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Formaldehyde–free sticklac and arhar stick composite board

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Sticklac has been used as a binding material to prepare formaldehyde-free composite board from *arhar (Cajanus cajan)* stick agro waste. Effects of sticklac obtained from *kusmi* and *rangeeni* strain, binder content, press-cycle, particle type, moisture content, density of board and wax emulsion as additive are studied on physical and mechanical properties of board. Tests of modulus of rupture, tensile strength perpendicular to surface of board, screw withdrawal force, water absorption and thickness swelling have indicated that composite board prepared using sticklac in alcoholic solution can meet required standard for interior grade with regard to above properties.

Keywords: *Arhar* stick, Composite board, Formaldehyde-free resin, Sticklac

Introduction

Lac, a commercial natural resin, is hardened secretion of tiny insects, mainly *Kerria lacca* (Kerr)[1,2]. Sticklac, which is encrustation gathered from twigs, contains impurities such as sand, dead insects, bark, twigs and wood chips. A semi-refined product obtained after winnowing, crushing and washing of sticklac is known as seedlac, which contains impurities (3-7%) including sand and wood-chips. Further, refined lac is called shellac. Sticklac is produced from two strains of insects (*kusmi* and *rangeeni*); *Kusmi* gives better quality lac than *rangeeni*. Total sticklac production in India is about 20,000 tonnes/year[3] produced by 3-4 million cultivators, mostly tribals[4]. A major portion (about 85%) of the total annual production of lac is being exported.

Wood composite board[5-8] consists essentially of pulverized wood or other ligno-cellulosic waste materials bonded together with a resin adhesive binder under the combined action of heat and pressure. Synthetic resins (urea formaldehyde and phenol formaldehyde), which are mostly used in India as binder for panel board, are petrochemical based resins and also have the tendency for emission of free formaldehyde[7,9,10]. For environment-friendly products, there has been an enhanced interest in using naturally occurring adhesives for making composite board[11-13]. Lac resin, a resinous constituent of sticklac, contains a number of aliphatic and sesquiterpenic acids as lactones, lactides and inter-esters[2]. Lac (mol wt, ~1000) is known[2,14] to have thermoplastic as well as thermo hardening properties besides its solubility in alcoholic or alkaline solutions.

Arhar (*Cajanus cajan* Linn.) sticks with a total production in India about 1.8 million tonnes per year[15], are widely grown throughout the country for the pulse crop and can also be used as a lac-host[16]. Present work has been undertaken to develop medium density formaldehyde-free composite board (CB) from *arhar* stick particles using sticklac as binder.

Materials and Methods

Preparation of Raw Materials

Sticklac obtained from Indian Lac Research Institute (ILRI) farm was made free from dust, sand and twigs by winnowing. It was then powdered to pass through 40-mesh sieve. Sun dried *arhar* sticks were pulverized using a hammer type disintegrator. Pulverized sticks contained fibrous materials (10%) in addition to wood powder and splinters. Particles passing through 40-mesh sieve were separated from splinters (av length 1.2 cm, diam 0.3 cm) and fibrous materials.

Preparation of Composite Board (CB)

Sticklac was used in solution form in alcoholic and aqueous medium separately, since in dry powder form, it causes sticking of board to the mould plates. Alcoholic solution contained sticklac: methanol (2:3), while aqueous solution due to its more viscous nature contained sticklac: water (2:7). Aqueous solution contained alkali (10% by wt of sticklac). *Arhar* stick

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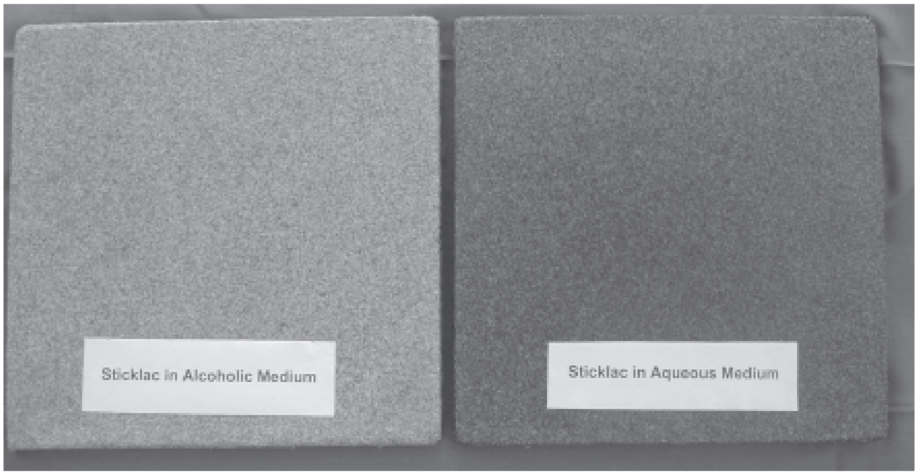

Fig.1—Composite board from a*rhar* stick using sticklac in alcoholic and aqueous medium respectively

particles were mixed properly by hand with required amount of sticklac in solution form. Solvent was then allowed to evaporate by air and sun drying. The material was formed into a mat and pressed in an electrically heated hydraulic press. Time, temperature and pressure were adjusted so that binder was properly set and desired thickness was achieved. CBs (12 cm x 12 cm x 1.2 cm and/or 27 cm x 27 cm x 1.2 cm) thus prepared were conditioned and tested for various properties.

