NATIONAL DESIGN SPECIFICATION

for

STRESS-GRADE LUMBER

and

ITS FASTENINGS

1944

Recommended by

NATIONAL LUMBER MANUFACTURERS ASSOCIATION

Washington, D. C.

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NATIONAL DESIGN SPECIFICATION

for

STRESS-GRADE LUMBER and ITS FASTENINGS

THIS specification is based on and recognizes the value of competent engineering design, accurate fabrication and adequate supervision of construction where stress-grade lumber is used. With the lumber preparation, its installation and joining, and its fastenings conforming to good engineering practice, the application of the Specification affords a means of realizing more efficient and economical lumber structures.

Material which is qualified for the working stresses assigned to the grade is assured by the use of stress-grades of lumber identified by the grade mark of, or certificate of inspection issued by, a lumber grading or inspection bureau or agency recognized as being competent.

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NATIONAL LUMBER MANUFACTURERS ASSOCIATION
Washington, D. C.

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Foreword

IN formulating the provisions of the Specification, the most reliable data available from laboratory tests and practical experience with structures in service were carefully analyzed and evaluated for the purpose of providing a technically sound national standard of practice.

This National Design Specification for Stress-Grade Lumber and Its Fastenings was developed over a period of more than three years of study and consultation by the Technical Advisory Committee of the National Lumber Manufacturers Association. The committee had access to the knowledge and long experience of engineers, architects, and contractors, lumber fabricators, organizations publishing grading rules, agencies grading and inspecting lumber, and various governmental agencies concerned with structures and lumber research. It assembles in convenient form many data which have been widely disseminated and proved in common use.

Acknowledgment is made to the Forest Products Laboratory, Forest Service, U. S. Department of Agriculture, for data and publications generously made available during the committee's investigations and which served as the principal bases for the specification.

The detailed development and technical correlation of the specification, under the general supervision of Richard G. Kimbell, Director of Technical and Lumber Standards Divisions, National Lumber Manufacturers Association, was the responsibility of Frank J. Hanrahan, Structural Engineer and Deputy Director of Lumber Standards Division.

B. R. ELLIS, Chairman
Technical Advisory Committee
National Lumber Manufacturers Association

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PART I. GENERAL—STRESS-GRADE LUMBER

100—SCOPE

100–A. This specification defines the practice to be followed in design with, and in fabrication and erection of stress-grade lumber (see par. 102-B), and also in design with and installation of the fastenings defined herein when used to connect stress-grade lumber.

100–B. The allowable unit stresses given in Table No. 1 and the requirements in Part II are for designs made and carried out under competent supervision and for lumber of assured stress-grade.

100–C. Allowable unit stresses for species and grades not given in the following tables should be established in accordance with the principles set forth in American Lumber Standards, Simplified Practice Recommendation R16-39, and Guide to the Grading of Structural Timber and Determination of Working Stresses, Miscellaneous Publication No. 185, United States Department of Agriculture, dated February, 1934, using 120 per cent of the values in Columns 2, 3, 4 and 5 of Table 8 therein, and the supplement thereto, dated May, 1940.

101—GENERAL REQUIREMENTS

101–A. The quality of the wood and the design for load-supporting members when stress-grades are used shall conform to the standards hereinafter specified.

101–B. All members shall be so framed, anchored, tied, and braced that they have the necessary strength and rigidity.

101–C. In the engineering design, care should be taken that the connections, both at joints and splices, are such that each individual piece carries its proportional stress and consideration is given to stresses resulting from moment in joints.

102—STRESS-GRADE LUMBER

102–A. Lumber grades shall be specified by commercial grade names.

102–B. Stress-grade lumber consists of lumber classifications known as "Beams and Stringers," "Joists and Planks," and "Posts and Timbers," to each grade of which is assigned proper allowable unit stresses.

102–B–1. *Beams and Stringers.* Lumber of rectangular cross-section, 5 or more inches thick and 8 or more inches wide, graded with respect to its strength in bending when loaded on the narrow face.

102–B–2. *Joists and Planks.* Lumber of rectangular cross-section, 2 inches to but not including 5 inches thick and 4 or more inches wide, graded with respect to its strength in bending when loaded either on the narrow face as a joist or on the wide face as a plank.

102–B–3. *Posts and Timbers.* Lumber of square or approximately square cross-section 5 by 5 inches and larger, graded primarily for use as posts or columns carrying longitudinal load but adapted for miscellaneous uses in which strength in bending is not especially important.

PART II. ALLOWABLE UNIT STRESSES FOR STRESS-GRADE LUMBER

200—GENERAL STRESS PROVISIONS

200–A. Each wood structural member shall be of sufficient size to carry the dead and required live loads* without exceeding the allowable unit stress hereinafter specified. Adequate bracing and bridging to resist wind and other lateral forces shall be provided. Lower unit stresses than those herein specified for the grades listed in Table No. 1 shall not be used in the calculations for the design of the structure when stress-grade lumber is used.

200–B. When stress-grade lumber is resawn, it shall be regraded and allowable unit stresses for the regraded material shall apply.

200–C. Minimum sizes of lumber members required by this specification refer to nominal sizes. American Lumber Standard dressed sizes (reference No. 1, Appendix G) shall be accepted as the minimum net sizes conforming to nominal sizes. Computations to determine the required sizes of members shall be based on the net dimensions (actual size) and not the nominal sizes. If rough sizes or finish sizes greater or smaller than American Lumber Standard dressed sizes are to be used, computations shall be predicated upon such actual sizes, provided they are specified on the plans or in a statement appended thereto. For convenience, nominal sizes may be shown on the plans.

200–D. Induced stresses, in pounds per square inch, computed on the basis of actual dimensions, shall not exceed the allowable unit stresses except as hereinafter modified for the respective species and grades in Table No. 1. When the allowable unit stresses in this table are used, the lumber shall be identified by the grade mark of, or certificate of inspection issued by, a lumber grading or inspection bureau or agency recognized as being competent.

200–E. The allowable unit stresses in Table 1 and modifications thereof apply to lumber when seasoned or in any condition of seasoning.

201—MODIFICATION OF ALLOWABLE UNIT STRESSES FOR SERVICE CONDITIONS

201–A. The allowable unit stresses in Table 1 and modifications thereof apply to lumber used under conditions continuously dry such as in most covered structures.

201–B. The allowable unit stresses in Table 1 and modifications thereof apply to lumber pressure-impregnated by an approved process and preservative and to the heartwood of a durable species under dry or other conditions of use.

201–C. Where the conditions of paragraphs 201-A and 201-B are not met or other adequate protective measures are not taken, in permanent construction appropriate modifications should be made of stresses in Table 1 and modifications thereof.

202—ALLOWABLE UNIT STRESSES FOR PERMANENT LOADING

202–A. The allowable unit stresses in Table No. 1 apply for permanent loading, i. e., long-time loading whether live or dead.

203—ALLOWABLE UNIT STRESSES FOR SNOW, WIND, EARTHQUAKE OR SHORT TIME LOADING

203–A. The allowable unit stresses in Table No. 1 may be increased by 15 percent for snow loading combined with dead load, and 50 percent for wind or earthquake loading. Where maximum snow load remains permanently on the structure, the allowable stresses shall not be increased. For other loading not exceeding a duration of 5 minutes, the allowable stresses may also be increased by 50 percent. The above increases are not cumulative. For wind in combination with permanent loading, the allowable unit stresses in Table No. 1 may be increased by 50 percent, provided that the resulting structural members are not smaller than those required for permanent loading alone. The provisions of this paragraph do not apply to the modulus of elasticity. These increases apply to mechanical fastenings except as otherwise noted.

204—ALLOWABLE UNIT STRESSES FOR IMPACT

204–A. Allowable unit stresses given in Table No. 1 for permanent loading may be used without regard to impact if the stress induced by impact does not exceed the allowable unit stress for per-

* Live loads as used herein include wind, snow, impact, earthquake and other applied loads.

manent loading; but the sum of stresses induced by any combination of loading, e. g., impact with dead, long-time live, and/or short-time live loading, shall not exceed twice the allowable unit stress for permanent loading. The provisions of this paragraph do not apply to the modulus of elasticity.

205—ALLOWABLE UNIT STRESSES FOR FLEXURE

205–A. Allowable unit stresses in flexure for Joist and Plank grades apply to material with the load applied to either the narrow or wide face.

205–B. Allowable unit stresses in flexure for Beam and Stringer grades apply only to material with the load applied to the narrow face.

205–C. Beam grades ordinarily are graded for use on simple spans. When used as a continuous beam, the grading provisions customarily applied to the middle third of the length of simple spans shall be applied to the middle two-thirds of the length of pieces to be used over double spans and to the entire length of pieces to be used over three or more spans.

205–D. For design formulas, see paragraph 400.

206—ALLOWABLE UNIT STRESSES FOR COMPRESSION PARALLEL TO GRAIN

206–A. Allowable unit stresses in Table No. 1 for compression parallel to grain in POST AND TIMBER grades apply to columns with an l/d ratio of 11 or less. The allowable unit stresses in Table No. 1 for compression parallel to grain given for JOIST AND PLANK and BEAM AND STRINGER grades apply to columns with an l/d ratio of 11 or less, when the following additional provisions are applied to these grades:

The sum of the sizes of all knots in any 6 inches of the length of the piece shall not exceed twice the maximum permissible size of knot. Two knots of maximum permissible size shall not be within the same 6 inches of length on any face.

206–B. For other l/d ratios, allowable unit stresses shall be determined by the column formulas given in paragraph 401.

207—ALLOWABLE UNIT STRESSES FOR COMBINED COMPRESSION AND FLEXURE

207–A. When members are subjected to loading which induces combined flexure and axial compressive stresses, JOIST AND PLANK or BEAM AND STRINGER grades shall be used. (See Table No. 1.)

207–B. For design formulas, see paragaph 403-B.

208—ALLOWABLE UNIT STRESSES FOR TENSION AND COMBINED TENSION AND FLEXURE

208–A. Allowable unit stresses in tension parallel to grain given in Table No. 1 for JOIST AND PLANK and BEAM AND STRINGER grades apply for members in direct tension, or in combined tension and flexure, when the following additional provisions are applied to these grades:

The sum of the sizes of all knots in any 6 inches of the length of the piece shall not exceed twice the maximum permissible size of knot. Two knots of maximum permissible size shall not be within the same 6 inches of length of any face.

208–B. For design formulas, see paragraphs 403-A and 404-A.

209—ALLOWABLE UNIT STRESSES FOR SHEAR

209–A. Induced stresses in horizontal shear shall be computed in accordance with paragraph 400-D.

209–B. Allowable unit stresses for shear in joint details may be 50 percent greater than the horizontal shear values otherwise permitted.

210—ALLOWABLE UNIT STRESSES FOR BEARING PERPENDICULAR TO GRAIN

210–A. In joists supported on a ribbon or ledger board and spiked to the studs, the allowable unit stresses in Table No. 1 for compression perpendicular to grain may be increased by 50 percent.

210–B. Allowable unit stresses in compression perpendicular to grain may be increased for bearings less than 6 inches in length and located 3 inches or more from the end of a timber in accordance with paragraph 400-E.

211—ALLOWABLE UNIT STRESSES FOR END BEARING OF COMPRESSION MEMBERS ON METAL PLATES OR STRAPS

211–A. If a wood compression member that bears on a metal plate or strap, e. g., as at the heel joint of a truss, contains no knot at the bearing greater in diameter than 1½ inches or one-fourth the minimum cross-sectional dimension of the member, whichever is the lesser, the allowable unit stress for bearing is the value for the species given in Table No. 2, or, if the loading is at an angle to grain, shall be determined by the Hankinson formula (par. 405 and Appendix C), using the allowable unit stress parallel to grain from Table No. 2 and allowable unit stress perpendicular to grain from Table No. 1.

212—ALLOWABLE UNIT STRESSES FOR COMPRESSION AT ANGLE TO GRAIN

212–A. The allowable unit stresses in compression on surfaces inclined to the grain shall be determined by the Hankinson formula. See paragraphs 211-A and 405 and Appendix C.

212–B. For end to end bearing on metal plate, see paragraph 401-D.

213—SPECIFICATIONS AND PLANS

213–A. Lumber shall be specified by species and commercial grade names.

213–B. The allowable unit stresses used in the design should be indicated on the plans and working drawings. Whether the design is based on standard dressed, standard rough or special sizes should also be indicated.

Note to Designer—This may be accomplished by using indications as follows:

List I:
$f=$——psi, $t=$——psi, $H=$——psi,
$c=$——psi, $c\perp=$——psi, and $E=$——psi

List II:
$f=$——psi, $t=$——psi, $H=$——psi,
$c=$——psi, $c\perp=$——psi, and $E=$——psi

(List III, etc.)

