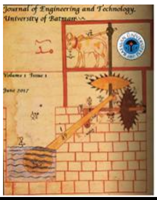
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Experimental investigation of strength of embedded strap lap joints under tensile loads

Bahattin İşcan

Batman University, Institute of Science, Mechanical Engineering, 72060, BATMAN/TURKEY

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* Corresponding author.
E-mail address:
bahattin.iscan@batman.edu.tr

A B S T R A C T

In this study, stress behavior of double strap joints under tensile load experimentally investigated. For reinforcing the joint, the strap plates were embedded in the main adherend. Dewveld 530 was used as adhesive material and glass fiber reinforced epoxy adhesive as adherend for experiments. Experiments were carried out for different adherend thicknesses, embedded heights, and overlap lengths. Results showed that increasing the height of the embedded cover plate resulted in decreased stress values in the adhesive layer. The most effective parameter was overlap length to on the strength of specimens.

1. Introduction

In the developing world, the increased need for energy has led to researchers to work on different materials and different manufacturing techniques. Composite materials and adhesive connection are gains of this situation. The usage of composite materials has increased steadily in automotive, aircraft, aerospace and marine structures and for combining composites different methods have been applied [1-3]. Especially in applications where weight is a critical parameter, the structures are typically formed with the aid of adhesive connections [4].

The most widely used models of the adhesive joints are the single lap joint, double lap joint, scarf lap joint and strap lap joint[5]. Several studies using different geometries and of the different methods are given below.

Sayman [6] has investigated elasto-plastic strain behavior of the adhesive bond analytically and by finite element methods. As a result of the study, it was found that the high shear stress occurs in the thin plate, increase of the plate thickness reduces the shear stress. Topkaya and Solmaz [7] investigated the mechanical properties of the hybrid assembled, rivet and adhesive joints by the progressive failure analysis method. They found that the mechanical properties of the connection were enhanced with increasing of the overlapping distance. Temiz investigated application of bi-adhesive in double strap joints under bending load. It was seen that using bi-adhesive technique is increased the strength of joint [8]. Reis et al. investigated the effect of adhesive overlap length on the ultimate joint strength, experimentally and numerically. They found that the overlap length should be 15–30 mm and by increasing this length, the values of peel and shear stresses increase [9]. The effect of surface treatment on the strength of adhesive joints was investigated by Rudawska. Results showed that the applied mechanical treatment favorably affected the strength of adhesive joints. The highest shear strength was obtained for the joints whose surfaces were subjected to lapping [10]. Zou et al. [11] in their research work based on analytical and numerical analyses, investigated single lap and single strap joints in terms of shear and peel stresses. They proposed a solution which was capable of determining the boundary forces at the two overlap edges (i.e., the shear and tensile forces, as well as bending moment), as a function of the applied loads. The integrity of the proposed solution was evaluated through several case studies. The results obtained from the analytical solution were compared with those obtained from a finite element analysis, and a reasonable agreement was found in all cases investigated.

In the present study, the strap lap joint is subjected to tensile tests. The 530 Dewveld was used as adhesive material while the glass fiber reinforced composites are used as adherends. The parameters used for the study are the overlap length, adherend thickness and height of the embedded part.

2. Materials and Methods

In present study, the embeddedjoint of glass-fiber reinforced composite material was made and for different overlap length (L), the embedding depth (H) and the adherend thickness (C) the failure loads were determined experimentally.

Table 1. Material properties

Material	E1 ,E2 (GPa)	ν_{21}	ν_{32}
GFRP Composite	20.5	0.3	0.25
Adhesive	1.82	0.37	

The image and dimensions of the models are given in Figure 1. The values shown as L, C and H and represent the parameters used during the study. All surfaces of the reinforced plate and adherends connected were coated with 0.2 mm layer of adhesive. A mold designed to adjust the adhesive layer thickness, and the samples were allowed to cure in the prepared mold.

