Synthesis of Novel adhesive for Bamboo Joinery and comparison of its Mechanical Properties with adhesives available in the Market

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Abstract

In this study, novel adhesive applicable for bamboo joinery has been synthesized using liquefied bamboo (Timber Bamboo) as an alternative to traditional phenol formaldehyde resins. The most objective of this work is to test the feasibility of using liquefied bamboo as stuff for the synthesis of Adhesive. The newly synthesized adhesive was analyzed for its physico-chemical parameters and mechanical properties using different bamboo species and was compared with those of adhesives available within the market. Mechanical properties like tensile strength, compressive strength and shear strength were tested on different samples of bamboo species using newly synthesized adhesive and the adhesives available within the market. The tests were administrated on Universal Testing Machine at room temperature. The results showed that the most values for mechanical properties were obtained when Asian Paints (Loctite touch) was used as an adhesive.

Keywords: *Adhesive, Bending strength, Compressive strength, Mechanical properties, Tensile strength, Shear strength*

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1. Introduction

Bamboo can be harvested in 3-4 years from the time of the plantation and this is the principal reason for replacement of wood by bamboo [1][2]. “Bamboo being a non wood lignocellulosic material and is used widely for construction, furniture and many daily domestic uses”. In recent times, it has been used as a raw material for wood products manufactured in Asian factories, such as for paper and pulp, plywood, Medium Density Fiberboard (MDF), particleboard (PB) and Oriented Strand Board (OSB) because of its high strength and properties [3]. “Bamboo has many uses including bamboo culm or stem as a raw material for domestic household products to industrial applications”. In Asian countries, it is a common material used for bridges, scaffolding and housing where it supplied as a suitable material. It is economically cheap and abundantly available for construction of economical houses [4]. Since in some of centuries bio-based adhesives was used for bonding of wood. In 20th century, because of more effectiveness and low cost synthetic adhesives took over. This is increase in the utilization of engineered wood products with more use of wood as well as other plant resources, such as bamboo [5]. Many adhesive have been reported to be synthesized from wood, paper pulp and coconut shell [6].However, utilization of liquefied bamboo in the synthesis of adhesive has not been reported yet. The main objective of this work is to check the feasibility of using liquefied bamboo as a raw material for the synthesis of adhesive [8]. The liquefied bamboo was used as a source of lignocellulosic filler whereas wheat flour is used as a proteinaceous extender.

Material characteristics

Liquefaction of Bamboo:

Bamboo dust of timber bamboo (Bambusa Oldhamii) is used for the production of liquefied bamboo. During liquefaction of bamboo Glycerol was used as a reaction agent and sulphuric acid was used as a catalyst. The Glycerol of Organo Biotech Laboratories Private Limited Company with 98% purity is used. The ratio of bamboo dust and glycerol used is 1:3 by mass and 3% sulphuric acid is added as a catalyst. This mixture is taken in a round bottom flask and heated in an oil bath at 1800C for 90 minutes. After the reaction is complete the round bottom flask was removed and cooled immediately under cold water to quench the reaction.

Fig 1. Oil bath with flask showing the liquefaction of bamboo

Preparation of Adhesive Mixture:

The adhesive mixture is prepared by mixing 25% liquefied bamboo (Prepared with timber bamboo dust and Glycerol) and 75% phenol formaldehyde. Phenol formaldehyde is a resins used to manufacture high-pressure laminates. These resins are typically produced by

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reacting phenol and formaldehyde by means of an alkaline catalyst such as sodium hydroxide. A cyclic urea prepolymer in phenol/formaldehyde resins works as a plasticizer for the resin. Five parts of wheat flour is added as proteinaceous extended to 100 parts of this mixture.

Fig 2. Oil bath with flask showing Adhesive mixture

The main objective of using phenol formaldehyde in this preparation is having several advantages such as high mechanical strength, heat resistance and dimensional stability as well as high resistance against various solvents, acids and water (Knop et al., 1985; Kopf and Little, 1991; Gardziella et al., 2000). In addition to this "they also have excellent electrical and thermal insulation capabilities and excellent cost performance characteristics" [6]. Specific advantages which make its use more special are low levels of formaldehyde release and low thickness swelling of phenol bonded boards [8].

Result and Discussion:

Physico-Chemical properties of synthesized adhesive:

The newly synthesized adhesive is found to be insoluble in water, chloroform, benzene, alcohol, dimethyl formamide in cold condition, however, partially soluble in water, alcohol and dimethyl formamide in hot condition. The specific gravity is 1.17 tested by using ASTM D792 method and moisture content is found to be 10.00% tested by ASTM D6980. Both these tests was carried out in Fan Services, Materials and Product Testing Laboratory, Nasik.

