EFFECTS OF WOOD DECAY BY *POSTIA PLACENTA* ON THE LATERAL CAPACITY OF NAILED ORIENTED STRANDBOARD SHEATHING AND DOUGLAS-FIR FRAMING MEMBERS

Scott M. Kent

Graduate Research Assistant

Robert J. Leichti

Associate Professor

David V. Rosowsky

Professor and Richardson Chair in Wood Engineering

and

Jeffrey J. Morrell†

Professor

Department of Wood Science & Engineering

Oregon State University

Richardson Hall 119

Corvallis, Oregon 97331-5751

(Received November 2003)

ABSTRACT

The effect of wood decay on the single shear strength of nailed oriented strandboard (OSB) sheathing to Douglas-fir framing member connections was investigated. The connections evaluated in this study were representative of those present in lateral force resisting system components of light-framed wood structures, including shear walls and horizontal diaphragms. Strength and stiffness of the nailed connections were characterized using monotonic testing of samples exposed for increasing intervals to the brown rot fungus, *Postia placenta.* After the destructive tests, portions of the sheathing and framing member from the samples were further evaluated for dowel bearing strength and weight loss. The results indicated that existing yield models used for design of nailed connections can predict nominal design values for nailed connections of OSB sheathing and Douglas-fir framing members with various levels of decay damage, provided that the dowel bearing capacity of the wood materials can be assessed.

Keywords: Wood decay, brown rot, *Postia placenta,* connections, yield models, OSB (oriented strandboard), nails.

INTRODUCTION

Brown rot fungi are primarily basidiomycetes that consume portions of the wood structure, leaving the decayed wood looking dark brown, dry, and heavily checked across the grain (Eaton and Hale 1993). Brown rot is considered the most destructive and economically important decay type for commercial softwoods. It is estimated that up to 80% of the cases of fungal decay in wood building materials are caused by brown rot fungi (Green and Highley 1997). Interestingly, this group accounts for only 6% of the wood deterioration in forested areas (Gilbertson and Ryrarden 1980). At the early stages of brown rot decay, or incipient decay, significant

† Member of SWST.

Wood and Fiber Science, 36(4), 2004, pp. 560–572

reductions in the mechanical properties can occur with little observable changes in the physical properties, making early decay damage very difficult to detect. The modulus of rupture of solid wood can change 13 to 50% with only a 2% weight loss (Wilcox 1978).

The effect of decay on the properties of wood connections has received little attention in the literature. Only one reference to nailed connections was found. Merrill and French (1964) studied the effect of nailhead pull-through strength at various levels of decay damage and found that a 12–15% weight loss caused an approximate 50% reduction in pull-through strength.

Laterally loaded nailed connections are designed according to the National Design Specification® for Wood Construction (NDS) using yield models (AFPA 2001). As an engineering mechanics-based approach, yield models incorporate connection geometry and wood and fastener material properties to predict the connection yield strength. The wood property used in the yield models is the dowel bearing yield strength, determined according to ASTM D 5764 (ASTM 2003a). Fig. 1 shows the definition of the dowel bearing yield load, $P_{5\%}$, which is defined as the intersection of the load-deformation curve and a line parallel to the initial linear region of the load-deformation curve that is offset by a distance of 5% of the dowel diameter. The dowel bearing yield stress (MPa) is computed by dividing $P_{5\%}$ (N) by the projected contact area between the nail shank and the wood test specimen (mm^2). The nail property used in the yield models is the bending yield strength, determined according to ASTM F 1575 (2003b). Dowel bearing strength for wood products has been described by Wilkinson (1991), and its use for the design of laterally loaded wood connections is given in a technical report by AFPA (1999).

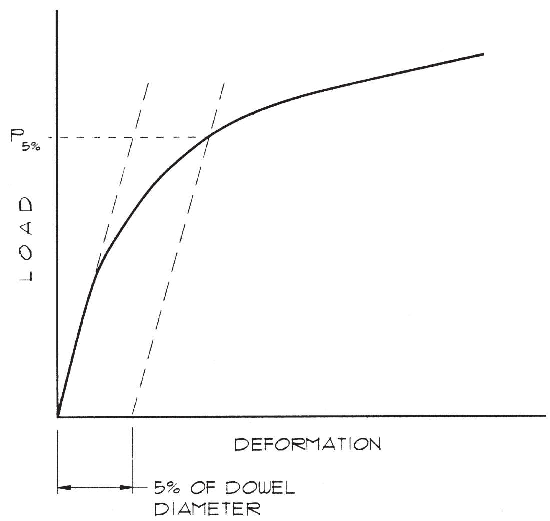

FIG. 1. Dowel bearing load-deformation curve showing definition of yield load ($P_{5\%}$).

This study investigated the effects of fungal decay on the properties of three types of oriented strandboard (OSB) sheathing to Douglas-fir framing member connections found in light-framed wood shear walls and horizontal diaphragms. A principal component of this study was to determine if existing connection yield models could be used to predict the nominal design capacity for connections with various levels of fungal damage using dowel bearing strength values determined from the decayed materials.

EXPERIMENTAL DESIGN

The experiment was organized as a completely randomized design with a full factorial treatment structure with main effects of connection geometry at three levels, inoculation at two levels, and incubation time at five levels (see Table 1). Ten replications were assessed per treatment combination. Three connection geometries were considered: field, edge, and plate to represent different locations in typical light-framed wood shear walls and horizontal diaphragms as shown in Fig. 2 (shear wall example shown). Samples were either inoculated with the brown rot fungus *Postia placenta* or not inoculated (control). Five incubation times were considered for examination of the mechanical properties at various levels of decay ranging from no decay damage to extreme decay damage: 0, 5, 10, 20, and 30 weeks. The *a priori* alpha level for tests of significance in this study was set at 0.05. Probability values (p-values) for comparisons between test groups were adjusted using Tukey's Honest Significant Difference (Steel et al. 1997).

TABLE 1. *Combinations of connection geometries and incubation times used to assess the effects of fungal attack.*

Test group identification	Connection geometry (main effect, three levels)	*P. placenta* inoclution level (main effect, two levels)	Incubation times (weeks main effect, five levels)	Replications per main effect combination	Total number of samples in test group
EC	Edge	Control	0, 5, 10, 20, 30	10	50
FC	Field	Control	0, 5, 10, 20, 30	10	50
PC	Plate	Control	0, 5, 10, 20, 30	10	50
EI	Edge	Inoculated	0, 5, 10, 20, 30	10	50
FI	Field	Inoculated	0, 5, 10, 20, 30	10	50
PI	Plate	Inoculated	0, 5, 10, 20, 30	10	50
				Total	300

Note: E-Edge, F-Field, P-Plate, I-Inoculated, C-Control.