Stress values not pertinent to the design may be omitted.

The preceding lists, i. e., List I, List II and List III, etc., can be extended as indicated to include all stress-grades used in the design. If more than one stress-grade is required, the notation of each list number should be placed on the drawing so as to identify each typical member. It is suggested that this can best be accomplished by a line diagram.

TABLE No. 1.—*Allowable unit stresses for stress-grade lumber*

[The allowable unit stresses below are for permanent loading. See other provisions of Part II for modifications of these tabulated allowable unit stresses]

1 Species and commercial grade [1]		2 Rules under which graded	Allowable unit stresses in pounds per square inch: 3 Extreme fiber in bending "f" and tension parallel to grain [2] "t"	4 Horizontal shear "H"	5 Compression perpendicular to Grain "c⊥"	6 Compression parallel to grain [3] "c"	7 Modulus of elasticity "E"
ASH, WHITE:							
2150 f Grade	J.&P.	National Hardwood Lumber Association.	2, 150	145	600	1, 700	1, 500, 000
1900 f Grade	J.&P.-B.&S.		1, 900	145		1, 500	
1700 f Grade	J.&P.-B.&S.		1, 700	145		1, 325	
1450 f Grade	J.&P.-B.&S.		1, 450	120		1, 150	
1300 f Grade	B.&S.		1, 300	120		1, 050	
1450 c Grade	P.&T.		-----	-----		1, 450	
1200 c Grade	P.&T.		-----	-----		1, 200	
1075 c Grade	P.&T.		-----	-----		1, 075	
BEECH:							
2150 f Grade	J.&P.	National Hardwood Lumber Association.	2, 150	145	600	1, 750	1, 600, 000
1900 f Grade	J.&P.-B.&S.		1, 900	145		1, 525	
1700 f Grade	J.&P.-B.&S.		1, 700	145		1, 350	
1450 f Grade	J.&P.-B.&S.		1, 450	120		1, 150	
1550 c Grade	P.&T.		-----	-----		1, 550	
1450 c Grade	P.&T.		-----	-----		1, 450	
1200 c Grade	P.&T.		-----	-----		1, 200	
BIRCH:							
2150 f Grade	J.&P.	National Hardwood Lumber Association.	2, 150	145	600	1, 750	1, 600, 000
1900 f Grade	J.&P.-B.&S.		1, 900	145		1, 525	
1700 f Grade	J.&P.-B.&S.		1, 700	145		1, 350	
1450 f Grade	J.&P.-B.&S.		1, 450	120		1, 150	
1550 c Grade	P.&T.		-----	-----		1, 550	
1450 c Grade	P.&T.		-----	-----		1, 450	
1200 c Grade	P.&T.		-----	-----		1, 200	
CHESTNUT:							
1450 f Grade	J.&P.	National Hardwood Lumber Association.	1, 450	120	360	1, 200	1, 000, 000
1200 f Grade	J.&P.-B.&S.		1, 200	120		950	
1075 c Grade	P.&T.		-----	-----		1, 075	
CYPRESS, SOUTHERN:							
1700 f Grade	J.&P.-B.&S.	National Hardwood Lumber Association.	1, 700	145	360	1, 425	1, 200, 000
1300 f Grade	J.&P.-B.&S.		1, 300	120		1, 125	
1450 c Grade	P.&T.		-----	-----		1, 450	
1200 c Grade	P.&T.		-----	-----		1, 200	
CYPRESS, TIDEWATER RED:							
1700 f Grade	J.&P.-B.&S.	Southern Cypress Manufacturers' Association.	1, 700	145	360	1, 425	1, 200, 000
1300 f Grade	J.&P.-B.&S.		1, 300	120		1, 125	
1450 c Grade	P.&T.		-----	-----		1, 450	
1200 c Grade	P.&T.		-----	-----		1, 200	
DOUGLAS FIR, COAST REGION: [8]							
Par. 214a Grade [7]	J.&P.	West Coast Bureau of Lumber Grades and Inspection.	2, 150	145	455	1,550	1, 600, 000
Par. 218a Grade [7]	B.&S.		2, 150	145	455	1,550	
Par. 214 Grade	J.&P.		1, 900	120	415	1,450	
Par. 218 Grade	B.&S.		1, 900	120	415	1,450	
Par. 215a Grade [7]	J.&P.		1, 700	145	455	1,325	
Par. 219a Grade [7]	B.&S.		1, 700	145	455	1,325	
Par. 215 Grade	J.&P.		1, 450	120	390	1,200	
Par. 219 Grade	B.&S.		1, 450	120	390	1,200	
Par. 216 Grade	J.&P.		1, 100	110	390	1,075	
Par. 210a Grade [7]	P.&T.		-----	-----	455	1,550	
Par. 210 Grade	P.&T.		-----	-----	415	1,450	
Par. 200 Grade	P.&T.		-----	-----	390	1,325	

See footnotes at end of table.

TABLE No. 1.—*Allowable unit stresses for stress-grade lumber*—Continued

1 Species and commercial grade [1]		2 Rules under which graded	Allowable unit stresses in pounds per square inch: 3 Extreme fiber in bending "f" and tension parallel to grain [3] "t"	4 Horizontal shear "H"	5 Compression perpendicular to grain "c⊥"	6 Compression parallel to grain [3] "c"	7 Modulus of elasticity "E" [7]
DOUGLAS FIR, INLAND EMPIRE:							
Select Structural [7]	J.&P.	Western Pine Association.	2,150	145	455	1,750	1,600,000
Structural	J.&P.		1,900	100	400	1,400	1,500,000
Common Structural	J.&P.		1,450	95	380	1,250	1,500,000
Select Structural [7]	P.&T.				455	1,750	1,600,000
Structural	P.&T.				400	1,400	1,500,000
Common Structural	P.&T.				380	1,250	1,500,000
ELM, ROCK:							
2150 f Grade	J.&P.	National Hardwood Lumber Association.	2,150	145	600	1,750	1,300,000
1900 f Grade	J.&P.–B.&S.		1,900	145		1,525	
1700 f Grade	J.&P.–B.&S.		1,700	145		1,350	
1450 f Grade	J.&P.–B.&S.		1,450	120		1,150	
1550 c Grade	P.&T.					1,550	
1450 c Grade	P.&T.					1,450	
1200 c Grade	P.&T.					1,200	
ELM, SOFT:							
1700 f Grade	J.&P.	National Hardwood Lumber Association.	1,700	120	300	1,225	1,200,000
1450 f Grade	J.&P.–B.&S.		1,450	120		1,050	
1200 f Grade	J.&P.–B.&S.		1,200	120		875	
1075 c Grade	P.&T.					1,075	
GUM, BLACK AND RED:							
1700 f Grade	J.&P.	National Hardwood Lumber Association.	1,700	120	360	1,225	1,200,000
1450 f Grade	J.&P.–B.&S.		1,450	120		1,050	
1200 f Grade	J.&P.–B.&S.		1,200	120		875	
1075 c Grade	P.&T.					1,075	
HEMLOCK, EASTERN:							
Select Structural	J.&P.–B.&S.	Northern Hemlock and Hardwood Manufacturers Association.	1,300	85	360	850	1,100,000
Prime Structural	J.&P.[5]		1,200	60		775	
Common Structural	J.&P.[5]		1,100	60		650	
Utility Structural	J.&P.[5]		950	60		600	
Select Structural	P.&T.					850	
HEMLOCK, WEST COAST: [6]							
Par. 498 Grade	J.&P.	West Coast Bureau of Lumber Grades and Inspection.	1,450	100	360	1,075	1,400,000
Par. 500 Grade	B.&S.		1,450	100		1,075	
Par. 499 Grade	J.&P.		1,100	90		850	
Par. 503 Grade	P.&T.					1,075[4]	
HICKORY:							
2150 f Grade	J.&P.–B.&S.	National Hardwood Lumber Association.	2,150	145	720	1,725	1,800,000
1900 f Grade	J.&P.–B.&S.		1,900	145		1,550	
1700 f Grade	J.&P.–B.&S.		1,700	145		1,350	
1550 c Grade	P.&T.					1,550	
1450 c Grade	P.&T.					1,450	
1325 c Grade	P.&T.					1,325	
LARCH:							
Select Structural [7]	J.&P.	Western Pine Association.	2,150	145	455	1,750	1,300,000
Structural	J.&P.		1,900	120	415	1,450	
Common Structural	J.&P.		1,450	120	390	1,325	
Select Structural [7]	P.&T.				455	1,750	
Structural	P.&T.				415	1,450	
Common Structural	P.&T.				390	1,325	
MAPLE, HARD:							
2150 f Grade	J.&P.	National Hardwood Lumber Association.	2,150	145	600	1,750	1,600,000
1900 f Grade	J.&P.–B.&S.		1,900	145		1,525	
1700 f Grade	J.&P.–B.&S.		1,700	145		1,350	
1450 f Grade	J.&P.–B.&S.		1,450	120		1,150	
1550 c Grade	P.&T.					1,550	
1450 c Grade	P.&T.					1,450	
1200 c Grade	P.&T.					1,200	

See footnotes at end of table.

TABLE No. 1.—*Allowable unit stresses for stress-grade lumber*—Continued

1		2	Allowable unit stresses in pounds per square inch				7
			3	4	5	6	
Species and commercial grade [1]		Rules under which graded	Extreme fiber in bending "f" and tension parallel to grain [2] "t"	Horizontal shear "H"	Compression perpendicular to grain "c⊥"	Compression parallel to grain [3] "c"	Modulus of elasticity "E"
OAK, RED AND WHITE:							
2150 f Grade	J.&P.	National Hardwood Lumber Association.	2,150	145	600	1,550	1,500,000
1900 f Grade	J.&P.–B.&S.		1,900	145		1,375	
1700 f Grade	J.&P.–B.&S.		1,700	145		1,200	
1450 f Grade	J.&P.–B.&S.		1,450	120		1,050	
1300 f Grade	B.&S.		1,300	120		950	
1325 c Grade	P.&T.		---	---		1,325	
1200 c Grade	P.&T.		---	---		1,200	
1075 c Grade	P.&T.		---	---		1,075	
PECAN:							
2150 f Grade	J.&P.–B.&S.	National Hardwood Lumber Association.	2,150	145	720	1,725	1,800,000
1900 f Grade	J.&P.–B.&S.		1,900	145		1,550	
1700 f Grade	J.&P.–B.&S.		1,700	145		1,350	
1550 c Grade	P.&T.		---	---		1,550	
1450 c Grade	P.&T.		---	---		1,450	
1325 c Grade	P.&T.		---	---		1,325	
PINE, NORWAY:							
Prime Structural	J.&P.[5]	Northern Hemlock and Hardwood Manufacturers Association.	1,200	75	360	900	1,200,000
Common Structural	J.&P.[5]		1,100	75		775	
Utility Structural	J.&P.[5]		950	75		650	
PINE, SOUTHERN LONGLEAF:							
Select Structural [7]	J.&P.–B.&S.	Southern Pine Inspection Bureau of the Southern Pine Association.	2,400	120 [6]	455	1,750	1,600,000
Prime Structural [7]	J.&P.–B.&S.		2,150	120 [6]		1,550	
Merchantable Structural.[7]	J.&P.–B.&S.		1,900	120 [6]		1,450	
Structural S.E.&S.[7]	J.&P.–B.&S.		1,900	120 [6]		1,450	
No. 1 Structural [7]	J.&P.–B.&S.		1,700	120 [6]		1,200	
No. 1 Dimension [7]	J.&P.[5]		1,700	---		1,200	
No. 2 Stress Dimension.[7]	J.&P.[5]		1,250	---		1,025	
Select Structural [7]	P.&T.		---	---		1,750	
Prime Structural [7]	P.&T.		---	---		1,550	
Merchantable Structural.[7]	P.&T.		---	---		1,450	
Structural S.E.&S.[7]	P.&T.		---	---		1,450	
No. 1 Structural [7]	P.&T.		---	---		1,200	
PINE, SOUTHERN SHORTLEAF:							
Dense Select Structural.[7]	J.&P.–B.&S.	Southern Pine Inspection Bureau of the Southern Pine Association.	2,400	120 [6]	455	1,750	1,600,000
Dense Structural [7]	J.&P.–B.&S.		2,150	120 [6]	455	1,550	
Dense Structural S. E. & S.[7]	J.&P.–B.&S.		1,900	120 [6]	455	1,450	
Dense No. 1 Structural.[7]	J.&P.–B.&S.		1,700	120 [6]	455	1,200	
No. 1 Dense Dimension.[7]	J.&P.[5]		1,700	---	455	1,200	
No. 1 Dimension	J.&P.[5]		1,450	---	390	1,075	
No. 2 Dense Stress Dimension.[7]	J.&P.[5]		1,250	---	455	1,025	
No. 2 Med. Grain Stress Dimension.	J.&P.[5]		1,100	---	390	875	
Dense Select Structural.[7]	P.&T.		---	---	455	1,750	
Dense Structural [7]	P.&T.		---	---	455	1,550	
Dense Structural S. E. & S.[7]	P.&T.		---	---	455	1,450	
Dense No. 1 Structural.[7]	P.&T.		---	---	455	1,200	

[1] See footnotes at end of table.