Measurement of Physical Properties

Density[17] of CB was determined. Tensile strength (TS) perpendicular to surface of CB (~ 5 cm x 5 cm x 1.2 cm) was measured by a KMI tensile tester[17]. Modulus of rupture (MOR) was determined by three point bending test using the formula[18], $R = 3FL/2bh^2$, where F is maximum load, L is distance between supports; b and h are width and thickness of test piece. Screw withdrawal forces[17] were determined for test pieces (~9 cm x 4.5 cm x 1.2 cm). To measure water absorption and thickness swelling, increase[17] (%) in weight and thickness with respect to original weight and thickness for test pieces of ~5 cm x 5 cm x 1.2 cm and 9 cm x 4.5 cm x 1.2 cm, immersed in water at ambient temperature, was determined after 2 h and 24 h. respectively.

Results and Discussion

Analysis[19] of *arhar* stick gave: holocellulose, 76.5; α-cellulose, 42.7; hemicellulose, 33.8; and lignin, 20.4%. Sticklac based CBs, prepared in aqueous medium, has a prominent lac dye colour (Fig. 1), a lower TS perpendicular to surface of CB (~0.6N/mm^2) and higher water absorption (~84%) on 24 h immersion compared to CB made using sticklac in alcoholic medium (TS, ~0.8N/mm^2; water absorption, ~50%). This may be because in alcoholic solution, lac[1,2] is present in molecular or colloidal form depending upon concentration while in aqueous solution lac occurs in ionic form. Lac, being an acidic resin, dissolves in aqueous alkaline solution due to salt formation. Aqueous solutions of lac have low wetting power and aqueous varnishes of lac yield more brittle and less water resistance films than alcoholic solutions[1]. Low wettability of fibres in CB may results in more voids, which are stress concentrators and cause failure at a lower load[20]. Using sticklac in aqueous medium, water content of mat to be hot pressed was found a major factor controlling bonding and hence strength properties of CB. MOR is optimum at around 30% of water content (Fig. 2).

Press Cycle

Press-cycle duration (35 min) gives CB (~ 12 mm thickness) of optimum MOR and free from patch marks on both the faces (Fig. 3). Press-cycle duration or total hot press time = basic setting time + time under pressure. After a basic setting time (10 min), mat was kept under a contact pressure (22 kg/cm^2) for 25 min.

Sticklac from Different Strain

MOR and TS perpendicular to surface are better for *kusmi* than *rangeeni* strains obtained from *ber* and *palas* respectively (Table 1). Lac resin is comparatively lower in *rangeeni* from *palas*. In view of cost and availability, *rangeeni* sticklac from *ber* gives satisfactory results.

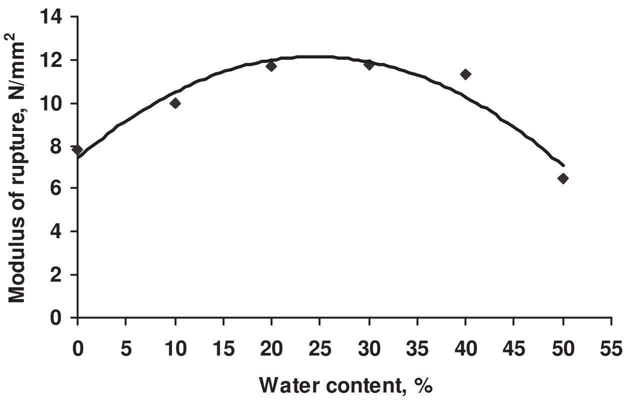

Fig. 2—Effect of water content of mat to be hot pressed on modulus of rupture of composite board using sticklac in aqueous medium

