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BENDING MOMENT CAPACITY OF L-TYPE FURNITURE CORNER JOINTS CONSTRUCTED OF PARTICLEBOARD PRODUCED FROM VINE PRUNING RESIDUES

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ABSTRACT

Tests were carried out to investigate the utilization of vineyard pruning residues in panel products as a structural material for manufacturing of the furniture cases. For this purpose, bending moment capacities of L-type corner joints that are constructed of vineyard pruning residues panels were determined. Experimental panel materials were produced under laboratory conditions at different ratios of vine pruning residues (VP) and Scotch pine (*Pinus sylvestris* L.) wood chips (WC). Urea formaldehyde (UF) adhesive was used as binder in all mixtures during the production process. In assembling the L-type specimens, 2 types of joint techniques were utilized that included screws and dowels. L–type corner joints were tested under static diagonal compression and tension loads for determining the bending moment capacity. According to the test results generally, the panels constructed of vine pruning in various ratios yielded allowable bending moment capacities compared to the control (E) panels as a structural material for construction of the case furniture. However, it was taken into consideration that some strength improvements should be made in order to reach the strength values that are given in standards. Results indicated that some properties at certain proportions of pruning/wood particles can give satisfactory values.

KEYWORDS: Vine pruning parts, agricultural residue, particleboard, bending moment capacity, corner joints, case furniture.

INTRODUCTION

Today, the world's populations with the replication of human needs are increasing day by day. However, the value of forests in the world is increasing demand for materials in the particleboard industry, is now re-evaluating and finding alternative raw materials, such as the development of environmental solutions, has become mandatory. In this context, these types of studies both in Turkey and the world economy will provide great benefits so far prevented effective evaluation of the product will be a subsidiary of specified.

General manufacturing sector had a share of 4 % cut from each tree in order to meet the need for forest products should be evaluated relative to 100 %. In addition to the evaluation of solid wood, chip, fiber, wood laminated sheet production methods that were developed and less faulty assessment of industrial waste and wood panel manufacturing industry, contributing more than the economy should gradually seek alternative supplies.

In many countries, the increasing number of industry based on wood raw material and the resulting difficulty in finding wood chips, agricultural wastes interest in the production of composite plate increases by the day. This study of the wine-growing activities in the Aegean region as a common bond of pruning residues from the particleboard industry, research and evaluation of the panels was carried out to investigate the availability of furniture and building industry.

Until today studies the production of particleboard wood raw material to replace the many alternative materials have been tested. Tea waste (Yalınkılıç et al. 1998), vine pruning residues (Grigoriou and Ntalos 2001), cotton stubble (Güler et al. 2001), kiwi pruning residues (Nemli et al. 2003), cotton boll, (Alma et al. 2005) and sunflower stalks (Bektas et al. 2002) chipboard made. In addition, vineyard pruning residues were considered as a raw material as an alternative to chipboard industry.

In the world, approximately 60 to 62 million tons of grapes produced. While 530.000 hectares of vineyard area in Turkey, the Aegean area in the area of 160.000 hectares. The pruning of winter pruning residue obtained from viticulture area of 1 hectare of about 3 to 3.5 tons (Grigoriou and Ntalos 2001). Only in the vineyard pruning residue in the Aegean Region is estimated to be approximately 480.000 to 560.000 tons. Turkey, this surplus could not be used in any industry. For this area just use the current situation as a possible fuel calorific value is less than the vineyard pruning residue is not efficient.

Material evaluation studies so far were as chipboard. In this study, the first vine pruning made with material obtained from the boxes will be tested.

The aim of this study was to investigate that the feasibility of using the vineyard pruning residues that are loom large in Turkey in panel products as a structural material for manufacturing of the furniture cases.

MATERIAL AND METHODS

Raw materials and production of test panels

In this study, Sultana (*Vitis vinifera* L. cv. *Sultani*) type vineyard residues obtained from winter pruning and Scots pine (*Pinus sylvestris* L.) wood chips was used as a raw material for producing the test panels. Scots pine was procured from a local commercial supplier.

The test panels were produced in laboratory conditions. UF adhesive was utilized for producing the panels. Test panels were prepared by using three different ratios of vineyard pruning residue and pine chip mixtures. Furthermore, the control panels; one has only vineyard pruning residues while the other one has only pine chips were prepared for comparisons.