TABLE No. 1.—*Allowable unit stresses for stress-grade lumber*—Continued

1		2	Allowable unit stresses in pounds per square inch				
Species and commercial grade[1]		Rules under which graded	3 Extreme fiber in bending "f" and tension parallel to grain[1] "t"	4 Horizontal shear "H"	5 Compression perpendicular to grain "c⊥"	6 Compression parallel to grain[2] "c"	7 Modulus of elasticity "E"
POPLAR, YELLOW:							
1500 f Grade	J.&P.	National Hardwood Lumber Association.	1,500	110	300	1,200	1,100,000
1250 f Grade	J.&P.–B.&S.		1,250	110		950	
1075 c Grade	P.&T.		----------	--------		1,075	
REDWOOD:							
Dense Sel. All-Heart Structural.[7]	J.&P.–B.&S.	California Redwood Association.	1,700	110	320	1,450	1,200,000
Select All-Heart Structural.[7]	J.&P.–B.&S.		1,450	95		1,225	
Bulkhead Structural.[7]	J.&P.		1,300	95		1,325	
Heart Structural	J.&P.		1,300	95		1,325	
Dense Sel. All-Heart Structural.[7]	P.&T.		----------	--------		1,450	
Select All-Heart Structural.[7]	P.&T.		----------	--------		1,325	
SPRUCE, EASTERN:							
1450 f Structural Grade.	J.&P.	Northeastern Lumber Manufacturers Association, Inc.	1,450	110	300	1,050	1,200,000
1300 f Structural Grade.	J.&P.		1,300	95		975	
1200 f Structural Grade.	J.&P.		1,200	95		900	
TUPELO:							
1700 f Grade	J.&P.	National Hardwood Lumber Association.	1,700	120	360	1,225	1,200,000
1450 f Grade	J.&P.–B.&S.		1,450	120		1,050	
1200 f Grade	J.&P.–B.&S.		1,200	120		875	
1075 c Grade	P.&T.		----------	--------		1,075	

[1] Abbreviations: J.&P., Joists and Planks; B.&S., Beams and Stringers; P.&T., Posts and Timbers; S.E.&S., Square Edge and Sound. (For description of classification of material, see par. 102-B.)

[2] When graded in accordance with par. 208.

[3] When graded according to par. 206 and when the l/d ratio is 11 or less.

[4] When slope of grain is not more than 1 in 10.

[5] Available in thickness of 2 inches only.

[6] Allowable unit shearing stresses of 145, 170 and 196 pounds per square inch may be used when these grades are specified to conform to the standard 120, 140 and 160 pound shear grades respectively in paragraphs 368 and 450 of the grading rules.

[7] These grades include requirements for density.

[8] These paragraph numbers refer to paragraphs in the Standard Grading and Dressing Rules of the West Coast Bureau of Lumber Grades and Inspection.

TABLE No. 2.—*Allowable unit stress in bearing parallel to grain* ON METAL PLATES, *in pounds per square inch.*

Species:		Species:	
Ash, white	1,750	Hickory	2,400
Beech	1,925	Larch, dense	2,050
Birch	1,925	Larch, close grained	1,875
Chestnut	1,275	Larch	1,750
Cypress, southern	1,750	Maple, hard	1,925
Cypress, tidewater	1,750	Oak, red and white	1,600
Douglas fir, all regions, dense	2,050	Pecan	2,400
Douglas fir, coast region, close grained	1,875	Pine, Norway	1,275
Douglas fir, coast region	1,750	Pine, southern longleaf	2,050
Douglas fir, inland region, close grained	1,775	Pine, southern shortleaf, dense	2,050
Douglas fir, inland region	1,650	Pine, southern shortleaf	1,750
Elm, rock	1,925	Poplar, yellow	1,275
Elm, soft	1,275	Redwood, close grained	1,700
Gum, black and red	1,275	Redwood	1,600
Hemlock, eastern	1,125	Spruce, eastern	1,275
Hemlock, western	1,450	Tupelo	1,275

PART III. DESIGN LOADS

300—LOADS AND FORCES

300–A. Wood structures shall be designed to sustain the actual loads and forces applied, including:

300–A–1. ***Dead load.***

300–A–2. ***Live load.****

(*a*) Impact.

(*b*) Wind and other lateral, longitudinal, and uplift forces.

(*c*) Erection loads.

(*d*) Other forces.

301—DEAD LOADS

301–A. The dead load consists of the weight of the appropriate portion of the wood structure and all material fastened thereto or permanently supported thereby.

302—LIVE LOADS

302–A. The live loads* depend on the code under which the structure is designed, or if no code governs, the designer's estimates of the particular service requirements for the structure, local weather conditions, and seismic disturbances, but this specification is predicated on the condition that the actual maximum loading is the loading assumed in the design.

303—RECORDING OF LIVE LOADS

303–A. The live loads* used in the design of structures covered by this specification should be clearly marked on the design plans and working drawings.

304—POSTING OF LIVE LOADS

304–A. Posting of commercial and industrial structures indicating the design live loads is recommended (as additional assurance against overloading).

305—IMPACT

305–A. For wood structures carrying live loads which induce impact or vibration, the stresses should be computed as indicated in paragraph 204.

* Live loads as used herein include wind, snow, impact, earthquake, and other applied loads.

306—WIND

306–A. Adequate provision shall be made for all stresses caused by wind both during erection and after completion of the structure. The allowable unit stresses are specified in paragraph 203.

306–B. All roofs, as well as other affected portions of the structure, shall be designed for anchorage to resist uplift from wind. The actual dead weight of the portions of the structure affected may be deducted to determine net uplift. Roof decks shall be anchored to beams and beams anchored to columns, bearing partitions, or well down on the walls. Vertical anchorage from column to column shall be provided to give a dead load sufficient to resist the uplift. Columns and walls shall be anchored to footings if necessary. For uplift, the design values for the withdrawal and lateral resistance of metal fastenings in wood and allowable unit stresses for lumber may be increased 50 percent above those for permanent loading. The design procedure for uplift should be in accordance with references Nos. 6 and 7, Appendix G, except that the design values for lumber and fastenings given in this specification shall apply.

307—EARTHQUAKES AND OTHER FORCES

307–A. Structures in localities subject to earthquakes, hurricanes, and other extraordinary conditions shall be designed with due regard for such conditions and the relation of duration of loading to allowable unit stresses. See Part II.

307–B. Structures designed to resist earthquake shock shall be designed and constructed to resist forces applied horizontally from any direction at each floor or roof above the ground level.

308—ERECTION

308–A. Proper provision shall be made to resist the short time stresses induced during erection increasing allowable unit stresses for the short time loading. See Part II.

PART IV. DESIGN FORMULAS AND PROVISIONS

400—WOOD BEAMS

400–A. ***Notation*** (except where otherwise noted): Symbols used in the following formulas are:

b=breadth of section, inches;
D=deflection, inches;
E=modulus of elasticity;
f=unit stress in extreme fiber in bending;
h=depth of section, inches;
H=unit stress in horizontal shear;
I=moment of inertia of the section;
M=bending or resisting moment, maximum;
n=distance from neutral axis to extreme fiber, inches;
P=total concentrated load, pounds;
L=span, feet;
l=span, inches;
S=section modulus;
V=total vertical end shear or end reaction, pounds;
W=total uniformly distributed load, pounds.

400–B. Beam Span

For simple beams the span shall be taken as the distance from face to face of supports plus one-half the required length of bearing at each end, and for continuous beams the span is the distance between centers of bearings on supports over which the beam is continuous.

400–C. Flexure

400–C–1. The extreme fiber stress in bending for a wood beam is:

$$f=\frac{Mn}{I}=\frac{M}{S}$$

400–C–2. For a rectangular beam b wide and h deep, this becomes:

$$f=\frac{M}{S}=\frac{6M}{bh^2}$$

400–C–3. For solid rectangular and square beams with the neutral axis perpendicular to depth at center:

$$I=\frac{bh^3}{12}=\text{moment of inertia}$$

$$S=\frac{I}{n}=\frac{bh^2}{6}=\text{section modulus}$$

400–C–4. A beam of circular cross section is assumed to have the same strength in flexure as a square beam having the same cross-sectional area. If a circular beam is tapered, it shall be considered a beam of variable cross section.

400–C–5. For cross sections of unusual shape such as extremely deep, narrow beams, I beams, and box beams, see reference No. 2, Appendix G (pages 153 to 155).

400–C–6. Insofar as possible, notching of beams shall be avoided. For a beam notched at or near the middle of the span, the net depth shall be taken when determining the flexural strength. Notches at the ends do not affect flexural strength directly. For effect of notch on shear strength, see paragraph 400-D. The stiffness of a beam as determined from its gross section is practically unaffected by notches of reasonable depth and length, i. e., a notch depth equal to one-sixth the beam depth and a notch length equal to one-third the beam depth at any point along the beam.

400–C–7. Lateral moment distribution of a concentrated load from a critically loaded beam to adjacent parallel beams should be calculated. (See Appendix A.)

400–C–8. Design procedure for panels with stressed covering shall conform to reference No. 17, Appendix G.

400–D. Shear

400–D–1. ***Vertical Shear.*** Ordinarily it is unnecessary to compute or check the strength of beams in cross-grain (vertical) shear.

400–D–2. ***Horizontal Shear.*** The maximum horizontal shearing stress in a wood beam shall be calculated by means of the formula

$$H=\frac{VQ}{It}$$

in which

Q=the statical moment of the area above or below the neutral axis.
t=the width of the beam at the neutral axis.

For a rectangular beam b inches wide and h inches deep, this becomes

$$H=\frac{3V}{2bh}$$

This formula indicates shearing stresses greater than the actual stress. When calculating shear in a beam:*

(a) Take b as the full thickness of the beam.

(b) Select the allowable unit shearing stress for the species and grade. (Allowance for checks, end splits and shakes has been made in the allowable unit stresses.)

(c) When calculating the reactions:

(1) Take into account any relief to the beam resulting from load being distributed to adjacent parallel beams by flooring or other members of the construction. (See Appendix A.)

(2) Neglect all loads within a distance from either support equal to the depth of the beam.

(3) If there are moving loads, place the largest one (keeping others in their normal relation) at three times the depth of the beam from the support or at the quarter point, whichever is the closer to the support.

(4) Consider all other loads in the usual manner. If a timber does not qualify for shear resistance under the foregoing procedure, the reactions shall be determined by the formulas:

For concentrated load

$$R=\frac{10P(l-x)(x/h)^2}{9l[2+(x/h)^2]}$$

For uniformly distributed load

$$R=\frac{W}{2}\left(1-\frac{2h}{l}\right)$$

in which

h=depth of beam in inches;
l=span in inches;
P=concentrated load in pounds;
R=total modified end reaction or end shear in pounds;
W=total uniform load in pounds;
x=distance in inches from reaction to load.

For allowable unit stresses in shear, see Part II.

For notched beams, the shearing strength of a short, relatively deep beam notched on the lower face at the end is decreased by an amount depending on the relation of the depth of the notch to the depth of the beam. When designing a beam having a notch at its end, the desired bending load shall be checked against the load obtained by the formula

$$V=\left(\frac{2Hbd}{3}\right)\left(\frac{d}{h}\right)$$

in which d is the actual end depth above the notch. A gradual change in cross section compared with a square notch increases the shearing strength nearly to that computed for the actual depth above the notch.

For allowable unit stresses in shear for joint details, see paragraph 209-B.

400–E. Compression Perpendicular to Grain

400–E–1. Also see paragraph 210. The allowable unit stresses for compression perpendicular to the grain, in Table No. 1, apply to bearings of any length at the ends of the beam, and to all bearings 6 inches or more in length at any other location. When calculating the bearing area at the ends of beams, no allowance shall be made for the fact that, as the beam bends, the pressure upon the inner edge of the bearing is greater than at the end of the beam.

For bearings of less than 6 inches in length and not nearer than 3 inches to the end of a member, the maximum allowable load per square inch is obtained by multiplying the allowable unit stresses in compression perpendicular to grain by the following factor:

$$\frac{l+3/8}{l}$$

in which l is the length of bearing in inches measured along the grain of the wood.

