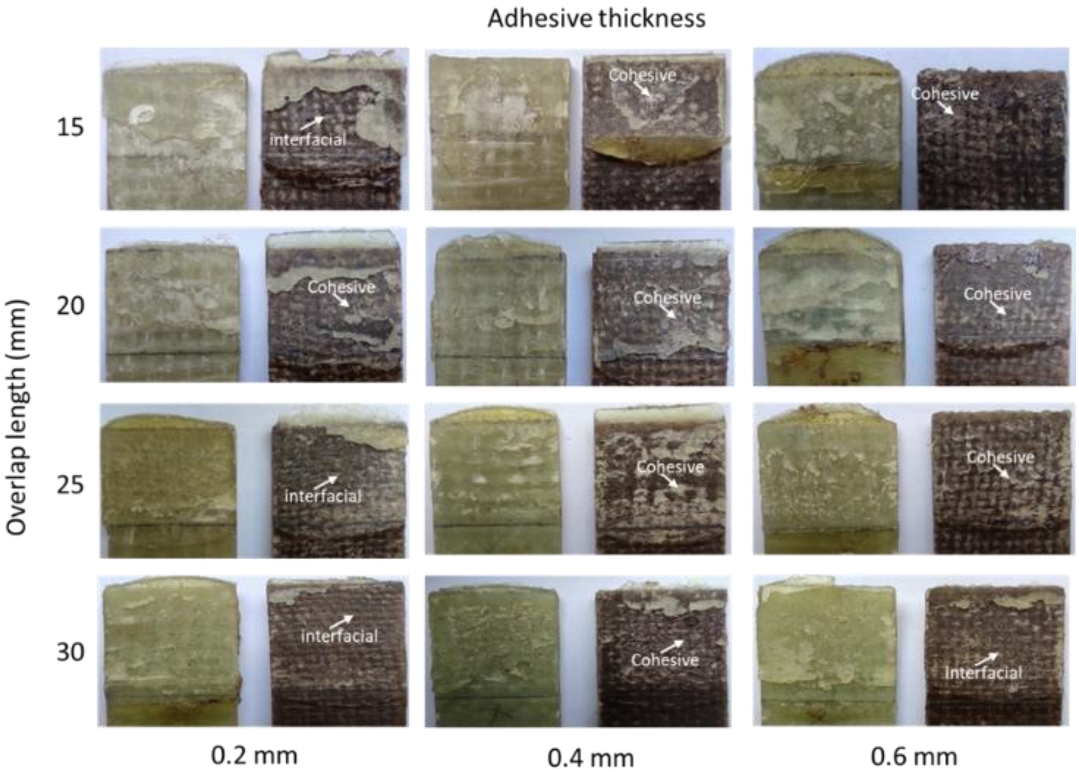

Figure 5 Fracture of jute composite and fibreglass composite joint specimens. Images may not represent the actual size

4. Conclusions

Based on the research and discussion results, it can be concluded that the effects of overlap length and adhesive thickness on the shear strength of jute-fibreglass composite joints are significant. The shear strength generally decreases with increasing overlap length between 15 mm and 30 mm. The effect of thickness is significant at overlap lengths of 15 mm and 20 mm, but at 25 mm and 30 mm, it does not show a significant difference. The highest shear strength is obtained at a 20 mm overlap length joint with a 0.4 mm adhesive thickness. Based on the findings, a shorter overlap length of up to 20 mm and an adhesive thickness not exceeding 0.4 mm are recommended for joining natural fibre-reinforced composites with fibre-glass-reinforced polymer composites.

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