# Allowable Stresses for Glued Laminated Timbers

## In Structures Built Prior to 1970, Based on Present Methods of Determining such Stresses

*By: Robert M. Powell, P.E. & F, ASCE*

*Some concerns have been expressed as to the effect of increased research and knowledge in the field of timber engineering on the validity of the stresses used in the design of glued laminated timber members prior to 1970.*

Factors promoting such concerns are as follows:

1. **Tension Parallel to Grain**: Prior to 1970, it was assumed that the extreme fiber stress in bending was equal to the tension parallel to grain values. Limited full scale testing in tension parallel to grain resulted in failure of the wood in compression perpendicular to the grain in the grips of the tension machine before the specimen failed in tension parallel to the grain in the wood of the specimen.

In the development of machine grading of lumber, it became necessary to develop better grips for the specimens in tension testing machines in order to establish a relationship between modulus of elasticity values and the tension parallel to grain values of the specimens. As a result of this testing program, the tension parallel to grain value was reduced to approximately 55% of extreme fiber stress in bending value. This change becomes obvious when values in the 1967 edition of the Uniform Building Code are compared with the values in the 1970 edition of the Uniform Building Code.

The progress in the testing of solid sawn lumber was closely monitored by the engineers engaged in the manufacture and/or design of structural glued laminated timber members. As a member subject to bending increases in depth, the outer lamination in the tension face of the member becomes more uniformly stressed in tension parallel to grain and approaches the condition observed in the tension testing of lumber in the preceding section. Based on this concern, the American Institute of Timber Construction (AITC) performed destructive testing of full-size structural glued laminated timber members in 1968 and 1969. The results of these test indicated a need for the upgrading of the laminations in the outer 10 percent of the depth in the tension face of bending members. Effective January 1, 1970, AITC required the use of tension grade laminations 301-22, 301-24, and 301-26 in production of structural glued laminated members. The 301-26 tension grade lamination was dropped to a lack of supply available for production. The 301-20 tension grade lamination was adopted by AITC for production of structural glued laminated timber members in 1971. The requirements for tension grade laminations for structural glued laminated members were set forth for the first time in the 1973 Edition of the Uniform Building Code.

2. **Compression Perpendicular to Grain**: The degree of compression in the bearing area was changed from 0.02″ to 0.04″ for determining the allowable stress for compression perpendicular to the grain. Adjustments for duration of load are not applicable.

3. **Horizontal Shear**: Present values are based on the full scale test of short glued laminated timber beams tested by EWS of the American Plywood Associations instead of the shear test data performed on shear block test.

4. **Radial Tension**: Limited to 15 PSI for all loadings except wind and seismic for Douglas Fir.

Present stresses for glued laminated timber members are determined by the AITC "GLDESVAL" Computer Program for Determining Design Stresses for Structural Glued-laminated Timber approved for use under National Evaluation Report NER-466. Using the required raw data on the structural laminations in the layup of the members at the time of the original manufacture of the members, the allowable stresses for the members based on the present technology can be determined by the NER-466 "AITC GLVD" program in the review of the structural adequacy of the glued laminated timber members in an existing structure built prior to 1970. A comparative study between the original design values and the NER-466 "AITC" GLVD" values of the Douglas fir, Coast for stress-grade combinations Nos. 5, 10 and 11 produced prior to 1963, and stress-grade combinations A, B and C produced prior to 1970 shown in *Table 1* and *Table 2*.

