Development of Engineering Properties for Structural Panels

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Abstract

North America has seen both the rapid growth of production of structural panels, such as oriented strand board (OSB), and changes in manufacturing techniques. APA - The Engineered Wood Association represents nearly 80% of the panel production capacity of Canada and the U.S. Included in its activities is an extensive program to develop engineering design information on its members products. Tests conducted over the past ten years, plus recent intensive efforts, have resulted in new recommendations in both the Allowable Stress Design (ASD) format and the new Load and Resistance Factor Design (LRFD) method. Data collection, data base management, data analysis, and design recommendations are discussed.

Keywords: Structural-use panels, Design capacity, Characteristic value, Load factor

Introduction

The design specification for structural-use panels, *Design Capacities of APA Performance Rated Structural-Use Panels (APA Technical Note N375),* was published in 1988 based on mechanical test data collected from 1981 to 1986 (Elias and O'Halloran, 1988). Design values given in the 1988 TN 375 were limited to dry-use applications. The effects of moisture content on the mechanical properties of structural-use panels were included in the 1991 version of TN 375 (TN 375A, 1991) as a result of several studies conducted by APA and other research institutes. In addition, more data have been collected under the APA's Quality Assurance Program since the publication of Technical Note N375. These data offer an opportunity for reevaluation of the published design capacities and reflect the up-to-date capacity level of APA trademarked panels. Current design capacities for structural-use panels were revised in 1995 (TN 375B, 1995).

Background

The primary market for structural-use panels is light-frame construction (generally one to three story structures). These wood-based products tend to be long-lived, durable goods which are manufactured and distributed in standard sizes and grades. In the case of panels, these standard grades are manufactured in over 170 facilities in North America. Production in 1994 was over 28.8 million cubic meters (32.6 billion square feet on a 3/8 inch basis).

The Standards

Structural panels manufactured in North America are manufactured in accordance with two different types of standards. While the methodologies of the standards are different, the end use remains the same.

Product Standards - Historically, standards against which wood structural panel products have been manufactured have been product standards such as PS 1 for Construction and Industrial Plywood, or ANSI A208.1 for Mat-formed Wood Particleboard. National consensus standards are most frequently promulgated through organizations such as the American National Standards Institute (ANSI) or the U.S. Department of Commerce. Product standards provide a manufacturing prescription for minimum product. Requirements are most often centered around the specific manufacturing process and often do not address the question of product application. For example, the 1995 version of PS 1 (PS 1-95) establishes requirements for the principal types and grades of construction and industrial plywood and provides a basis for common understanding among producers, distributors, and users of the product.

Performance Standards - Performance standards, such as those promulgated by the APA for Rated Sheathing (PRP-108) or PS 2-92, approach the standards process from a different perspective. Performance standards are oriented toward the end use of the product and do not prescribe by what means the product will be manufactured. The objective of a performance standard is to assure, for a particular end use, that the product will satisfy the requirements of the application for which it is intended. The performance standard should describe performance criteria and test methods.

The Products

Structural-use panels are typically either plywood or OSB. All structural-use panels are trademarked under a common system. The Span Rating system identifies the use for sheathing or single layer floor applications. It is this common application scheme that allows mechanical property values to be recommended.

Plywood - Conventional plywood, as manufactured in North America, is produced both under the product and performance standards. Plywood is comprised of alternating layers of veneer (plies). Each layer consists of one or more plies. Structural-use plywood panels are assembled with waterproof adhesive applied between plies. The adhesive cures upon application of heat and pressure.

OSB - OSB is manufactured under the performance standard in the United States, and under the performance standard or product standard in Canada. OSB is comprised of thin rectangular wood strands arranged in a minimum of three cross-aligned layers and bonded under heat and pressure with a waterproof and boil-proof adhesive.

COM-PLY - COM-PLY is manufactured under the performance standard. COM-PLY was developed as a cooperative effort of the U.S. Forest Service and APA to more efficiently utilize the wood resource. There is currently one active manufacturer in North America. COM-PLY panels are composite panels of wood veneer and other wood-based material. COM-PLY panels are typically manufactured with five layers.

Product Evaluation

In order to develop recommended design values for structural-use panels, APA has been conducting a production evaluation study. This work is based on provisions of the APA performance standard and provides a basis to develop significant technical data on characteristics of the products produced by members of the APA.

Material

Panels represented in APA design information are produced and sampled as part of the ongoing Quality Assurance Program. Accordingly, the data represent only APA trademarked products and cannot be extrapolated to materials marked under other quality assurance programs.

Sampling

Panel sampling occurs at two stages. Sampling is done both when panels are qualified under the standard and during routine periodical sampling under the Quality Assurance Program. Both samplings are conducted on full sized 1220 x 2440 mm (4x8-ft) panels. The samples under the Quality Assurance Program consist of ten panels per plant per sampling period (OSB samples are taken over a three-month period, and plywood samples are taken over a 12-month period). These quality assurance sampling panels provide an ongoing measure of product performance and continuing confirmation that the products are conforming to the provisions of the performance standard, and serve as a basis for making end use recommendations.

