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Standard Guide for Evaluating System Effects in Repetitive-Member Wood Assemblies[1]

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INTRODUCTION

The apparent stiffness and strength of repetitive-member wood assemblies is generally greater than the stiffness and strength of the members in the assembly acting alone. The enhanced performance is a result of load sharing, partial composite action, and residual capacity obtained through the joining of members with sheathing or cladding, or by connections directly. The contributions of these effects are quantified by comparing the response of a particular assembly under an applied load to the response of the members of the assembly under the same load. This guide defines the individual effects responsible for enhanced repetitive-member performance and provides general information on the variables that should be considered in the evaluation of the magnitude of such performance.

The influence of load sharing, composite action, and residual capacity on assembly performance varies with assembly configuration and individual member properties, as well as other variables. The relationship between such variables and the effects of load sharing and composite action is discussed in engineering literature. Consensus committees have recognized design stress increases for assemblies based on the contribution of these effects individually or on their combined effect.

The development of a standardized approach to recognize "system effects" in the design of repetitive-member assemblies requires standardized analyses of the effects of assembly construction and performance. Users are cautioned to understand that the performance improvements that might be observed in system testing are often related to load paths or boundary conditions in the assembly that differ from those of individual members. This is especially true for relatively complex assemblies. For such assemblies, users are encouraged to design the test protocols such that internal load paths, as well as summations of "loads in" versus "loads out" are measured (see X3.11.7.1). Data from testing, preferably coupled with analytical predictions, provide the most effective means by which system factors can be developed. When system factors are intended to apply to strength (rather than being limited to stiffness), loads must be applied to produce failures so that the effects of nonlinearities or changes in failure modes can be quantified.

1. Scope

1.1 This guide identifies variables to consider when evaluating repetitive-member assembly performance for parallel framing systems.

1.2 This guide defines terms commonly used to describe interaction mechanisms.

1.3 This guide discusses general approaches to quantifying an assembly adjustment including limitations of methods and materials when evaluating repetitive-member assembly performance.

1.4 This guide does not detail the techniques for modeling or testing repetitive-member assembly performance.

1.5 The analysis and discussion presented in this guideline are based on the assumption that a means exists for distributing applied loads among adjacent, parallel supporting members of the system.

1.6 Evaluation of creep effects is beyond the scope of this guide.

1.7 This guide does not purport to suggest or establish appropriate safety levels for assemblies, but cautions users that designers often interpret that safety levels for assemblies and full structures should be higher than safety levels for individual structural members.

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[1] This guide is under the jurisdiction of ASTM Committee D07 on Wood and is the direct responsibility of Subcommittee D07.05 on Wood Assemblies.

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NOTE 1—Methods other than traditional safety factor approaches, such as reliability methods, are increasingly used to estimate the probability of failure of structural elements. However, the extension of these methods to assemblies or to complete structures is still evolving. For example, complete structures will likely exhibit less variability than individual structural elements. Additionally, there is a potential for beneficial changes in failure modes (that is, more ductile failure modes in systems). These considerations are beyond the scope of this guide.

1.8 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.9 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.10 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D245 Practice for Establishing Structural Grades and Related Allowable Properties for Visually Graded Lumber

D1990 Practice for Establishing Allowable Properties for Visually-Graded Dimension Lumber from In-Grade Tests of Full-Size Specimens

D2915 Practice for Sampling and Data-Analysis for Structural Wood and Wood-Based Products

2.2 *Other Documents:*

ANSI/ASAE EP559.1 Design Requirements and Bending Properties for Mechanically-Laminated Wood Assemblies[3]

ASCE/SEI 7 Minimum Design Loads and Associated Criteria for Buildings and Other Structures[4]

ANSI/AWC SPDWS Special Design Provisions for Wind and Seismic[5]

ANSI/AWC NDS National Design Specification (NDS) for Wood Construction[5]

ANSI/TPI 1 National Design Standard for Metal Plate Connected Wood Truss Construction[6]

3. Terminology

3.1 *Definitions:*

3.1.1 *composite action, n*—interaction of two or more connected wood members that increases the effective section properties over that determined for the individual members.

3.1.2 *element, n*—discrete physical piece of a member such as a truss chord.

3.1.3 *global correlation, n*—correlation of member properties based on analysis of property data representative of the species or species group for a large defined area or region rather than mill-by-mill or lot-by-lot data.

3.1.3.1 *Discussion*—The area represented may be defined by political, ecological, or other boundaries.

3.1.4 *load sharing, n*—distribution of load among adjacent, parallel members in proportion to relative member stiffness.

3.1.5 *member, n*—structural wood element or elements such as studs, joists, rafters, trusses, that carry load directly to assembly supports.

3.1.5.1 *Discussion*—A member may consist of one element or multiple elements.

3.1.6 *parallel framing system, n*—system of parallel framing members.

3.1.7 *repetitive-member wood assembly, n*—system in which three or more members are joined using a transverse load-distributing element.

3.1.7.1 *Discussion*—Exception: Two-ply assemblies can be considered repetitive-member assemblies when the members are in direct side-by-side contact and are joined together by mechanical connections or adhesives, or both, to distribute load.

3.1.8 *residual capacity, n*—ratio of the maximum assembly capacity to the assembly capacity at first failure of an individual member or connection.

3.1.9 *sheathing gaps, n*—interruptions in the continuity of a load-distributing element such as joints in sheathing or decking.

3.1.10 *transverse load-distributing elements, n*—structural components such as sheathing, siding and decking that support and distribute load to members.

3.1.10.1 *Discussion*—Other components such as cross bridging, solid blocking, distributed ceiling strapping, strongbacks, and connection systems may also distribute load among members.