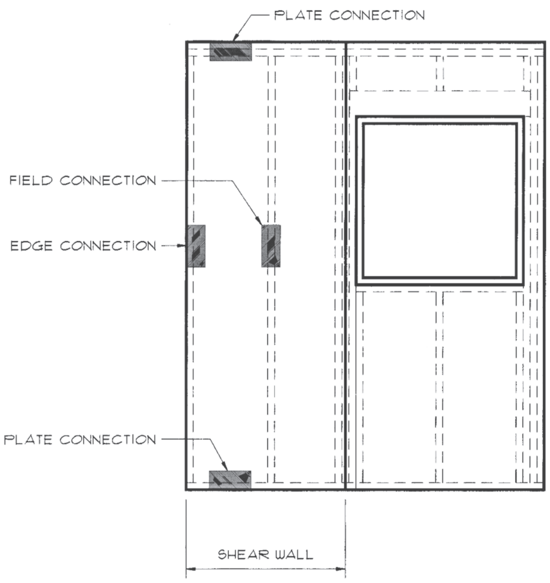

FIG. 2. Examples of where the three connection geometries, evaluated in decay tests, might appear in a light-framed wood shear wall.

MATERIALS AND METHODS

The nailed single-shear connection samples were constructed from 11.9-mm-thick aspen OSB sheathing (9% *Populus balsamifera* L. and 91% *Populus tremuloides* Michx.), 38-mm × 89-mm Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) lumber and a single pneumatically driven smooth-shank nail (2.87-mm diameter by 63.5 mm long). A diagram of the three connection geometries is shown in Fig. 3. The field and edge connection geometry samples were similarly constructed with the exception of the saw kerf in the OSB of the edge geometry samples, 11 mm from the nail centerline (four nail diameters), which were provided to simulate an OSB sheathing panel boundary. Nails were centered in the thickness of the framing members. Fixtures were designed to hold the sheathing and framing members in a fixed position so the nails could be reproducibly driven in the same relative location in each connection sample. The moisture content of the wood materials at the time of fabrication was approximately 8% (oven-dry basis).

After construction, each sample was immersed in a water bath for 4 weeks both to increase the moisture content of the wood materials and to leach compounds that could affect growth of the decay fungi (Curling and Murphy 1997). Afterwards, each sample was sterilized by heating to 121°C for 45 min. Immediately after sterilization, each sample was placed into its own polyethylene bag and sealed under sterile conditions.

Postia placenta (Fr.) M. Lars. et Lomb. (Madison 698) inoculum was prepared by inoculating 200 mL of one-percent malt extract with an agar plug cut from the actively growing edge of a culture of the test fungus. The malt extract was incubated for 2 weeks and the resulting mycelium was collected with a filter, washed with sterile distilled water, and then resuspended in sterile distilled water. The resulting mixture was fragmented in a blender for 30 s.

One-half of the samples from each configuration were randomly selected and inoculated with

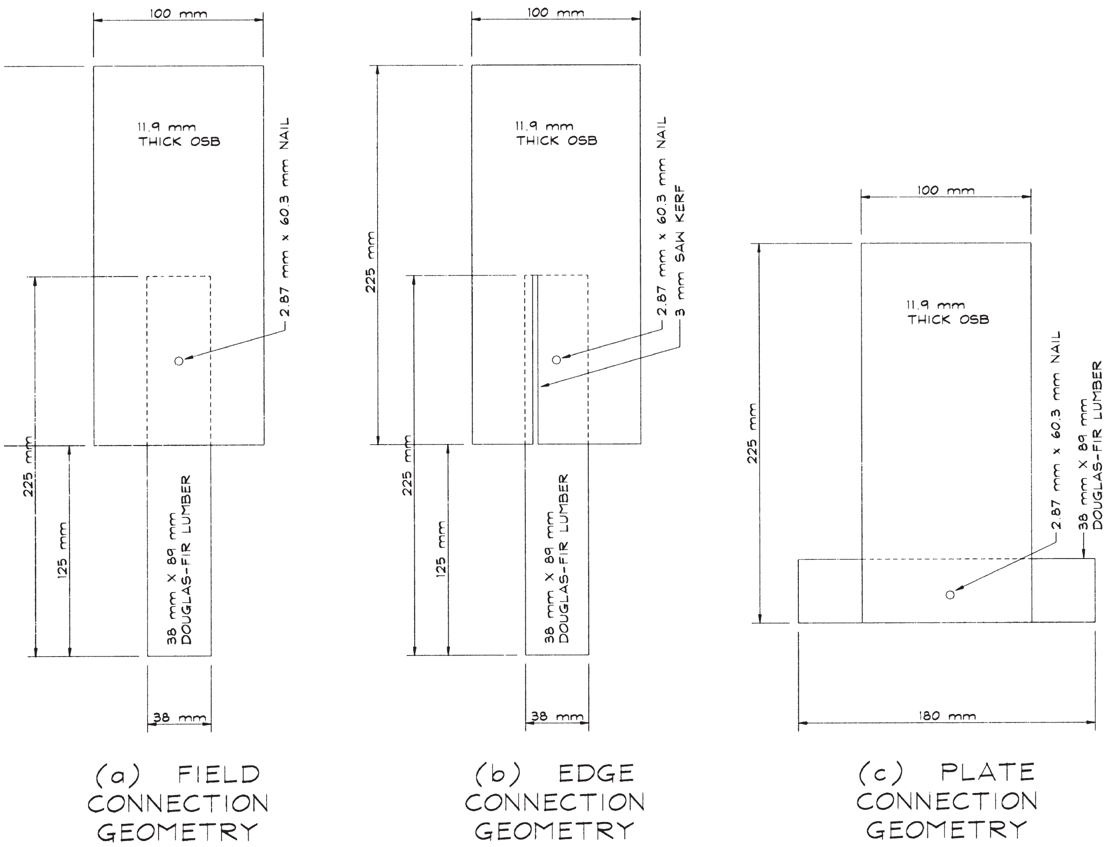

FIG. 3. Diagrams of the three connection geometries used to study effects of fungal decay on connection behavior.

two 200-μL doses of the inoculum. The inoculum was injected between the OSB and Douglas-fir, one dose on either side of the nail using the pipette tip to pierce the polyethylene bag. The bag was repaired with tape after inoculation.