Methods

Panels are tested in the dry, as-received condition. The panels are cut in half. The half-panels are tested for bending strength and stiffness according to the principles of ASTM D3043 Method C (large panel flexural testing) and the remains are used for other testing such as panel shear, tension and compression tests, etc. Each of these mechanical and physical properties are measured with stress along and across the major panel axis of the products when appropriate.

Panel Capacity

Panel mechanical properties are reported in capacity format rather than material stress format. A capacity is simply the product of the material stress and geometry. For example, bending stiffness is the product of the modulus of elasticity (E) and the moment of inertia (I) of the panel which is reported as EI in units of pound-inch-squared per foot of width. Bending strength is the product of the allowable extreme fiber stress (F_b)

and the section modulus (S) which is reported as maximum moment in pound-inch per foot of width. The advantage of capacity format is that no assumptions are required for estimating geometry.

Data Base Management

Over 35,000 panel data have been collected since 1980. A computer data base management system is utilized to accommodate such comprehensive sampling data, encompassing a large number of products. The current computer-based data system provides for easy assemblage of data schemes providing for quick ad hoc reporting as well as routine data manipulation and updating. The computer-based data system is utilized for ongoing evaluation of panels via statistical analysis of mechanical and physical property data.

Data Analysis

Quarterly panel testing data collected under the Quality Assurance Program (Quarterly Reexamination) are the basis for reevaluation of the published design capacities and reflect the up-to-date capacity level of APA trademarked panels. Accordingly, this analysis is appropriate for APA trademarked products and cannot be extended to other products. Panel testing data collected for the past 10 years (from 1986 to 1995) were used to reevaluate and update the published design values. To maintain the brevity of this paper, only panel flexural bending stiffness and strength capacities are covered in this paper. Tables 1 and 2 summarize data analysis results for dry panel bending stiffness and strength.

Bending Stiffness EI - Panel stiffness is the capacity to resist deflection and is represented in bending equation as EI. The E is the modulus of elasticity of the material and the I is the moment of inertia of the cross section. Load factors for various constructions based on panel stiffness data collected for the past 10 years are provided in Table 1. A load factor for bending stiffness is the ratio of the characteristic value to APA's recommended design value. Characteristic values for bending stiffness are average values of the test data and are estimated according to ASTM D2915. Load factors for stiffness-related properties for wood engineered products usually are considered acceptable at a level of 1.0 or greater. Table 1 shows all constructions are in excess of their recommended design capacities, which indicates our recommended design bending stiffnesses for these products are conservative. Generally, the products with high variations (coefficients of variation) have higher load factors.

Table 1. Load factors of dry panel stiffness for selected APA member production (1986-1995) tested according to ASTM D3043 Method C

Panel Type	Direction (1)	No. Tested	Load Factor (2)
OSB	Along	10,446	1.02 - 1.20
OSB	Across	10,241	1.20 - 2.24
Plywood	Along	9,838	1.14 - 1.24
Plywood	Across	9,756	1.10 - 1.87

(1) Direction is along or across the major panel axis.
(2) Load factor is the ratio of characteristic value (mean stiffness) to recommended design capacity listed in APA Technical Note N375B.

Bending Strength F_bS - Bending strength capacity is the design maximum moment, represented in bending equation as F_bS, product of the allowable extreme fiber stress (F_b) and the section modulus (S). Load factors for various constructions based on panel stiffness data collected for the past 10 years are provided in Table 2. A load factor for bending strength is the ratio of the characteristic value to APA's recommended design value. Characteristic values for bending strength are 5th percentile values of the test data. Lower 5th percentile values are estimated by 5% nonparametric point estimate (NPE) according to ASTM D2915. Load factors for bending strength property for engineered wood products in the United States usually are considered acceptable at a level of 2.1 or greater. Table 2 shows the test data support the published design capacities. Generally, load factors for bending strengths in the across direction are excessively high. These values are expected to increase their design values in future revisions.

Table 2. Load factors of dry panel strength for selected APA member production (1986-1995) tested according to ASTM D3043 Method C

Panel Type	Direction (1)	No. Tested	Load Factor (2)
OSB	Along	10,440	2.56 - 4.88
OSB	Across	10,207	2.97 - 5.14
Plywood	Along	9,792	2.24 - 3.46
Plywood	Across	9,744	3.74 - 5.90

(1) Direction is along or across the major panel axis.
(2) Load factor is the ratio of characteristic value (5th percentile value) to recommended design capacity listed in APA Technical Note N375B.