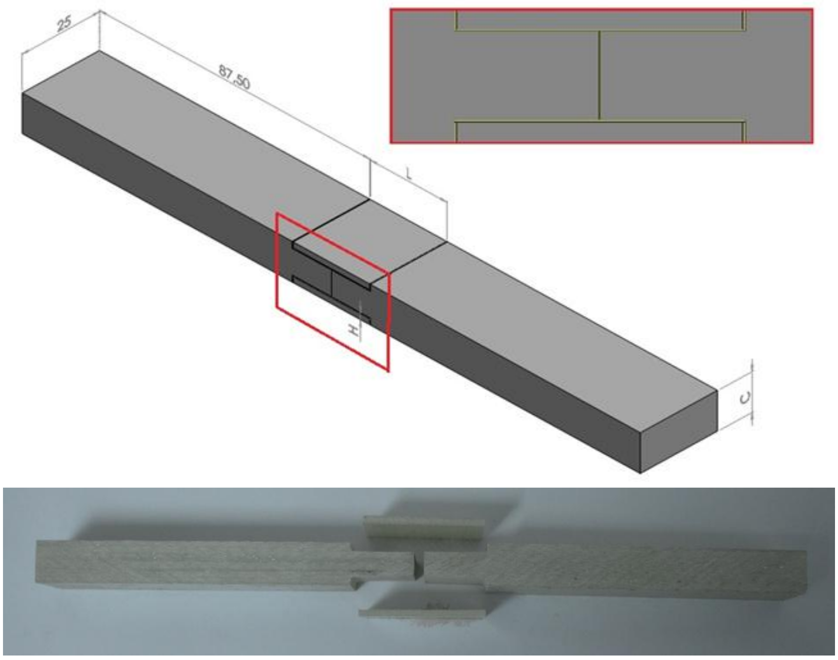


Figure 1. Dimensions of models

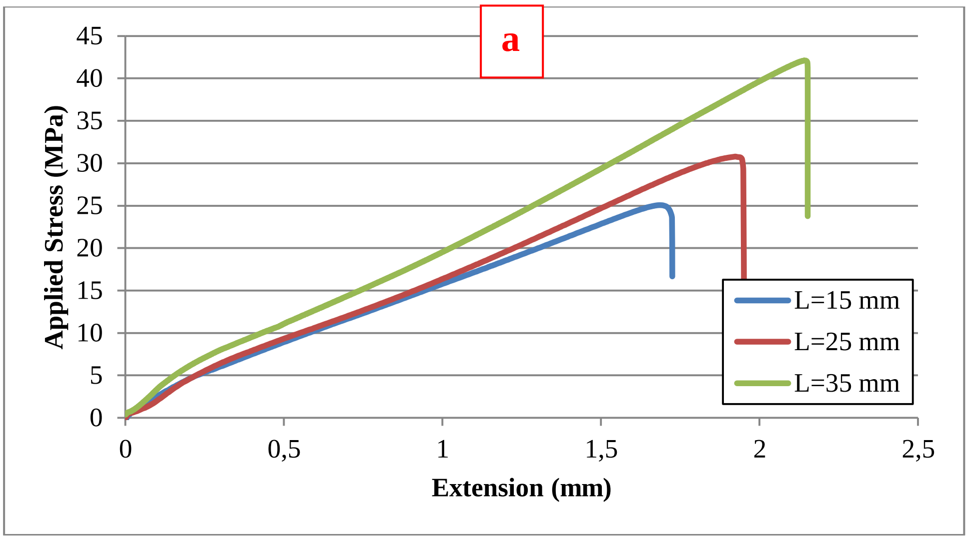
Mechanical properties of Dewveld 530, used as an adhesive for glass fiber-reinforced composite sheet used as adherend, are shown in Table 1. Devweld 530 was as two parts 1-1 methacrylate adhesive designed for structural bonding of thermoplastic, metal and composite assemblies. Devweld 530 offers a combination of high strength and stiffness as well as the ability to bond a wide range of materials.

