FASTENERS RESISTANCE OF NON-WOVEN AND MELT-BLENDED COMPOSITE PANELS MADE FROM CORNSTALK FIBERS AND RECYCLED PLASTICS

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ABSTRACT

Cornstalk fiber-based thermoplastic composite panels were developed and their mechanical fastener resistance properties were evaluated. The cornstalk fibers are collected from the corn crop farms in the Midwest of the United States of America. To form the composite panels, three methods of mat forming were used: a) steam-pressure refined cornstalk fibers were resin-blended with both virgin and recycled high density polyethylene (HDFE) to make medium density fiberboard (MDF) type of composite panel mat: b) air-laid non-woven mats were made using pressure-refined cornstalk fibers and polypropylene fiber; and c) melt-blended technology formed mats were made using pre-formulated and pelletized stocks made from hammermilled cornstalk and recycled lowdensity polyethylene (LDPE). For comparison purpose, a kenaf fiber was also used. All mats were hot-pressed into panels. These Composite panels could be used as elements in both building and furniture construction. Both staples and nails were used to determine the direct withdrawal resistance, head-pull through, and lateral resistance of the composites. These tests meant to simulate the condition encountering when wind or earthquake forces pull building panels away from a wall, roof, or floor structures.

INTRODUCTION

Composite construction materials, and pulp and paper using plant fibers other than wood fiber are in an increasing demand in today's industrial marketplace in many countries deficient in forest resource. In the United States, this has also become a concern due to the dwindling supply of wood fibers and the emerging laws that limit fiber extraction from certain forestland. The presence of vast agricultural residue fibers such as cornstalks and corncobs in the Midwest of the United States creates an opportunity for new product and additional economic development in its large farming communities if the available fiber materials are properly harnessed. This report presents one of the outcomes of an on-going research project to demonstrate the viability of using cornstalk, an Illinois agricultural fiber and plastics in producing thermoplastic composites products. These panels could be used as elements of in both building and furniture construction as a substitute for wood-based panels. Wood materials are often attached with nails, staples, and other fasteners. The stability and safety of the wall, siding (cladding), and roof system of a house or furnitures made of wood materials depends on the type of wood-based material, fasteners, and the fastening methods used (1). Performance and proper use of mechanical fasteners are of utmost important because of rapidly increasing engineering use of newly developed composite panels (2,3,4). New information on the performance of fasteners in new cornstalk fibers-plastic composite panels for house sheathing and siding, and furniture applications are needed.

OBJECTIVES

Our objectives in these experiments are to determine the direct withdrawal resistance, head-pull through, and lateral resistance of the cornstalk natural fiber based thermal plastic composite panels when staple, nail. and screw are used as fasteners. For comparison purpose, the minimum requirements for fastener resistance cited in different commercial specifications (Table 4) have been used as standards (5-10).

MATERIALS

The agricultural waste materials in the form of cornstalks or maize fibers (Zea mays) were harvested from the experimental plots at University of Illinois. U-C Campus, Illinois. and USA. They were steam-pressure refined to long fibers for making the resin-blended type of medium-density fiberboard (MDF) plastic composite panels. Both the virgin high-density polyethylene (VHDPE) and the recycled HDPE were used (Table 1). To produce the air-laid non-woven mat, both the steam-pressure refined cornstalk fibers and the polypropylene (PP) fibers were employed. The small amount of HDPE and PP was used as the adhesive or resin for the composite panels. Some of the cornstalk and kenaf stalks were hammermilled and screened to −35 mesh, which is almost equivalent to a common grade of commercial wood flour fillers for making the melt-blended plastic composite panels which used a recycled low density polyethylene (LDPE). The composite panels had a thickness of 1/2 inch or 12.7 mm (A-D, G-J). and 1/4-inch or 6.4-mm (E-F). The panels G-J all contained LDPE, which is recycled Low-Density Polyethylene. These were pelletized. The LDPE selected was from post-consumer waste such as grocery bags. The fasteners that were used in the test were 7/16 gauge and ½-inch or 12.7-mm crown power driven staples, 6-penny nails. and No. 10AB sheet metal screws. These were all used according to ASTM standards (5-10).

PROCESSING

To form the panels, three methods of mat forming were used as shown in Table 1

1. To form the resin-blended mat, a small amount of virgin HDPE (10 and 20 percent) and recycled HDPE (10 and 20 percent) was blended into the steam-pressure treated cornstalk fibers in a mechanical mixer. The medium density fiberboard (MDF) type of composite panels with a thickness of 12.7-mm and a specific gravity 0.7 was made in a steam-heated hot-press.

