

FINITE ELEMENT ANALYSIS OF MOSO BAMBOO-REINFORCED SOUTHERN PINE OSB COMPOSITE BEAMS

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ABSTRACT

A finite element (FE) analysis was performed to investigate the flexural properties of a structural composite lumber—Moso bamboo (*Phyllostachys pubescens*) reinforced southern pine oriented strand-board (OSB). Parametric analyses were conducted to investigate the stress and displacement distributions. Various beam configurations as affected by glue, web structure, flange composition, and bamboo-OSB combination were considered. The comparison of the numerical results from the selected models with those from bending tests was also performed. Finally, a rational design criterion for this type of composite beam was proposed based on the analytical and experimental studies. Bamboo is capable of improving the flexural properties of the OSB for use as a structural beam or joist. At a given cross section of about 30×140 mm, for instance, two-layer (6.4-mm thickness each) laminated bamboo flange can increase the OSB beam's maximum bending stress by 60 to 70% and double its stiffness. The total flange thickness, rather than the thickness of each layer, controls the beam deflection while the flange with a thinner layer (3.2 mm) resulted in higher bending, vertical, and transverse stresses but lower in-plane shear stress. More reinforcing material in the composite beam could reduce the maximum bending stress but would likely increase beam weight and processing cost. From this study, it is suggested that a two-layer flanged composite beam would be favorable from a material processing standpoint as well as superior in engineering performance over other configurations of bamboo-OSB composite beam product.

Keywords: Finite element analysis, experimental bending test, bamboo-OSB composite beam, flexural behavior, stress distributions.

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INTRODUCTION

A significant change in engineering technology to utilize our renewable natural resources in the forest products industry has been taking place over the past forty years. More materials from commercially grown species, forest/mill residues, and by-products, as well as underutilized species are being used to produce various value-added engineered wood composite products. Oriented strandboard (OSB) is known as a cost-efficient, environmentally friendly, and material-saving structural product. However, it has relatively poor flexural performance when used as a beam member. Previous studies have been focused on increasing the strength of OSB by using steel, aluminum, fiber-glass plastics, or higher strength wood products as reinforcing materials (Davalos et al. 1993; Bulleit et al. 1989; Koenigshof 1986). However, these materials are costly, either in materials or in processing. With the continuously increasing demands for timber-based structural materials in the booming construction market, further research work is needed to develop new engineering products from available natural resources. Since bamboo possesses much higher tensile strength than common wood material along the longitudinal direction (Lee et al. 1994), this study attempts to analyze and demonstrate the characteristics of bamboo-reinforced southern pine OSB as a structural beam member.

Moso bamboo (*Phyllostachys pubescens*), a renewable and fast-growing natural resource, has been successfully grown in the southeastern United States for more than seventy years (Adamson et al. 1978). Native in Asia, Moso bamboo can reach over 20 m in height and 15 to 18 cm in diameter, and can tolerate temperature to -15°C . In the past decades, researchers in the United States have been studying the propagation, plantation, and fundamental characteristics of this species regarding processing and potential industrial applications (Lee et al. 1994; Adamson et al. 1978; Glenn 1956). It has been found that, compared to commercial wood species such as loblolly

pine and yellow-poplar, Moso bamboo generally has the following specific characteristics:

- Faster growing and fully mature within 3–5 years
- More dimensionally stable in longitudinal direction
- Higher tensile strength along the culm direction
- Higher specific stiffness and specific strength.

The objectives of this paper are: (1) to simulate a bamboo-OSB composite beam and evaluate its flexural performance under a third-point loading pattern (ASTM 1994) using three-dimensional (3-D) finite element (FE) analysis; (2) to study the effect of several selected composite configurations in terms of glue, web structure, flange layer and thickness, and bamboo-OSB combinations on the stress and displacement distributions; (3) to verify the model with tests of full-size beams; and (4) to develop a rational design criterion for this type of wood/bamboo composite whose structural performance will meet the commercial and industrial standards for engineered wood composite products.

Although material properties and proposed dimensions are for bamboo-OSB composites, the modeling techniques and results are generally applicable to other systems of orthotropic materials as well as to other geometric configurations of composite products, such as an I-beam and a structural wood component or system. The long-term goals of this effort are to provide additional material supply for the forest products industry and to make more productive use of diverse natural resources.

FINITE ELEMENT MODELING

Since physically testing enough samples to define material behavior for various structural sizes and configurations may be practically and economically infeasible, a mathematical model is often used. However, exact solutions, accounting for all material properties, the behavior of joints or overlaps, and interactive performance among the composite compo-