Figure 2. Experimental setup

After the bonding process, three samples for each parameter were subjected to tensile tests. Tensile tests were conducted at Schimadzu brand universal testing machine with a capacity of 250 kN at ambient conditions. During the experiments, the jaw speed is set as 0.5 mm/min. A specimen, connected to the test device, is given Figure 2.

3. Results and Discussion

As a result of the experiments, for different adherend thickness, the effects of the total overlap lenght on applied force- total deformation behavior are given in Figure 3.



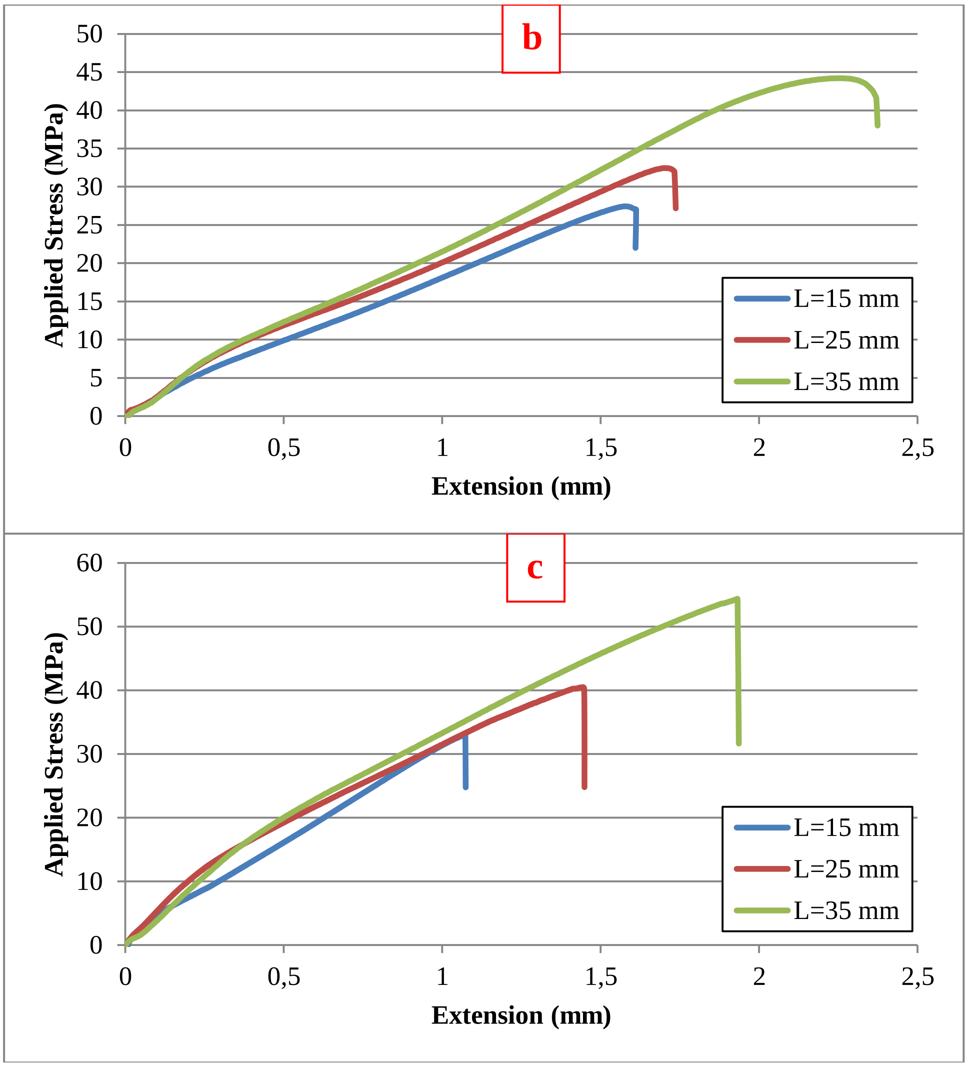


Figure 3. a. For H = 1 mm, b. H = 1.5 mm, c. H = 2 mm, the effects of length of overlap on the behaviour of applied force-deformation

For three different overlap distance and H values, the effect of adherend thickness on applied load-displacement behavior is given in Figure 4.

