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Bond Strength of Natural Euphorbia Abyssinica Adhesive with Wood

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Abstract : An adhesive is a substance that fastens two surfaces together. The purpose of this study was to determine bond strength, effect of bond line thickness on strength of natural *Euphorbia Abyssinica* adhesive with wood. The single lap joint specimen pressed with 10 kg weight during bonding with the studied adhesive for 4 days and left for 5 days without weight to cure at room temperature and humidity, then after 11 days tensile test performed using Universal Testing Machine. The result shows that the bond strength of the studied adhesive with wood was found to be 14.76 MPa with standard deviation of 3MPa. The shear strength of the studied adhesive bond with wood was larger than adhesives like polyurethane and polyvinyl acetate bond strength. This paper concludes that the shear strength data found in this research could be used to predict failure strength of the bond during design so that the adhesive applied in assembling engineering product parts.
Key words: *Euphorbia Abyssinica* naturaladhesives, curing time, single lap joint, polyurethane, polyvinyl acetate, shear strength.

1. Introduction

An adhesive is a polymeric material that binds two surfaces together and resists separation.

Adhesives join similar or dissimilar materials with or without the mechanical fastening methods like bolting. In reference[1,2], it has been suggested that the different joint types are scarf joint, step lap joint, double strap joint, single strap joint, double lap joint and single lap joint. Because of the simplicity, easy and cheap to manufacture and efficient geometry to characterize an adhesive joint, industries use single lap joint in assembling product parts most of the time was studied in[1-3]. This study also accommodate single lap joint for its simplicity.

For the analysis of adhesive bond strength in single lap joint different assumptions are made as follows was studied in[1-3] :-Linear elastic analysis: consider un-deformable substrates with a constant shear stress state.

Volkersen's analysisconsiders substrate deformation and single lap joint has no bending moment and therefore substrates are in pure tension. Goland and Reissner analysis introduce adherent bending and with it a peel stress in the adhesive layer.

In this paper, the linear elastic analysis for similar materials is taken to calculate shear stress in single lap joint adhesive layer for its simplicity.

In reference[1,3,4], it has been suggested that for adhesive bonded joints, according to ASTM standard D: 5573-99 there is seven classes of failure modes in adhesive joints.

Adhesive failure (AF) (sometimes referred to as interfacial failure), separation appears to be at the adhesive-substrate interface.

Cohesive failure (CF): separation is within the adhesive.Thin layer cohesive failure (TLCF) (sometimes referred to as inter-phase failure): failure similar to cohesive failure, except that the failure is very close to the adhesive – substrate interface, characterized by a light dusting of adhesive on one substrate surface and a thick layer of adhesive left the other.

Wood as an engineering material should be improved to apply in building construction and furniture industry. The dimensional stability and mechanical properties of wood is improved through laminating (layering) like plywood and cross laminated timber panels are best examples. In reference[5], it has been suggested that shear strength of adhesive bonded wood evaluated by means of standard test methods like the standard shear lap joint testing method corresponding to EN 205(European committee for standardization 2003) used for the evaluation of adhesive bonds in solid wood materials. This study follows the same standard in determining of bond strength of the studied adhesive with wood.

The thickness of the adhesive in bonding should be controlled. The studies[6,7] show that to get the required thickness of adhesive in the bond shim inserted during bonding. Tabs cut from the same material were bonded at each end to improve alignment and reduce the eccentricity of the load path that causes out of plane bending when the specimen is tested was studied in[8].

In adhesive bonding, wetting is a procedure that determines the diffusion of adhesive over a solid surface (substrate), creating an intimate contact between them. Good wet ability of a surface is a prerequisite for adhesive bonding was studied in[9]. In reference[10], it has been suggested that application of pressure during fastening of materials using adhesive increases the wet ability of a surface as a result bond strength increases where as excessive pressure decreases bond strength.

In reference[11], it has been suggested that how the wood specimen clamped during tensile test was determinant to get good data. Adhesives depend on load rate and time to failure should be (60 to 90 seconds) and the minimum number of specimens should be five was studied in[12]. This study was taken five samples, 60 to 90 seconds failure time.