All panels were produced in accordance with the procedures described in Nemli et al. (2003). The vine pruning stalks and wood were chipped by a universal chipper then the particles were dried to 3 % moisture content. Dusts in the chips are removed by an electrical fan. Prior to blending, vine pruning and industrial wood particles were screened by a screening apparatus through meshes with 3, 1.5 and 0.8 mm apertures to remove oversize and undersize particles and separate the core and surface layer particles. No water-repelling agent was used during the board construction. The mat configuration was three-layer and formed by manual distribution after adhesive application in blender. The proportion was 35 % for surface and 65 % for core layer.

The UF adhesive was applied to particles by spraying into a rotating drum that designed and built for this study. Based on oven dry particle weight, 8 and 10 % UF adhesive were applied for the face and core layers, respectively. The mat configuration was formed by hand distribution in a template after resin application. The mat has been pre-pressed than the template removed and pressing process started. The particleboards were pressed at a maximum pressure of 0.00025 N.mm^{-2}, 150°C, for 7 min. The target dimensions of panels were 560 by 560 by 20 mm and target density for all panel types was 0.70 g.cm^{-3}. Various mixtures of vine pruning particles and pine wood chips were used as furnishes for three-layer particleboards. All layers consisted of various proportions of mixed VP and PW. For each mixed model, three experimental panels were manufactured. After pressing, panels were conditioned at a temperature of 20°C and 65 % relative humidity, edge trimmed to 550 by 550 mm.

Preparation of L-type corner joint specimens

Overall, 5 different panel type (A, B, C, D, E) and 2 different joint techniques (screw and dowel) consisting of 5 replications each; or, a total of 100 L-type corner joint specimens (50 for diagonal compression, 50 for diagonal tension) were constructed for static bending moment capacity tests. Totally, 100 specimens were prepared and tested.

The general configuration of the L-type corner joint specimens used for this study is shown in Fig. 1. The specimen consists of two structural members, namely, a face member and a butt member. The face member measured 270 x 150 x 18 mm, whereas the butt member measured 270 x 132 x 18 mm.

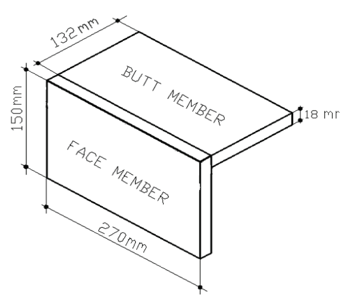

Fig. 1: General configuration of L-type corner joint specimens.

Two connection techniques were utilized for constructing the L-type specimens. Half of the specimens were constructed with glued dowels and the remaining half was constructed with screws without glue. In the dowel joints, the members were jointed to each other with 3 pieces of 8 mm diameter and 39 mm length beech (*Fagus orientalis* L.) dowels with polyvinylacetate (PVAc) glue. The glue was spread over the dowel surfaces and dowel holes with approximately 150 g.m^{-2} calculation. Screw corner joints were assembled with only 3 screws without adhesive. In the joints, 4 by 50 mm steel phillips head wood screws with 40 ± 3 degree thread angle were used which are widely used in case furniture industry. Root diameter, outside diameter, and thread per mm were 2.4 ± 0.25, 4.0 ± 0.3, 1.8 mm for screws, respectively. Screws were driven to the center of thickness of butt member which had pre-drilled pilot holes. The diameters of the pilot holes were equal to approximately 80 % of the root diameter of the screws, and depths of the pilot holes were equal to approximately 75 % of the penetration of the screws (Eckelman 2003).

Fig. 2 shows a typical placement of dowel and screw centers in the L-type corner joints used in this study. Specimens were kept in a conditioning chamber at 20°C ± 2 and 65 ± 3 % relative humidity prior to test in order to avoid moisture content variations.

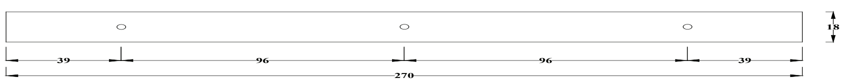

Fig. 2: Typical placement of dowel and screw centers in the L type corner joint.