For all adherend thickness (C) values and embedded part height (H) values, the total overlap length has increased the failure load (FL). The effect of increase of the total overlap length from 25 mm to 35 mm on FL is more apparent than the case of 15 mm to 25 mm. In the case of C=12 mm, and H=1.5 mm FL has 12632 N values for the model. For the same C and H values, in case of 25 mm decrease in overlap length the FL value was decreased by 37% and has the value of 9236.7 N. In the case of overlap length of 15 mm, in comparison to the case of 25 mm overlap length, the FL value was 23% lower and FL value has been seen as 7519.531 N. For models in which C = 10 mm and H = 1 mm, in overlap distances of 15, 25 and 35 mm, FL values were observed 7079,688 N, 8389.844 11304.69 N, respectively. As for the model in which C = 8 and H = 2 mm and for overlap length of 15 mm, FL value was 6450.781 N, for overlap length of 25 mm, it was found as 7818.75 N and for overlap length of 35 mm it has been as 9425,781 N.

For 15 mm overlap distance, in the model in which H = 1.5 mm, for C = 8 mm FL = 6563,281 N, for C = 10, FL = 6910,156 N and for C = 12 mm FL = 7519,531 N. for 25 mm overlap distance, in the model in which H = 1 mm, for C = 8 mm FL = 8097.656 N, for C = 10, FL = 8389.844 N and for C = 12 mm FL = 9385.156 N. for 35 mm overlap distance, in the model in which H = 2 mm, for C = 8 mm FL = 9425.781N, for C = 10, FL = 11050.78 N and for C = 12 mm FL = 12188.28 N.