2. To form the air-laid non-woven mats, small amount (10 and 20 percent) polypropylene and steam- pressure refined cornstalk fibers (80 and 90 percent) were used to form the ma:. The forming machine produces a 355-mm wide continuous mat. Following the mat-forming process is a needler, which consolidates the mat, and improves the mat integrity. A multi-layered mat was hot-pressed into a composite panel at a thickness of 6.4-mm and an average specific gravity of 1.00.

3. For the melt-blended cornstalk plastic composite, hammermilled cornstalk and kenaf stalk and recycled low density polypropylene powder (LDPE) were compounded at the U.S. Forest Products Laboratory using a Davis Standard 32mm twin screw extruder at 40% by weight of filler. The compounded materials were then pelletized and dried at 105° C for 24 hours before forming a desired mat dimension of 355 mm x 355 mm. The mats were hot-pressed to 12.7 mm thick in a steam heated platen press at a pressure of about 5 Mpa at 177 degree centigrade. Two specific gravity levels (0.7 and 0.8) of the panels were used. Using the compounded pellets in a hydraulic hot press made the melt-bended cornstalk- and kenaf-

plastic composite panels. Four replicated panels were made for each type of composites. A total of forty panels (355-mm x 355-mm) were made.

SPECIMEN TESTING

The cornstalk or kenaf and the recycled LDPE panels (G, H, I, J) were subjected to eight different kinds of ASTM 1037 and 1761 tests (11). These were staple withdrawal, lateral staple resistance (3/8-in. or 9.5-mm from edge), staple head pull-through, lateral nail resistance (3/8-in. or 9.5-mm from edge), nail withdraw, nail-head pull through, screw edge, and face tests The specimens were obtained from four replicated panels made for each type of composites. They were all cut to the specified dimensions needed for each test. The dimensions were 3-inch or 76-mm x 6-inch or 152.4-mm.for all tests. All specimens were tested at 65% Relative Humidity and 68° F (20 degree C) condition. The specimens were tested using a Tinus-Olsen machine at 1,200 pound setting level At least eight to ten tests were conducted for each type of composites, fasteners, and test methods. These tests were run to find the maximum load that could be held until the fastener could be removed or pulled through the test specimen.

RESULTS AND SUMMARY

Table 2 shows the average fastener resistance values of resin-blended steam-pressure refined cornstalk-HOPE composite panels A, B, C, D, and air-laid non-woven processed cornstalk-polypropylene composite panels E and F. At the end of table 2, values of the minimum standard requirement for various fastener properties used in wood-based panel products were derived from Table 4 for comparison purpose. It shows that better fastener resistance properties (except the screw holding power) obtained from the hot-pressed non-woven mats made from steam-pressure refined cornstalk fibers and polypropylene fiber (10- and 20-%) than those of the CS-HDPE panels made from the resin-blended process, regardless of the original sources of HDPE. The average values of the fastener resistance properties (except the edge screw holding power) obtained from the pressure-refined cornstalk –fiber/polypropylene composite panels do meet the minimum requirement of the commercial standards shown in Table 4. Table 3 shows the average tested values obtained from specimens of panels G, H, I, and J which were made from 40 % of the hammermilled cornstalk or kenaf and 60 % of the recycled low density polyethylene (RLDPE). The specific gravity between 0.7 and 0.8 in cornstalk or kenaf
-RLDPE composite panels did affect both staple and nail holding power capacity. It appears that the recycled plastic composite panels made from the cornstalk performed as well as the kenaf stalk. Most of these cornstalk or kenaf-LOPE composites possessed staple and nail holding power properties equal to or better than the minimum required values for commercial hardboard siding, oriented strandboard (OSB), and plywood. Low average screw holding power values were obtained, especially the edge screw holding from all cornstalk- plastics composite panels. In summary, the test results show that some of the steam-pressure refined cornstalk fibers-polypropylene fibers composite panels (made from air-laid non-woven process), and the cornstalk-recycled LDPE composite panels (made from melt-blended process) are suitable for both consumer and building panel uses, as far as the staple resistance properties and the nail holding power are concerned.

