AMERICAN INSTITUTE OF TIMBER CONSTRUCTION

Tech Note 26

Design Values for Structural Glued Laminated Timber in Existing Structures

April 2023

253.835.3344 | info@aitc-glulam.org | aitc-glulam.org

Introduction

The structural evaluation of an existing building or its components may be necessary due to changes in use or occupancy, changes in ownership, changes in design requirements, or changes to the structure itself, such as renovations or additions. A proper evaluation must take into consideration the materials and standards at the time of construction as well as current understanding of materials and loads. The evaluation may result in the determination of suitability (or unsuitability) for a proposed use, recommended remedies or changes in the case of structural inadequacy, or probable cause in the case of a failed structure.

Structures that have been performing well and are not subject to changes in use or occupancy generally do not need to be evaluated. When evaluation is necessary, building codes typically dictate the requirements for existing structures. For example, the International Existing Building Code requires alterations or additions to existing structures to comply with the requirements of new construction, however, portions of the structure that are not altered or affected by the alteration are not required to comply with the requirements for a new structure (2021 IEBC).

Scope

Structural glued laminated timber has performed very well since its U.S. beginnings in 1934, however, changes of which the designer needs to be aware have occurred in the requirements for this material. This guideline was developed to assist architects and engineers with the evaluation of structural glued laminated timber in existing structures in light of the relevant changes.

The guidance herein is restricted to laminated timbers that are in good condition, free of decay or damage. Analysis and repair of damaged or decayed timbers is beyond the scope of this document. This information is applicable only to timbers that were manufactured in a laminating plant using equipment and processes meeting the requirements of recognized standards. The evaluation of field-laminated assemblies is beyond the scope of this standard.

Structural Glued Laminated Timber

Structural glued laminated timber is an engineered, stress-rated product of a timber laminating plant, comprising assemblies of suitably selected and prepared wood laminations bonded with adhesives. The grain of all laminations is approximately parallel longitudinally. Glued laminated timber is permitted to be comprised of pieces end-joined to form any length, of pieces placed or bonded edge-to-edge to make any width, and/or of pieces bent to curved form during bonding.

Investigation and Identification

Before design values can be assigned to the laminated timber, the material needs to be identified. Sometimes specifications, plans, or shop drawings can be located, which will indicate the size, species, and grade of the laminated timbers used and, perhaps, the manufacturer of the timbers. Certificates of conformance to a particular standard may also be available in building records. These are the preferred methods for identifying the material used. Often, however, this information is not available and design values must be assigned based on engineering judgment after inspection of the member and consideration of the most likely grades of material used.

After verifying that the timbers are in good overall condition, several pieces of information should be obtained through inspection to assist the designer in assigning design values. These include: Species, size, type of end joints, face lumber quality, and quality marks.

Species

Several wood species are suitable for the manufacture of structural glued laminated timber. Both softwoods and hardwoods have been used successfully. The most common species used in the United States are Douglas fir and Southern Pine species. Douglas fir is commonly used in the western United States with Southern Pine being used predominantly in the East. However, geographic location should not be the sole means of identifying the lumber species. Species identification can often be accomplished by visual inspection, or a sample can be taken to a laboratory for identification.

Sizes

Standard sizes of laminated timbers have varied over the years since this product made its debut in the U.S. Changes in both standard widths and standard depths have occurred based on the available dimension lumber sizes. Both the overall member dimensions and the lamination thickness can be useful in rough estimations of age of the member. In some cases, the lamination thickness can also provide insight into the species used. For example, in modern structural glued laminated timber, Southern Pine laminations are typically surfaced to a thickness of 1.375 inches, while most other species use a lamination thickness of 1.5 inches.

Prior to 1970, dry dimension lumber was surfaced to a standard thickness of 1.625 inches. Consequently, this was the standard lamination thickness for Western Species laminated timber. Southern Pine laminations were typically purchased as 1-¾ in. and resurfaced by the laminator to a thickness of 1.625 inches for laminating. In 1970 the standard thickness of dry dimension lumber was changed to 1.5 inches. Standard lamination thicknesses correspondingly changed to 1.5 inches and 1.375 inches for Western Species and Southern Pine timbers, respectively.

End Joints

Early structural glued laminated timber utilized scarf joints to join the ends of pieces of lumber to make longer laminations, and butt joints were also allowed to be used with restrictions. In 1962, a new type of joint called a finger joint (Figure 1) was introduced. By the early 1970's finger joints had largely replaced scarf joints as the preferred end joint. Both horizontal finger joints (finger profile visible on the narrow face of lamination) and vertical finger joints (finger profile visible on the wide face of lamination) are used in modern laminating.