The multiplying factors for indicated lengths of bearing on such small areas as plates and washers become:

Length of bearing in inches	½	1	1½	2	3	4	6 or more
Factor	1.75	1.38	1.25	1.19	1.13	1.10	1.00

In using the preceding formula and table for round washers or bearing areas, use a length equal to the diameter.

400–E–2. Primary members acting as beams should be supported at or near the bottom or unloaded edge. If mechanical fastenings are used in shear to support the end of the beam, they should be placed near the bottom or unloaded edge as shown in Figure 1.

* For a graphical representation of the total, single-beam, and two-beam reaction incorporated in these provisions, see appendix E.

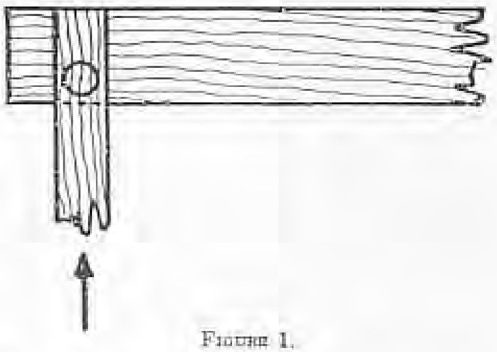


FIGURE 1.

400–F. Deflection

400–F–1. *Vertical Deflection.* If deflection is a factor in design, it shall be calculated by standard methods of engineering mechanics. Under design loading permanently applied, timber acquires a permanent set about equal to the original deflection, but the strength is not reduced.

400–F–2. *Lateral Deflection—Floor Joists.* (The dimensions in the following provisions are nominal—not actual.) Joists should be bridged at intervals not exceeding 8 feet between bridging or between bridging and bearing. Joists having a depth greater than 6 times their breadth should be bridged at intervals of not more than 6 times their depth.

400–F–3. *Lateral Deflection—Beams and Roof Joists.* (The dimensions in the following provisions are nominal—not actual.)

The designer should apply the following approximate rules in providing lateral restraint for rectangular beams and roof joists.

(a) If the ratio of depth to breadth is 2 to 1, no lateral support is needed.

(b) If the ratio is 3 to 1, the ends shall be held in position.

(c) If the ratio is 4 to 1, the piece shall be held in line as in a well-bolted chord member in a truss.

(d) If the ratio is 5 to 1, one edge shall be held in line.

(e) If the ratio is 6 to 1, the provisions of paragraph 400-F-2 may be applied.

(f) If the ratio is 7 to 1, both edges shall be held in line.

(g) If a beam is subject to both flexure and compression parallel to grain, the ratio may be as much as 5 to 1, if one edge is held firmly in line; e. g., by rafters (or by roof joists) and diagonal sheathing. If the dead load is sufficient to induce tension on the under side of the rafters, the ratio for the beam may be 6 to 1.

(h) Where roof joists, not purlins, are used between trusses, the depth rather than the breadth of a top chord member (compression member) may be taken as its least dimension in determining the l/d, provided that the roof joists are placed so that their upper edges are at least one-half inch above the tops of the trusses, but also placed low enough to provide adequate lateral support and the roof sheathing is applied diagonally and securely nailed to the roof joists.

(i) When the roof joists are on top of the top chords, the breadth of the individual chord member must be used as the least dimension (d) in determining l/d.

(j) If the above conditions for lateral support are not provided, see reference No. 2, Appendix G, (pp. 159 to 162), for guidance when determining strength.

401—WOOD COLUMNS

Wood columns shall be designed in accordance with the following formulas and requirements. (For allowable unit stresses, see Part II):

401–A. Notation

A=area of column cross section, square inches.

c=allowable unit stress in compression parallel to grain modified in accordance with paragraphs 202, 203, and 204.

d=dimension of least side of solid column and least side of individual members of spaced columns, inches.

E=modulus of elasticity.

l=unsupported over-all length, in inches, between points of lateral support of simple columns or from center to center of lateral supports of continuous or spaced columns.

l_2=distance from center of connector in end blocks to center of spacer block, inches.

K=a constant depending on the E and c of the material. K is the l/d ratio at which the curves of the intermediate (parabolic) and long (Euler) column formulas are tangent and at which the allowable unit stress for the column is two-thirds the allowable unit stress for a short column. (See par. 401-E-2.)

P=total load, pounds.

P/A=maximum load per unit of cross-sectional area.

401–B. Column Classifications

401–B–1. ***Simple Solid Wood Columns.*** Columns consisting of a single piece or pieces properly glued together to form a single member. They are classified as follows:

(a) Short columns, length not exceeding 11 times the least dimension.

(b) Intermediate columns, length between 11 and K times the least dimension.

(c) Long columns, length exceeding K times the least dimension.

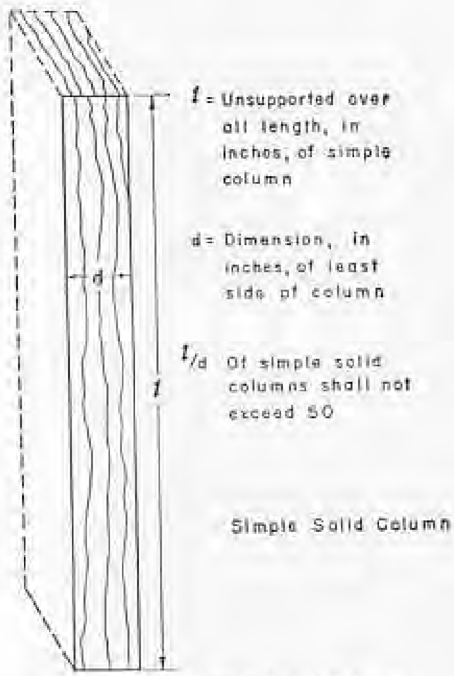


Figure 2—Simple Solid Column

401–B–2. ***Spaced Columns, Connector Joined.*** Formed of two or more individual members with their longitudinal axes parallel, separated at the ends and middle points of their length by blocking and joined at the ends by timber connectors capable of developing the required shear resistance. The individual members of a spaced column are designed as simple solid columns with the exception that for intermediate and long columns increased load capacity is obtained due to fixity factors when designed as indicated herein. Spaced columns are classified as to fixity factor, i.e. condition "a" or condition "b." (See Fig. 3.)

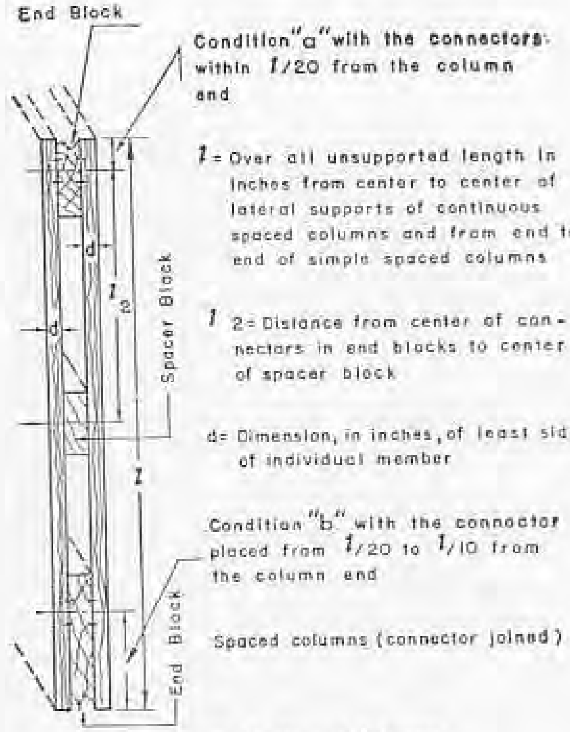


Figure 3—Spaced Column

401–B–3. ***Built Up Columns*** (other than con nector-joined, spaced columns and glued, lami nated columns) shall not be designed as soli columns but shall be designed in accordance witl references No. 2 and 23, Appendix G, except tha the allowable unit stresses herein apply.

401–C. l/d Limitations

401–C–1. For simple solid columns, l/d sha not exceed 50.

401–C–2. For individual members of a space column, l/d shall not exceed 80, nor shall $l_2/$ exceed 40.

401–D. Compression Members Bearing En to End Parallel to Grain

401–D–1. For end-to-end bearing of wood short compression members, e. g., at splices the upper chords of trusses, the full allowab compressive stress parallel to grain c may used provided that there is adequate lateral r straint, end cuts are accurately squared a parallel, and a metal plate of not less than gage is inserted with a drive fit between abutti ends.

401–D–2. The bearing stress parallel to gr P/A shall not exceed c where P is the appli load and A is the end area in bearing.

For allowable unit stress in compression paral to grain, see c, Table 1 and provisions of Part

401–E. Simple Solid Columns

401–E–1. ***End Conditions.*** These formulas for simple solid columns are based on pin-end conditions but shall be applied also to square-end conditions.

401–E–2. ***Allowable Unit Loads for Simple Solid Columns.*** (Modify c value in Table No. 1 in accordance with duration of loading provisions in pars. 202, 203, and 204.)

(a) Short Columns (l/d ratios equal to 11 or less):

$$P/A=c$$

(b) Intermediate Columns (l/d ratios between 11 and K):

$$P/A=c\left[1-\frac{1}{3}\left(\frac{l}{Kd}\right)^4\right]$$

in which

$$K=\frac{\pi}{2}\sqrt{\frac{E}{5c}}=0.702\sqrt{\frac{E}{c}}$$

(c) Long Columns (l/d ratios equal to or greater than K):

$$P/A=\frac{0.329E}{(l/d)^2}$$

401–F. Spaced-Column Design

401–F–1. ***Location of Spacer and End Blocks.*** A single spacer block shall be located within the middle tenth of the column length (l), and, if so located, connectors are not required for this block. If there are two or more spacer blocks, the distance between any two blocks shall not exceed one-half the distance between centers of connectors in the end blocks. The requirements for connectors in spacer blocks when two or more blocks are used are the same as for end blocks.

End blocks shall be so placed that sufficient end and edge distances and spacings (see Part V) for the required minimum size and number of connectors are maintained in both end blocks and individual members, and connectors so placed that they comply with conditions "a" or "b," (Fig. 3), depending on fixity factor assumed.

For spaced-columns used as members of a truss, e. g., compression chords, a panel point which is stayed laterally shall be considered as the end of the spaced-column and the portion of the web members between the individual pieces making up a spaced-column may be considered as the end blocks. For spaced-column web members, joints at the tension chord may be considered stayed laterally by the tautness of the tension chord and by customary lateral braces between trusses.

If there are two or more connectors in a contact face, the position of the center of gravity of the group of connectors shall be used in measuring the distance from connectors in the end block to the end of the column for determining fixity condition "a" or "b" (Fig. 3).

Where the l/d of the individual member of a spaced-column is 11 or less, no blocks are required and the individual members need not be fastened to each other as spaced-column action is not obtained when the l/d is 11 or less.

401–F–2. ***Dimensions of Spacer and End Blocks.*** The thickness of spacer and end blocks shall not be less than that of the individual members of the spaced-column nor shall the thickness, width, and length of spacer and end blocks be less than that required for installation of connectors of a size and number (see Part V) capable of carrying a load equal to that computed from Table No. 3 in paragraph 401-F-3. Spacer and end blocks of a thickness between that required above and one-half that thickness may be used, provided that the length of the blocks is made inversely proportional to the thickness in relation to required length of a full thickness block. Blocks thicker than a side member do not appreciably increase the load capacity. The load shall be considered to be applied in either direction parallel to the longitudinal axis of the individual member.

TABLE No. 3.—*End spacer block constants for connector joined spaced-columns*

l/d ratio of individual member in the spaced column [1]	End spacer block constant [2]			
	Group A connector loads	Group B connector loads	Group C connector loads	Group D connector loads
0 to 11	0	0	0	0
15	41	35	29	24
20	92	78	65	54
25	143	122	102	84
30	194	165	138	114
35	245	208	174	144
40	296	252	211	174
45	347	295	247	204
50	398	339	283	234
55	449	382	320	264
60 to 80	500	425	356	294

[1] Constants for intermediate l/d ratios may be obtained by straight line interpolation.
[2] For data on connector load groups, see Part V.

401–F–3. ***Load Capacity of Connectors in End Spacer Blocks.*** To obtain spaced-column action the connectors in each pair of mutually contacting surfaces of end blocks and individual members at each end of a spaced-column shall be of a size and number to provide a connector load capacity in pounds equal to the cross-sectional area in square inches of one of the individual members times the appropriate end-spacer block constant in Table No. 3.

If connector-joined spaced-columns are used in locations other than dry, the connector loads should be modified for such conditions in accordance with the provisions of Part V.