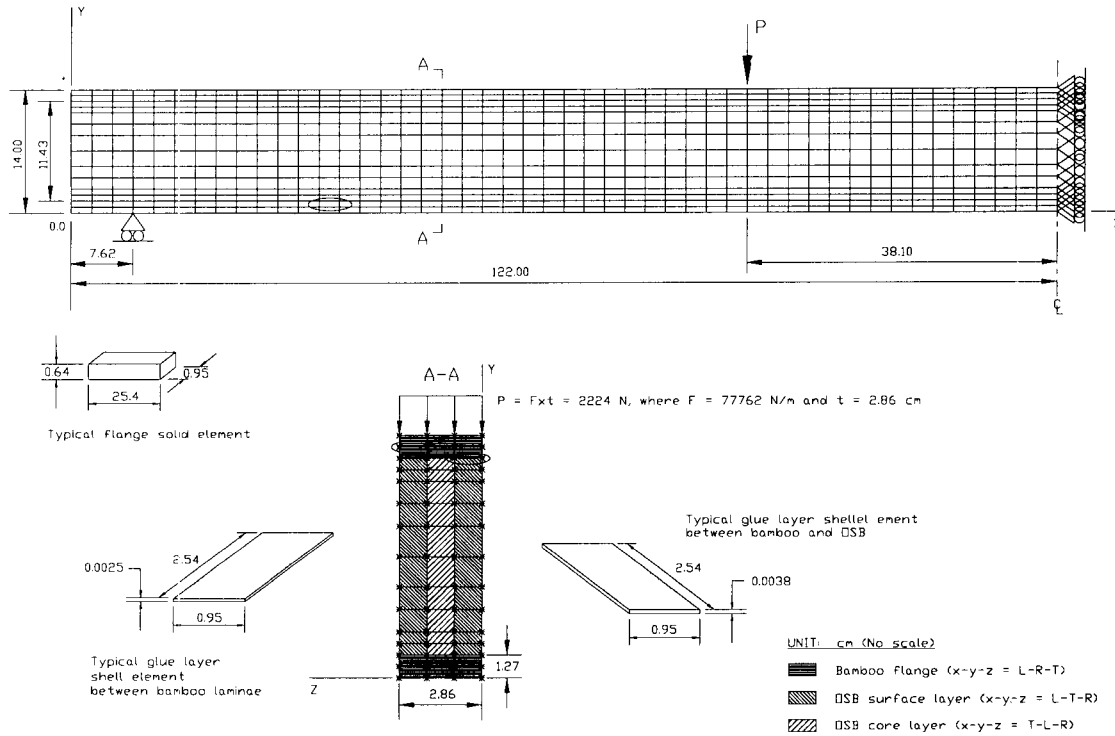


FIG. 1. Finite element mesh, boundary conditions, and element properties for bamboo-OSB composite beam.

nents, would be very difficult to formulate. Therefore, a numerical approach is a choice for complementing the experimental results (Lee et al. 1997). In this study, the I-DEAS simulation software (SDRC 1994) is used to perform the 3-D finite element analysis of bamboo-reinforced OSB composite beams.

Mesh generation

A finite element mesh is schematically shown in Fig. 1. This bamboo-OSB composite beam contains two-layer (6.4-mm thickness each) bamboo laminates as the flanges and a three-layered OSB as the web (Lee et al. 1997). The beam has a dimension of 2.44 m (length) by 14.00 cm (depth) by 2.86 cm (width). Because of the symmetry about the midspan of the beam, only one-half of the beam is modeled. There are a total of 2,940 nodes, and of 2,016 solid elements and 576 thin shell elements for this particular mesh. The modeling considerations for each individ-

ual component in the structure are described as follows.

Bamboo flange.—Each layer in the laminated bamboo flange is assumed to be a 3-D orthotropic material and its engineering elastic properties are presented in Table 1. The flange is modeled using a linear 8-node hexahedral solid element, which has a dimension of 25.4 (length) by 9.5 (width) by 6.4 (depth) mm (Fig. 1). The elements are assumed to be continuous with constant material properties throughout the flange. The upper and lower flanges are identical for the beam, and each includes 288 such solid elements uniformly distributed over the beam.

OSB web.—The OSB is assumed to be a three-layered orthotropic material. Variations of material properties among the layers are associated with different principal directions of the beam as indicated in Fig. 1. For instance, as its longitudinal (L), tangential (T), and radial (R) directions are respectively parallel to

TABLE 1. *Material properties for bamboo-OSB components*¹.

Moso bamboo ² (Orthotropic)	Southern pine OSB ² (Orthotropic)	Resorcinol-phenol-formaldehyde ³ (Isotropic)
$E_L = 10,350$ Mpa	$E_L = 4,000$ Mpa	$E = 6,900$ Mpa
$E_T = 690$ Mpa	$E_T = 2,400$ Mpa	
$E_R = 500$ Mpa	$E_R = 690$ Mpa	
$G_{LT} = 900$ Mpa	$G_{LT} = 690$ Mpa	$G = 2,650$ Mpa
$G_{LR} = 830$ Mpa	$G_{LR} = 170$ Mpa	
$G_{RT} = 290$ Mpa	$G_{RT} = 207$ Mpa	
$\nu_{LT} = 0.341$	$\nu_{LT} = 0.150$	$\nu = 0.300$
$\nu_{LR} = 0.390$	$\nu_{LR} = 0.300$	
$\nu_{RT} = 0.308$	$\nu_{RT} = 0.300$	

¹ L and T denote the longitudinal and transverse dimensions in plane of bamboo strip and OSB, respectively, while R is dimension perpendicular to that plane.

² Data are from Bai (1996).

³ Data are from Triche (1988).

the x-, y-, and z-axis, the surface layer of OSB is represented by an x-y-z = L-T-R mode. Similarly, the core layer of OSB is denoted as an x-y-z = T-L-R mode, because its T, L, and R directions are coincided with x-, y-, and z-axis, respectively. The material properties for OSB are given in Table 1. The OSB is modeled using the same type of solid elements as the bamboo flange. However, because a stress gradient is expected through the depth of the web, large elements are used in the central zone of the web, while small elements are distributed close to the flange-web interfaces as shown in Fig. 1. As a result, the total number of elements is reduced from 2,592 for uniform mesh to 1,140 for gradient mesh without influencing the accuracy of the result.

Glue layer and bamboo/OSB-adhesive interphase zone.—Compared to other FE analyses of structural wood composite beams (Leitchi and Yoo 1992; Wang et al. 1992; Fawcett and Sack 1977), the model developed here is unique in that it tries to simulate the glue effect on the elastic performance of proposed composite beam. Theoretically, there may exist two kinds of action between the adhesive and porous substrate, such as wood. One is the interphase region including a mixture of adhesive and cell-wall material and the other is the interface adhesive layer between the substrates.