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Table 1: Formations and a List of the Abbreviations Representing the Materials Used

Code	Plastic	Percent	Natural Fiber	Percent (%)
Resin-Elend (1/2 in. or 12.7 mm thick)				
A	Virgin HDPE	10	Cornstalk (Refined)	90
B	Virgin HDPE	20	Cornstalk (Refined)	80
C	Recycled HDPE	10	Cornstalk (Refined)	90
D	Recycled HDPE	20	Cornstalk (Refined)	80
Non-Woven (1/4 in. or 6.4 mm thick)				
E	PP(Polypropylene)	10	Cornstalk (Refined)	90
F	PP(Polypropylene)	20	Cornstalk (Refined)	80
G	Recycled LDPE (0.7)	60	Cornstalk (Hammermilled)	40
H	Recycled LDPE (0.8)	60	Cornstalk (Hammermilled)	40
I	Recycled LDPE (0.7)	60	Kenaf (Hammermilled)	40
J	Recycled LDPE (0.8)	60	Kenaf (Hammermilled)	40

Table 2: Results of Mechanical Fastener Tests on Plastic Composite Panels

Panel Type	Staple		Nail		Screw	
	Withdrawal	Head Pull-thru	Withdrawal	Head Pull-thru	Face	Edge
Pounds (Newtons)						
A 90% CS 10%VHDPE	22.8 (101)	144.1(641)	17.4(77)	139.2(620)	56.4 (251)	Failed
B 80% CS 20%VHDPE	37.4 (144)	130.0(578)	18.8(84)	179.1(796)	94.2 (419)	56.2 (250)
C 90% CS 10%RHDPE	24.8 (110)	129.1(575)	18.1(81)	174.9(778)	86.3 (384)	Failed
D 80% CS 20%RHDPE	19.3(86)	138.9(618)	37.5(167)	136.4(607)	67.1 (298)	52.3 (233)
E 90% CS 10% PP	31.7(141)	199.8(889)	35.9(160)	244.4(1807)	324.4 (1443)	118.1(525)
F 80% CS 20% PP	29.8(133)	230.0 (1023)	37.6(167)	259.1(1152)	273.4 (1216)	163.6(727)
Minimum Standard Requirement	20(89)	150(667)	20 (89)	150(667)	202 (900)	180(800)

Table 3: Results of Mechanical Fastener Tests on Melt-Blended Plastic/Natural Fiber Composite Panels (1/2 inch or 12.7 mm thick)

Panel Type	Staple			Nail			Screw	
	Withdrawal	head Pull-thru	Lateral	Withdrawal	Head Pull-thru	Lateral	Face	Edge
Pounds (Newtons)								
G 40% CS 60% RLDPE (0.7)	27.2 (121)	149.7 (666)	153.1 (681)	36.2 (162)	148.2 (659)	211.5 (941)	172.8 (769)	68.7 (305)
H 40% CS 60% RLDPE (0.8)	38.1 (169)	156.4 (695)	176.7 (786)	56.1 (250)	168.6 (750)	231.8 (1031)	162.3 (722)	101.4 (451)
I 40% Kenaf 60% RLDPE (0.7)	35.8 (159)	159.3 (709)	175.7 (782)	48.6 (216)	156.5 (696)	209.3 (931)	156.5 (696)	104.6 (465)
J 40% Kenaf 60% RLDPE (0.8)	34.3 (152)	165.6 (737)	201.8 (898)	59.9 (266)	183.1 (815)	230.5 (1025)	170.5 (758)	113.5 (505)
Minimum Standard Requirement	20 (89)	150 (667)	150 (667)	20 (89)	150 (667)	150 (667)	202 (900)	180 (800)

Comparison studies (3,4) showed the equivalent performance of wood-based panels in withdrawal and lateral resistance of 6-penny nails and 16-guage staples.

Table 4 Existing Direct Fastener Withdrawal, Head Pull-through, and Lateral Nail Resistance Performance Standards (1/2 in. or 12.7 mm thick panel tested with 6-penny nail or No. 10AB sheet metal screw)

Lateral Nail Resistance		Minimum, Pounds (Newtons)
	Edge	
Hardboard Siding (ANSI A 135.6-1998)(5)	3/8 in. (9.5 mm)	150 (667)
APA (Plywood)(6)	1 in (25.4 mm)	120(531)
FHA (Ext. Particleboard)(7)	¼ in. (6.1 mm)	90 (400)
	½in. (12.7 mm)	200 (889)
OSB (PS2-92)(8)	1 in (35.4 mm)	120 (531)
FHA (Ext. Particleboard)(7)		250 (1112)

Direct Nail Withdrawal

Fiber Insulation Board(9)		40 (178)
APA (Plywood)(6)		20 (89)
OSB (PS2-92)(8)		20 (89)
FHA (Ext. Particleboard)(7)		30 (133)
Screw (Face)	**Screw Type**	
Standard particleboard (ANSI A 208. 1-1993)(10)	10 AB	202 (900)
Screw (Edge)		
Standard particleboard (ANSI A 208. 1-1993)(10)	10 AB	180 (800)

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