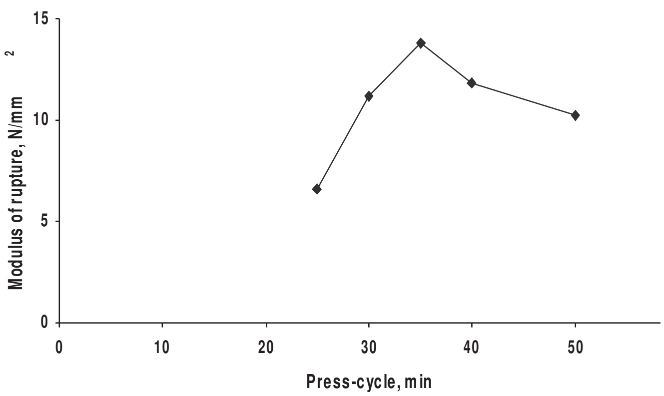

Fig.3—Effect of press-cycle on modulus of rupture of composite board

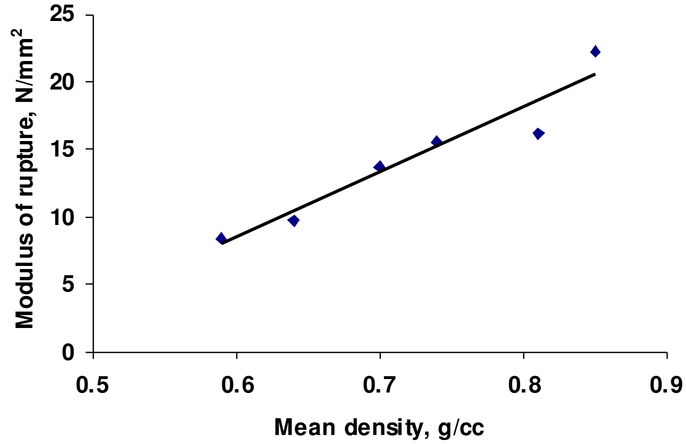

Fig.4—Change in modulus of rupture with density of composite board

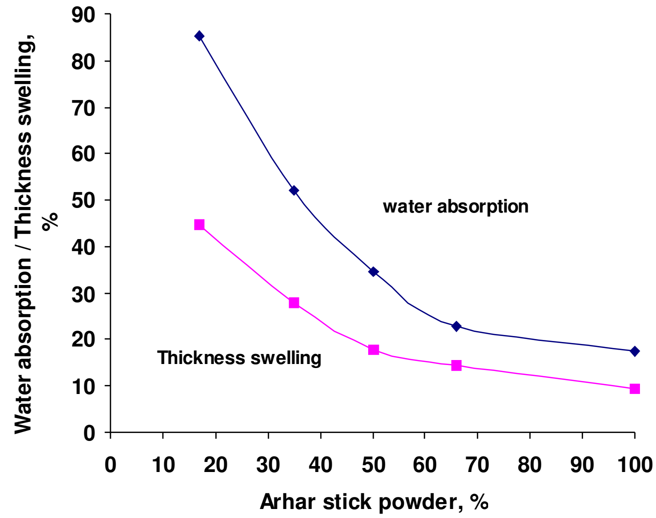

Fig.5—Influence of particle size on water absorption and thickness swelling of composite board

Density of Board and Binder Content

MOR increases with increase in density (Fig. 4). A MOR value (around 15 N/mm^2) is obtained for CB of mean density (~ 0.75 g/cc). CBs (mean density, 0.73 g/cc), prepared by varying sticklac content on weight basis, are lighter in colour below 15% sticklac content. Strength and water resistance properties of CB improve on increasing sticklac content; sticklac (17-20%) appears to be adequate (Table 2).

Water Resistance Behaviour

Arhar stick particles passing through 40-mesh sieve (powder) were mixed with splinters in different proportions. CBs (density ~ 0.80 g/cc) were prepared with 1% paraffin wax emulsion as sizing agent. Water absorption and thickness swelling diminish with increase in proportion of powder probably due to decrease in porosity of CB (Fig. 5). To impart CB a required degree of water repellency, effect of paraffin wax emulsion as additive was studied on water absorption, thickness swelling and MOR of CB. CBs were prepared using sticklac in aqueous solution. Wax emulsions containing different percentage of paraffin wax were added to *arhar*

Table 1 - Composite board from arhar stick using sticklac from different strain

Sticklac from different strain	Lac resin content, %	Modulus of rupture, N/mm2	Tensile strength perpendicular to surface, N/mm2
Kusmi (Kusum)	76	15.5	0.85
Rangeeni (Ber)	70	15.1	0.77
Rangeeni (Palas)	60	12.2	0.55

Table 2—Effect of sticklac content on strength and water absorption properties of composite board

Sticklac content %	Mean density g/cc	Modulus of rupture N/mm^2	Tensile strength perpendicular to surface of board N/mm^2	Water absorption 24h %	Thickness swelling 24h %
10	0.73	12.9	0.76	111.1	57.6
12	0.71	14.0	0.83	109.0	52.6
15	0.73	14.9	0.87	97.2	47.3
17	0.74	15.8	0.88	94.8	44.0
20	0.73	15.9	0.89	92.3	43.5
25	0.73	16.1	1.29	70.3	26.4