Infrared Spectral Studies:

IR is used both to gather information about the structure of a compound and analytical tool to assess the purity of a compound. It is useful for identifying certain functional groups and bonds present in a compound. Thus, an IR spectrum of a given compound is unique and can therefore serve as a fingerprint for this compound. However, the spatial scale at which is very important chemistry take place in wood cell wall is often well below the diffraction limit of conventional infrared spectroscopy (3–10 µm), so molecular-scale interactions cannot be easily studied in situ.

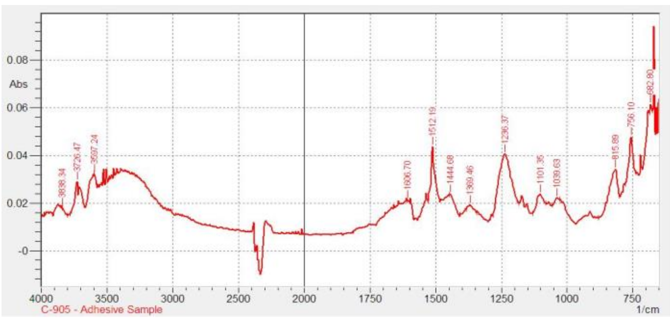

Fig 3: FTIR-ATR Spectroscopy synthesized adhesive

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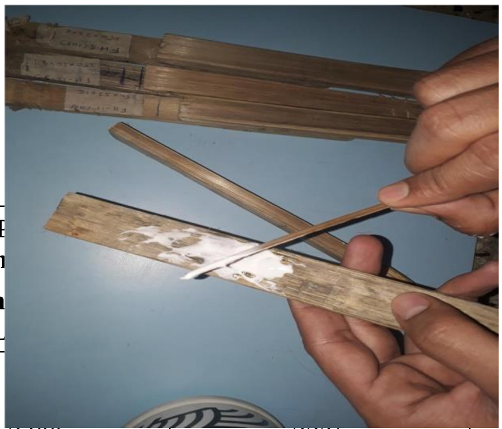
Table 1 : FTIR-ATR of Phenol Formaldehyde and Synthesized Adhesive

A bamboo fibre mainly consists of Cellulose (45-50)%, Hemicellulose (20-25)%, Lignin (20-30)% and Extractives (2.5-5)%. The IR band of synthesized sample at 1039 cm-1 and1236 cm-1 on the spectra may be attributed to C-O the stretching vibration in cellulose and hemicellulose while the absorption band at 1606 cm-1 and 1525 cm-1 may be attributed to C=C the stretching vibration in aromatic ring of phenol of phenol formaldehyde. The band at 1039 cm-1 and 1101 cm-1 appeared in the IR spectra of synthesized adhesive may correspond to the C-O-C aliphatic ether. In accordance with the literature the cross linking reactions of -OH group of bamboo polymer and phenol formaldehyde resin are seen in the synthesized adhesive

Mechanical properties:

The Mechanical properties such as tensile strength, compressive strength and shear strength were tested on different samples of bamboo species using newly synthesized adhesive and the adhesives available in the market. The tests were carried out on Universal Testing Machine at room temperature on the lap joint of different species of bamboo. The samples were prepared with specification of 250 X 30 X 10 mm and dried at room temperature for 7-10 days.

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O-H Stretching Vibration	[illegible]	[illegible]
C=C aromatic ring	1610	1606 & 1525
CH2 Scissoring	1460	1444
O-H in the plane (Phenolic)	1378	1369
Asymmetric the stretch of phenolic C-C-OH	1237	1236.37
C-O Stretching	1153	1101
-C-OH	1023	1039
C-H out of plane stretch B' glycoside linkage	885	815

Fig 4: Samples for testing

Fig 5: Application of adhesives on the sample

The test was carried on the samples for load displacement curves for specimens are almost bi-linear up to ultimate load. It is found that tensile failure strength and compressive strength of the market adhesives and synthesized adhesive was near about same. Maximum tensile strength and compressive strength of the specimens were observed as 0.026 N/mm^2 and 0.022 N/mm^2 respectively. Similarly for synthesized adhesive Maximum tensile strength and compressive strength of the specimens were observed as 0.020 N/mm^2 and 0.023 N/mm^2 respectively.