As a mixed structure, the interphase zone can be assumed to have a similar orthotropic

behavior to wood. There are nine independent elastic properties to be determined. Generally, a numerical analysis such as a sensitivity study of finite element modeling may help to estimate some of major properties, for instance, longitudinal modulus of elasticity (E_L) in terms of approximate global characteristics of an adhesive-wood interaction zone. First, an initial E_L is assigned to the interphase in finite element model while assuming other properties of the substrates and mixture as constants. After simulation, the comparison between the predicted global E_L and the average experimental value is made. The modification of assumed value is needed if the two values do not closely match each other. However, because of the lack of experimental data, those minor properties must be assumed based upon the given wood and adhesive properties. To understand the real interaction mechanism and the properties of wood-adhesive interphase zone, further studies will be needed.

In case of bamboo-bamboo bonding, the inspection of some failed specimens indicated that a clear interphase zone was not found between bamboo and adhesive because the resin could not easily penetrate into the highly densified structure of Moso bamboo (Bai 1996). Like bonding metal, a thin film of the adhesive is formed and may dominate bamboo bonding. In the bamboo-OSB bonding, a much more complicated situation is created. There is limited access to the cell walls, most of which are

either crushed or already filled by the resin during OSB manufacturing. However, there are a lot of voids and gaps existing on the rough edge of OSB. Some of the resin may easily fill in these discontinuous voids, leading to developing some uneven gluelines under pressing.

Many studies have contributed to determining the characteristics of adhesive behavior. It has been reported that the resin for wood naturally is an isotropic material. The resin properties defined in Table 1 are based upon Triche's study (1988) of aligned wood strand composite, in which the modulus of elasticity of phenol-formaldehyde resin is estimated to be 6,900 MPa and Poisson's ratio is simply assumed 0.300.

As a result, this study assumes that the interface adhesive layer will make significant contributions to the beam properties and therefore ignores the effect from the undefined interphase zone. Using the given material properties in Table 1, a sensitivity study of finite element analysis based on a 2-ply laminated bamboo specimen approximately gives a glue layer thickness of 0.0025 mm between the bamboo. It is expected that more glue will be needed at the interface between the flange and web in order to take account for the losses of adhesive into the edge voids of OSB as well as to avoid shear delamination. Then, a thickness of 0.0038 mm, 50% more than 0.0025 mm, is assigned to the adhesive layer between the flange and web. The linear 4-node thin shell elements are used to model these adhesive layers (Fig. 1). There are a total of 288 such elements for each type of glue element.

Loading and boundary conditions.—A load resultant of 2,224 N is applied as a uniformly distributed load across the beam width. This load is about one-half of the average load at proportional limit obtained from a preliminary test on bamboo-OSB composite beam (Lee et al. 1997), and is placed at the one-third point along the longitudinal dimension of the beam.

At the support located 7.62 cm from the end of the beam, the vertical deflection along the y -axis is completely prevented as shown in

Fig. 1. Due to the symmetry about midspan, only one half of the beam is modeled, and the longitudinal displacement along the x -axis is constrained at the center of the beam.

RESULTS AND DISCUSSIONS

Analysis of flexural behavior

A linear static analysis of this FE model is performed to estimate the flexural and shear behavior of the composite beam. It is indicated that the reinforcing flanges support a part of the stress concentrations around both the support and the load zones. For instance, in Fig. 2, normal stress σ_{xx} and in-plane shear stress τ_{xy} are significantly high at these critical locations as expected, but the general distributions of σ_{xx} and τ_{xy} along the span obey beam theory under a third-point loading. The transverse stress σ_{zz} , however, only exists inside the flanges with a maximum value located at the middle of flanges for a given cross section (C-S) plane, while extreme high values of vertical stress σ_{yy} can be found at the supporting and loading points. Interlaminar shear stresses τ_{xz} and τ_{yz} would be ignored due to their relatively small value across the beam domain.

The detailed distributions of stress components within the C-S plane at the one-sixth span of the beam are presented in Fig. 3 for several composite configurations. As illustrated, the component σ_{xx} , having an antisymmetrically distributed stress about the neutral axis, increases from zero at the neutral plane of the beam to the interfaces of the web and flange and then, due to discontinuity of material, jumps up to maximum value at the surface of the beam. The vertical stress σ_{yy} distribution is also antisymmetric about the neutral axis with larger magnitude existing at the top of the flanges. The τ_{xy} component, however, has a parabolic distribution with a maximum shear stress at the neutral axis of the beam.

Results from this study indicate that bamboo flanges can improve OSB's flexural performance by significantly increasing the maximum bending stress σ_{xx} of the beam (Fig. 3a),