Static diagonal tension and compression tests

Some physical and mechanical properties of test panels were determined in accordance with the procedures described in ASTM D 4442 (2001) and ASTM D 1037-99 (2001). In addition, screw and dowel holding strengths of panels from edge and face were tested according to procedures set by Erdil et al. (2002), and Erdil and Eckelman (2001). The diameters and depth of penetration of the pilot holes and all parameters were the same as the assembly of L-type corner joint specimens owing to provide a reasonable comparison. All screw and dowel holding tests were carried out on a 50 kN capacity universal testing machine. Rate of loading was 2 mm.min^{-1}. Ultimate loads were taken as the screw and dowel holding strength of panels. Moment capacities of the joints when subjected to loads that tended to open the joints (tension) or loads that tended to close the joints (compression) were evaluated. Fig. 3a) and b) show compression and tension loading diagrams in testing joint moment resistances to close and open action forces, respectively.

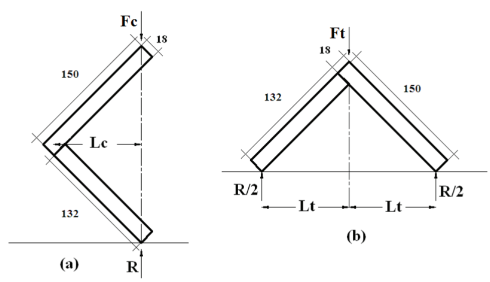

Fig. 3: Compression a) and tension b) loading diagrams.

All of the tests were carried out on a 50 kN capacity universal testing machine at a loading rate of 6 mm.min^{-1}. In the case of tension test; each member was placed on rollers in order to the joint was forced to open. This action tends to enlarge the angle formed by members joined together. In the case of compression test; specimens were placed with the movable head and the base of the testing machine in order to joint was forced to close. This action tends to reduce the angle formed by the members joined together (Tankut and Tankut 2004; Zhang and Eckelman 1993).

Joint failure modes and maximum failure loads were recorded in Newton (N). Both tension and compression loadings were used to calculate the bending moment capacity. The relations between the bending moment capacity and applied maximum failure loads under tension (F_t) and compression (F_c) were different. The bending moments were calculated by means of the formulas:

$$M_T = 0.5F_t \times L_t \quad \text{(Nm)} \tag{1}$$

$$M_C = F_c \times L_c \quad \text{(Nm)} \tag{2}$$

where: M_T, M_C - bending moment capacity under tension and compression loadings, respectively (Nm),
F_t, F_c - applied ultimate force of tension and compression (N),
L_t, L_c - moment arms for tension and compression tests (m).

Moment arm was calculated 0.09334 m for both tension and compression loadings by using right triangle relation respectively.

RESULTS AND DISCUSSION

Some physical and mechanical properties of the prepared test panels and coding system used in the tests are summarized in Tab. 1. The static bending strength values of all experimental panels varied from 4.49 to 5.85 N.mm^{-2}. The highest bending strength value (5.85 N.mm^{-2}) was measured for the particleboard having density of 0.590 g.cm^{-3}, the lowest one (4.49 N.mm^{-2}) is for board having a density of 0.560 g.cm^{-3}. This might be due to the effect of vine pruning proportion. The negative effect of vine particles on board bending strength is partially attributable to their lower length to thickness (slenderness) ratio in comparison to wood particles. The negative effect of vine pruning particles was not only evident on bending strength but on all mechanical properties which is probably because of the fact that they incorporate certain amounts of pith particles. According to Grigoriou and Ntalos (2001), vine pruning particles were characterized by higher bulk density and lower slenderness ratio than industrial wood particles.

Tab. 1: Some physical and mechanical properties of panels used in the study and coding system.

Panel type	Raw material usage (%) (Vine pruning: wood)	MC (%)	Density (g.cm^{-3})	(N.mm^{-2})	MOE (N.mm^{-2})	Tension parallel to surface (N.mm^{-2})	IB (N.mm^{-2})
A	100:0	9	0.56	4.49	675.08	2.07	0.16
B	75:25	15	0.56	5.60	917.71	2.48	0.43
C	50:50	14	0.59	5.85	1037.14	2.28	0.15
D	25:75	14	0.58	4.61	892.69	1.91	0.54
E	0:100	13	0.58	5.27	1181.26	1.86	0.21

VP : Vine pruning, WC : Wood chips

Values of tensile strength parallel to the surface is analyzed in Tab. 1, E (0 %) (control) group, according to the vine pruning plates made by mixing plates, A (100 %) 11 % of plate-type, B (75 %) type plates of 33 %, C (50 %) type plates of 23 % and D (25 %) type plates of 3 % resulted in increase. Tensile strength parallel to the surface, the amount of glue used in the production of particleboard, glue quality, chip geometry, chip length and chip depends on the density of the plate. Production values of tensile strength parallel to the surface with the regulations may be obtained better results.