The preceding reduction in bending stress for structural glued laminated timber members is reflected in Section 12.1 of ASTM D 3737-96, Standard Practice for Establishing Stresses for Glued Laminated Timber (Glulam) as follows

*"12. Tension Laminations for Bending Members*

*12.1 The result of full-size beam tests reported in Refs 1, 5 and 6 have yielded an empirical relationship between the size of knots in the tension zone and bending strength. This relationship dictates special grading considerations in the outer 10% of the beam depth on the tension side. This tension side may exist on the top or bottom of the beam, or both, depending on the design considerations and conditions. If the beams are fabricated without these special considerations, the design strength is obtained by multiplying the design value predicted by the IK/IG theory by 0.85 if the depth of the member is 15 in. or less or by 0.75 if the depth exceeds 15 in."*

Experience indicates that a large percentage of the engineers are not aware of the problem created by the lack of tension grade laminations in the production of structural glued laminated timber members prior to January 1, 1970 in their review of the structural adequacy of existing buildings. This problem is further compounded by the reviewing engineer

checking the existing structure for conformance to the building code in effect code at the time of the original design and to the state of the art that existed at the time of the original design only. A full design review requires that the structural adequacy be based on the requirements of the building code in effect at the time of the design review and the state of the art that existed at the time of the review.

Some design values determined by the NER-466 "AITC GLVD" will vary based on the number of laminations in the individual member. Contact AITC at 7012 S. Revere Parkway, Suite 140, Englewood, CO 80112-5092 for guidance in determination of allowable stresses for structural glued laminated timber members for a specified stress-grade combination, species, and number of laminations.

It is hoped that dissemination of this data will eliminate one of the problems faced by the engineer in the design review of existing structures. ■

*Robert M. Powell was conferred Honorary Member status in the American Institute of Timber Construction (AITC,) following decades of service and Professional Membership. Mr. Powell served as Chairman of the AITC Technical Advisory Committee, Chairman of the AITC Technical Review Board, Chairman of the AITC Evaluation of Existing Structures and the Field Drilling and Notching Task Committees.*



## References

1. AITC letter of October 3, 1985 on "Implementation of Tension Lamination Requirement-Visually Graded Lumber".

2. ASTM D 3737-02 *Standard Practice for Establishing Allowable Properties for Structural Glued Laminated Timber (Glulam)*, Section 10.1

3. *Uniform Building Code 1958 Edition & Uniform Building Code Standards*; 23-13-58 and 25-14-58.

4. *Uniform Building Code and Building Code Standards*, 1964 Edition.

5. *Uniform Building Code Standards*, 1973 Edition.

## To contact AITC:

7012 S. Revere Parkway Suite 140
Englewood, CO 80112
Phone: (303) 792-9559
FAX: (303) 792-0669
Email: **info@aitc-glulam.org**
Web: **www.aitc-glulam.org**

| *Allowable Stresses for Glued Laminated Timber Members in Existing Buildings, Douglas-fir, coast* | | | | | | |
|---|---|---|---|---|---|---|
| **Stress-Grade Combination** | **5** | | **10** | | **11** | |
| **Source of Stress Value** | **1958 UBC** | **AITC GLVD** | **1958 UBC** | **AITC GLDV** | **1958 UBC** | **AITC GLDV** |
| Bending about X-X Axis | | | | | | |
| Fbx | *2,600 | 1,800 | *2,600 | *2,400 | 2,600 | 1,800 |
| Fc prep x tension face | 415 | 560 | 415 | 560 | 415 | 560 |
| Fc perp x compression face | 415 | 560 | 415 | 560 | 415 | 560 |
| Fvx impact & cyclic loads | 165 | 190 | 165 | 190 | 165 | 190 |
| Fvx all other loads | 165 | 240 | 165 | 240 | 165 | 190 |
| Fvx wane both sides | | | | | | |
| Ex Modulus of Elasticity | 1,800,000 | 1,800,000 | 1,800,000 | 1,800,000 | 1,800,000 | 1,800,000 |
| Bending about Y-Y Axis | | | | | | |
| Fby | | 2,150 | | 1,950 | | 1,750 |
| Fc perp y | | 560 | | 560 | | 560 |
| Fvy impact & cyclic loads | | 165 | | 165 | | 165 |
| Fvy all other loads | | 210 | | 210 | | 210 |
| Fvy multiple width-impact & cyclic loads | | 70 | | 70 | | 70 |
| Fvy multiple width-all other loads | | 90 | | 90 | | 90 |
| Ex Modulus of Elasticity | | 1,700,000 | | 1,700,000 | | 1,600,00 |
| Axially Loaded | | | | | | |
| Ft tension parallel | 2,800 | 1,400 | *2,200 | 1,300 | 2,400 | 1,100 |
| Fc compresseion parallel | *2,200 | 2,100 | **1,900 | 1,950 | 2,000 | 1,550 |
| E axial-Modulus of Elasticity | 1,800,000 | 1,900,000 | 1,800,000 | 1,900,000 | 1,800,000 | 1,900,000 |
| End Grain Bearing | | | | | | |
| Fg full bearing | | 2,360 | | 2,360 | | 2,360 |
| Fg partial bearing | | 2,360 | | 2,360 | | 2,360 |
| Radial Strength | 55 | 15 | 55 | 15 | 55 | 15 |
| Frt tension | 55 | 15 | 55 | 15 | 55 | 15 |
| Frt wind & seismic | 55 | 55 | 55 | 55 | 55 | 55 |
| Frc Radial Compression | 415 | 560 | 415 | 560 | 415 | 560 |
| *Add 200 PSI for 15 or more laminations<br>**Add 100 PSI for 15 or more laminations | | | | | | |