In villages of Ethiopia (Tigray region) *Euphorbia Abyssinica* natural adhesive had been in use in fastening wood and paper for years traditionally. But till now, no enterprise or workshop that manufacture or assemble wood furniture use this natural adhesive rather use imported adhesive in wood assembly. This was because no scientifically determined design data on bond strength of *Euphorbia Abyssinica* natural adhesive on wood to predict failure strength during design was determined.

The purpose of this paper was to determine bond strength of Euphorbia Abyssinica natural adhesive on wood and the effect of bond line thickness on bond strength. The study[13] shows that polyurethane and polyvinyl acetate are wood adhesives and their shear strength with wood was calculated.

This paper will open researches on Euphorbia Abyssinica natura adhesive bonding capability with different materials and solve the shortcomings through improvement to the adhesive.

2. Methods and Materials

2.1 Experimetal Test to Determine Bond Strength

There are different joint types like scarf joint, step lap joint, double strap joint, single strap joint, double lap joint and single lap joint to determine bond strength of Euphorbia Abyssinica adhesive. This study determines bond strength of the adhesive on wood using single lap joint because it was cheap, easy and simple to manufacture.

2.1.1 Experimental procedure for wood bond strength test

A) Bond strength test specimen dimension

A.1) Standard bond strength specimen dimension

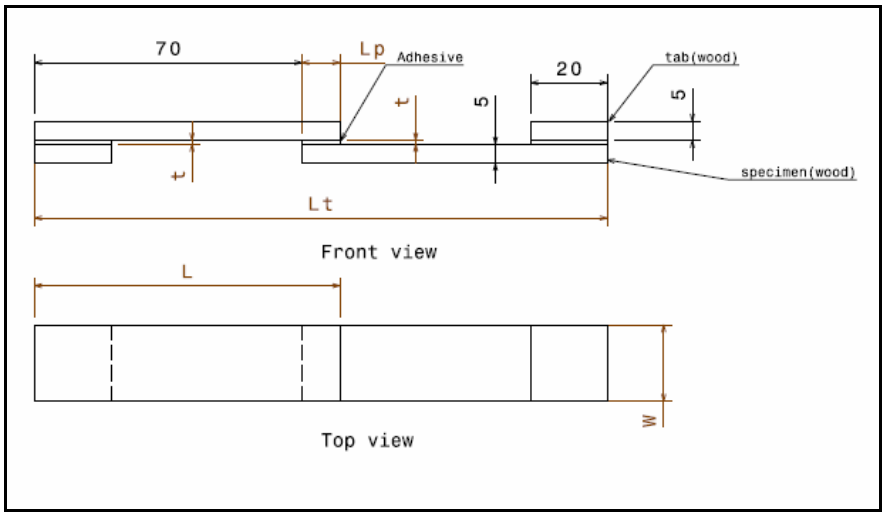

Figure 2 .1 wood specimen dimension in mm according to EN205:2003 standard

According to the standard EN 205:2003[5] the dimensions of the variables in figure 2.1 above:- L=80mm, w =20mm, Lp=10mm,Lt=150mm.

But (t=cactus bond thickness) was not specified in the standard.

A.2) Bonding wood specimen by varying adhesive thickness (t=0.25mm,t=0.5mm and t=0.8mm)

In this research bond strength determination of the adhesive on wood based on the standard figure 2.1 dimension and varying bond thickness (t=0.25mm, t=0.5mm and t=0.8mm) was performed. The standard specimen dimension (80*20*5mm) and tab dimension (20*20*5mm) was made from the same material (wood) using hack saw.

To get the required thickness of adhesive in the bond, bonding shim was inserted during bonding. The shim used in this experiment were 0.25mm thick aluminum foil prepared using small scissor, 0.5mm and 0.8mm thick sheet metals prepared using metal cutting machine.

To make the assembled specimen as shown in figure 2.1, the two specimens should be bonded using adhesive. To make such a bond, the adhesive was poured carefully into the bond area, after that the shim, spacer, the second specimen and tab was put on their position as shown in figure 2.2. The assembling was done on flat table which was coated with releasing agent (silicone) for specimen not to fasten with table and others. After that a 10 Kg load was loaded to make the adhesive to spread at room temperature and humidity of the lab.