The internal bond strength values of experimental panels varied from 0.15 to 0.54 ($N.mm^{-2}$). The reduction in IB for the A, C, and E type boards that constructed from vine pruning and wood is probably attributable to manufacturing parameters which is consistent but incomparable to standard particleboard manufacturing.

The results indicated that all mechanical properties (static bending and modulus of elasticity, tensile strength parallel to surface, tensile strength perpendicular to surface, shear parallel to surface, screw withdrawal from face and edge, and dowel withdrawal from face and edge) generally decreased as the amount of vine pruning particles increased in the range from 25 to 100 %. Similar results had also been observed with previous studies on various raw materials and wood mixture by Ntalos and Grigoriou (2002), and Nemli et al. (2003). Aside from the low slenderness ratio, another negative characteristic of vine pruning particles is probably the fact that they incorporate certain amounts of pith particles which is reported to reach approximately 7 % at the top according to Ntalos and Grigoriou (2002). Nemli et al. (2003) points out that as pith consists of parenchyma cells, which are softer and shorter than the other cells, strength properties of these cells are. Pith influences the physical properties negatively, too. The increase in density, as it was expected, improves the mechanical but not the physical properties.

Screw and dowel holding strengths (from edge and face) from the panels used in the tests are presented in Tab. 2. Except for the (C) type panel from edge, all mean screw-holding strength values from edge and face were higher than the minimum value of screw-holding strength from face (7.2 $N.mm^{-2}$) required in BS-2684 2004 standard for general purpose particleboards. There are no any standard values about dowel holding strength. Therefore, dowel holding strength values of the panels from face and edge were compared to the test results of the study that were carried out by İmirzi (2007) with commercial particleboards. As a result of the comparison, it was seen that all dowel holding strength values of this study were lower than the mentioned study.

Tab. 2: Screw and dowel holding strengths from edge and face of the panels used in the tests.

Panel type	Screw holding strength		Dowel holding strength	
	From edge (N)	From face (N)	From edge (N)	From face (N)
A	7.77	11.30	3.34	4.64
B	11.29	13.06	2.65	5.07
C	6.91	11.57	3.27	5.18
D	11.31	8.56	2.81	3.76
E	10.58	14.03	3.68	4.88

A two-factor analysis of variance (ANOVA) general linear model procedure was performed for individual data both bending moment capacity of L-type corner joints under tension and compression to analyze main effects and interaction factors on bending moment capacity of L-type corner joints. ANOVA results indicated that for bending moment capacity of L-type corner joints under both tension and compression loads were statistically significant at 5 %

significance level.

The least significant difference (LSD) multiple comparisons procedure at 5 % significance level was performed to determine the mean differences of bending moment capacities of corner joints tested considering the significant two-factor interactions in the ANOVA results mentioned above.

Mean bending moment capacities of L-type corner joints and their coefficients of variation are given in Tab. 3. According to results for diagonal tension, C (50 %) type plate-screw joints. Diagonal compression test results show that A (100 %) type plate-dowel joints assembling technique and the high moment capacity according to the variety of materials has a value of bilateral interaction.

Tab. 3: Diagonal tensile and compression strength tests as a result of resistance from the statistics of the values of moment capacity.

Loading type	Joint technique	Panel type	Mean (Nm)	COV (%)	HG
Diagonal tension	Dowel joint	A	49.26	20.29	CD
		B	52.70	5.28	BC
		C	57.05	6.16	AB
		D	48.47	4.31	CD
		E	45.03	10.76	D
	Screw joint	A	30.90	12.61	E
		B	44.71	4.69	D
		C	63.65	2.89	A
		D	32.70	1.20	E
		E	52.31	2.09	BC
Diagonal compression	Dowel joint	A	65.73	20.61	A
		B	29.08	12.05	DE
		C	41.28	20.45	BC
		D	11.42	15.23	F
		E	35.79	11.53	BCD
	Screw joint	A	20.72	12.41	EF
		B	45.29	16.86	B
		C	32.66	14.35	CD
		D	18.05	9.78	F
		E	31.86	10.93	CD

A,B,C,D,E,F: values having the same letter are not significantly different and vice versa

COV (%) : Coefficients of variation, LSD for Diagonal tension: 6.929; LSD for Diagonal compression: 10.42.