If spaced-columns are a part of a truss system or other similar framing, the connectors required by joint design may be sufficient for end block connectors but should be checked against Table 3.

401–F–4. ***Fixity Factor.*** When the formulas for solid columns are applied to spaced-columns, a restraint or fixity factor is introduced as a multiplier of E in the formula for K for intermediate columns and in the Euler formula for long columns as follows:

Condition "a": If connectors in end blocks are placed at the ends of a column or not exceeding a distance of $l/20$ from the ends, this factor is 2½.

Condition "b": If the connectors in end blocks are placed a distance of $l/20$ to $l/10$ from the ends of a column and the blocks extend to the ends of the column, this factor is 3.

401–F–5. ***Allowable Unit Stresses for Spaced-Columns.*** (Modify c value in Table No. 1 in accordance with duration of loading provisions in pars. 202, 203, and 204.) The total safe load P for a spaced-column is the safe unit load P/A obtained from the following formulas multiplied by the sum of the cross-sectional areas A of the individual column members of the spaced-column.

(a) Short Columns (l/d ratios of an individual member equal to 11 or less):

The total load capacity of a short spaced-column is the sum of the total load capacities of the individual members taken as simple solid short columns without regard to the fixity factor.

$$P/A = c$$

(b) Intermediate Columns (l/d ratios of an individual member between 11 and K):

For condition "a":

$$K_a = 0.702\sqrt{\frac{2.5E}{c}} = K\sqrt{2.5} = K \times 1.5811$$

$$P/A = c\left[1 - \frac{1}{3}\left(\frac{l}{K_a d}\right)^4\right]$$

For condition "b":

$$K_b = 0.702\sqrt{\frac{3E}{c}} = K\sqrt{3} = K \times 1.7320$$

$$P/A = c\left[1 - \frac{1}{3}\left(\frac{l}{K_b d}\right)^4\right]$$

(c) Long Columns (l/d ratios of an individual member equal to or greater than K)

For condition "a":

$$P/A = \frac{0.329E \times 2.5}{(l/d)^2}$$

For condition "b":

$$P/A = \frac{0.329E \times 3}{(l/d)^2}$$

(d=dimension of least side of an individual member of a spaced-column, inches.)

(d) Check of Load Capacity. The total load capacity determined from paragraphs 401-F-5-(a), (b) and (c) should be checked against the sum of the load capacities of the individual members taken as simple solid columns without regard to fixity factor using their greater d and the l between the lateral supports which provide restraint in a direction parallel to the greater d.

401–G. Round Columns

The allowable load for a column of round cross-section shall not exceed that for a square column of the same cross-sectional area.

401–H. Tapered Columns

In determining the d for column design, the diameter of a column tapered at one or both ends shall be taken as the sum of the minimum diameter and one-third the difference between the minimum and maximum diameters, but in no case shall it be assumed as more than one and one-half times the minimum diameter. The induced unit compressive stress at the small end of a tapered column shall not exceed the allowable unit stress for a short column.

402—WOOD COLUMN BRACING

402–A. Column bracing shall be installed where necessary to resist wind or other lateral forces. In buildings, for forces acting in a direction parallel to the truss or beam, bracing may be provided by knee braces or, in the case of trusses, by extending the column to the top chord of the truss where the bottom and top chords are separated sufficiently to provide adequate bracing action. In a direction perpendicular to the truss or beam, bracing may be provided by wall construction, knee braces or bracing between columns. Such bracing between columns should be installed preferably in the same bays as the bracing between trusses. (See paragraph 407.)

403—FLEXURAL AND AXIAL LOADING COMBINED

403–A. Flexure and Axial Tension Combined (Fig. 4)

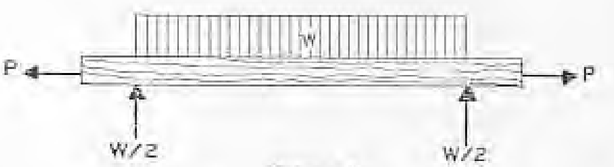


FIGURE 4.

403–A–1. ***Unit Stresses Induced by Loads:***

Unit flexural stress=M/S

Unit axial tensile stress=P/A

403–A–2. ***Allowable Unit Stresses.*** Members subjected to both FLEXURE AND AXIAL TENSION shall be so proportioned that

$$\frac{P/A}{t}+\frac{M/S}{f} \text{ shall not exceed ONE.}$$

403–B. Flexure and Axial Compression Combined (Fig. 5)

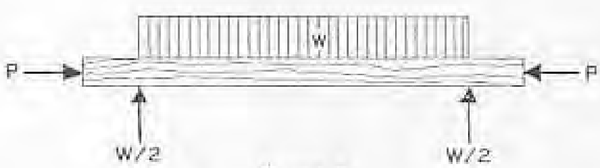


FIGURE 5.

403–B–1. ***Unit Stresses Induced by Loads:***

Unit flexural stress=M/S

Unit axial compressive stress=P/A.

403–B–2. ***Allowable Unit Stresses.*** Members subjected to both FLEXURE AND AXIAL COMPRESSION shall be so proportioned that

$$\frac{P/A}{c}+\frac{M/S}{f} \text{ shall not exceed ONE.}$$

in which

P=total axial load, pounds.

A=area of cross-section of member, square inches.

M=total bending moment, inch-pounds.

S=section modulus of member.

f=allowable unit stress in pounds per square inch that would be permitted if flexure only existed.

c=allowable unit stress in compression parallel to grain in pounds per square inch that would be permitted for column if axial compression only existed, i. e., for the l/d of the column under consideration.

t=allowable unit stress in tension parallel to grain in pounds per square inch, if tension only existed.

403–C. In the case of spaced-columns this combined stress formula may be applied only if the bending is in a direction parallel to the greater d of the individual member.

403–D. Formulas for more accurate calculation of combined stresses are given in Appendix B.

404—TENSION

404–A. Tension Parallel to Grain

The induced unit stress in axial tension parallel to grain of wood, P/A, shall not exceed t.

For allowable unit stress in tension, t, see Table No. I and provisions of Part II.

404–B. Tension Perpendicular to Grain

Tension perpendicular to grain is provided for in the allowable loads for a single mechanical fastening. (See Parts V to IX.) Where multiple fastenings are used and the load is at an angle to grain with eccentricity, insofar as possible, the fastenings should be placed so that the wood between them will be in compression rather than tension (Fig. 6). Insofar as possible, eccentricity in joint details should be avoided.

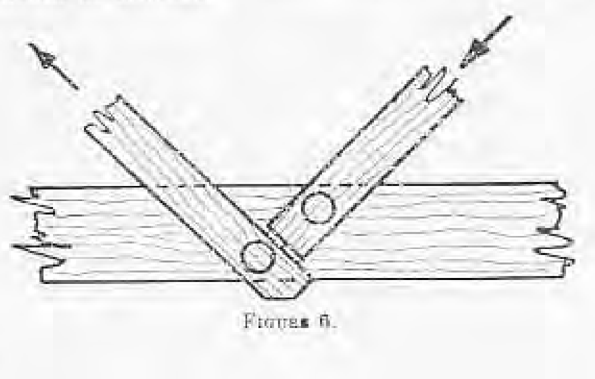


FIGURE 6.

405—COMPRESSION AT ANGLE TO GRAIN (Fig. 7)

405–A. The allowable unit stress in compression at an angle of load to grain between 0° and 90° shall be computed from the Hankinson formula:

$$N=\frac{PQ}{P\sin^2\theta+Q\cos^2\theta}$$

in which

N=allowable unit stress acting perpendicular to the inclined surface.

P=allowable unit stress in compression parallel to the grain.

Q=allowable unit stress in compression perpendicular to the grain.

θ=angle between the direction of the load and the direction of the grain.

For tabulated values of $\sin^2\theta$ and $\cos^2\theta$ and graphical solution of Hankinson formula, see Appendix C.

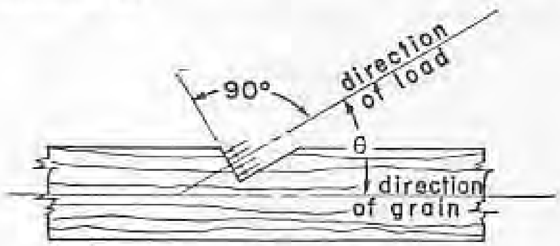


FIGURE 7.

406—TIMBER-CONCRETE COMPOSITE CONSTRUCTION

406–A. For design procedure on timber-concrete composite construction, see reference Nos. 15 and 16, Appendix G, but use the allowable unit stresses and design values for lumber and fastenings given in this specification.

407—TRUSS BRACING

407–A. Truss bracing adequate to resist lateral forces shall be installed. In buildings, such bracing may be provided as follows:

407–A–1. Diagonal lateral bracing between top chords of trusses may be omitted when the provisions of paragraph 400-F-3-(h) are followed or when the roof joists rest on and are securely fastened to the top chords of the trusses and are covered with diagonal wood sheathing.

Except in large structures, when wood roof sheathing is not laid diagonally but roof joists and purlins are fastened securely to the trusses, diagonal lateral bracing between top chords of trusses may be omitted. In large structures, top chord diagonal bracing should be installed if conditions warrant.

Where sheathing other than wood is applied, top chord diagonal lateral bracing shall be installed.

407–A–2. In all cases, vertical sway bracing should be installed in each third or fourth bay at intervals not greater than 35 feet measured parallel to trusses.

Also, bottom chord lateral bracing should be installed in the same bays as the vertical sway bracing and extend from side wall to side wall.

In addition, struts should be installed between bottom chords at the same truss panels as vertical sway bracing and should extend continuously from end wall to end wall. If the roof construction does not provide proper top chord strut action separate additional members should be provided

PART V. TIMBER CONNECTOR JOINTS

For timber connector joints using stress-grade lumber and the timber connector devices defined herein, the provisions of Part V and the tabulated allowable connector loads herein apply:

500—BASIC DESIGN CONSIDERATIONS AND LIMITATIONS

500–A. Connector Unit

500–A–1. For purposes of specifying allowable connector loads herein, a connector unit shall consist of one of the following:

(a) One split ring with its bolt in single shear;

(b) One toothed-ring with its bolt in single shear;

(c) Two claw plates, one male and one female, in combination with their bolt in single shear; or one male claw plate with its bolt in single shear used in conjunction with a steel strap or shape in a timber-to-metal joint; or

(d) Two shear plates used back to back in the contact faces of a timber-to-timber joint with their bolt in single shear; or one shear plate with its bolt in single shear used in conjunction with a steel strap or shape in a timber-to-metal joint.

500–A–2. In installation of connectors and bolts, a nut shall be placed on each bolt, and washers not smaller than the size specified in Tables Nos. 8, 9, 10, and 11 shall be placed between the outside wood member and the bolt head and between the outside wood member and nut. When an outside member is a steel strap or shape, the washer may be omitted except when the steel strap or shape is used in connection with a male claw plate or when needed to extend bolt length to prevent metal plate or shape from bearing on threaded portion of bolt when used in conjunction with shear plates.

500–B. Number of Connectors

500–B–1. Tabulated loads are for ONE connector unit with bolt in shear in any joint of any number of members.

500–B–2. For a joint assembly in which two or more connector units of the same or different sizes are used in the contact faces with the connectors concentric with the same bolt axis or in which two or more bolts are used with connectors on separate bolts, the total allowable connector load shall be the sum of the allowable connector loads given for each connector unit used. This provision applies to all conditions except that connectors shall not be placed concentrically on the same bolt in the same timber surface except as provided in paragraph 500-B-3 and 500-B-4. (Also see par. 500-M-4.)

500–B–3. If grooves for two sizes of split rings are cut, concentric in the same timber surface, rings shall be installed in both grooves and the total allowable load shall be the tabulated load for the larger ring only.

500–B–4. Two toothed rings in combination of the sizes 2 and 3⅜ inches, 2 and 4 inches, or 2⅝ and 4 inches may be concentric to the same bolt between the same timber surfaces. For these combinations the total allowable connector load shall be the tabulated allowable load for the larger ring plus 25 percent of the tabulated load for the smaller ring.

500–C. Allowable Connector Loads

The allowable connector loads given in Tables Nos. 8, 9, 10, and 11 and modifications thereof for various conditions of loading and of lumber apply as follows for the connectors described in paragraph 500-D:

500–C–1. *Condition of Loading:*

(a) For permanent loading, i. e., long-time loading whether live or dead, the tabulated allowable connector loads for all types of connectors apply.

(b) For that portion of the load which is not applied continuously for periods exceeding 3 months' duration, and also for such loading in combination with permanent loading when the permanent loading does not exceed 25 percent of the total combined load, the tabulated allowable connector loads for split rings and shear plates may be increased by 15 percent (except that the limitations in notes on Table No. 11 apply for shear plates) and tabulated allowable connector loads for toothed rings and claw plates apply.