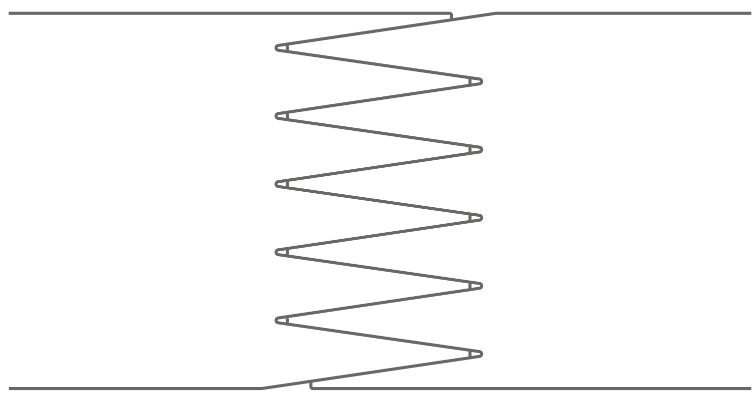

Figure 1. Horizontal Finger Joint Profile

Quality Marks

Structural glued laminated timbers manufactured in accordance with recognized standards will commonly be marked with the quality mark of a third-party inspection agency. The mark will typically include the name of the inspection agency, the manufacturing standard, and a plant identification number. Other information may include the species, the laminating combination or allowable fiber stresses assigned at the time of manufacture, the appearance grade of the member, and an indication of wet-use or dry use adhesives. In addition to the quality mark, manufacturers typically mark the date of manufacture and a job or batch number to ensure traceability. AITC maintains a list of plant identification numbers and corresponding manufacturers, and can help with interpretation of the information obtained from quality marks.

Quality marks are typically placed where they won't be visible in the final structure, so access to them may not be readily available. The most common location for quality marks is on the top surface of a beam, near the ends. If the roof or floor above a laminated timber is partially or wholly removed for repair or replacement, the top surfaces of the supporting beams can be inspected for quality marks. Photographs or detailed drawings of any quality marks found should be included in the inspection report.

Design Values

With the structural glued laminated timber material identified, the first step in assigning design values is to determine the original design values for the material. AITC has historical glulam standards on file and can assist with this determination. However, it is not sufficient to stop there. Several changes have been made to the rules for assigning design values to structural glued laminated timbers, based on increased understanding and experience gained over the years regarding the use of engineered timbers. Significant changes to the procedures for assigning design values are discussed below.

Tension Parallel to Grain

From at least as early as the 1930's until the late 1960's the tensile strength of lumber was believed to be equal to or exceeding that of its bending strength. The following statement from the 1935 Wood Handbook reflects this belief, "The tensile strength of wood is greater than the modulus of rupture as obtained from bending tests. Hence stresses in the body of a tension member fully equal to those given for fiber stress in bending… are justified." (Wood Handbook, 1935, p. 105). Limited full-scale testing in tension parallel to grain resulted in failure of the wood specimens due to crushing in the test machine grips prior to tension failure.

This belief was held until the 1960's when improved grips for tension testing were developed to determine the tensile strength of machine graded lumber. With improved grips, the testing of full-scale specimens indicated that the tensile strength was significantly lower than previously assumed. By 1970 virtually all of the lumber grading agencies had reduced their published design values for tension parallel to grain to reflect this new knowledge.

As would be expected, tension design values for structural glued laminated timber were subject to the same erroneous belief and subsequent adjustments to rules for assigning design values. The allowable stresses in lumber used in modern structural glued laminated timber are approximately ⅝ of the values assigned for the same grades prior to 1970 (ASTM D3737-18). A reduction of tension design values to ⅝ of their published values is recommended for laminated timbers manufactured prior to 1970.

Bending-Horizontally Laminated Members

In a laminated beam, the outer lamination on the tension face is highly stressed in tension parallel to grain. Therefore, the results of the solid-sawn lumber tests in tension raised questions regarding the allowable design stresses for structural glued laminated timber stressed in bending.

Full-scale tests of structural glued laminated timber beams indicated a need for more stringent grading requirements for the tension laminations, particularly in the outer 5% of beam depth, to justify the design values commonly used by the industry. The laminating industry adopted the use of AITC special tension lamination grades in 1970. Without the use of these specially graded tension laminations, bending design values for modern structural glued laminated timber beams are required to be reduced by 15% for beams up to 15 inches deep and by 25% for beams deeper than 15 inches (ASTM D3737-18).

The same reductions are recommended for analyzing beams manufactured prior to 1970, unless inspection demonstrates that the face lamination meets the stringent requirements of the special tension lamination grade (based on inspection of the three visible sides). It is possible for the tension lamination to meet the requirement, even though the special rules were not originally considered, because the lamination may have exceeded the minimum requirements of the standard in place when the beam was manufactured. This technique is not valid for beams with more than 20 laminations, because the outer lamination in beams with more than 20 laminations accounts for less than 5% of the depth.

