IRG/WP 02-40225

THE INTERNATIONAL RESEARCH GROUP ON WOOD PRESERVATION

Section 4 Processes and properties

Durability of Wood/Plastic Composites Made From *Parthenium* species

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Paper prepared for the 33rd Annual Meeting
Cardiff, Wales
12-17 May

IRG Secretariat
SE-100 44 Stockholm
Sweden

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ABSTRACT:

Previous study indicated that the natural chemical constituents of the guayule plant (*Parthenium argentatum*) improved some durability properties of wood when it was treated with resin extracted from guayule. At present, there are about a dozen species of *Parthenium* growing in the North American continent. P. *argentatum* is the only species with harvestable amounts of the rubber latex. Other species such as P. *incanum* and *P. tomentosum* produce primarily resinous materials, but which could be as useful as the *P. argentatum* species for making composites. The predicted commercialization of guayule for its hypoallergenic latex will result in a significant amount of waste plant material or bagasse that can be put to use in making wood products and would otherwise be a disposal problem. Thus, the guayule fiber residues can be a source of natural wood preservative to improve the durability of wood/plastic composites. Preliminary laboratory tests were conducted to determine the resistance of wood/plastic composites made from three *Parthenium* species against Eastern subterranean termite. The physical properties of these three types of composites were also measured, namely dimensional stability (water absorption, thickness swelling, two-hour boil, and linear expansion), and the strength properties such as bending and internal-bond (IB) or tensile stress perpendicular to face. The results were compared with a wood/plastic composite made from the commercial pine wood flour or fibers.
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KEY WORDS: Dimensional stability, durability, *Parthenium* species, termite, thickness swell, linear expansion, bending, water-boil, wood/plastic composites.

I. INTRODUCTION

The resinous material extracted from the guayule plant (*Parthenium argentatum* Gray) was found to have termite resistant property (Bultman et al., 1991). At present, there are about a dozen species of *Parthenium* growing in the North American continent. *P. argentatum* is the only species with harvestable amounts of the rubber latex. Other species such as *P. incanum* and *P. tomentosum* produce primarily resinous materials, which could be as useful as the *P. argentatum* species for making composites. This resin material is a by-product from the process for extracting rubber from the guayule shrub (Bultman et al., 1998). At present, the predicted commercialization of guayule for its hypoallergenic rubber latex will result in the production of a significant amounts of wood residue or bagasse, which would be considered waste material that must be disposed. It is estimated that about 60 t/ha of bagasse will remain after latex extraction. Several hundred thousand hectares of guayule will be required to fulfill the hypoallergenic latex requirement of the United States alone. Because the bagasse still contains the resinous material with its biocontrol properties, it should be a good natural source for making insect- and fungal-resistant wood. The bagasse can be directly incorporated with adhesives to make composite wood (Nakayama et al., 2001).

In recent years, wood supply for making wood composites has become scarce and expensive in the United States because of competition from the paper industry for wood fiber. Thus, board producers will be forced to seek other non-wood plant fiber sources to supply the increasing raw material requirement in the future. Because of the high cost of lumber products, the increase in production of wood-based panels including the wood/plastic composites has been substantial in recent years. In fact, the United States has been both the world's leading user and producer of wood composite panels. More than one-half of these panels are used in both residential and commercial construction including interior walls and exterior wall sheathing, floors, sidings, and roof sheathing.

When wood-based panel becomes wet, it swells mostly in thickness and length, and bonding degradation occurs (Chow et al., 1980). Generally, only exterior grade of preservative-treated wood composites are preferred in building construction for protection against termite, water and high humidity environment.

The objective of this preliminary study was to determine the termite resistance, the durability properties, and some of the strength properties of wood/plastic composites made from three *Parthenium* species. The results were compared with a wood/plastic composite made from the commercial pine wood flour or fibers.

II. MATERIALS AND PROCEDURE

1. The harvested whole shrubs of three species of *Parthenium*, i.e., *argentatum*, t*omentosum*, and *incanum* were used in this study. They were milled to small particles with a hammermill. Bagasse plant residue of the *P. argentatum* species obtained from the rubber processing operation was also used. The bagasse material

contained about 3% rubber and 10% resinous materials after air-dried for preparing the wood/plastic composite boards or panels.

2. The thermoplastic resin used was high-density polyethylene (HDPE) made from recycled plastic milk containers. It had a melt flow index number of 0.7 with a granulated size of approximately 40 mesh.