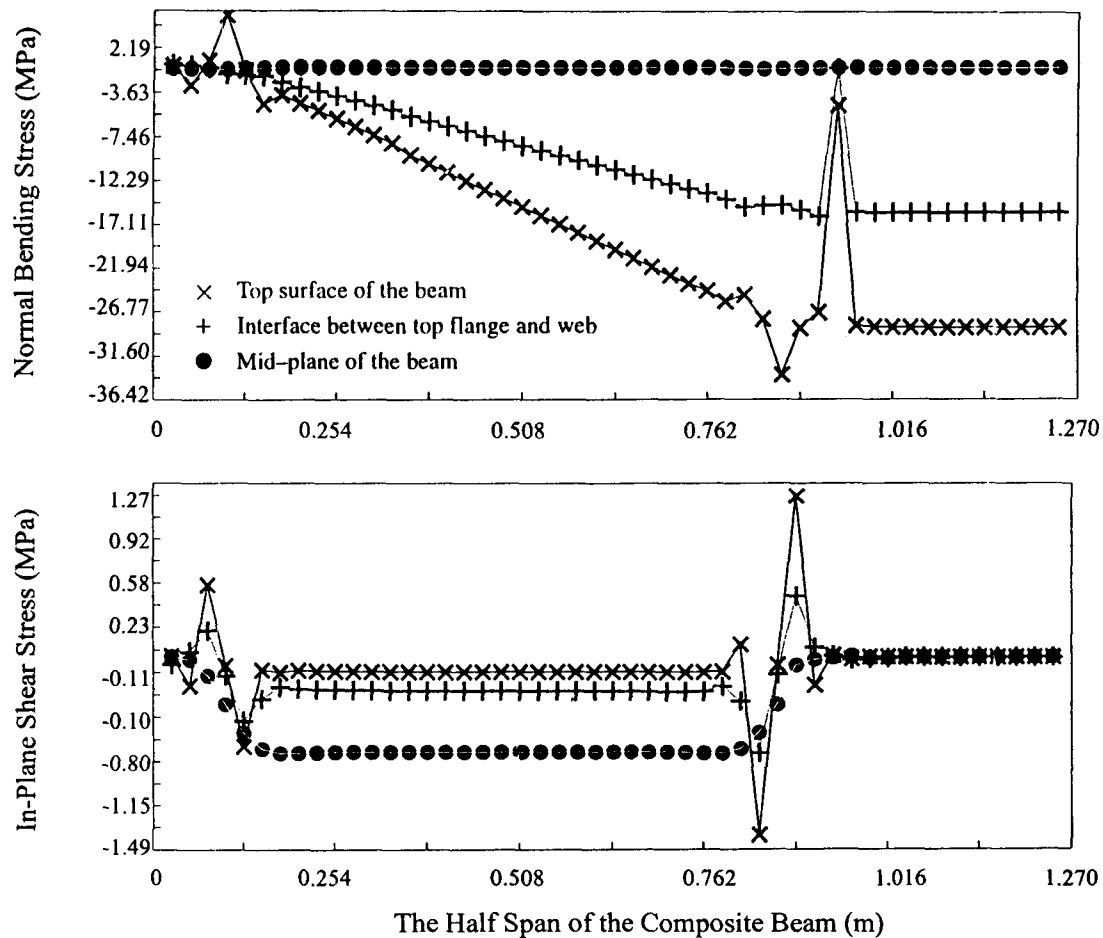


FIG. 2. Stress distributions along the length of bamboo-OSB composite beam: (a) Bending stress; (b) In-plane shear stress.

but they also reduce the maximum in-phase shear stress τ_{xy} of the structure (Fig. 3b). The maximum magnitudes of other stress components are summarized in Table 2.

Effects of the components

The effects of adhesive, OSB's web structure, and layer number and thickness of bamboo flanges on stress components are evaluated based on a C-S plane at the one-sixth span, or the middle of the C-S plane between the support and load.

The adhesive considerably contributes to reducing the potential delamination between the flange and web as well as between the two

layers of the flanges. Based on the assumptions, Fig. 4 illustrates that a model with consideration of a glue layer in the structure results in reducing σ_{xx} and τ_{xy} by increasing σ_{zz} within the flanges of the beam. However, the glue element does not influence the beam's maximum values of major stress components, σ_{xx} and τ_{xy} . A slight effect of glue element on the other stress components exists. Figure 5 indicates that the distributions of the σ_{xx} within the flanges are different between a uniform OSB web and a layered one. As shown in Fig. 6, for a given thickness of the flange, increasing the number of the layers does not significantly influence any stress components. This