(c) For maximum snow loading combined with dead load, the tabulated connector loads for split rings and shear plates may be increased by 15 percent (except that the limitations in notes on Table No. 11 shall apply). Where maximum snow load remains permanently on the structure, the tabulated connector loads shall not be increased. Tabulated allowable connector loads for toothed rings and claw plates shall not be increased for snow loading.

(d) For maximum wind, earthquake, or other loading not exceeding a duration of 5 minutes, the tabulated connector loads for split rings and shear plates shall be increased by 50 percent (except that limitations in notes on Table No. 11 apply for shear plates) and tabulated connector loads for toothed rings and perpendicular-to-grain connector loads for claw plates may be increased by 30 percent (except that allowable perpendicular-to-grain connector loads for claw plates shall not exceed the allowable parallel-to-grain connector loads). For wind in combination with permanent loading, this provision shall apply, provided the resulting sizes and number of connectors are not smaller than those required for permanent loading alone.

(e) For impact loading, the tabulated allowable connector loads for split rings may be applied without regard to impact if the load on the connector induced by impact does not exceed the allowable connector load for permanent loading, but the sum of loads on the connector induced by any combination of impact and other loading, e. g., impact with dead, long-time live, and/or short-time live loading, shall not exceed twice the allowable connector load for permanent loading. This provision applies for toothed rings without regard to impact up to 30 percent of the allowable connector load. For impact on shear plates and claw plates, the full impact load shall be considered.

500–C–2. *Condition of Lumber:*

(a) For connectors used in lumber which is seasoned to approximately 15 percent moisture content to a depth of three-fourths inch from the surface before fabrication and which will remain dry in service, the tabulated allowable connector loads as modified by paragraph 500-C-1 apply for all connectors.

(b) For connectors used in lumber which is fabricated before it is seasoned to a depth of three-fourths inch from the surface and which later is seasoned either before erection or while in the structure, 80 percent of the tabulated allowable connector loads as modified by paragraph 500-C-1 shall apply for all connectors.

(c) For lumber partially seasoned when fabricated, proportional intermediate connector values may be used.

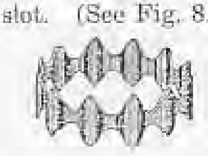
(d) For connectors used in lumber which is fabricated in a seasoned or unseasoned condition and will remain wet in service, 67 percent of the tabulated allowable connector loads as modified by paragraph 500-C-1 shall apply for all connectors.

500–D. Quality of Connectors

500–D–1. Specifications for timber connectors and tabulated loads and modifications thereof given herein are for connectors of a quality as follows:

(a) Split ring timber connectors manufactured from hot rolled carbon steel meeting Society of Automotive Engineers Specification SAE-1010 (1943). Each ring shall form a closed true circle with the principle axis of the cross-section of the ring metal parallel to the geometric axis of the ring. The ring shall fit snugly in the precut groove. This may be accomplished with a ring the metal section of which is beveled from the central portion toward the edges to a thickness less than at midsection or by any other method which will accomplish equivalent performance. It shall be cut through in one place in its circumference to form a tongue and slot. (See Fig. 8.)

SPLIT-RING
Figure 8.



TOOTHED-RING
Figure 9.

(b) Toothed ring timber connectors stamped cold from U. S. Standard 16 gage hot rolled sheet steel conforming to American Society for Testing Materials Standard Specifications for Carbon Steel A 17-29, Type A, Grade 1, and bent cold to form a circular, corrugated, sharptoothed band and welded into a solid ring. The teeth on each ring shall be on a true circle and shall be parallel to the axis of the ring. The central band shall be welded to fully develop the strength of the band. (See Fig. 9.)

(c) Claw plate timber connectors of malleable iron castings, manufactured according to American Society for Testing Materials

Male CLAW PLATES Female

Figure 10.

Standard Specifications A 47-33, Grade 35018. Each claw plate shall consist of a perforated circular flanged plate with three-sided teeth arranged about the perimeter of one face. The male plate shall have integral cylindrical hubs on both faces concentric to a bolt hole through the center of the plate. The female plate shall be flat on the side opposite the teeth but shall have an integral cylindrical hub concentric to the central bolt hole on the face with the teeth. (See Fig. 10.)

Front Back Front Back
Pressed-Steel Malleable Iron
SHEAR PLATES

Figure 11.

(d) Shear plate timber connectors:

(1) Pressed Steel Type—Pressed steel shear plates manufactured from hot rolled carbon steel meeting Society of Automotive Engineers Specification SAE-1010 (1943). Each plate shall be a true circle with a flange around the edge, extending at right angles to the face of the plate and extending from one face only, the plate portion having a central bolt hole and two small perforations on opposite sides of the hole and midway from the center and circumference. (See Fig. 11.)

(2) Malleable Iron Type—Malleable iron shear plates manufactured according to American Society for Testing Materials Standard Specifications A 47-33, Grade 35018, for malleable iron castings. Each casting shall consist of a perforated round plate with a flange around the edge extending at right angles to the face of the plate and projecting from one face only, the plate portion having a central bolt hole reamed to size with an integral hub concentric to the bolt hole and extending from the same face as the flange. (See Fig. 11.)

500–D–2. The tolerances in dimensions of the connector shall not be greater than those conforming to standard practices for the machine operations involved in manufacturing the connector.

500–E. Species of Lumber

500–E–1. The tabulated loads for Groups A, B, C, and D in Tables Nos. 8, 9, 10, and 11 apply to stress-grades (Table No. 1) of species as listed in Table No. 7.

500–F. Grade of Lumber

500–F–1. Tabulated connector loads shall apply to all stress-grades of a given species except where modifications for density are made as indicated in Table No. 7.

500–G. Grooves, Daps and Bolt Holes

500–G–1. Grooves, daps and bolt holes of dimensions and shape given in Tables 8, 9, 10, and 11 as appropriate for the type and size of connector used shall be accurately cut or bored and oriented in contacting faces.

500–H. Tightness of Joints

500–H–1. The allowable loads for connectors are based on the assumption that the faces of the members are brought into contact when the connectors are installed.

500–H–2. Tabulated connector loads and modifications thereof assume and allow for seasonal variations after the lumber has reached the moisture content normal to the conditions of service.

500–H–3. When lumber is not seasoned to the moisture content normal to the conditions of service, the joints should be drawn up by turning down the nuts on the bolts periodically until moisture equilibrium is reached so as to keep the adjacent faces of the members in contact.

500–I. Side Members—Materials

500–I–1. Tabulated connector loads are for side members of wood.

500–I–2. If metal plates instead of wood side plates are used, the tabulated allowable connector loads for parallel-to-grain loading shall be modified in accordance with the notes on Tables Nos. 10 and 11.

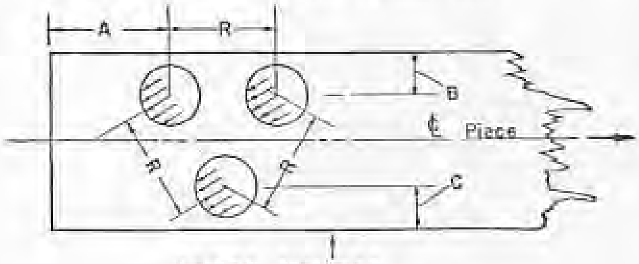
500–J. Thickness of Lumber

500–J–1. Tabulated loads shall not be used for connectors installed in lumber of a net thickness less than specified in the Tables Nos. 8, 9, 10, and 11.

500–K. Edge Distance, Connector

(See Tables Nos. 8, 9, 10, and 11.)

500–K–1. ***Edge distance*** is the distance from edge of member to center of connector closest to the edge of the member measured perpendicular to the edge. (See Figs. 12 and 13.)



End distance, Edge distance and Spacing

FIGURE 12.

500–K–2. ***Member Loaded Parallel to Grain (0°):***

(a) The tabulated edge distances for parallel-to-grain loading for each connector are for maximum allowable loads and also are the minimum edge distances to be used.

500–K–3. ***Member Loaded Perpendicular to Grain (90°):***

(a) Unloaded-Edge Distance (at Edge Opposite Loaded Edge).

(1) Tabulated unloaded-edge distances for perpendicular-to-grain loading for each connector are those for maximum allowable loads, and are also the minimum unloaded-edge distances to be used, and are the same for all angles of load to grain.

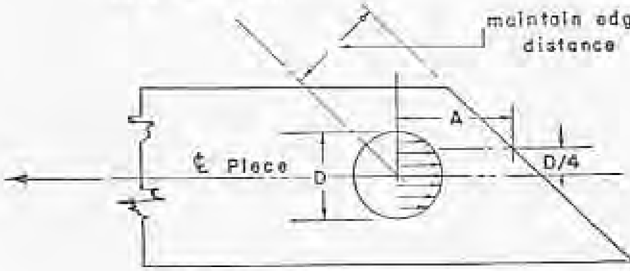
(b) Loaded-Edge Distance. (For Edge Toward Which Connector Load Acts.)

The loaded-edge distance for perpendicular-to-grain loading is the distance from the center of the connector to the edge toward which the load acts.

(1) The first loaded-edge distance tabulated for each thickness for each connector is the minimum loaded-edge distance which may be used.

(2) The second loaded-edge distance tabulated for each thickness is the least loaded-edge distance which gives the maximum allowable load, i. e., any additional edge distance will not increase the load capacity.

(3) For loaded-edge distances intermediate of (1) and (2) the appropriate allowable connector loads are obtained by straight line interpolation between allowable loads given for maximum and minimum tabulated loaded-edge distances.



End distance for member with sloping end cut

FIGURE 13.

(4) For angles of load to grain of 45° to 90°, the tabulated loaded-edge distance for 90° shall be applied. For angles of load to grain of 0° to 45°, interpolate on a straight line between the tabulated loaded-edge distance for 0° and the tabulated loaded-edge distance for 90°.

500–L. End Distances, Connector

(See Tables Nos. 8, 9, 10, and 11.)

500–L–1. ***End distance*** is the distance measured parallel to the grain from center of connector to the square cut end of the member. (See Fig. 12.)

500–L–2. ***If the end of the member is not cut at right angles to its length,*** the end distance measured parallel to the center line of the piece from any point on the center half of the connector diameter which is perpendicular to the center line of the piece shall not be less than the end distance required for a square cut member. In no case shall the perpendicular distance from center of connector to sloping end cut of a member be less than the required edge distance. (See Fig. 13.)

500–L–3. ***End Distances for Members Loaded Parallel to Grain (0°):***

(a) Tension Member:

(1) For a tension member, the first tabulated tension-end-distance for each connector is the minimum tension-end-distance which may be used. With minimum tension-end-distances, the loads permitted are 62½ percent of tabulated loads for split rings, claw

plates and shear plates and 67 percent for toothed rings.

(2) The second tabulated tension-end-distance is the least tension-end-distance which gives the maximum allowable load.

(3) For tension-end-distances intermediate of (1) and (2) the appropriate allowable connector loads are obtained by straight line interpolation between allowable loads given for maximum and minimum tabulated tension-end-distances.

(4) If cross bolts are inserted near end of tension member, the maximum compression-end-distance given for compression member at 0° angle of load to grain shall apply for maximum allowable load in tension.

(b) Compression Member:

(1) For a compression member, the first tabulated compression-end-distance for each connector is the minimum end distance which may be used. With minimum compression-end-distances, the loads permitted are 62½ percent of the tabulated loads for split rings, claw plates and shear plates and 100 percent for toothed rings.

(2) The second tabulated compression-end-distance is the least end distance which gives the maximum allowable load.

(3) For compression-end-distances intermediate of (1) and (2) the appropriate allowable loads are obtained by straight line interpolation between allowable loads given for minimum and maximum tabulated end distances.

500–L–4. ***End Distances for Members Loaded Perpendicular to Grain (90°):***

(a) Tension or Compression Member:

(1) The first tabulated loaded-perpendicular-to-grain end-distance is the minimum end distance which may be used. With minimum end distances, the loads permitted are 62½ percent of tabulated allowable loads for split rings, claw plates and shear plates and 67 percent for toothed rings.

(2) The second tabulated loaded-perpendicular-to-grain end-distance is the least end distance which gives the maximum allowable load.

(3) For end distances intermediate of (1) and (2), the loads are obtained by straight line interpolation between allowable loads given for minimum and maximum tabulated end distances.

500–L–5. ***End Distances for Members Loaded at Angles to Grain Other Than 0° and 90°:***

(a) Tension or Compression Member:

(1) For loading at angles intermediate of 0° and 90°, the end distances shall be determined by straight line interpolation.