4. Significance and Use

4.1 This guide covers variables to be considered in the evaluation of the performance of repetitive-member wood assemblies. System performance is attributable to one or more of the following effects:

4.1.1 Load sharing,

4.1.2 Composite action, or

4.1.3 Residual capacity.

4.2 This guide is intended for use where design stress adjustments for repetitive-member assemblies are being developed.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American Society of Agricultural and Biological Engineers (ASABE), 2950 Niles Road, St. Joseph, MI 49085, http://www.asabe.org.

[4] Available from American Society of Civil Engineers (ASCE), 1801 Alexander Bell Dr., Reston, VA 20191, http://www.asce.org.

[5] Available from American Wood Council, 50 Catoctin Circle NE, Suite 201, Leesburg, VA 20176.

[6] Available from Truss Plate Institute, 218 N. Lee Street, Ste. 312, Alexandria, VA 22314.

4.3 This guide serves as a basis to evaluate design stress adjustments developed using a combination of analysis and testing.

NOTE 2—Enhanced assembly performance due to intentional overdesign or the contribution of elements not considered in the design are beyond the scope of this guide.

5. Load Sharing

5.1 *Explanation of Load Sharing:*

5.1.1 Load sharing reduces apparent stiffness variability of members within a given assembly. In general, member stiffness variability results in a distribution of load that increases load on stiffer members and reduces load on more flexible members.

5.1.2 A positive strength-stiffness correlation for members results in load sharing increases, which give the appearance of higher strength for minimum strength members in an assembly under uniform loads.

NOTE 3—Positive correlations between modulus of elasticity and strength are generally observed in samples of "mill run" dimension lumber; however, no process is currently in place to ensure or improve the correlation of these relationships on a grade-by-grade or lot-by-lot basis. Where design values for a member grade are based on global values, global correlations may be used with that grade when variability in the stiffness of production lots is taken into account. Users are cautioned to not extrapolate bending strength and stiffness correlations to other properties. As discussed in the appendices, early implementation of repetitive-member factors focused on sawn lumber flexural members. The beneficial load sharing in these systems was often characterized as being related to the positive correlation between flexural strength and stiffness in these elements. For other systems where stresses are primarily axial (compression or tension), the appropriate property correlation (if used in the analysis) should relate axial strength and stiffness rather than flexural correlations.

5.1.3 Load sharing tends to increase as member stiffness variability increases and as transverse load-distributing element stiffness increases. Assembly capacity at first member failure is increased as member strength-stiffness correlation increases.

NOTE 4—From a practical standpoint, the system performance due to load sharing is bounded by the minimum performance when the minimum member in the assembly acts alone and by the maximum performance when all members in the assembly achieve average performance.

5.2 *Variables Affecting Load Sharing Effects on Stiffness Include:*

5.2.1 Loading conditions;

5.2.2 Member span, end conditions, and support conditions;

5.2.3 Member spacing;

5.2.4 Variability of member stiffness;

5.2.5 Ratio of average transverse load-distributing element stiffness to average member stiffness;

5.2.6 Sheathing gaps;

5.2.7 Number of members;

5.2.8 Load-distributing element end conditions;

5.2.9 Lateral bracing; and

5.2.10 Attachment between members.

5.3 *Variables Affecting Load Sharing Effects on Strength Include:*

5.3.1 Load sharing for stiffness (5.2), and

5.3.2 Level of member strength-stiffness correlation.

6. Composite Action

6.1 *Explanation of Composite Action:*

6.1.1 For bending members, composite action results in increased flexural rigidity by increasing the effective moment of inertia of the combined cross-section. The increased flexural rigidity results in a redistribution of stresses which usually results in increased strength.

6.1.2 Partial composite action is the result of a non-rigid connection between elements which allows interlayer slip under load.

6.1.3 Composite action decreases as the rigidity of the connection between the transverse load-distributing element and the member decreases.

6.2 *Variables Affecting Composite Action Effects on Stiffness Include:*

6.2.1 Loading conditions,

6.2.2 Load magnitude,

6.2.3 Member span,

6.2.4 Member spacing,

6.2.5 Connection type and stiffness,

6.2.6 Sheathing gap stiffness and location in transverse load-distributing elements, and

6.2.7 Stiffness of members and transverse load-distributing elements (see 3.1.5).

6.3 *Variables Affecting Composite Action Effects on Strength Include:*

6.3.1 Composite action for stiffness (6.2), and

6.3.2 Location of sheathing gaps along members.

7. Residual Capacity of the Assembly

7.1 *Explanation of Residual Capacity:*

7.1.1 Residual capacity is a function of load sharing and composite action which occur after first member failure. As a result, actual capacity of an assembly can be higher than capacity at first member failure.

NOTE 5—Residual capacity theoretically reduces the probability that a "weak-link" failure will propagate into progressive collapse of the assembly. However, an initial failure under a gravity or similar type loading may precipitate dynamic effects resulting in instantaneous collapse.

7.1.2 Residual capacity does not reduce the probability of failure of a single member. In fact, the increased number of members in an assembly reduces the expected load at which first member failure (FMF) will occur (see Note 6). For some specific assemblies, residual capacity from load sharing after FMF may reduce the probability of progressive collapse or catastrophic failure of the assembly.

NOTE 6—Conventional engineering design criteria do not include factors for residual capacity after FMF in the design of single structural members. The increased probability of FMF with increased number of members can be derived using probability theory and is not unique to wood. The contribution of residual capacity should not be included in the development of system factors unless it can be combined with load sharing beyond FMF and assembly performance criteria which take into account general structural integrity requirements such as avoidance of progressive collapse (that is, increased safety factor, load factor, or reliability index). Development of acceptable assembly criteria should consider the desired reliability of the assembly.