Dowel assembly technique can be seen in the Tab. 2 has a value of the high moment capacity for diagonal tension and diagonal compression.

According to material types for moment capacity of joints comparing the effects of the averages in Tab. 3 the table C (50 %), plate type has a value of the high moment capacity for diagonal tension, but table A (100 %) plate type has a value of the high moment capacity for diagonal compression.

L-type corner joints tensile strength and compression test showed respectively that the dowel joints by 12 % higher and the rate of 20 % compared to joints with dowel screw assemblies has a higher than the moment provided by screw joints. According to the type of material for tension, the highest moment value of the C (50 %) had type particle boards, the lowest in the A (100 %) were type chip boards, and for compression the A type plate has the highest moment value, D type chip has been the lowest moment value .

Diagonal tensile dowel and screw joints values in Tab. 4, are examined, the E (0 %) (control) group, according to the vine pruning plates made by mixing plates, A (100 %)-type plate diagonal tensile strength increased by 9 % of dowel joints, screw joints 41 % observed a decrease of. B (75 %) joints with dowel-type plate diagonal tensile strength increased by 17 % and 15 % decrease seen in screw joints. C (50 %) joints with dowel-type plate diagonal tensile strength increased by 27, 22 % increase was seen with screw joints. D (50 %) increased by 8 % in type plaque diagonal tensile strength dowel joints, screw joints is decreased by 37 %.

Diagonal dowel and screw joints pressure values in Tab. 4 are examined in, E (0 %) (control) group, according to the vine pruning plates made by mixing plates, A (100 %)-type plate diagonal compression strength increased by 84 % of dowel joints, screw joints 35 % observed a decrease of. B (75 %) joints with dowel-type plate diagonal compression strength decreased by 19 and 42 % increase was seen with screw joints. C (50 %) type C of the sheet resistance of diagonal 3 % while the dowel joints, screw joints have increased 15 %. D (50 %) joints with dowel-type plate diagonal compression strength decreased by 68, 43 % decrease seen in screw joints.

CONCLUSIONS

The aim of this study was to investigate the utilization of vineyard pruning residues in production of panel products as a structural material for manufacturing of the furniture cases.

The evaluation of the mechanical and physical properties of experimental panels showed the following results. In general, partial substitution of wood by vine pruning negatively affects the board properties. All type particleboards were that met the minimum requirement for the medium density particleboard. But the A- type particleboards resulted in lower bending and internal bond strength values.

The particleboards manufactured utilizing vine pruning gave relatively high thickness swelling values. Adding water repellent chemicals such as paraffin during the board production could easily reduce the rate of thickness swelling.

Results indicated that some properties at certain proportions of pruning/wood particles can give satisfactory values. However, it was taken into consideration that some strength improvements should be made in order to reach the strength values that are given in standards.

For enhancing the properties of vine pruning particleboard, as Grigoriou and Ntalos suggested (2002), further research should be carried out in order to find appropriate methods for pith separation from the whole stalk. In addition, properties of vine pruning particleboard can be enhanced by alternative resins, such as isocyanides, and/or a reduction in furnish particle size, or involvement of plastic, fiber and or other materials in panels during manufacturing.

The results indicated that it is possible to produce particleboard from the chips of vine pruning stalks (*Vitis vinifera* L. cv. *Sultani*). When the amount of the waste material is considered, it is always reasonable to strive to convert vine prunings to a valuable raw material for composite particleboard production.

It can be deduced that corner joint construction of furniture case are sensitive to the panel type and joint technique. This study provides some information to case furniture manufacturers concerning the effect of panel type (different types of particleboard produced from vine pruning residues) and joint technique on moment resistances of corner joints of L-type corner joints. The information could give helpful insight to engineers in product engineering of furniture cases.

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