3. The experimental guayule-wood/HDPE plastic composite panels were made from ground guayule shrub and bagasse without any thermosetting binder. Seventy percent of guayule wood fiber and 30% of the HDPE powder were used for the composites. Guayule composition boards approximately 279 by 279 mm were made with a specific gravity of 1.00 and thickness of from 6.5 to 7.0 mm. All composite boards were pressed on a steam-heated hydraulic press at about 160EC at pressures of between 7.3 MPa and 10.4 MPa. Three replicate panels were made for each *Parthenium* species of guayule wood/plastic composite except for the composite panel made from guayule bagasse as shown in Table 1. For purposes of comparison with these composites, three wood/plastic composite panels were also made from 70% commercial pine wood flour and *30%* HDPE.

4. The termite resistance test specimens cut from experimental panels were tested according to ASTMD-3345 (ASTM, 2001) using Eastern subterranean termites *(Reticulitermes* spp.). Termite activity in each bottle was observed and rated after one week. Specimens of commercial pine lumber were also tested for comparison purpose.

5. Prior to tests, all specimens were conditioned at 65% relative humidity (RR) and 20E C. Three-point static bending modulus (MOR) and modulus of elasticity (MOE),and tension perpendicular to face or internal bond (IB) were mechanically tested using a universal testing machine. For physical properties evaluation, specimens were tested for 24-hour water soak, 2-hour water boil, and exposure to 900/0RH from 50% RR condition. Thickness swell, water absorption and linear expansion were determined. All tests followed the methods described in American Society for Testing and Materials (ASTM D-1037, 2001).

III. RESULTS

1. The average thickness and specific gravity of the experimental guayule wood/HDPE composite panels are listed in Table 1.

2. The termite resistances of composite panels made from HDPE, and wood particles of three species of *Parthenium,* bagasse from *P. argentatum,* commercial pine wood flour, and a solid pine lumber are shown in Table 2.

3. Measurements of both the modulus of rupture and modulus of elasticity in static bending, and tensile stress perpendicular to face or internal bond (IB) properties are presented in Table 3. The table includes the minimum average values for meeting requirements of the Service and Industrialite grades of commercial wood hardboard (American National Standard For Basic Hardboard, 1995).

4. The thickness swelling and the water absorption values obtained from both the 24-hour water soaking test and the 2-hour water boil tests are listed in Table 4. Average values of linear expansion, thickness swell, and water absorption obtained from the high 90% RH exposure test are given in the same table and also includes the maximum allowable values for the commercial wood hardboard siding product (American National Standard For Commercial Hardboard Siding, 1998).

IV. SUMMARIES

The following summaries can be made from this study:

1. The wood/plastic composite panels made from shrub-wood of the three species of *Parthenium*, *P. argentatum, P. tomentosum,* and *P. incanum* with 30% HDPE were highly resistant to Eastern subterranean termite. The composites made from bagasse after the water-extraction of latex rubber from *P. argentatum* and 30% HDPE also showed good anti-termitic properties.

2. The composite made from commercial pine wood flour did not have as much termite control as the *Parthenium* species, and the composite made from wood flour of the commercial pine lumber and 30% HDPE had no resistant to termites.

3. The average water absorption values (obtained from the 24-hour water-soak test) of all composites made from three species of *Parthenium*, and commercially ground pine flour met their water absorption requirement for commercial hardboard siding products. In thickness swelling property, only composites made directly from the shrub of the *P. incanum* and *P. argentatum* species, and pine flour met the standard requirement.

4. After 2 hours of water boiling, composites made from three *P. incanum* and *P. argentatum* (including shrub-wood and bagasse) performed better than composite made from commercial pine flour in thickness swelling property. However it was not the case in water absorption property including composite made from *P. tomentosum.*

5. The linear expansion property for composites made from the *Parthenium* species of *tomentosum* wood and *argentatum* bagasse met the minimum requirement for commercial hardboard siding material. Composite made from commercial pine exhibited better performance than most of those composites made from all *Parthenium* species in both water absorption and thickness swell properties after exposure to the 90% RH condition.

6. Composites made from all species of *Parthenium* tended to have higher average water absorption values than the composites made from commercial wood of pine species in all three water resistance tests (24-hour water soak, 2-hour water boil, and 50% to 90% RH exposure). They did not show the same trend in the dimensional stability property of thickness swelling property.

7. For strength properties, all composites met the minimum required values of modulus of rupture in bending and internal bond or tensile stress perpendicular to face for commercial Service and Industrialite grades of basic hardboard. Although there is no minimum requirement of modulus of elasticity (MOE) in bending for commercial hardboard products, all composite panels made in this experiment showed rather low MOE values or low in stiffness property. This might be attributed to the fact that all composites consisted of the plastic at 30% of HDPE.