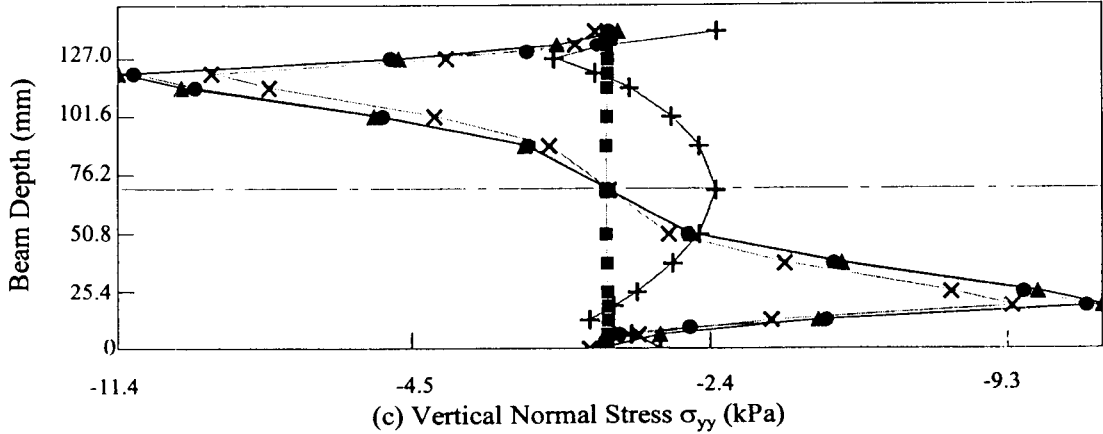
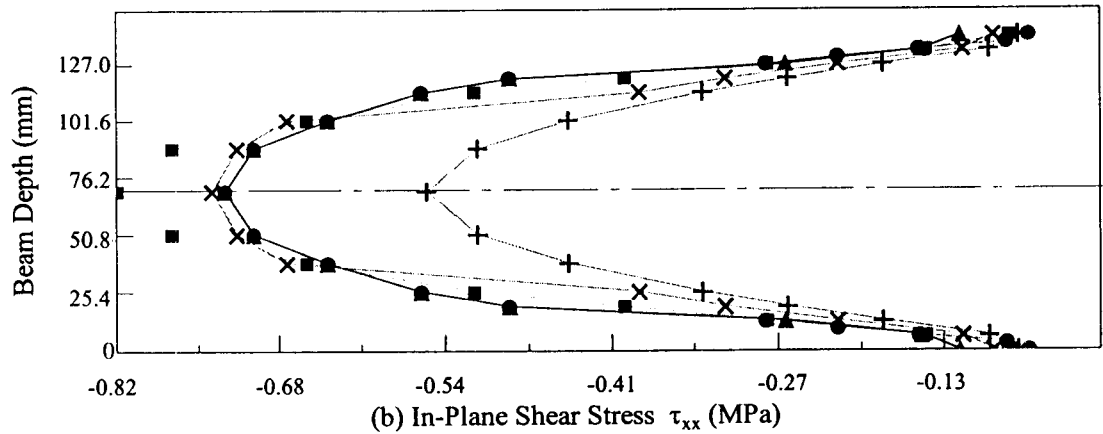
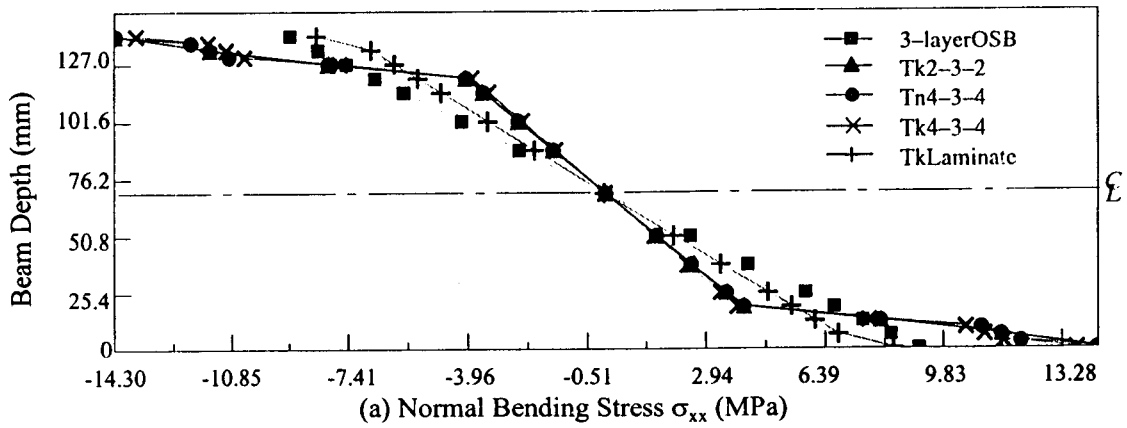


FIG. 3. Comparisons of major stress distributions of several bamboo-OSB beam configurations within a cross-section plane at the one-sixth of the beam ($x = 0.46$ m or 18 nodes from the left end of beam).

TABLE 2. Summary of maximum stresses and deflections from different bamboo-OSB composite beams.

Composite beam code ¹	Finite element meshing		Maximum magnitudes of the stress components						Maximum deflection (Δ_y)
	Node	Element	σ_{xx}	τ_{xy}	σ_{yy}	τ_{xz}	τ_{yz}	σ_{zz}	
			MPa						-mm-
3-Layered OSB ²	2,548	1,728	21.08	0.96	8.90	0.15	0.22	1.06	10.06
Tk2-3-2	2,940	2,592 ³	33.72	1.38	7.69	0.86	0.90	4.05	22.48
Tn4-3-4	3,724	3,744 ³	35.52	0.94	9.21	1.02	0.39	6.39	22.43
Tk4-3-4	3,332	3,456 ³	29.28	1.47	7.63	0.92	0.92	4.18	17.65
TkLaminate	4,508	6,152	23.37	0.85	4.13	0.23	0.49	1.41	13.62

¹ Tk and Tn denote the thick (@6.4 mm) and thin (@3.2 mm) bamboo strips as the reinforced flanges, respectively; the first and third numbers indicate the top and bottom flange layers while the middle one represents the OSB layered structure.

² A load resultant of 140 pounds, one-half of the average load at proportional limit for the OSB beam loaded edgewise in experimental test, was applied as a uniformly distributed load across the beam width (Bai 1996).

³ One-dimensional shell elements for adhesive are included.

could lead to a significant saving in glue by using thicker flanges. On the other hand, increasing the flange thickness results in changing all stress distributions and magnitudes within the composite beam as shown in Fig. 7. When using thicker flanges, the maximum σ_{xx} at the beam surface is significantly reduced, and a more uniform distribution of the σ_{xx} through the depth of the beam is presented, which is not an effective design for a structural beam member. In addition, the distribution of shear stress τ_{xy} becomes narrow within the web region, but its maximum value re-

mains constant. The minor stress components are also varied due to an increase in flange thickness (Fig. 7).

According to a third-point loading and boundary conditions of FE mesh, the maximum displacement of the beam is expected to occur at the midspan of the composite beam. It is found that, from this study, adding adhesive and increasing flange thickness could result in higher beam stiffness and therefore reduce the deflection of the beam. However, a multilayer OSB web could result in reducing the beam stiffness.