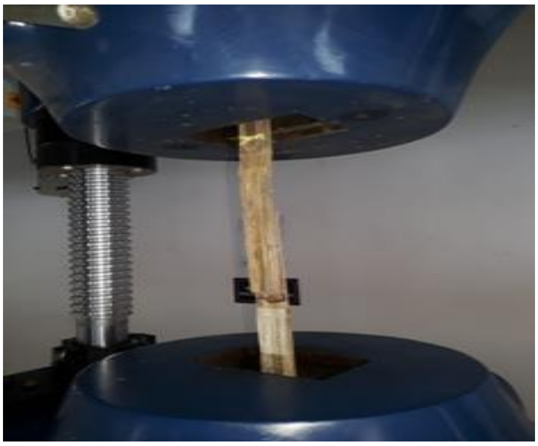

Fig 6: Tensile Strength Test

Fig 7: Compressive Strength Test

Table2: Tensile Strength of Market Adhesives and Synthesized Adhesive

Sample size	Tensile strength of Adhesives					
	Asian Paint	**Fevicol SR 998**	**Araldite**	Dendrite Supreme	**Fevicol Heat X**	**Synthesized Adhesive**
	Strength KN/mm2					
250*30*12	0.012	0.012	0.013	0.013	0.013	0.011
250*28*10	0.023	0.012	0.027	0.022	0.020	0.012
250*26*10	0.023	0.018	0.024	0.024	0.026	0.024
250*26*10	0.030	0.028	0.023	0.021	0.026	0.021
250*25*10	0.030	0.020	0.021	0.020	0.015	0.020
250*24*80	0.017	0.015	0.013	0.012	0.015	0.013
250*24*80	0.015	0.016	0.015	0.015	0.018	0.014
250*24*10	0.024	0.019	0.022	0.019	0.023	0.020
250*23*12	0.027	0.026	0.021	0.018	0.024	0.026
250*22*11	0.025	0.025	0.022	0.023	0.022	0.023

Table3: Compressive Strength of Market Adhesives and Synthesized Adhesive

Sample size	**Compressive strength of Adhesives**					
	Asian Paint	**Fevicol SR 998**	**Araldite**	Dendrite Supreme	**Fevicol Heat X**	**Synthesized Adhesive**
	Strength KN/mm2					
250*30*12	0.022	0.011	0.01	0.013	0.011	0.011
250*28*10	0.017	0.012	0.018	0.009	0.009	0.018
250*26*10	0.016	0.021	0.011	0.010	0.007	0.010
250*26*10	0.017	0.023	0.011	0.014	0.020	0.014
250*25*10	0.022	0.022	0.016	0.007	0.010	0.010

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250*24*80	0.023	0.014	0.015	0.005	0.005	0.014
250*24*80	0.023	0.014	0.021	0.006	0.007	0.007
250*24*10	0.018	0.021	0.022	0.008	0.009	0.019
250*23*12	0.019	0.008	0.020	0.013	0.008	0.010
250*22*11	0.017	0.018	0.028	0.008	0.007	0.020

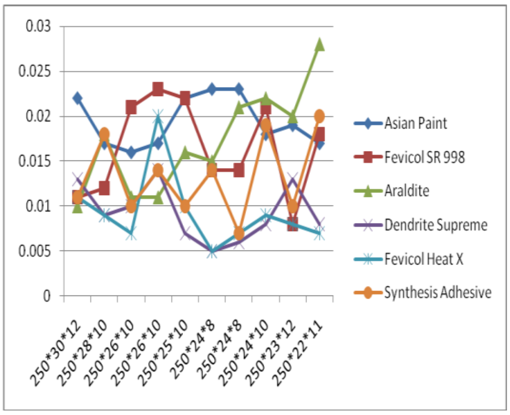

Fig 8: Graph showing Sample Size Vs Tensile Stress

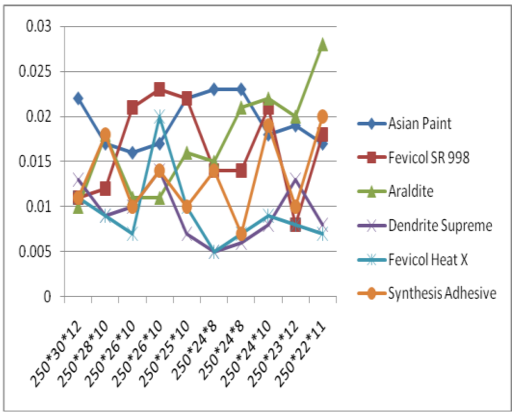

Fig 9: Graph showing Sample Size Vs Compressive Stress

Conclusions

In this study, checking the feasibility of use of liquefied bamboo as a raw material for the synthesis of Adhesive has been carried out. The important points obtained from this study can be summarized as below:

(a)The physico chemical properties of synthesized adhesives showed expected results.

(b)The experimental investigations show that tensile and compressive strength of the synthesized adhesive are in accordance with those of market adhesives.

(d) Longitudinal cracking was responsible for failure on the single timber bamboo in tensile strength in the case of market adhesive and synthesized adhesive.

(e) In the case of compressive test the load was acted on the lap joint and joint did not failed but the additional pat of the bamboo got fractured.

(g) It may be said that with the help of the lap joint the strength of the bamboo species increased. These bamboo species are used for a small setup of mechanical applications such as four bar link mechanism, Single slider and many more small setups

(h) The results showed that the maximum values of mechanical properties were obtained when Asian Paints (Loctite touch) was used as an adhesive.

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