10 kg weight was used to press the joint for 4 days and then the specimen remained for 7 days without weight.The test was done after 11 days. Figure 2.3 shows specimens after shim, spacer removal.

Tabs cut from the same material, were bonded at each end to improve alignment and reduce the eccentricity of the load path that causes out of plane bending when the specimen is tested.

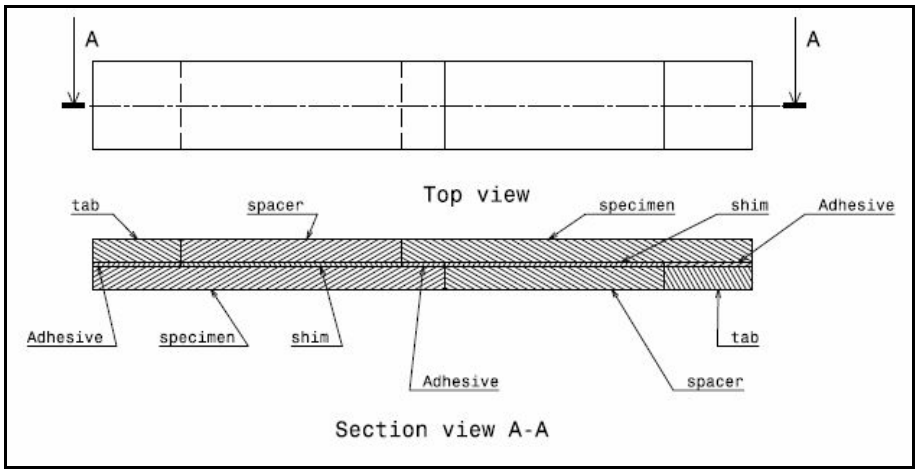

Figure 2 .2Section view of Euphorbia Abyssinica adhesive bonding components using modeling software CATIA

Figure 2.3Single lap joint wood specimen after shim and spacer removal before test

B) Test procedure

B.1) Test setup and loading equipment

The machine used in bond strength determination was a universal testing machine (testometric) M500-50KN capacity. The specimen was connected to the load cell and 500Kgf load cell installed as shown figure 3.4 . The pair of the grips where the specimen was inserted has knurl which can press soft specimen like wood and not to slide during testing. The testing Machine controller was set to raise the cross head at a speed of 6 mm/min, and time to failure was 65 seconds. In each test, the peak load where the adhesive/wood bond fails was displayed.

B.2**) Instrumentation and measurement**

The result of data reading based on the input was displayed on the screen of computer of the machine. After that the data was taken by capturing through camera. The output data needed in the adhesive/wood bond strength determination was peak load, the load where the bond fails. The sample size taken in bond strength determination was 5 specimens per each bond line thickness tested.

Figure 3.4 Single lap joint wood specimen clamped by the knurled jaw for testing

3. Results and Discussions

3.1 Results

3.1.1 Experimental test to determine bond strength

The specimens were subjected to uniaxial load until they failed in the universal testing machine (testometric) as mentioned in methodology. The cross head speed was maintained at a rate of 6mm/minute and the specimen failed within 65 seconds. The test was performed at room temperature and humidity in material testing lab room.

The tensile test results of Euphorbia Abyssinica adhesive bonded with wood specimen stayed for 11 days before test(4 days pressed with load) and with 5 number of specimens each for different bond line thickness was arranged .

A) Average failure load Vs bond line thickness of Euphorbia Abyssinica adhesive with wood

Table 3.1 shows the result of single lap joint bond strength test for natural Euphorbia Abyssinica adhesive bonded to wood.