The inoculated and control samples were incubated at 30°C and 95% relative humidity (RH) for 0, 5, 10, 20, and 30 weeks. At each scheduled incubation time, sets of ten randomly selected samples were removed from the incubation room for each treatment combination. The samples were removed from their polyethylene bags and placed in an environmental chamber at 30°C and 25% RH for 48 h where the average moisture content in the OSB decreased below 30%, as determined with a resistance-type moisture meter, inhibiting further growth of the fungus. The samples were then conditioned at 20°C and 65% RH for 5 weeks until the wood components reached an equilibrium moisture content of approximately 12%.

The loading geometry and setup of the test fixture was based on the study by Polensek (1988). The connection samples were tested in a computer-controlled hydraulic-actuated testing machine at a constant load head velocity of 5 mm per min. Two setups were used to test the connection samples. The first setup was used for the field and edge connection geometries as shown in Fig. 4. Compression clamps gripped the sheathing on the top end and an aluminum plate mechanically fastened to the framing member with wood screws at the bottom end. A linearly variable differential transducer (LVDT) with a useable linear range of 19 mm measured the relative slip between the sheathing and the framing member; the internal LVDT in the hydraulic actuator was used to measure deformations beyond 19

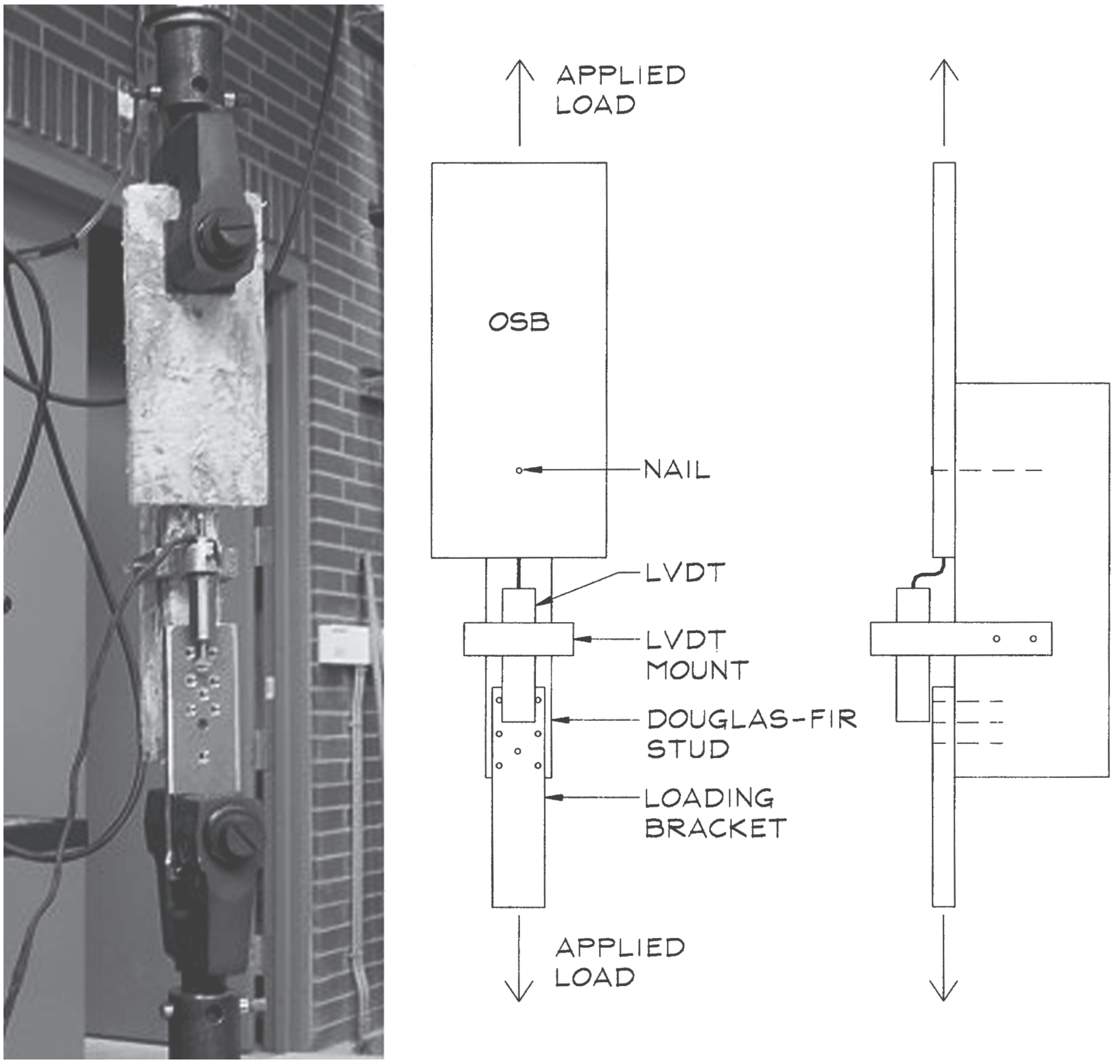

FIG. 4. Configuration of the assembly used to assess the effects of fungal exposure on field and edge connections.

mm. A similar test configuration was used for the plate connection geometry, the primary differences being the shape and attachment of the metal plate, which was fastened to the framing member on either side of the sheathing, and location of the LVDT as shown in Fig. 5.

To minimize the inherent eccentricity of connection specimens, the slip surface between the sheathing and framing member was positioned along the centerline of the hydraulic actuator and load cell by adjusting the lateral position of the clamps. The metal bracket between the bottom clamp and the test specimen was approximately the same thickness as the swelled sheathing to accommodate proper positioning.

After destructive testing of the connection samples, sub-samples of each sample were cut from the sheathing and framing member. The sub-samples were obtained as close as possible to the original position of the nail, as shown in Fig. 3. Dowel bearing strength (FI group only), moisture content (oven-dry basis), and specific gravity (based on oven-dry dimensions and weight) were measured.