Modulus of Elasticity

The rules for assigning modulus of elasticity design values have changed over the years, resulting in a need for careful consideration when evaluating an existing structure. Modulus of elasticity design values are important for determining the serviceability of laminated timbers under design loads and can be critical for stability calculations, such as beam and column buckling or ponding.

Prior to the development of the first AITC laminating specification (AITC 117-71), laminated timber layups and design values were provided by regional lumber grading agencies. These agencies typically assigned modulus of elasticity design values as the average modulus of elasticity for the species, regardless of grade. Table 1 shows the values assigned to each species in those regional specifications. This practice was non-conservative for many laminated timber combinations, particularly those utilizing lower grades with lower allowable flexural stresses.

Table 1. Pre-1971 assigned modulus of elasticity values in regional laminating specifictions

Species	Assigned Modulus of Elasticity (E) (million psi)
Douglas Fir	1.8
Southern Pine	1.8
Western Hemlock	1.5
Western Larch	1.8

From 1971-1978, the AITC 117 laminating specifications included more accurate design values for modulus of elasticity based on transformed section analysis, reflecting the effect of grade. However, the published values did not account for the effect of shear deformations on the stiffness of laminated beams, leading to the modulus of elasticity design values being overstated by approximately 5%, relative to modern standards. In 1978, the first version of ASTM D3737 was published. This standard represented a consensus of professionals regarding the assignment of design values for structural glued laminated timber. It included a 5% reduction of the modulus of elasticity based on transformed section analysis to account for shear deformations in beams at a typical span-to-depth ratio of approximately 20. Updated design values and the current system of combinations symbols were published in AITC 117-79. Requirements since 1979 have been similar to modern requirements.

Based on the previous discussion, the average modulus of elasticity design values in Table 2 are recommended for use in evaluating horizontally laminated timbers manufactured prior to 1979. For critical deflection applications, such as for ponding, it may be appropriate to further reduce the value of the modulus of elasticity used for design to account for the variability of properties between beams. The Timber Construction Manual provides guidance on calculating a lower 5th percentile modulus of elasticity, E_{05}, for use when a reduced value is needed.

Table 2. Recommended average modulus of elasticity, E_x, design values for laminated timber prior to 1979

Species	Published Flexural Stress (psi)	Recommended E_x (million psi)
Douglas Fir, Larch	2600	1.8
	2400	1.7
	2200	1.7
	2000	1.6
	1800	1.6
	1600	1.5
Southern Pine	2600	1.8
	2400	1.7
	2200	1.6
	2000	1.6
	1800	1.5
Western Hemlock, Hem-Fir	2400	1.6
	2000	1.5
	1800	1.5

Compression Perpendicular to Grain

Modern compression perpendicular to grain design values for lumber and structural glued laminated timber are typically higher than historical values, due to a change from a 0.02 in. deformation limit to a 0.04 in. deformation limit for determining allowable stresses. The use of modern design values in compression perpendicular to grain for older structural glued laminated timbers is reasonable and acceptable.

Horizontal Shear

Horizontal shear design values have increased in recent years. Tests of full-scale short-span glulam beams have led to increased design values for prismatic members not subject to dynamic loads. For non-prismatic members and members subject to cyclic loading the shear values are similar to the historical values for most species. The use of the modern shear design values for older structural glued laminated timber is reasonable and acceptable.

Radial Tension

Prior to 1970, radial tension value for curved glulam members was assigned as one-third of the shear value. For modern glulam made of softwood species other than Southern Pine, the radial tension design value is limited to 15 psi, unless radial reinforcement is used to carry all of the radial stresses, except for wind and seismic loads. In the case of reinforced members or members subject to wind and seismic loads, the radial tension design value is limited to one third of the shear parallel to grain value for non-prismatic members. Radial tension values for Southern Pine are limited to one-third of the shear value for non-prismatic members.

Adjustment Factors

In addition to changes in the reference design values, increased understanding of structural glued laminated timbers has led to some changes in the factors used to adjust reference design values to allowable stresses. When analyzing laminated timbers in existing structures, it is appropriate to use the adjustment factors specified in the current edition of the TCM or NDS.

Conclusion

The evaluation of existing structures may be necessary for remodels, additions, or for forensic investigations. In each case, it is necessary to determine allowable material properties with a reasonable degree of accuracy. Increases in experience and understanding of material performance lead to changes in design standards and building codes, which must be considered when evaluating components of an existing structure.

Of necessity, the assignment of allowable design stresses requires careful judgment by the design professional. This technical note provides guidance to assist the architect or engineer in making that judgment for structural glued laminated timber members.