Table 3.1Effect of bond line thickness on failure load

Specimen Material	Number of specimen	Lap length(mm)	Bond line thickness(mm)	Average Peak load(KN)
wood	5	10	0.25	2.95?0.60
wood	5	10	0.5	1.8?0.57
wood	5	10	0.8	1.33?0.40

B) Average failure shear stress Vs bond line thickness of Euphorbia Abyssinica adhesive with wood

Based on the shear stress equation, the calculated result was as follows:-

Table 3.2shear strength of Euphorbia Abyssinica with wood bond based on failure load results

Specimen material	Bond line thickness(mm)	Lap length(mm)	Average failure load(KN)	Shear area (mm^2)	Average shear stress(MPa)
wood	0.25	10	2.95?0.60	200	14.76?3.00
wood	0.50	10	1.8?0.57	200	9.07?2.90
wood	0.80	10	1.33?0.40	200	6.63?2.00

C) Failure mode

The following specimens are captured through camera after tensile testing of Euphorbia Abyssinica adhesive with wood bond strength failure. The number written on the specimen (t=0.25) were to show the standard bond line thickness and lap length of 10mm. The failure modes were shown in the figures below.

Figure 3.1Results of 0.25mm bond line thickness and lap length 10mm specimen after bond failure

3.2 Discussions

3.2.1 Experimental test to determine bond strength

A) Effect of bond line thickness on Euphorbia Abyssinica adhesive bond with wood

Based on figure 3.2, it was easy to break the bond when the bond line thickness increases. This is because as bond line thickness increases the probability of void and crack creation on the bond which leads to weaken bond strength increases as studied in [7].

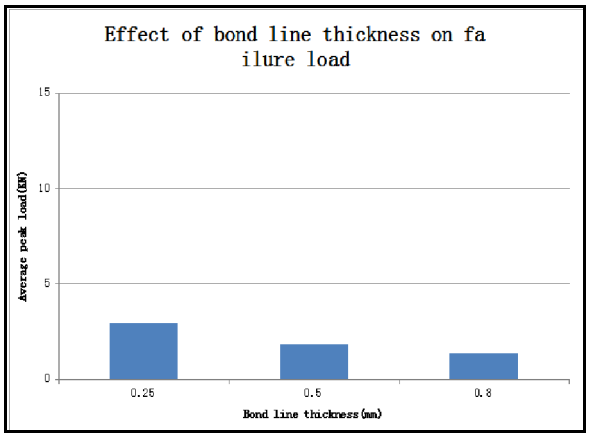

Figure 3.2Average failure load Vs bond line thickness of Euphorbia Abyssinica adhesive bond with wood

B) Failure shear strength Vs bond line thickness of Euphorbia Abyssinica adhesive bond with wood

The shear strength on the single lap joint based on the failure load and lap area was calculated and it was decreasing with bond line thickness as shown in figure 3.3 below.

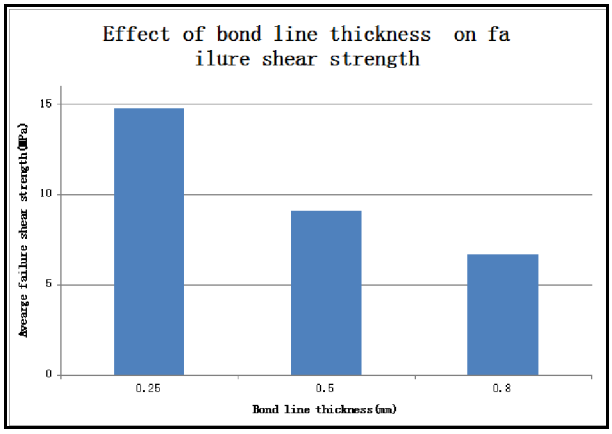

Figure 3.3Average failure shear strength Vs bond line thickness of Euphorbia Abyssinica adhesive bond with wood

C) Failure mode of Euphorbia Abyssinica adhesive bond with wood

From the figure3.1, the result of bond strength five pairs of specimen where each pair was one bond was shown. The failure mode for the bond strength is as follows- the first pair specimen in figure3.1was thin layer cohesive failure because more adhesive is on one substrate and small adhesive remain on the other substrate; the second , third and fourth pair specimen from figure 3.1, were cohesive failure because the bond fails in the adhesive leaving equal adhesive on both substrates after failure. The fifth pair specimen from figure 3.1 was adhesive failure because the entire adhesive is on one substrate.

Cohesive failure within the adhesive or one of the substrates shows the maximum strength of the materials in the joint has been reached was studied in[8]. In this study many specimens fail cohesively at the substrate (wood) rather than on the adhesive bond because of the high shear strength of *Euphorbia Abyssinica* adhesive relative to wood.