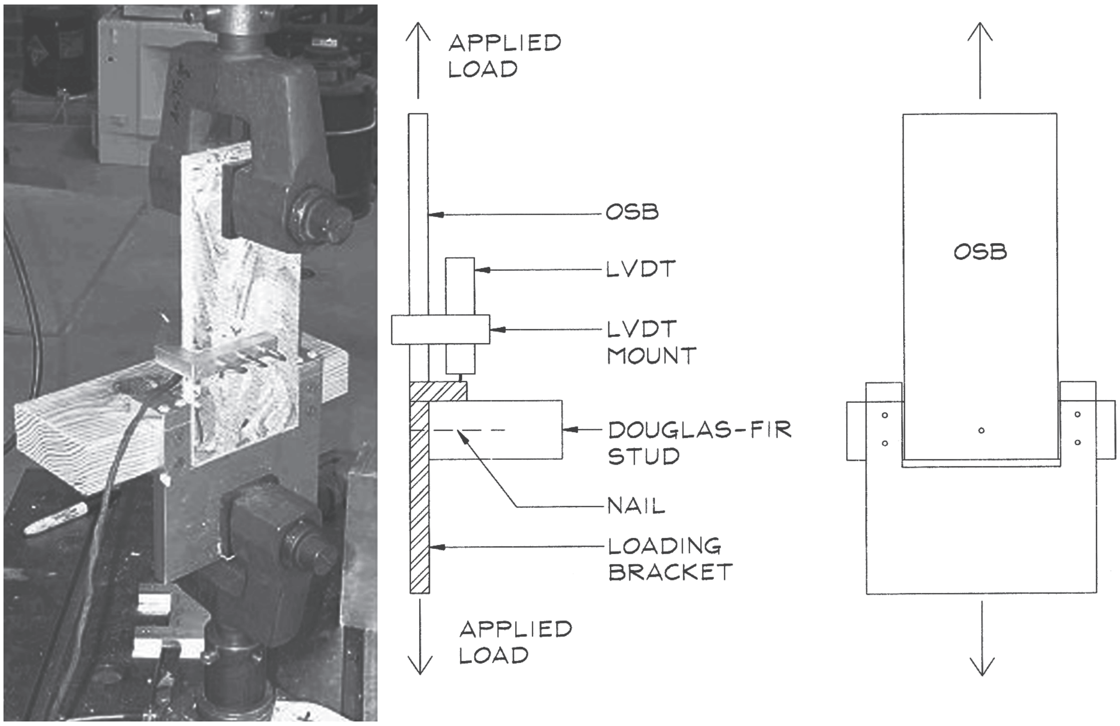

FIG. 5. Configuration of the assembly used to assess the effects of fungal exposure on plate connections.

Dowel bearing strength of the sub-samples was determined in accordance with ASTM D 5764 (2003a). A 2.95-mm-diameter half-hole was machined in one face of each sheathing and framing member sub-sample by clamping a piece of OSB to the interface of the sub-sample where the hole was to be positioned, then drilling a 2.95-mm-diameter hole at the seam of the two abutting pieces. The half-hole was placed on the side of the sheathing and framing member sub-samples originally facing the nail. The normal procedure for producing this type of dowel bearing test sample as described in ASTM D 5764 requires drilling a pilot hole at the seam with a diameter between 75 and 90% of the nail shank diameter, then driving a fastener perpendicular to, and through, the pilot hole to produce the half-hole. However, for this study, nails were not driven through pilot holes because of the possibility of damaging the heavily decayed samples.

The dowel bearing test sample was placed in a small vice, which provided lateral support and was positioned on top of a load cell and directly below a hydraulic actuator. A 2.87-mm-diameter by 60.3-mm-long nail was placed in the half-hole of the test sample. The hydraulic actuator compressed the nail shank at a constant velocity of 1.3 mm per min. into the sub-samples (Fig. 6). An LVDT recorded the movement of the hydraulic actuator, and a load cell measured the load applied to the top surface of the nail. The test proceeded until the nail was embedded for a distance of half the nail diameter, 1.4 mm, and the load head came in contact with the sub-sample. The moisture content and specific gravity were then evaluated for each sample.

RESULTS

The average and coefficient of variation for ultimate and yield loads are presented in Table 2. Plots of the ultimate and yield loads for the three connection geometries are shown in Fig. 7. The ultimate load of the inoculated samples experi-

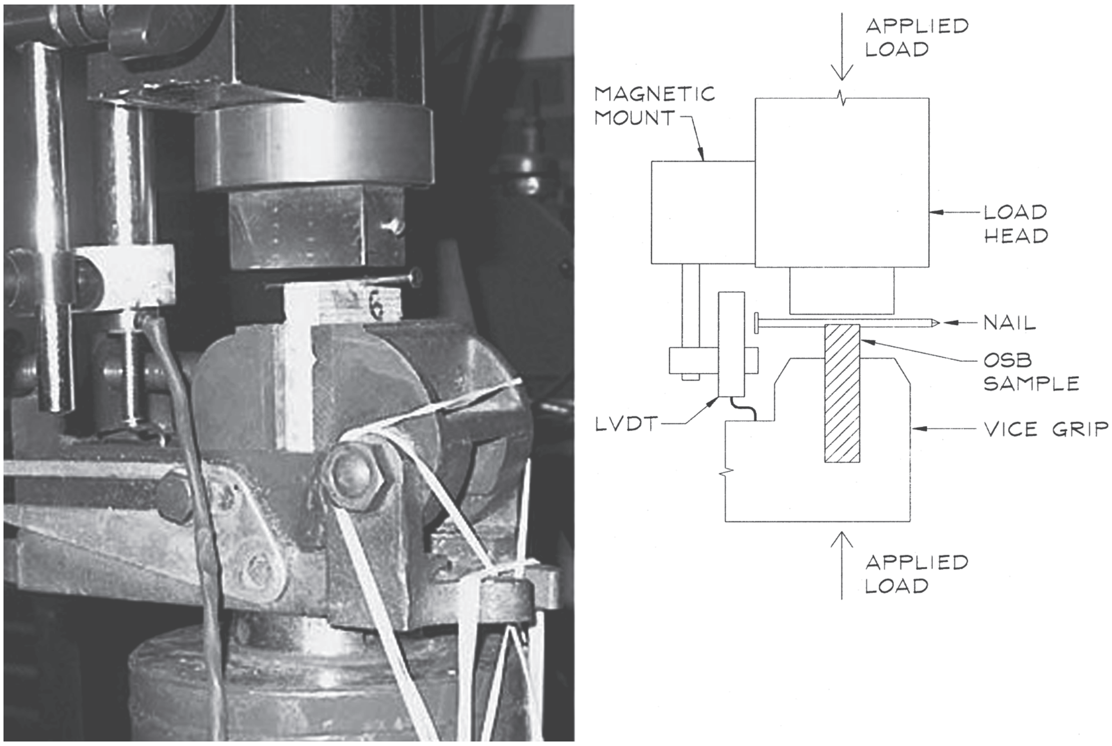

FIG. 6. Configuration used to test the effects of fungal exposure on dowel bearing strength of nailed Douglas-fir framing member and OSB sheathing samples.