*Table 1*

| *Allowable Stresses for Glued Laminated Timber Members in Existing Buildings, Douglas-fir, coast* | | | | | | |
|---|---|---|---|---|---|---|
| **Stress-Grade Combination** | **A** | | **B** | | **C** | |
| **Source of Stress Value** | **1964 UBC** | **AITC GLVD** | **1964 UBC** | **AITC GLDV** | **1964 UBC** | **AITC GLDV** |
| Bending about X-X Axis | | | | | | |
| Fbx | 2,600 | 1,800 | 2,400 | 1,800 | 2,200 | 1,600 |
| Fc prep tension face | 450 | 650 | 450 | 650 | 450 | 650 |
| Fc perp compression face | 450 | 650 | 450 | 650 | 450 | 650 |
| Fvx impact & cyclic loads | 165 | 190 | 165 | 190 | 165 | 190 |
| Fvx all other loads | 165 | 240 | 165 | 240 | 165 | 240 |
| Fvx wane | | | | | | |
| Modulus of Elasticity | 1,800,000 | 1,800,000 | 1,800,000 | 1,800,000 | 1,800,000 | 1,700,000 |
| Bending about Y-Y Axis | | | | | | |
| Fby | | 1,650 | | 1,550 | | 1,550 |
| Fc perp y | | 560 | | 560 | | 560 |
| Fvy impact & cyclic loads | | 165 | | 165 | | 165 |
| Fvy all other loads | | 210 | | 210 | | 210 |
| Fvy multiple width-impact & cyclic loads | | 70 | | 70 | | 70 |
| Fvy multiple width-all other loads | | 90 | | 90 | | 90 |
| Modulus of Elasticity | | 1,700,000 | | 1,600,000 | | 1,600,00 |
| Axially Loaded | | | | | | |
| Ft tension parallel | 1,600 | 1,150 | 1,600 | 1,100 | 1,600 | 1,050 |
| Fc compresseion parallel | 1,500 | 1,700 | 1,500 | 1,700 | 1,500 | 1,600 |
| E axial-Modulus of Elasticity | 1,800,000 | 1,800,000 | 1,800,000 | 1,600,000 | 1,800,000 | 1,700,000 |
| End Grain Bearing | | | | | | |
| Fg full bearing | | 2,460 | | 2,480 | | 2,460 |
| Fg partial bearing | | 2,360 | | 2,360 | | 2,360 |
| Radial Strength | | | | | | |
| Frt tension | 55 | 15 | 55 | 15 | 55 | 15 |
| Frt wind & seismic | 55 | 55 | 55 | 55 | 55 | 55 |
| Frc Radial Compression | 450 | 560 | 450 | 560 | 450 | 560 |

*Table 2*