500–M. Spacings, Connector

500–M–1. *Spacing* is the distance between centers of connectors measured along a line joining their centers. (See Fig. 12.)

500–M–2. ***Spacings for Members Loaded Parallel to Grain (0°):***

(See Tables Nos. 8, 9, 10, and 11.)

(a) Tension and Compression Members:

(1) Spacing Parallel to Grain, Loaded Parallel to Grain:

a. For tension and compression members, the first tabulated spacings for each connector are the minimum spacings which may be used for loading parallel to grain. With minimum spacings, the loads permitted are 75 percent of the tabulated allowable connector loads.

b. The second tabulated spacing is the least spacing which gives the maximum tabulated load.

c. For spacings intermediate between "a" and "b" above the appropriate allowable loads are obtained by straight line interpolation between allowable loads given for minimum and maximum tabulated spacings.

(2) Spacing Perpendicular to Grain, Loaded Parallel to Grain:

a. The tabulated perpendicular-to-grain spacings are for tabulated loads and are also minimum spacings.

500–M–3. ***Spacings for Members Loaded Perpendicular to Grain 90°:***

(See Tables Nos. 8, 9, 10, and 11.)

(a) Tension and Compression Members:

(1) Spacing Parallel to Grain, Loaded Perpendicular to Grain:

a. For tension and compression members, spacings given are minimum and are 100 percent of the tabulated load except as modified in paragraph 500–M–4.

(2) Spacing Perpendicular to Grain

Loaded Perpendicular to Grain:

a. For compression and tension members, the first tabulated spacing for each connector provides for the allowable load corresponding to that tabulated for the minimum loaded-edge distance.

b. The second tabulated spacing provides for the allowable load corresponding to that tabulated for the loaded-edge distance for the maximum allowable load.

c. For spacings intermediate between "a" and "b" above the appropriate allowable loads are obtained by straight line interpolation between allowable loads given for minimum and maximum tabulated spacings.

500–M–4. ***Spacings for Members Loaded at an Angle of Grain Other Than 0° and 90° and with Connector-Axis at Various Angles with Grain:***

(See Tables Nos. 4 and 5.)

(a) Tension and Compression Members:

(1) The connector-axis is a line joining the centers of two adjacent connectors located in the same contact face of a member in a joint.

(2) For tension and compression members loaded at an angle of load to grain (θ) other than 0° and 90° or with connector-axis at any angle (ϕ) to grain other than 0° and 90° and for both angle of load (θ) and angle of connector-axis (ϕ) at other than 0° and 90° to the grain, the least spacings for allowable connector loads obtained as provided by paragraphs 500-N and 500-O shall be determined from the following formula and values for A and B given in Table No. 4.

$$R=\frac{AB}{\sqrt{A^2\sin^2\phi+B^2\cos^2\phi}}$$

in which

R=least spacing of connectors, measured in inches along connector-axis, required for the angle of load to grain (θ) and angle of connector-axis to grain (ϕ) used.

A=value in column (3), Table No. 4, opposite the connector in column (1) and angle of load to grain in column (2) which are used.

B=value in column (4), Table No. 4, opposite the connector in column (1) and angle of load to grain in column (2) which are used.

ϕ=angle of connector-axis to grain.

(3) The values under C, column (5), Table No. 4, are minimum allowable spacings for any angle of load to grain (θ) other than 0° and 90°. They are also the minimum allowable spacings for any angle of connector-axis to grain (ϕ) other than 0° and 90°.

(4) For spacings intermediate between R and the minimum C from column (5), Table No. 4, the allowable load shall be determined by straight line interpolation between the load for R spacing and 75 percent of the load for R spacing, respectively.

TABLE No. 4.—*Values for use with paragraph 500–M–4*

1 Type and size of connector	2 Angle of load to grain (θ)	3 A	4 B	5 C (75 percent value)
	Degrees	*Inches*	*Inches*	*Inches*
2½-inch split ring or 2⅝-inch shear plate.	0	6¾	3½	3½
	15	6	3¾	3½
	30	5⅛	3⅞	3½
	*45	4¼	4⅛	3½
	*60–90	3½	4¼	3½
4-inch split ring or 4-inch shear plate.	0	9	5	5
	15	8	5¼	5
	30	7	5½	5
	*45	6	5¾	5
	*60–90	5	6	5
2-inch toothed ring	0	4	2½	2½
	15	3⅝	2⅝	2½
	30	3¼	2¾	2½
	*45	2⅞	2⅞	2½
	*60–90	2½	3	2½
2⅝-inch toothed ring	0	5¼	3⅛	3⅛
	15	4¾	3¼	3⅛
	30	4¼	3½	3⅛
	*45	3¾	3⅝	3⅛
	*60–90	3⅛	3¾	3⅛
3⅜-inch toothed ring	0	6¾	3⅞	3⅞
	15	6	4¼	3⅞
	30	5¼	4½	3⅞
	*45	4½	4¾	3⅞
	*60–90	3⅞	5	3⅞
4-inch toothed ring	0	8	4½	4½
	15	7⅛	4⅞	4½
	30	6¼	5⅛	4½
	*45	5⅜	5⅝	4½
	*60–90	4½	5¾	4½
2⅝-inch claw plate	0	7	3⅛	3⅛
	15	6	3¼	3⅛
	30	5	3½	3⅛
	*45	4	3¾	3⅛
	*60–90	3½	4	3⅛
3⅛-inch claw plate	0	7⅝	3⅞	3⅞
	15	6¾	4	3⅞
	30	5¾	4¼	3⅞
	*45	4¾	4½	3⅞
	*60–90	3⅞	4¾	3⅞
4-inch claw plate	0	9	4½	4½
	15	7⅞	4⅞	4½
	30	6¾	5¼	4½
	*45	5⅝	5⅝	4½
	*60–90	4½	5¾	4½

* See par. 500-M-4(b).

(b) Load Limitations for Multiple Connectors in a Single Piece. When the connectors on on the same face are not offset (from each other) perpendicular to grain a distance (measured between lines parallel to grain and passing through centers of connectors) equal to one connector diameter and the connector loads or components thereof all act in the same direction and at angles (θ) of 45° to 90° with the grain on the loaded faces of the piece, the maximum allowable loads for multiple connectors for this condition shall be taken as the summation of the allowable loads for each connector used, but the total allowable load for the group of connectors shall not exceed the load permitted for the single connector multiplied by the percentages in Table No. 5. For the conditions and allowable loads in this paragraph, the spacings shall not be less than those determined by paragraph 500-M-4(a).

TABLE No. 5.—*Values for use with paragraph 500-M-4(b)*

[Maximum allowable loads for 4 connectors in percent based on allowable loads for 1 connector]

Type and size of connectors	Thickness of loaded member, inches			
	1⅝	2	2⅝	3 and thicker
	Percent	*Percent*	*Percent*	*Percent*
2½-inch split ring or 2⅝ shear plate	300	300	300	300
4-inch split ring or 4-inch shear plate	230	248	269	300
2-inch toothed ring	300	300	300	300
2⅝-inch toothed ring	300	300	300	300
3⅜-inch toothed ring	300	300	300	300
4-inch toothed ring	225	250	300	300
2⅝-inch claw plate	X	300	300	300
3½-inch claw plate	X	250	300	300
4-inch claw plate	X	248	269	300

X—Not permitted in this thickness.
For each additional connector over the 4 connectors, add 33 percent of the allowable load for 1 connector.

500–N. Load at Angle to Grain

500–N–1. *The angle of load to grain* is the angle between the direction of the resultant load acting on the member and the longitudinal axis of the member.

500–N–2. *For angles of load to grain intermediate of parallel and perpendicular to grain,* the allowable connector load shall be determined by application of the Hankinson formula (see par. 405 and Appendix C) between the allowable connector loads for parallel and perpendicular-to-grain loading given in Tables Nos. 8, 9, 10, and 11, except that:

(a) For TOOTHED RINGS, allowable loads shall be determined as follows:

(1) The allowable connector loads for angles of load to grain of 45° to 90° shall be the same as the tabulated allowable connector load for an angle of load to grain of 90°.

(2) For angles of load to grain intermediate of 0° and 45°, the allowable connector loads shall be determined by application of the Hankinson formula between the allowable loads at angles of load to grain of 0° and 45°.

(b) For SHEAR PLATES when the tabulated allowable loads are equal to the limits imposed in the notes in Table No. 11, allowable loads at angles of load to grain other than parallel and perpendicular to grain shall be determined by the application of the Hankinson formula between the following limits. The parallel-to-grain load for use in the formula shall be taken as 143 percent of the perpendicular-to-grain load for the second loaded-edge distance tabulated for the thickness used. The tabulated perpendicular-to-grain load for the appropriate loaded-edge distance and thickness shall be used therewith in the formula. In no case, however, shall the allowable angle-to-grain load so determined be permitted to exceed the limits imposed by the notes in Table No. 11.

500–O. Inter-Relationship of Thickness, Distances and Spacing

500–O–1. Loads reduced because of thickness (see tabulated loads) do not permit any reduction of edge distance, end distance or spacing and conversely loads reduced for edge distance, end distance or spacing do not permit reduction of thickness.

500–O–2. When allowable load is reduced due to reduced edge distance, end distance or spacing, the reduced allowable load for each shall be determined separately and the lowest allowable load so determined for any one connector shall apply. Such load reductions are not cumulative. Conversely if the allowable load is reduced because of a reduced distance or spacing, the other distances or spacings may be reduced to those resulting in the same reduced allowable load.

501—USE OF LAG SCREWS INSTEAD OF BOLTS WITH TIMBER CONNECTORS

501–A. Type of Screw

501–A–1. The lag screw shall have a cut thread, not a rolled thread.

501–B. Diameter of Lag Screw

501–B–1. The shank of the lag screw shall have the same diameter as the bolt specified for the connector.

501–C. Hole For Shank and Threaded Portion

501–C–1. The hole for the shank shall be the same diameter as the shank.

501–C–2. The hole for the threaded portion of lag screw shall have a diameter equal to approximately 75 percent of that of the shank. (See par. 700-H.)

501–D. Allowable Loads

501–D–1. When lag screws instead of bolts are used with connectors, the allowable loads on connectors shall vary uniformly from full allowable load (allowable load for connector unit with common bolt) with an anchorage of threaded portion of lag screw equal to 9 times the diameter of the shank to 90 percent of full allowable load with an anchorage of 5 times the shank diameter. With anchorage of less than 5 times the shank diameter, 75 percent of full allowable connector load shall apply but the anchorage shall not be less than 3½ times the shank diameter.

502—NET SECTION

502–A. The net section shall be determined by subtracting from the full cross-sectional area of the timber the projected area of that portion of the connectors within the member and that portion of the bolts not within the connector projected area, located at the critical plane. (See Fig. 14.)

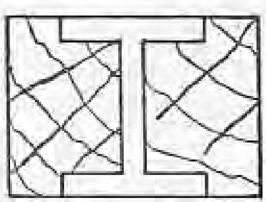


FIGURE 14.—Shaded area shows net cross-section of timber.

502–B. If knots occur at the critical section, the cross-sectional area of the knots outside the area deducted for connectors and bolts should also be deducted in determining the net section.

502–C. In tension members, the critical or net section of a timber in square inches shall not be less than that determined by dividing the total load in pounds which is transferred through the critical section of the member, by the appropriate constant in Table No. 6.

TABLE No. 6.—*Constants for use in determining required net section in square inches*

Duration of loading	Thickness of wood member in inches	Constants for each connector load group			
		Group A	Group B	Group C	Group D
Permanent.	4 inches or less	2500	2100	1800	1500
	Over 4 inches	2000	1700	1400	1200
Snow	4 inches or less	2900	2400	2000	1700
	Over 4 inches	2300	2000	1600	1400
Wind or earthquake.	4 inches or less	3700	3200	2700	2200
	Over 4 inches	3000	2600	2100	1800

TABLE No. 7.—*Connector load grouping of species when stress-graded*

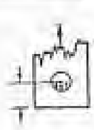
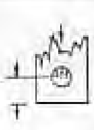
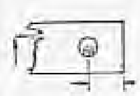
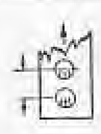
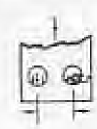
Connector load grouping	Species
Group A	Ash, white. Beech. Birch. Douglas fir (dense). Elm, rock. Hickory. Pecan. Maple, hard. Oak, red and white. Pine, southern (dense).
Group B	Douglas fir (coast region). Elm, soft. Larch, western. Maple, soft. Pine, southern. Gum, black or red.
Group C	Cypress, southern and tidewater red. Hemlock, west coast. Pine, Norway. Redwood. Poplar, yellow. Spruce, eastern. Spruce, Sitka.
Group D	Cedar, western red. Fir, commercial white. Hemlock, eastern. Pine, ponderosa. Pine, sugar. Pine, eastern white. Pine, western white. Spruce, Engelmann.