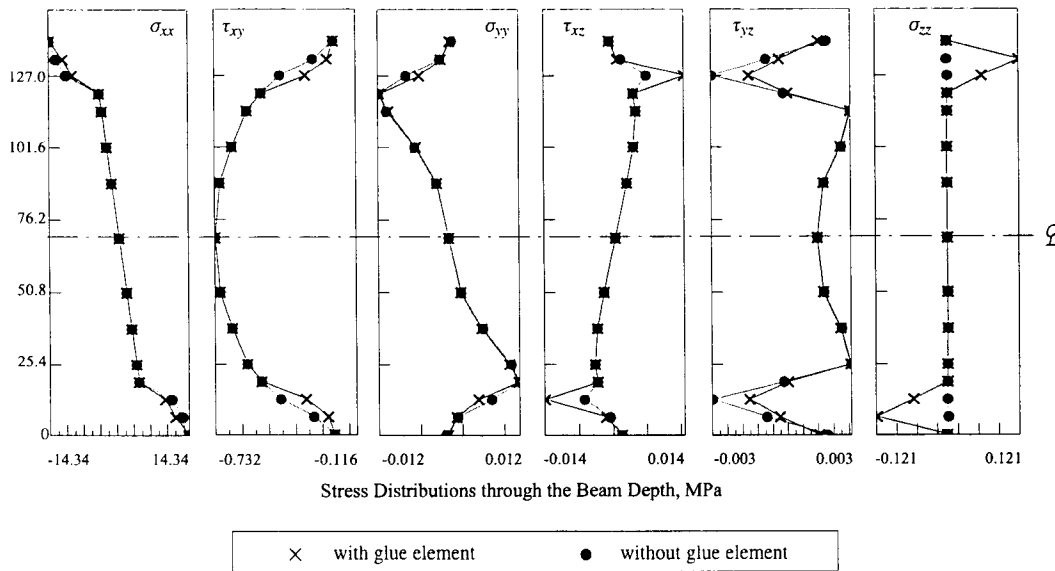


FIG. 4. Effect of glue layer on the stress distributions in a cross section plane at one-sixth of composite beam.

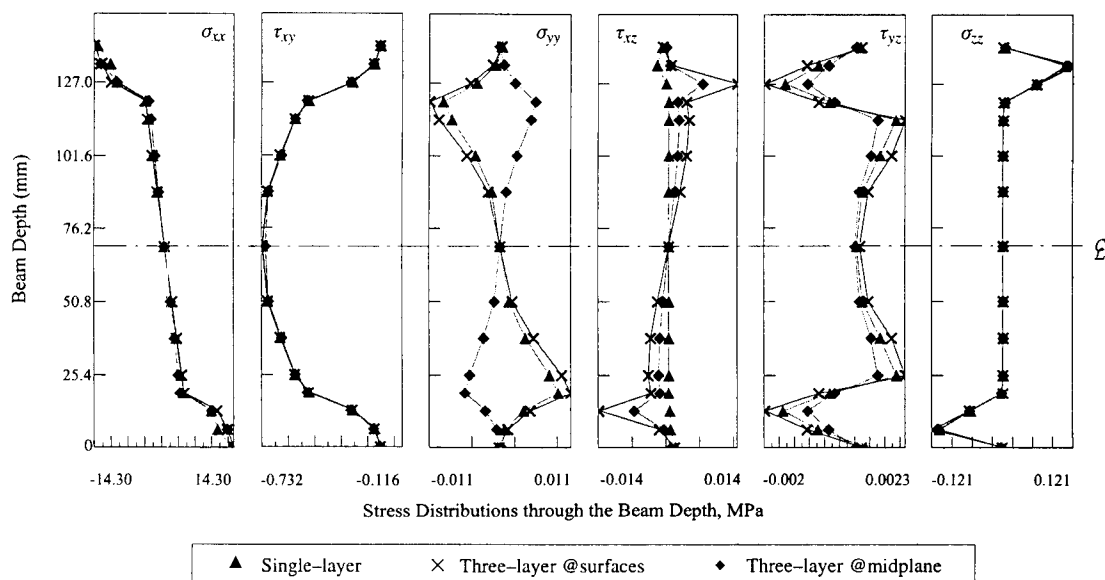


FIG. 5. Effect of OSB web structure on the stress distributions in a cross section plane at one-sixth of composite beam.

Mesh convergence

The replacement of the actual physical problem by a numerical model introduces approximations. However, the convergence of the FE analysis can be improved by meshing techniques. There are at least two ways to allow FE approximation to converge to the mathematical model of the physical problem, that is, reducing the size of linear element (H-version) or increasing the order of the polynomial interpolation functions (P-version).

Five FE meshes, including four models with different linear isoparametric 8-node solid elements and one with quadratic isoparametric 20-node solid elements, were analyzed. The convergence of the major stress components and displacements is evaluated based on their maximum values. The convergence of the flexural properties based on a selected point on the composite beam, which is located at the position between the lateral surface plane and the upper interface of the flange and the web cross the C-S plane of one-sixth span, is also investigated.

Table 3 presents the results of the convergence study. As indicated, the FE models are

converged with respect to the σ_{xx} and τ_{xy} as well as the deflection of the beam at the selected location. However, although the maximum deflection of the beam converges, the maximum σ_{xx} and τ_{xy} do not. This is perhaps because the locations of maximum stresses are changed as influenced by the stress concentrations around the supporting and loading zones. It has been found that an increase in nodal number resulted in increasing both maximum σ_{xx} and τ_{xy} . Compared with analytical solutions based on the theory of composite materials, the results from the FE analysis are fairly good in terms of stress magnitudes as well as displacements of this bamboo-OSB composite beam as shown in Table 3.