8. Additional studies are needed to find ways to increase the water resistance property of wood/plastic composites made from wood and bagasse of *Parthenium* species. There is also a need to investigate the fungal wood-rot resistant properties of composites made from the wood and bagasse of the various *Parthenium* plant species.

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VI. ACKNOWLEDGEMENT

This study was supported by funds administered through the Illinois Agricultural Experiment Station, University of Illinois, U-C Campus, Urbana, Illinois, the U.S. Forest Products Laboratory, USDA-FS, Madison, Wisconsin, and the U.S. Water Conservation Laboratory, USDA-ARS, Phoenix, Arizona, USA.

Table 1
Wood/Plastic Composite Panels Made from *Parthenium* species
(279 X 279 mm)

Panel No.	Parthenium species	Board Thickness (mm)	Specific Gravity %	Guayule(G) or Pine(P)	High Density Polyethylene (HDPE) %
Panels made from *Parthenium* species					
1	***P. incanum***	6.47	0.98	70 (G)	30
2	P. incanum	6.68	1.08	70 (G)	30
3	P. incanum	6.50	1.10	70 (G)	30
1	P. tomentosum	7.21	1.01	70 (G)	30
2	P. tomentosum	6.81	1.02	70 (G)	30
3	P. tomentosum	7.09	0.97	70 (G)	30
1	P. argentatum	6.53	1.07	70 (G)	30
2	P. argentatum	6.48	1.07	70 (G)	30
3	P. argentatum	6.63	1.07	70 (G)	30
1	Bagasse P. argentatum	7.06	1.01	70 (G)	30
Control Panels (Pine)					
1	Wood (Pine)	70.1	0.98	70 (P)	30
2	Wood (Pine)	7.01	0.97	70 (P)	30
3	Wood (Pine)	7.29	0.95	70 (P)	30

Table 2
Eastern Subterranean Termite Resistance of Wood/Plastic Composites
Made from *Parthenium* species

Wood/Plastic Composite Type	Observation (after one week)	Rating (ASTM)
70% *P. incanum* 30% HDPE	7% termites still alive	High or heavy mortality
70% *P. tomentosum* 30% HDPE	6% termites still alive	High or heavy mortality
70% *P. argentatum* 30% HDPE	5% termites still alive	High or heavy mortality
70% *P. argentatum* (Bagasse) 30% HDPE	5% termites still alive	High or heavy mortality
70% wood flour (Pine) 30% HDPE	40 % termites still alive	Low or moderate mortality
Solid Pine Lumber	100% termites still alive	No mortality

Table 3
Strength Properties of Wood/Plastic Composites

Wood/Plastic (HDPE) Composite (70:30)	Static Bending		Internal Bond or Tensile Stress Perpendicular to Plane (MPa)
	MOR (MPa)[a]	MOE (MPa)[b]	
30% HDPE 70% of *P. incanum*	17.93	1149.87	1.083
30% HDPE 70% *P. tomentosum*	23.04	1169.83	1.282
30% HDPE 70% *P. argentatum*	16.02	982.66	1.069
30% HDPE 70% *P. argentatum* (Bagasse)	19.88	1180.59	1.055
30% HDPE 70% flour wood (Pine)	19.76	1213.27	1.200
Standard Minimum (Requirement)[c]	13.8 – 20.7	--	0.17 – 0.34

[a] MOR—modulus of rupture
[b] MOE—modulus of elasticity
[c] Service and industialite grades of basic hardboard (American National Standard, 1995)

Table 4
Dimensional Stability of Wood/Plastic Composites

Wood/Plastic Composite (70:30)	24-Hour Water Soak		2-Hour Water Boil		Linear Expansion 50% to 90% Exposure		
	TH.S.[a] %	W.A.[b] %	TH.S. %	W.A. %	TH.S. %	W.A. %	L.E.[c] %
70% *P. incanum* 30% HDPE	3.2	6.7	7.5	18.2	5.6	6.3	0.48
70% *P. tomentosum* 30% HDPE	10.8	11.1	20.6	24.1	9.0	9.6	0.37
70% *P. argentatum* 30% HDPE	7.1	8.4	10.8	16.8	7.5	9.0	0.45
70% *P. argentatum* (Bagasse) 30% HDPE	19.2	9.4	14.6	22.4	6.0	6.5	0.23
70% Pine Wood Flour 30% HDPE	7.3	6.8	15.2	15.7	5.8	5.4	0.31
Hardboard Siding Standard (Maximum)[d]	8.0	15.0	-	-	-	-	0.36 to 0.40

[a]TH.S—thickness swell
[b]W.A—water absorption
[c] L.E.—linear expansion
[d]American National Standard for Hardboard Siding, 1998.