TABLE 2. *Ultimate and yield loads of nailed Douglas-fir framing member and OSB sheathing assemblies exposed to a decay fungus for zero to 30 weeks.*

Fungal exposure time (weeks)	Ultimate load (N) (coefficient of variation)						Yield load (N) (coefficient of variation)					
	EC	FC	PC	EI	FI	PI	EC	FC	PC	EI	FI	PI
0	1427 (0.17)	1398 (0.28)	1327 (0.19)	1340 (0.13)	1482 (0.19)	1245 (0.20)	383 (0.12)	358 (0.15)	456 (0.11)	342 (0.13)	382 (0.14)	484 (0.12)
5	1374 (0.24)	1456 (0.20)	1351 (0.10)	1287 (0.36)	1500 (0.24)	1192 (0.20)	396 (0.18)	394 (0.10)	407 (0.09)	353 (0.19)	381 (0.12)	393 (0.20)
10	1491 (0.20)	1683 (0.18)	1400 (0.20)	1236 (0.19)	1328 (0.31)	1180 (0.17)	388 (0.12)	393 (0.11)	421 (0.13)	352 (0.10)	367 (0.21)	414 (0.12)
20	1477 (0.27)	1683 (0.18)	1340 (0.09)	1308 (0.34)	1328 (0.31)	1133 (0.36)	394 (0.16)	393 (0.11)	472 (0.15)	365 (0.16)	367 (0.21)	408 (0.22)
30	1426 (0.30)	1464 (0.19)	1334 (0.15)	473 (0.25)	514 (0.43)	318 (0.29)	363 (0.22)	350 (0.10)	440 (0.10)	282 (0.28)	233 (0.27)	160 (0.30)

Note: E-Edge, F-Field, P-Plate, I-Inoculated, C-Control. Value represents means of 10 replicates, while values in parentheses represent coefficients of variation.

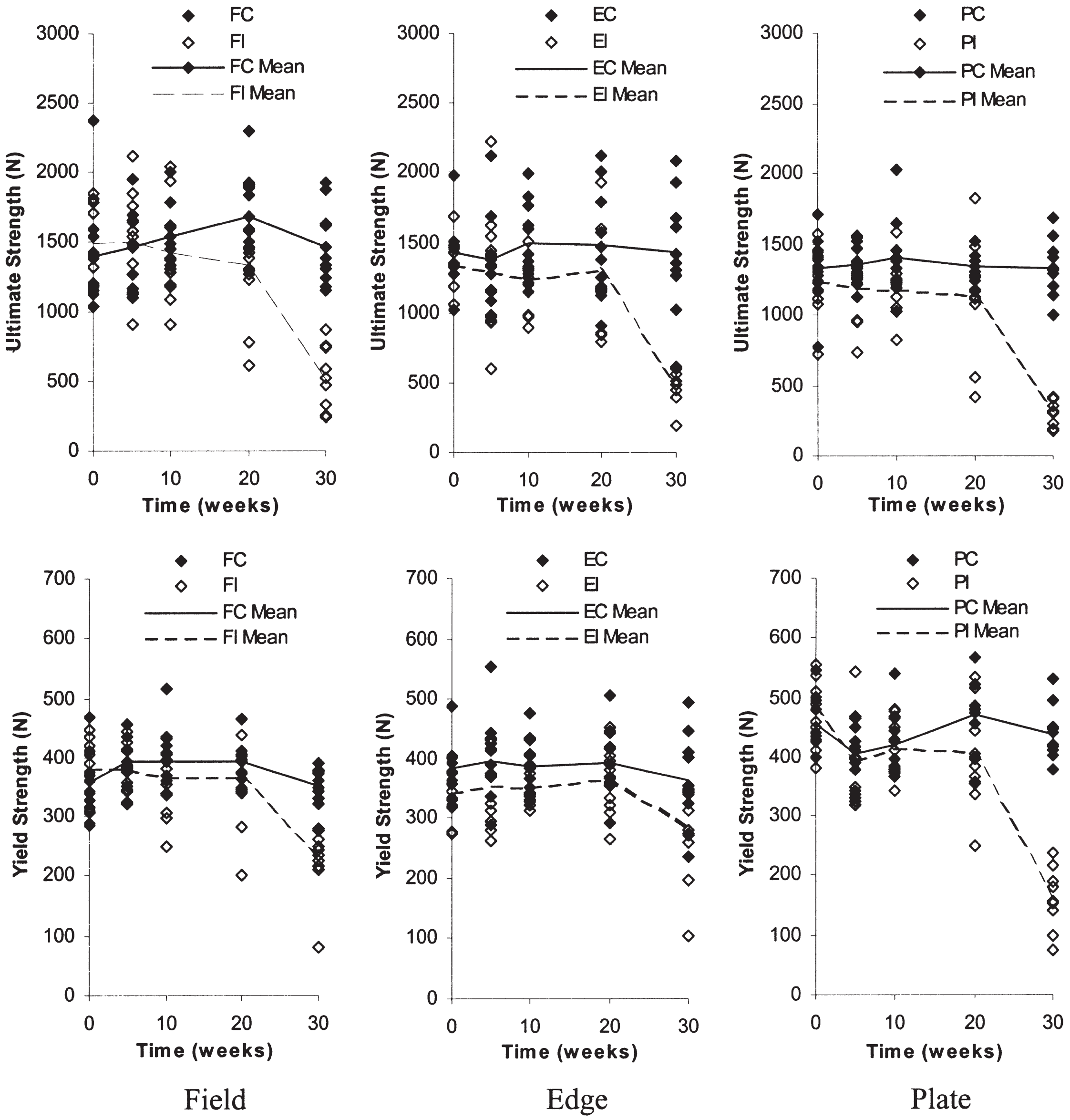

FIG. 7. Effects of fungal exposure on ultimate and yield strength of nailed Douglas-fir framing member to OSB sheathing connections of three geometries (field, edge, plate).

enced significant decreases, but only after 20 or 30 weeks of incubation. No significant effects were noted for ultimate strength between zero and 10 weeks for any of the three connection geometries (p-values of 0.66, 0.43, and 0.62 for the FI, EI, and PI groups, respectively, Table 3). The largest decrease over time occurred with the plate geometry, probably due to the close proximity of the nail shank and OSB panel boundary to the direction of loading. Yield strength decreases over time were observed for the FI and PI groups (p-values < 0.001), but the not for the EI group (p-value $= 0.89$, Table 3). Table 3 shows the ratio of treatment (inoculated) to con-

TABLE 3. *Ratios of fungal epxosed to non-exposed assembles for ultimate and yield loads over a 30-week exposure to* Postia placenta.