Table 3—Effect of paraffin wax emulsion on water absorption, thickness swelling and modulus of rupture of composite board

Wax	Water absorption, %		Thickness swelling, %		Modulus of rupture
%	2 h	24 h	2 h	24 h	N/mm^2
0	55.9	84.3	21.6	37.4	16.1
0.5	36.5	70.3	14.2	31.2	17.1
1.0	23.8	63.6	7.1	24.5	15.9
2.0	22.3	61.2	6.9	24.1	15.7
3.0	21.9	54.5	6.4	22.2	14.7
5.0	16.6	48.9	6.0	21.0	13.7

stick particles mixed with sticklac solution. Water absorption and thickness swelling of CB reduce considerably (Table 3) and also MOR decreases on increasing wax content (0-5%).

Screw Holding Behaviour

Face and edge screw withdrawal forces of CBs (12 mm thickness) were studied[17]. Screw holding was better in CB prepared using sticklac in alcoholic solution compared to that using sticklac in aqueous solution and face and edge screw withdrawal forces were observed to meet the requirements[21] of 1250 N and 700 N respectively. CB using sticklac in aqueous solution developed severe crack along the edge during edge screw holding test, might be due to high moisture content of mat material to be hot pressed. Drying of material before mat formation and hot press was found to deteriorate strength properties of CB probably due to poor adhesion between wood stick and lac particles. Hence, adhesion between wood stick and lac particles was improved by using an adhesive (polyvinyl acetate glue) and then mat material to be hot pressed was dried. CB thus prepared showed good strength as well as edge screw holding properties but increased thickness swelling and water absorption with regard to the standard requirements[21].

Composite Boards of Varying Thickness

CBs (thickness 7-26 mm) were prepared successfully (Fig. 6) by adjusting press-cycle duration. Press-cycle (duration ~1 h) was required for making CB of 26 mm thickness. Lower press-cycle duration with increased contact pressure (~44 kg/cm^2) caused debonding of CB layer.

Scaling-up Trial Experiment

Scaling-up trial experiments were carried out in collaboration with a board factory M/s Suruchi Agroplast, Kolkata using sticklac in both alcoholic and aqueous solutions. A hydraulic press having six daylights (openings) was used. CBs (thickness ~ 1.2 cm, size 7 ft x 3 ft and 8 ft x 4 ft) were prepared using sticklac as binding material.

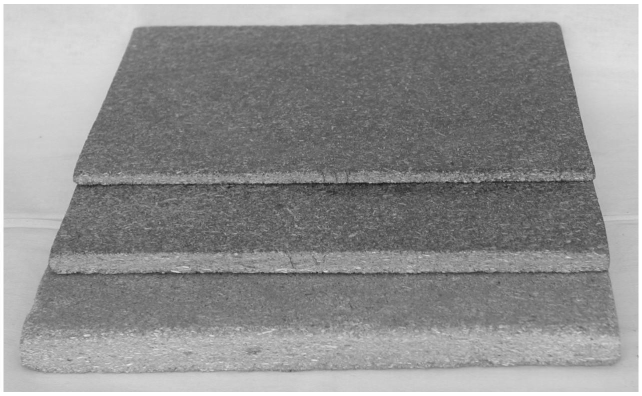

Fig. 6—Composite boards of varying thickness [7 mm, 12 mm & 20 mm (from top)] using sticklac

Economic Consideration

CB prepared using sticklac in alcoholic solution can meet required standard [IS: 3087-1985 (Type 2)] for interior uses. However, cost of sticklac is by far the most important of production cost of such CB. Further alcoholic solution of sticklac involves cost of methanol. Although resin constitutes a small proportion when considered on total surface area of CB to be bonded, on cost basis, resin/ binder accounts up to 50-60% of the total cost of board[6,22]. Hence, with price of sticklac as Rs.100/- per kg, cost of CB using sticklac in alcoholic solution can be calculated as Rs.50/- approx. per sq ft (30 cm x 30 cm x 1.2 cm). CB is expensive but it is all natural and free from harmful emission of formaldehyde.

Conclusions

Formaldehyde-free CBs from *arhar* sticks were developed using sticklac as binder. CB prepared using sticklac in alcoholic solution can meet the required standard [IS: 3087–1985 (Type 2)] for MOR, TS perpendicular to surface of CB, screw withdrawal force, water absorption and thickness swelling. Change in CB properties with variation in process variables indicates a considerable scope for adjusting CB properties for applications as panel products and furniture.

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