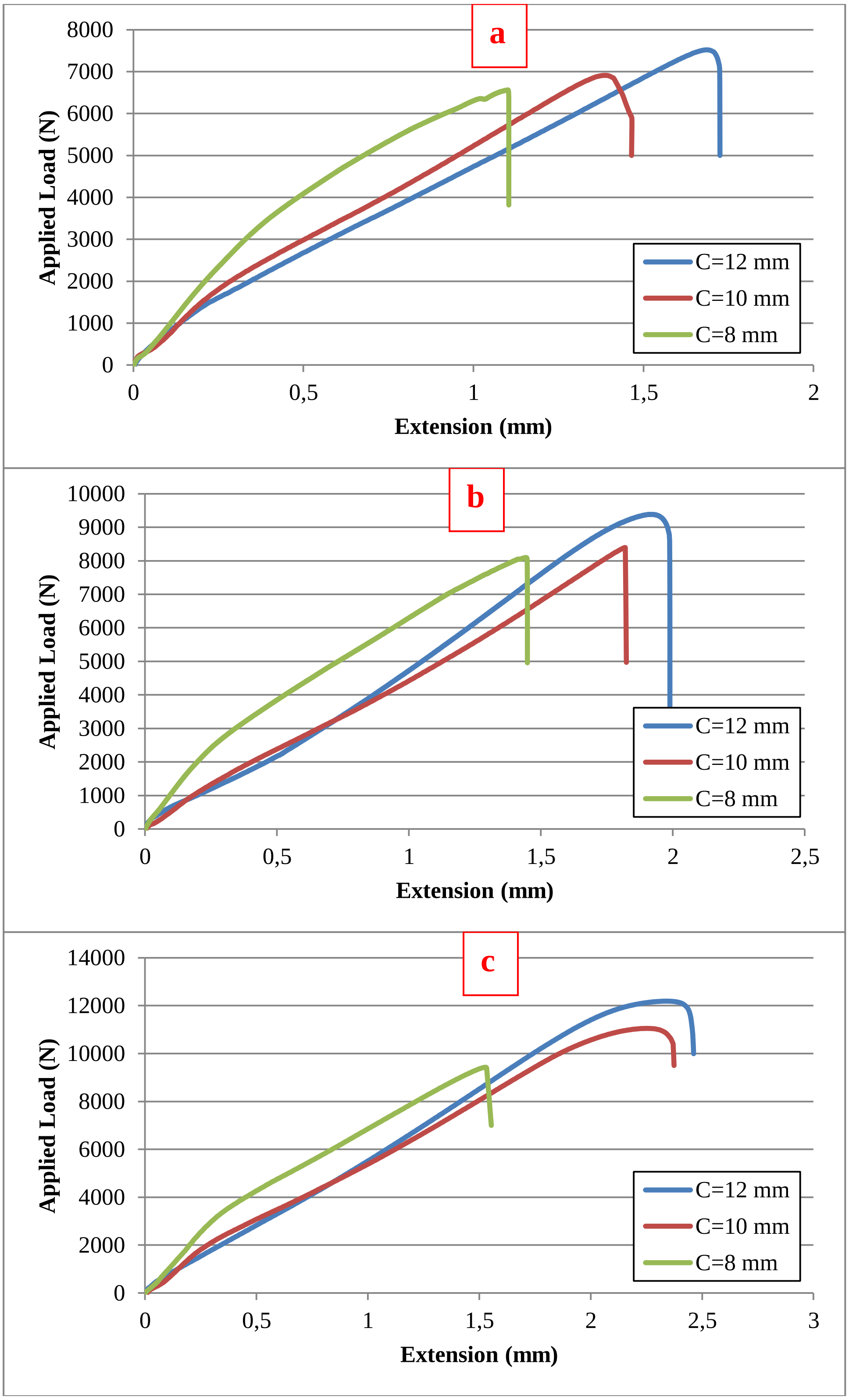


Figure 4. Effect on adherend thickness on behavior of applied load-displacement for L = 15 mm b. L = 25 mm c. L = 35 mm conditions

In the models with adherend thickness of 12 mm, for three different overlap length values, the effects of h value on behavior of applied load-displacement are given in Figure 5. for models with overlap length of 15 mm, when H = 1 mm, FL = 7713,281 N, for H = 1.5 mm, FL=7519,531 N and when H = 2 mm FL = 7490,625 N.