Time (weeks)	Description	Ultimate load			Yield load		
		Field	Edge	Plate	Field	Edge	Plate
0	Treatment/control	1.06	0.94	0.94	1.07	0.89	1.06
	p-value	0.530	0.514	0.540	0.361	0.112	0.284
	Tukey-adjusted p-value	1.000	1.000	1.000	1.000	0.999	1.000
5	Treatment/control	1.03	0.94	0.88	0.97	0.89	0.97
	p-value	0.742	0.512	0.231	0.619	0.101	0.592
	Tukey-adjusted p-value	1.000	1.000	1.000	1.000	0.999	0.999
10	Treatment/control	0.92	0.83	0.84	0.94	0.91	0.98
	p-value	0.379	0.055	0.099	0.027	0.158	0.805
	Tukey-adjusted p-value	1.000	0.986	0.999	0.922	0.999	1.000
20	Treatment/control	0.79	0.89	0.85	0.94	0.93	0.86
	p-value	0.008	0.005	0.120	0.330	0.270	0.014
	Tukey-adjusted p-value	0.651	0.529	0.999	1.000	1.000	0.795
30	Treatment/control	0.35	0.33	0.24	0.66	0.87	0.36
	p-value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Tukey-adjusted p-value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

trol (not inoculated) values for ultimate and yield loads and corresponding p-values for the difference between the inoculated and control groups.

The specific gravity and coefficient of variation for sheathing and framing member subsamples are presented in Table 4. Specific gravity values and mean weight losses for the sheathing and framing member at each incubation time for the inoculated and control groups are shown in Figs. 8 and 9, respectively. The weight loss values in Fig. 9 are an aggregate of all connection geometries, calculated based on the density of the subsamples compared to the average density of all samples at zero weeks of incubation time. The framing members in the inoculated groups experienced relatively minor fungal damage after 30 weeks of incubation with an average weight loss below 6%. Fungal damage of the framing members was not uniform through the cross section but tended to

TABLE 4. *Effect of fungal exposure on specific gravity of OSB and Douglas-fir subsamples.*

Fungal exposure time (weeks)	OSB specific gravity (coefficient of variation)						Douglas-fir specific gravity (coefficient of variation)					
	EC	FC	PC	EI	FI	PI	EC	FC	PC	EI	FI	PI
0	0.480 (0.03)	0.465 (0.03)	0.465 (0.03)	0.448 (0.02)	0.466 (0.02)	0.478 (0.03)	0.487 (0.14)	0.422 (0.16)	0.449 (0.14)	0.455 (0.15)	0.447 (0.17)	0.491 (0.11)
5	0.485 (0.03)	0.495 (0.02)	0.454 (0.02)	0.477 (0.02)	0.471 (0.03)	0.447 (0.02)	0.439 (0.13)	0.456 (0.11)	0.433 (0.13	0.479 (0.16)	0.479 (0.15)	0.426 (0.15)
10	0.459 (0.03)	0.473 (0.04)	0.446 (0.02)	0.449 (0.04)	0.417 (1.06)	0.444 (0.02)	0.441 (0.08)	0.443 (0.16)	0.435 (0.10)	4.433 (0.20)	0.427 (0.12)	0.449 (0.15)
20	0.456 (0.03)	0.473 (0.04)	0.462 (0.03)	0.418 (0.03)	0.417 (0.06)	0.399 (0.02)	0.451 (0.14)	0.448 (0.08)	0.442 (0.16)	0.424 (0.14)	0.439 (0.14)	0.435 (0.14)
30	0.456 (0.02)	0.478 (0.02)	0.466 0.04)	0.330 (0.03)	0.333 (0.02)	0.287 (0.03)	0.484 (0.12)	0.424 (0.10)	0.435 (0.12)	0.482 (0.16)	0.446 (0.19)	0.408 (0.19)

Note: E-Edge, F-Field, P-Plate, I-Inoculated, C-Control. Values represent means of 10 replicates, while values in parentheses represent coefficients of variation.