COMPARISON OF FE MODEL TO BENDING TEST

A test on the flexural properties of full-size bamboo-wood composite beam was conducted to verify the numerical FE analysis. Eight each of two-layer and four-layer reinforced beams, having the same dimensions as simulated in FE model, were fabricated, and an edgewise third-point loading test was applied after the beams were conditioned. Also, eight

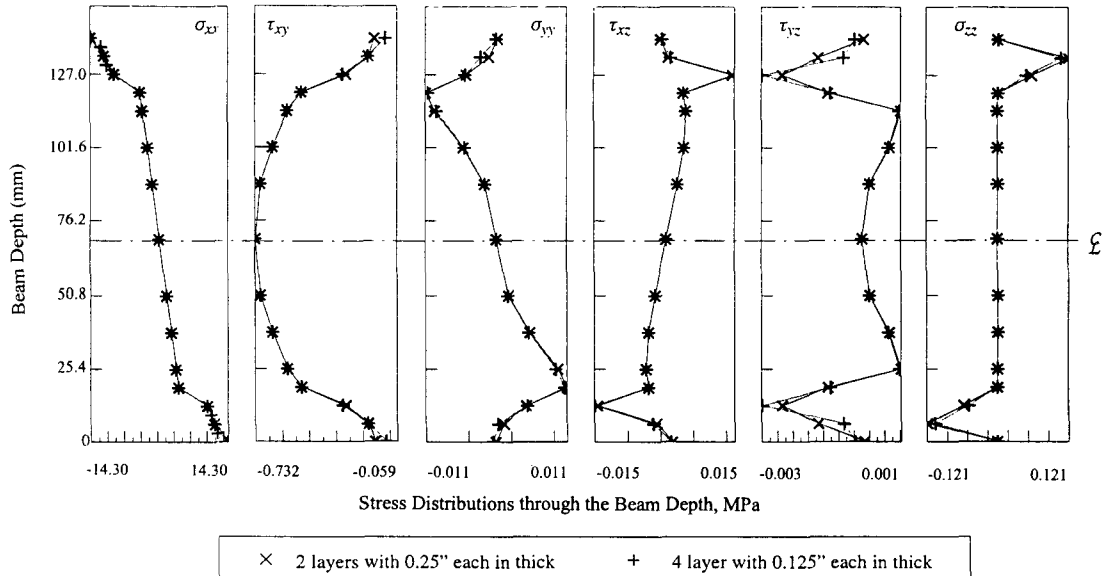


FIG. 6. Effect of the thickness of flange layer on the stress distributions in a cross section plane at one-sixth of composite beam.

full-size three-layer OSB beams were tested as a control. The comparison of maximum bending stress and deflection from FE analysis to those from flexural test is listed in Table 4.

It is found that the predicted maximum bending stress of composite beam is fairly close to tested value. However, the FE model underestimates bending stress by about 19%

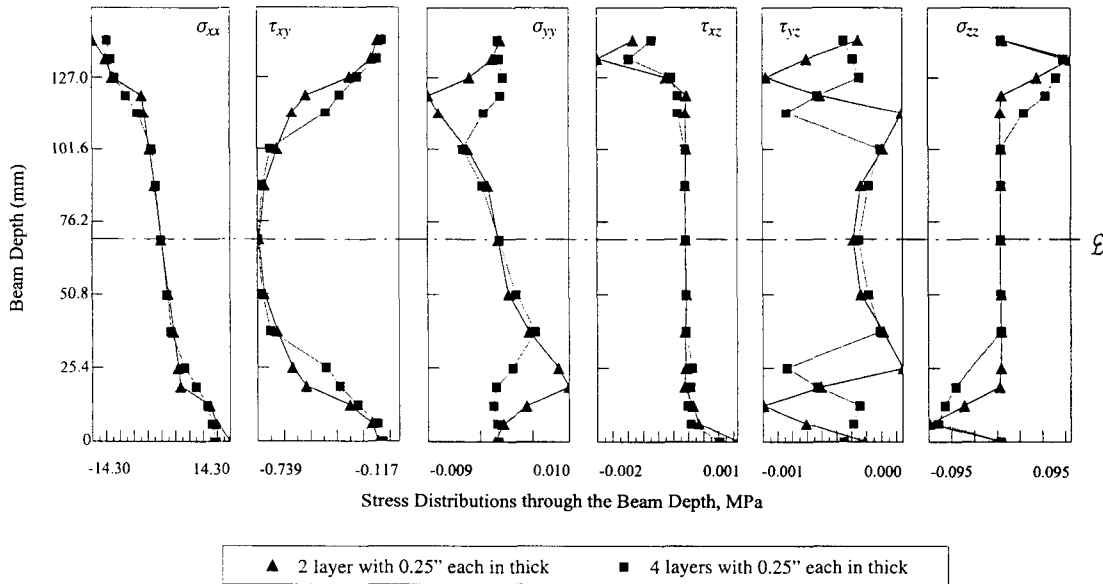


FIG. 7. Effect of the number of flange layer on the stress distributions in a cross section plane at one-sixth of composite beam.

TABLE 3. Convergence study for finite element analysis of bamboo-OSB composite beam¹.

Mesh type	Finite element modeling		Results from the selected point ²			Results for maximum magnitudes		
	No. of node	No. of element	Deflection (Δ_y)	Bending stress (σ_{xx})	Shear stress (τ_{xy})	Deflection (Δ_y)	Bending stress (σ_{xx})	Shear stress (τ_{xy})
			-mm-	-MPa-	-MPa-	-mm-	-MPa-	-MPa-
H-version								
Coarse	900	720	11.51	8.33	0.21	21.74	27.41	0.69
Medium	1,764	1,440	11.48	8.19	0.23	21.57	27.41	0.84
Standard	2,940	2,592	11.47	7.96	0.25	21.54	32.97	1.39
Fine	4,508	3,744	11.47	7.92	0.26	21.58	39.95	3.95
P-version ³	3,653	672	11.47	8.18	0.28	21.59	34.77	2.46
Analytical Solution ⁴			11.11	7.27	0.29	21.15	28.75	0.84

¹ The results are based on a composite beam of 3-layered southern pine OSB reinforced at the edges by 2-ply bamboo laminates using resorcinol-phenol-formaldehyde resin.