D) Comparison of Euphorbia abyssinica adhesive bond with other adhesives bond

The bond strength test for natural *Euphorbia Abyssinica* adhesive with wood was performed at rate of 6mm/minute, so that the adhesive bond to fail within 65 seconds to avoid rate effect. This test was performed at room temperature and humidity. To obtain the peak load at which the bond fails, the samples were tested according to EN 205 single lap joint dimension. The curing time and weight applied during bonding was 11 days and 10 kg respectively. In this study bond strength was tested at 0.25mm, 0.5mm and 0.8mm bond line thickness and total specimen dimension was according to[14]. For comparison 0.25mm bond line thickness which has large shear strength was selected. The studied adhesive bond with wood shear strength value is as shown in table 3.3.

The bond strength to be compared with the studied adhesive bond with wood was polyurethane (PU) adhesive/wood and polyvinyl acetate (PVAc) adhesive/wood bonds. In reference[5], suggested that PU and PVAc adhesives are widely used in the construction of layered wood materials as well as in the manufacturing process of wooden structures and furniture. The shear strength of these adhesives with 5 samples was tested according to EN 205 was studied in[5] which is the same with the studied adhesive. The bond strength was made to fail at 60 seconds in similar range with the studied adhesive according to standard (60seconds to 90seconds). The environment for PU and PVAc adhesive bonds with wood test was at 20?c and 65% relative humidity was studied in[15] which are similar with the studied adhesive environment room temperature and humidity. The difference with the studied adhesive wood bond test was thickness which do not mention on standard. The shear strength value for PU and PVAc adhesive bond with wood was as shown in table 3.4.

Table 3.3Shear strength of wood bonded with Euphorbia Abyssinica adhesive

Substrate	Adhesive	Bond line thickness(mm)	Average shear strength(MPa)
wood	Euphorbia Abyssinica	0.25	14.76

Table 3.4Shear strength of oak wood bonded with PU and PVAC adhesive [15]

Substrate	Adhesive	Average shear strength(MPa)
wood	PU	12
wood	PVAC	12.31

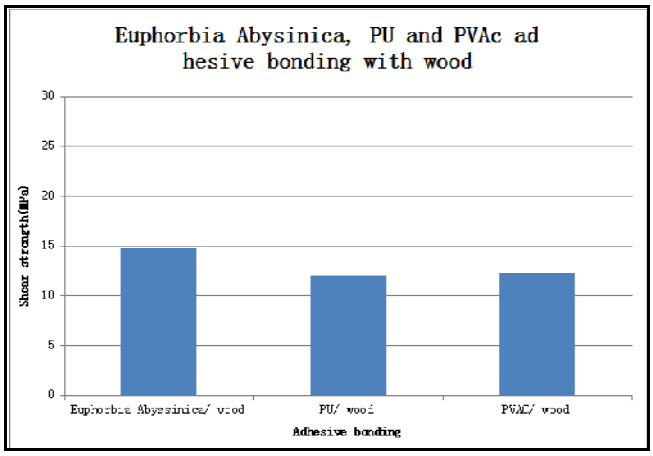

Figure 3.4 comparison of bond strength of Euphorbia Abyssinica, PU and PVAC adhesives with wood

According to the figure 3.4, the shear strength for Euphorbia Abyssinica adhesive/ wood was larger than PU adhesive/ wood and PVAc adhesive/ wood bonds even though everything is the same except the thickness of the bond which was not mentioned on the standard. This shows the bonding capability of Euphorbia Abyssinica adhesive for wood was better than the PU and PVAC adhesives. Hence applicability of Euphorbia Abyssinica adhesive in bonding wood on the furniture industry is acceptable.

4. Conclusions

Euphorbia Abysinica adhesive single lap joint shear strength test with wood was performed on different bond line thickness. The maximum shear strength was found at 0.25mm bond line thickness with value of 14.76MPa and standard deviation3. The shear strength at 0.5mm and 0.8mm bond line thickness was 9.07-2.9MPa and 6.63-2MPa respectively thus to conclude that the shear strength data found in this research could be used to predict failure strength of the bond during design so that the adhesive can be used and applied in assembling engineered products and components.

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