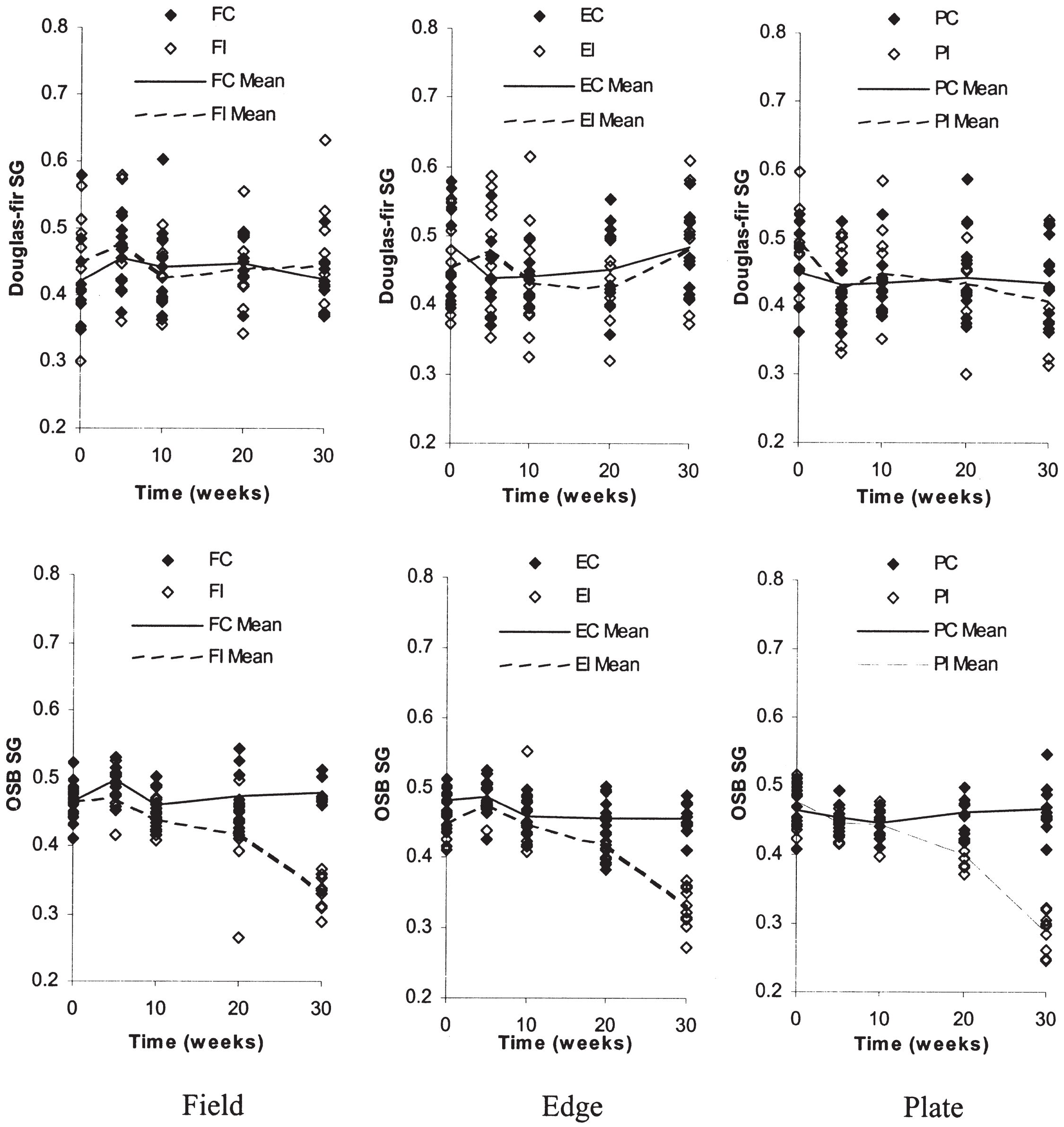

FIG. 8. Specific gravity of OSB sheathing and Douglas-fir framing members following exposure to *Postia placenta* for zero to thirty weeks.

occur on the surface. In contrast, the sheathing experienced extreme decay damage after thirty weeks of incubation with an average weight loss of 32%. The distribution of decay damage through the sheathing cross section was relatively uniform due to the presence of internal voids between the wood flakes from thickness swelling caused by the water immersion prior to sterilization.

DESIGN STRENGTH ESTIMATES

The discussion of predicted design strength and yield modes is limited to the field connec-

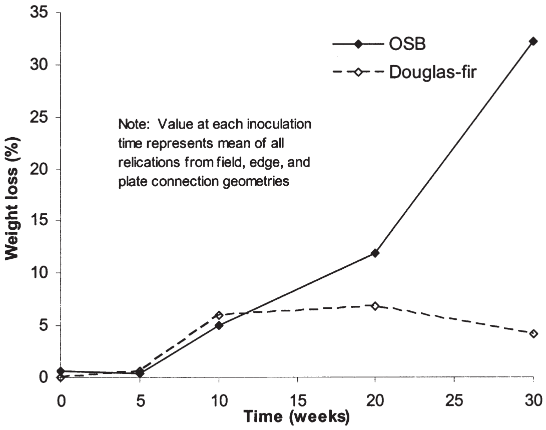

FIG. 9. Weight loss of OSB sheathing and Douglas-fir framing members following exposure to *Postia placenta* for zero to thirty weeks.

tion geometry because the other connection geometries are influenced by edge effects due to the proximity of the nail to sheathing panel boundaries (see Fig. 3). Dowel bearing strength calculations for the sheathing are based on the nominal panel thickness in the as-manufactured condition (11.9 mm).

The soaking and sterilization process caused a non-recoverable thickness swell in the OSB sheathing of approximately 31%; however, based on a comparison between field geometry connection samples tested in the dry condition without undergoing sterilization or inoculation (n=10) and the combined results from the control and inoculated field geometry samples at the zero-week incubation time (n=20), the effect of soaking and sterilization on the ultimate strength was not significant (p-value = 0.327). In addition, preliminary tests comparing the dowel bearing strength of OSB samples evaluated in the dry condition (no soaking or sterilization, n=23) and others tested after soaking and sterilization (n=17) indicated no significant difference at the *a priori* alpha level of 0.05 (p-value = 0.069).

Table 5 presents the dowel bearing yield strength results for sheathing and framing members (FI group only) and analysis of yield load and design strength determined using two different approaches. In the top part of Table 5, the sub-sample dowel bearing results from the FI group are used. The expected yield load and expected design load at each incubation time were calculated from yield models in the NDS (AFPA 2001). The expected design load is defined as the expected yield load (from the yield models) di-

TABLE 5. *Effects of fungal exposure on dowel bearing strengths from sub-samples and corresponding yield and design loads calculated per NDS (AFPA 2001).*

Time (weeks)	Nominal OSB dowel bearing yield strength F_{es} (MPa)	Douglas-fir dowel bearing yield strength F_{em} (MPa)	Basis: FLI group sub-sample dowel bearing tests	
			Expected yield load (N)	Expected design load (N)
0	28.21	37.12	548	249
5	28.00	43.05	559	254
10	22.85	35.79	488	222
20	18.47	39.87	460	209
30	8.13	30.15	275	125

Time (weeks)	Basis: FI group connection tests		Calculated reduction term[1]	Design ratio[2]
	Observed yield load (N)	Estimated design load (N)		
0	382	174	1.53	1.43
5	381	173	1.50	1.47
10	344	156	1.55	1.42
20	367	167	1.76	1.25
30	233	106	1.86	1.18

[1]Observed yield load from connection tests divided by expected design load as determined from results of sub-sample analysis.

[2]Expected design load based on sub-sample analysis divided by estimated design load from connection tests.

vided by the NDS reduction term, R_d, of 2.2 for the nail diameter used in this study (AFPA 2001). In the lower portion of Table 5, estimated design loads from the connection tests in the FI group were computed as the observed yield load divided by a reduction term of 2.2.