² The location is at the point between the lateral surface and the interface of the flange and web across the cross section plane at the one-sixth span of the beam.

³ Quadratic isoparametric elements with 20 nodes are used.

⁴ Timoshenko Beam Theory is applied for the calculation of the deflection and Transformed-Section Theory of Composite Materials for the stresses.

and 16% for two-layer and four-layer beams, respectively, as shown in Table 4. This is probably due to uncertainty of glue properties, lack of information on glue-wood interface behavior, and the setup of analytical model as well as experimental errors. In general, reducing element size or using higher-order element could significantly improve the convergence of the analysis. As shown in Table 4, using refined elements in an FE model reduces the difference between analytical and experimental results to about 4%. For OSB beam, the model overestimates the maximum bending stress by about 40%. This may be due to the nature of OSB product containing considerable gaps and/or overlaps among strands. Therefore, more accurate models, which may

appropriately account for these properties, may need to be investigated later.

In Table 4, the comparison of maximum deflections from finite element models to those from physical tests is also conducted. Although FE model overestimates the deflection of four-layer flanged composite beam, there is a fairly good match for that of two-layer flanged beam.

SOME IMPLICATIONS FOR THE DESIGN OF BAMBOO-OSB COMPOSITE BEAMS

The allowable tensile stress of the flange and shear strength of the web are two important parameters for the design of a composite beam. Based on the results of this FE analysis

TABLE 4. Comparison of flexural behavior of Bamboo-OSB beam from FE model and bending tests¹.

Composite beam code ²	Maximum bending stress (σ_{xx})			Maximum deflection (Δ_y)		
	Predicted	Tested	Error	Predicted	Tested	Error
	-MPa-	-MPa-	-%	-mm-	-mm-	-%
3-Layered OSB ³	21.08	12.47	+69.05	10.06	10.21	-1.5
Tk2-3-2	33.72	41.65	-19.04	22.48	21.76	+3.3
Tn4-3-4	35.52	42.26	-15.95	22.43	18.07	+24.1
Refined Tk2-3-2 ⁴	39.95	41.65	-4.08	21.58	21.76	-0.8

¹ Refer to the paper published by Lee et al. (1997) for the detailed experimental study.

² Tk and Tn denote the thick (@6.4 mm) and think (@3.2 mm) bamboo strips as the reinforced flanges, respectively; the first and third numbers indicate the top and bottom flange layers while the middle one represents the OSB layered structure.

³ A load resultant of 140 pounds, one-half of the average load at proportional limit for the OSB beam loaded edgewise in experimental test, was applied as a uniformly distributed load across the beam width (Bai 1996).

⁴ Refer to Table 3.

as given in Table 3, it is recognized that the maximum σ_{xx} of the OSB beam could be increased by 60 to 70% if a two-layer (6.4-mm thick each) or a four-layer (3.2-mm thick each) laminate is used as reinforcing flanges. However, more reinforcing material such as a four-layer flange with 6.4 mm each leads to only about 40% increase in maximum σ_{xx} . In addition, compared to the OSB beam, the maximum σ_{xx} of the laminated bamboo lumber beam increases only about 20%.

Although the σ_{yy} is not a critical design variable for a beam, its maximum value is found to be quite high in the bamboo-OSB composite beam at the supporting and loading regions. Normally, the largest σ_{yy} at a C-S plane occurs at the web zones close to the flanges as shown in Fig. 3c. As shown in Figs. 4 to 6, the σ_{zz} is an insignificant stress within the proposed composite beam.

The τ_{xy} in composite beam is considerably influenced by the reaction and applied load. The maximum τ_{xy} in composite beam is higher than those in the OSB and laminated bamboo lumber beams. Figure 3b shows that bamboo flanges obviously reduced the maximum τ_{xy} at the center of the web. In general, the shear stresses τ_{xz} and τ_{yz} may be ignored in composite beams. However, the maximum τ_{xz} and τ_{yz} are much higher in the composite beam than those in both OSB and laminated bamboo lumber beams.

It is found that the flange thickness can affect the beam deflection. The longitudinal stiffness of the OSB web is a major contributor to the stiffness of composite beam, and the different amount of glue is also a factor of the beam stiffness.

Based on the above analysis, the proposed beam made from two-ply bamboo laminates reinforcing a three-layered OSB web is a favorable structural combination in terms of the final product properties. Although the flanges with thinner layers are included in an attempt to efficiently utilize the upper portion of bamboo culm, its material properties are relatively poor, and also more glue and more processing are involved. A further increase in the rein-

forcing material does not give a positive result for this composite beam from the point of view of structural properties (such as maximum value and distribution of bending stress), material savings (glue and fiber), and processing cost (energy and labor).

CONCLUSIONS

A three-dimensional finite element analysis is conducted to evaluate the performance of an orthotropic composite lumber beam made from Moso bamboo-reinforcing southern pine OSB. An assumed one-dimensional adhesive layer element is introduced into the finite element models. The bending test for full-size beams was performed to verify the accuracy of the model. It has been found that bamboo is a potential reinforcing material to improve OSB's flexural properties. A bamboo-OSB composite beam with two-layer laminated flanges provides favorable structural properties not only in flexural performance but also in material savings and processing over other configurations of bamboo-OSB composite beams. This assessment is made using a parametric analysis considering the effects of glue, web structure, and the number and layer of the flange. Due to the stress concentrations caused by the reaction and applied load, all maximum stress components from the FE analysis are significantly larger than those from theoretical solutions. This study suggests that the 3-D FE analysis is an effective tool for simulating the structural properties of composite beams, for analyzing the detailed interactions between individual components and their contributions to the composite, and, furthermore, for assisting in design of high performance engineered wood composite materials.

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