Table 3. Panel dry design bending stiffness and strength capacities for APA trademarked products

Span Rating	Bending Stiffness (EI), kN-m²/m (lb-in²/ft)		Bending Strength (F_bS), kN-m/m (lb-in/ft)	
	Along	Across	Along	Across
Rated Sheathing				
24/0	0.565 (60,000)	0.034 (3,600)	0.093 (250)	0.020 (54)
24/16	0.734 (78,000)	0.049 (5,200)	0.119 (320)	0.024 (64)
32/16	1.083 (115,000)	0.076 (8,100)	0.137 (370)	0.034 (92)
40/20	2.118 (225,000)	0.169 (18,000)	0.232 (625)	0.056 (150)
48/24	3.766 (400,000)	0.278 (29,500)	0.313 (845)	0.083 (225)
Rated Sturd-I-Floor				
16 o.c.	1.412 (150,000)	0.104 (11,000)	0.154 (415)	0.037 (100)
20 o.c.	1.977 (210,000)	0.122 (13,000)	0.178 (480)	0.052 (140)
24 o.c.	2.824 (300,000)	0.245 (26,000)	0.237 (640)	0.080 (215)
32 o.c.	6.120 (650,000)	0.706 (75,000)	0.322 (870)	0.141 (380)
48 o.c.	10.827 (1,150,000)	1.506 (160,000)	0.593 (1,600)	0.252 (680)

Table 4. Adjustments to bending design capacities based on panel grade and constructions for APA trademarked products

	Strength Axis (1)			
	Perpendicular to Supports		Parallel to Supports	
	Other	Structural I	Other	Structural I
Panel Bending Stiffness				
3-Ply Plywood	1.1	1.1	1.0	1.5
4-Ply Plywood, COM-PLY	1.1	1.1	2.2	3.3
5-Ply Plywood (2)	1.1	1.1	3.1	5.2
OSB	1.0	1.0	3.1	5.2
Panel Bending Strength				
3-Ply Plywood	1.0	1.0	1.0	1.3
4-Ply Plywood	1.1	1.1	1.2	1.7
COM-PLY	1.2	1.2	1.2	1.7
5-Ply Plywood (2), OSB	1.2	1.2	1.8	2.8

(1) The strength axis is the long panel dimension unless otherwise identified.
(2) Adjustments apply to plywood with 5 or more layers; for 5-ply/3-layer plywood, use adjustments for 4-ply.

Design Capacity Adjustments

Panel design capacities listed in Table 3 are based on flat panel bending properties as measured by testing according to the principles of ASTM D3043 Method C. Panel design capacities listed in Table 3 are minimum for grade and Span Rating. These values reflect the baseline capacities for each span index for bending strength and stiffness. Panel design capacities shall be adjusted as required under the following provisions.

Panel Grade and Construction, C_G

Panel grade and construction adjustment (C_G) reflect performance differences between panel type and grade. Table 4 provides an example of panel and construction adjustment factors for bending stiffness and strength. For example, load factors for APA trademarked products shown in Tables 1 and 2 are the ratio of the testing values to the recommended design values that are adjusted by the factor C_G. The adjustment factors are applicable for use with capacities of APA trademarked structural-use panels.

Duration of Load, C_D

Design capacities listed are based on 'normal duration of load' as traditionally used for solid wood in accordance with U.S. Forest Products Laboratory Report R1916, and successfully used for plywood for approximately forty years. Adjustment factors for strength capacities are:

Table 5. Duration of load factor, C_D

Time Under Load	C_D
Permanent	0.90
Normal	1.00
Two Months	1.15
Seven Days	1.25
Wind or Earthquake	1.60 (1)

(1) Check local building code.

Creep, C_C

Wood-based panels under constant load will creep (deflection will increase) over time. For typical construction applications, panels are not normally under constant load and, accordingly, creep need not be considered in design. When panels sustain permanent loads which will stress the product to one-half or more of its design capacity, allowance should be made for creep. Limited data indicate that under such conditions, creep may be taken into account in deflection calculations by applying the applicable following adjustment factor (C_C) to panel stiffness EI. The following section shows additional adjustments related to service moisture conditions, which for EI is cumulative with the adjustment for creep.

Table 6. Creep adjustment factor, C_C

Moisture Condition	Plywood	OSB
Dry	1/2	1/2
16% m.c. or greater	1/2	1/6

Adjustments suggested in Table 6 are the result of the U.S. Forest Products Laboratory study in cooperation with Forintek Canada Corporation, APA, and the Waferboard Association (now the Structural Board Association).

Moisture Effect Factor, C_M

Design capacities apply to panels under moisture conditions which are continuously dry in service; that is, where equilibrium moisture content is less than 16%. Adjustment factors for conditions where the panel moisture content in service is expected to be 16% or greater are as follows:

Table 7. Moisture effect factor, C_M

Reference Capacity	C_M
Strength	
Bending, Tension, Shear	0.75
Stiffness	
Bending, Axial, Rigidity	0.85

Service moisture adjustments were developed in a study conducted by APA technical staff (APA Report T91-25).

Summary

The design specification for structural-use panels, *Design Capacities of APA Performance Rated Structural-Use Panels (APA Technical Note N375)*, was published in 1988 based on mechanical test data collected from 1981 to 1986. A large number of data has been collected under the APA's Quality Assurance Program since the publication of APA's recommended design values. These data offer an opportunity for reevaluation of the published design capacities and reflect the up-to-date capacity level of APA trademarked panels. Panel bending data supporting design recommendations published by APA have been presented and capacity adjustment factors have been reviewed. These recommendations are appropriate only for panels trademarked under the APA Quality Assurance Program.

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