The calculated reduction term in the lower part of Table 5 was determined by dividing the observed yield load of connection tests for the FI group by the expected design load of the sub-sample dowel bearing tests. The results are shown in Table 5 and plotted in Fig. 10. The design loads determined using sub-sample dowel bearing strength results and the design loads estimated from the connection test results decrease with increasing incubation time, as the level of fungal damage increases. The calculated reduction term ranges from 1.50 to 1.86, increasing as the incubation time increases.

The design ratio given in the lower part of Table 5 is an indicator of the suitability of using sub-sample analysis to estimate the nominal design capacity of the field connection geometry employed in this study. The ratio exceeded 1.0 in all cases, indicating that the sub-sample analysis approach tended to overestimate the estimated design load by 18 to 47% as determined by actual testing of the connection. However, the design ratio approaches unity as the level of decay increases. Furthermore, the sub-sample analysis approach predicts an expected design load for the FI group at an incubation time of zero weeks very close to the tabulated value in the NDS (AFPA 2001). Using the published dowel bearing yield ($P_{5\%}$) values for Douglas-fir and OSB of 32.1 MPa (specific gravity of 0.50 for both the Douglas-fir and OSB), the nominal design load of the field geometry connection is 258 N (AFPA 2001), which is consistent with the expected design load of 249 N shown in Table 5 at an incubation time of zero weeks (using the FI group sub-sample dowel bearing tests as a basis).

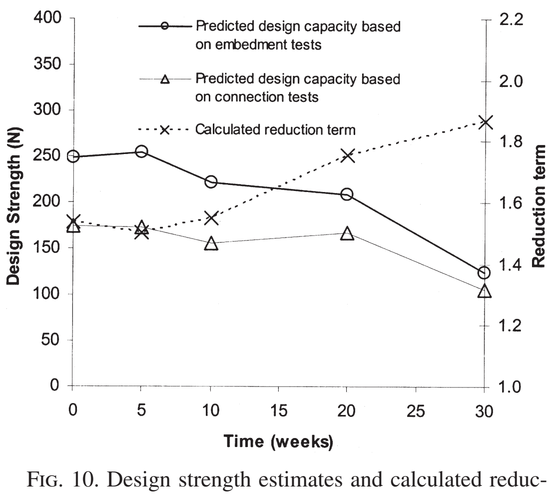

FIG. 10. Design strength estimates and calculated reduction terms for the yield mode equation.

The predicted yield mode for harvest times of 0, 5, 10, and 20 weeks based on the dowel bearing strength results from the sub-samples of the FI group and yield models (AFPA 2001) was III_s, bending of the nail at a point just beneath the surface of the Douglas-fir main member. At 30 weeks of fungal exposure, the predicted yield mode was I_s, crushing of the OSB side member. The yield mode predictions were consistent with the yield modes observed from the FI group, which were consistently III_s until the 30-week harvest time, where 40% of the connections experienced a I_s yield mode.

These results indicate that the nominal lateral capacity and failure mode of nailed sheathing to stud connections with varying levels of decay damage can be predicted using existing yield models, if the dowel bearing strength of the wood components is known. A reasonable sampling program could be established with sample sizes determined according to ASTM D 2915, section 3.4.2 (2003c) to quantify dowel bearing strength of wood components of connections *in-situ*. An estimate of the coefficient of variation (COV) is needed for the sample size calculation of ASTM D 2915. Based on the results of this study the COV should be on the order of 30 to 50% for OSB and 20 to 30% for Douglas-fir, depending on the severity of the decay damage.

CONCLUSIONS

In the laboratory, lateral capacity of nailed OSB sheathing to Douglas-fir framing members with various levels of decay damage is controlled predominately by the performance of the OSB, which decays at a much higher rate than Douglas-fir framing members. However, the lateral connection capacity is surprisingly robust through the early and intermediate stages of decay. When the OSB sheathing weight loss exceeded 12% (between the 20- and 30-week incubation times), the lateral capacity of the connections declined at an increased rate.

For design purposes, the nominal design capacity of lateral nailed connections of OSB sheathing and Douglas-fir framing members with various levels of decay damage can be estimated using the yield models of the NDS (AFPA 2001) through evaluation of the dowel bearing strength of the decay-damaged wood materials. Calculated reduction terms in the yield model equations ranged from 1.53 to 1.86 in this study.

REFERENCES

AFPA. 1999. General dowel equations for calculating lateral connection values. Tech. Rept 12. American Forest and Paper Association, Washington, DC.

———. 2001. National design specification® for wood construction. American Forest and Paper Association. Washington, DC. 174 pp.

American Society for Testing and Materials (ASTM). 2003a. Standard test method for evaluating dowel-bearing strength of wood and wood-base products. D 5764, American Society for Testing and Materials, West Conshohocken, PA. 5 pp.

———. 2003b. Standard test method for determining bending yield moment of nails, F 1575. American Society for Testing and Materials, West Conshohocken, PA. 4 pp.

———. 2003c. Standard practice for evaluating allowable properties for grades of structural lumber, D 2915. American Society for Testing and Materials, West Conshohocken, PA. 13 pp.

Curling, S., and R. Murphy. 1997. The effect of artificial ageing on the durability of wood-based board materials against basidiomycete decay fungi. Wood Sci. Technol. 33:245–257.

Eaton, R., and M. Hale. 1993. Wood decay, pests, and protection. Chapman and Hall, London, England. 546 pp.

Gilbertson, R., and L. Ryrarden. 1980. Woodprotting fungi of North America. Mycologia 72(1):1–49.

Green, F., and Highley 1997. Brown-rot wood delay—Insights gained from a low-decay isolate of *Postia placentai.* Trends in Plant Pathology. 1:1–17.

Merrill, W., and D. French. 1964. Wood fiberboard studies: A nailhead pull-through method to determine the effects of fungi on strength. Tappi 47(8):449–451.

Polensek, A. 1988. Effects of testing variables on damping and stiffness of nailed wood-to-sheathing joints. J. of Testing and Eval. 16(5): 474–480.

Steel, R., J. Torrie, and D. Dickey. 1997. Principles and procedures of statistics: A biometrical approach. McGraw-Hill, Inc., New York, NY. 672 pp.

Wilcox, W. 1978. Review of literature on the effect of early stages of decay on wood strength. Wood Fiber 9(4): 252–257.

Wilkinson, T. L. 1991. Dowel bearing strength. FPL-RP-505. USDA Forest Serv., Forest Prod. Lab., Madison, WI. 9 pp.