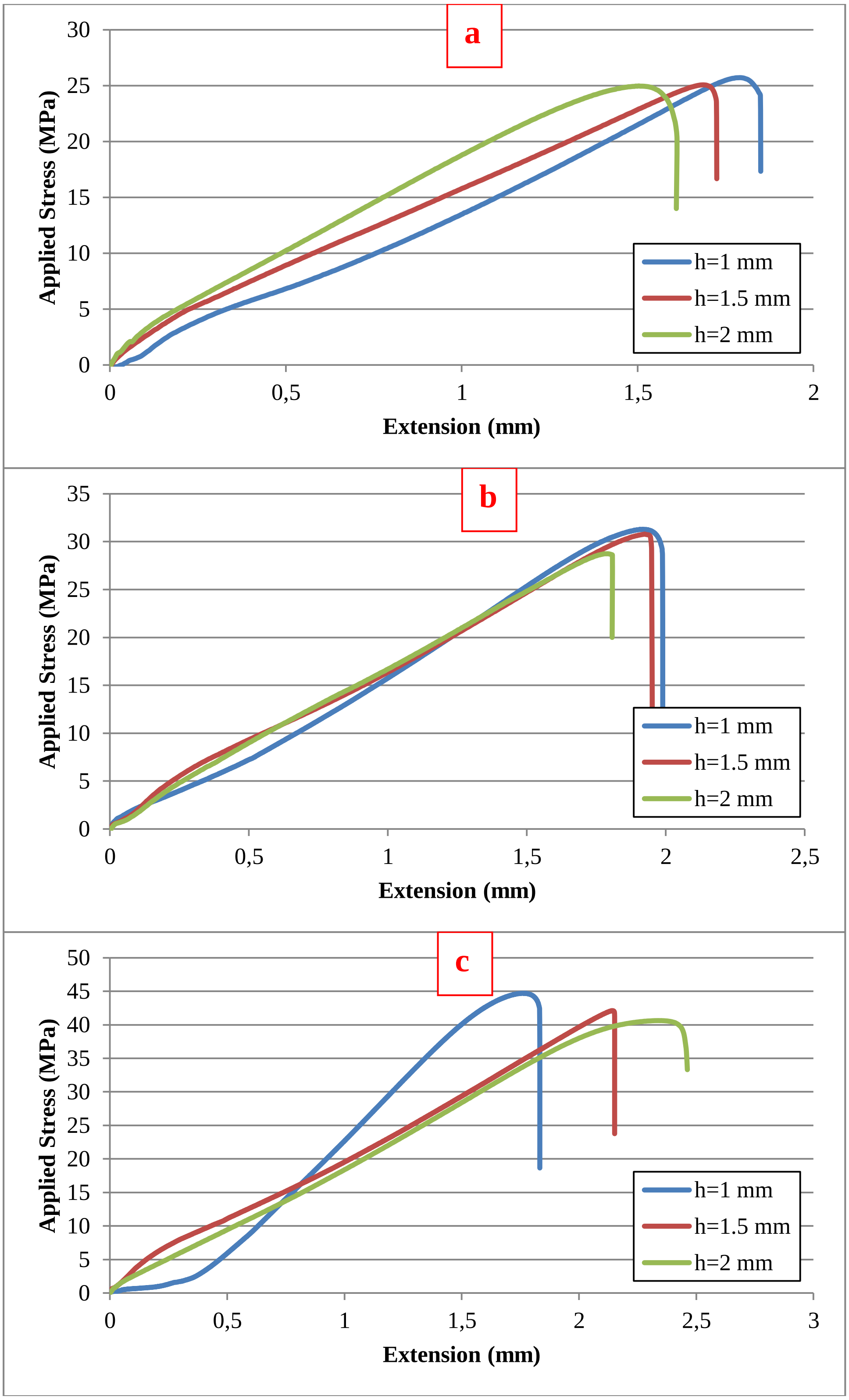


Figure 5. in the models with adherend thickness of 12 mm, for three different overlap length values(a.) L = 15 mm b.) L = 25 mm c.) L = 35 mm), the effects of h value on behavior of applied load-displacement

When compared to the conditions of 15 mm overlap length, in the case of overlap length increased to 25 mm, the FL values, for H = 1 mm, H = 1.5 mm and H = 2 mm, increased to 9385,156 N, 9236.7 N and 8621.1 N by ratios of 22%, 23%, and 15%,respectivelly. Overlap length 35 mm case of FL values of 25 mm overlap length according to H = 1 mm 43% increase 13409.38 N, H = 1.5 mm for the 37% increase 12632.81 N and H = 2 mm for the 41% increase 12188.28 N has value. when compared to the conditions of 25 mm overlap length, in the case of overlap length increased to 35 mm, the FL values, for H = 1 mm, H = 1.5 mm and H = 2 mm, increased to 13409.38 N, 12632.81 N and 12188.28 N by ratios of 43%, 37%, and 41%,respectivelly.

4. Conclusions

In the study, glass-fiber reinforced composite plates were bonded with the embedded strap lap joint technique. The effects of overlap length, adherend thickness and embedded part failure load height to the experimentally investigated. The evaluations that were made in the light of the obtained results are given below.

Results showed that failure load increases with the increas of overlap length. with the increase of overlap lenght, the bonded are is increased. This case clarifies the increasing value of FL. The increased adherend thickness (C) caused to higher failure load. The bonding of area between the composite plates with increased adherend thickness have also provided more area to be bonded. As described above, the increased bonding area increases FL value. In other words failure load increases with increasing bonding area. The increase in value of Embedded part height (H) has caused to decrease in the value of FL.

when the values of deformation existed during the experiments are examined, the highest variation between deformation values among the models are observed when the overlap length is changed. Increasing the height of the overlapping part led to decrease in deformation. the change of adherend thickness have slightly effected on behavior of applied load-displacement.

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