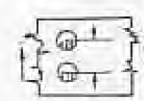
TABLE No. 8.—*Allowable loads for one* SPLIT-RING *and bolt in single shear*

Split-ring diam.	Bolt diam.	Number of faces of a piece containing connectors on same bolt	Thickness (net) of lumber	Loaded parallel to grain (0°): Edge distance	Loaded parallel to grain (0°): Allowable load per connector unit and bolt for— Group A woods	Group B woods	Group C woods	Group D woods	Loaded perpendicular to grain (90°): Edge distance: Unloaded-edge distance (edge opposite loaded edge)	Loaded-edge distance (edge toward which connector load acts)	Loaded perpendicular to grain (90°): Allowable load per connector unit and bolt for— Group A woods	Group B woods	Group C woods	Group D woods
Inches	*Inches*		*Inches*	*Inches*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Inches*	*Inches*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
2½	½	1	1 min.	1¾ min. or more	2,875	2,480	2,080	1,790	1¾ min. or more	1¾ min. 2¾ or more	1,720 2,045	1,475 1,750	1,230 1,460	1,055 1,255
			1⅝ and thicker	1¾ min. or more	3,450	2,975	2,500	2,140	1¾ min. or more	1¾ min. 2¾ or more	2,070 2,455	1,770 2,105	1,475 1,750	1,265 1,500
		2	1⅝ min.	1¾ min. or more	2,875	2,480	2,080	1,790	1¾ min. or more	1¾ min. 2¾ or more	1,720 2,045	1,475 1,750	1,230 1,460	1,055 1,255
			2 and thicker	1¾ min. or more	3,450	2,975	2,500	2,140	1¾ min. or more	1¾ min. 2¾ or more	2,070 2,455	1,770 2,105	1,475 1,750	1,265 1,500
4	¾	1	1 min.	2¾ min. or more	4,465	3,830	3,185	2,755	2¾ min. or more	2¾ min. 3¾ or more	2,585 3,110	2,220 2,665	1,850 2,220	1,595 1,915
			1⅝ and thicker	2¾ min. or more	6,695	5,735	4,780	4,135	2¾ min. or more	2¾ min. 3¾ or more	3,880 4,660	3,330 3,995	2,770 3,330	2,395 2,875
		2	1⅝ min.	2¾ min. or more	4,700	4,025	3,355	2,900	2¾ min. or more	2¾ min. 3¾ or more	2,725 3,270	2,335 2,800	1,945 2,335	1,680 2,015
			2	2¾ min. or more	5,400	4,630	3,860	3,330	2¾ min. or more	2¾ min. 3¾ or more	3,130 3,760	2,690 3,220	2,240 2,600	1,930 2,315
			2½	2¾ min. or more	6,575	5,635	4,700	4,055	2¾ min. or more	2¾ min. 3¾ or more	3,810 4,570	3,270 3,925	2,725 3,270	2,350 2,820
			3 and thicker	2¾ min. or more	6,695	5,735	4,780	4,135	2¾ min. or more	2¾ min. 3¾ or more	3,880 4,660	3,330 3,995	2,770 3,330	2,395 2,875

END DISTANCES AND SPACINGS FOR SPLIT-RINGS AND PERCENTAGES OF TABULATED LOADS TO USE

Split-ring diam. (inches)	End distance: Loaded parallel to grain (0°): Tension member (end toward which connector load acts): Tension end distance (inches)	Percentage of tabulated loads	Compression member (unloaded end): Compression end distance (inches)	Percentage of tabulated loads	Loaded perpendicular to grain (90°): End distance (inches)	Percentage of tabulated loads	Spacing—center to center of connectors: Loaded parallel to grain (0°): Spacing parallel to grain: Spacing (inches)	Percentage of tabulated loads	Spacing perpendicular to grain: Spacing (inches)	Percentage of tabulated loads	Loaded perpendicular to grain (90°): Spacing parallel to grain: Spacing (inches)	Percentage of tabulated loads	Spacing perpendicular to grain: For spacing in inches of—	Use 100 percent of load given for loaded-edge-distance of—
2½	2¾ min. 5½ or more	62.5 100	2½ min. 4 or more	62.5 100	2¾ min. 5½ or more	62.5 100	3½ min. 6¾ or more	75 100	3½ min. or more.	100	3½ min. or more.	See par. 500–M–4.	3½ min. 4¼ or more	1¾ min. 2¾ or more.
4	3¼ min. 7 or more	62.5 100	3¼ min. 5½ or more	62.5 100	3½ min. 7 or more	62.5 100	4½ min. 9 or more	75 100	5 min. or more.	100	5 min. or more.	See par. 500–M–4.	5 min. 6 or more	2¾ min. 3¾ or more.



DIMENSIONS IN INCHES

	2½″	4″
Split ring:		
Inside diameter at center when closed	2½	4
Thickness of metal at center	.163	.193
Depth of metal (width of ring)	.750	1.000
Groove:		
Inside diameter	2.56	4.08
Width	.18	.21
Depth	.375	.50
Bolt hole:		
Diameter, minimum	9/16	13/16

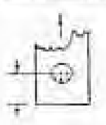
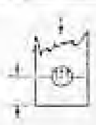
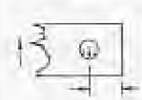
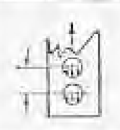
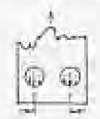
	2½″	4″
Washers, standard:		
Round, cast iron or malleable iron, diameter	2¼	3
Round, wrought iron (minimum):		
Diameter	1⅜	2
Thickness	5/32	5/32
Square plate:		
Length of side	2	3
Thickness	⅛	3/16
Projected area:		
Portion of one ring within member, sq. in.	1.10	2.25

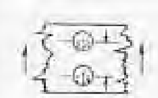
TABLE No. 9.—*Allowable loads for one* TOOTHED-RING *and bolt in single shear*

Toothed ring diam.	Bolt diam.	Number of faces of a piece containing connectors on same bolt	Thickness (net) of lumber	Loaded parallel to grain (0°): Edge distance	Loaded parallel to grain (0°): Allowable load per connector unit and bolt for— Group A woods	Group B woods	Group C woods	Group D woods	Loaded perpendicular to grain (90°): Edge distance: Unloaded-edge distance (edge opposite loaded edge)	Loaded-edge distance (edge toward which connector load acts)	Loaded perpendicular to grain (90°): Allowable load per connector unit and bolt for— Group A woods	Group B woods	Group C woods	Group D woods
Inches	*Inches*		*Inches*	*Inches*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Inches*	*Inches*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
2	½	1	1 min.	1¾ min. or more	1,320	1,200	1,080	940	1¾ min. or more	1¾ min.	880	800	720	625
										2 or more	1,000	910	820	710
			1⅝ and thicker	1¾ min. or more	1,450	1,320	1,190	1,030	1¾ min. or more	1¾ min.	964	880	790	685
										2 or more	1,105	1,000	900	780
		2	1⅝ min.	1¾ min. or more	1,320	1,200	1,080	940	1¾ min. or more	1¾ min.	880	800	720	625
										2 or more	1,000	910	820	710
			2 and thicker	1¾ min. or more	1,450	1,320	1,190	1,020	1¾ min. or more	1¾ min.	965	880	790	685
										2 or more	1,105	1,000	900	780
2⅝	⅝	1	1 min.	1¾ min. or more	1,950	1,800	1,620	1,405	1¾ min. or more	1⅞ min.	1,320	1,200	1,080	940
										2½ or more	1,500	1,370	1,230	1,060
			1⅝ and thicker	1¾ min. or more	2,470	2,250	2,030	1,750	1¾ min. or more	1⅞ min.	1,650	1,500	1,350	1,170
										2⅝ or more	1,880	1,705	1,540	1,330
		2	1⅝ min.	1¾ min. or more	1,950	1,800	1,620	1,405	1¾ min. or more	1⅞ min.	1,320	1,200	1,080	940
										2½ or more	1,500	1,370	1,230	1,060
			2	1¾ min. or more	2,190	1,990	1,795	1,555	1¾ min. or more	1⅞ min.	1,465	1,325	1,195	1,040
										2½ or more	1,660	1,510	1,360	1,180
			2⅝ and thicker	1¾ min. or more	2,470	2,250	2,030	1,750	1¾ min. or more	1⅞ min.	1,650	1,500	1,350	1,170
										2⅝ or more	1,880	1,705	1,535	1,330
3⅜	¾	1	1 min.	2¼ min. or more	2,575	2,340	2,105	1,825	2¼ min. or more	2¼ min.	1,715	1,560	1,405	1,220
										3¼ or more	2,010	1,835	1,670	1,445
			1⅝ and thicker	2¼ min. or more	3,475	3,155	2,845	2,465	2¼ min. or more	2¾ min.	2,315	2,105	1,895	1,645
										3¾ or more	2,755	2,510	2,250	1,950
		2	1⅝ min.	2¼ min. or more	2,575	2,340	2,105	1,825	2¼ min. or more	2¼ min.	1,715	1,560	1,405	1,220
										3¼ or more	2,010	1,835	1,670	1,445
			2	2¼ min. or more	2,820	2,560	2,305	2,060	2¼ min. or more	2¼ min.	1,880	1,710	1,535	1,330
										3¼ or more	2,230	2,030	1,825	1,665
			2⅝	2¼ min. or more	3,230	2,935	2,640	2,290	2¼ min. or more	2½ min.	2,155	1,955	1,760	1,525
										3½ or more	2,555	2,320	2,090	1,810
			3 and thicker	2¼ min. or more	3,475	3,155	2,845	2,465	2¼ min. or more	2¾ min.	2,315	2,105	1,895	1,645
										3¾ or more	2,755	2,500	2,250	1,950
4	¾	1	1 min.	2¾ min. or more	3,100	2,830	2,550	2,210	2¾ min. or more	2¾ min.	2,070	1,880	1,690	1,465
										3¾ or more	2,455	2,235	2,030	1,700
			1⅝ and thicker	2¾ min. or more	4,030	3,665	3,300	2,860	2¾ min. or more	2¾ min.	2,690	2,440	2,200	1,910
										3¾ or more	3,230	2,935	2,640	2,285
		2	1⅝ min.	2¾ min. or more	3,100	2,830	2,545	2,205	2¾ min. or more	2¾ min.	2,070	1,880	1,690	1,465
										3¾ or more	2,455	2,235	2,030	1,760
			2	2¾ min. or more	3,355	3,050	2,750	2,380	2¾ min. or more	2¾ min.	2,240	2,035	1,830	1,585
										3¾ or more	2,680	2,440	2,195	1,900
			2⅝	2¾ min. or more	3,780	3,440	3,090	2,680	2¾ min. or more	2¾ min.	2,520	2,290	2,065	1,790
										3¾ or more	3,025	2,750	2,470	2,140
			3 and thicker	2¾ min. or more	4,030	3,665	3,300	2,860	2¾ min. or more	2¾ min.	2,690	2,440	2,200	1,910
										3¾ or more	3,230	2,935	2,640	2,285

END DISTANCES AND SPACINGS FOR TOOTHED-RINGS AND PERCENTAGES OF TABULATED LOADS TO USE

Toothed ring diam. (inches)	End distance — Loaded parallel to grain (0°) — Tension member (end toward which connector load acts): Tension end distance (inches)	Percentage of tabulated loads	End distance — Loaded parallel to grain (0°) — Compression member (unloaded end): Compression end distance (inches)	Percentage of tabulated loads	End distance — Loaded perpendicular to grain (90°): End distance (inches)	Percentage of tabulated loads	Spacing—center to center of connectors — Loaded parallel to grain (0°) — Spacing parallel to grain: Spacing (inches)	Percentage of tabulated loads	Loaded parallel to grain (0°) — Spacing perpendicular to grain: Spacing (inches)	Percentage of tabulated loads	Loaded perpendicular to grain (90°) — Spacing parallel to grain: Spacing (inches)	Percentage of tabulated loads	Loaded perpendicular to grain (90°) — Spacing perpendicular to grain: For spacing in inches of—	Use 100 percent of load given for loaded-edge distance of—
2	2 min. 3½ or more	66.7 100	2 min. or more.	100	2 min. 3½ or more	66.7 100	2 min. 4 or more	75 100	2½ min. or more.	100	3½ min. or more.	See par. 500-M-4.	2¾ min. 3 or more	1¾ min. 2 or more.
2⅝	2⅝ min. 4½ or more	66.7 100	2⅝ min. or more.	100	2⅝ min. 4⅝ or more	66.7 100	2⅝ min. 5¼ or more	75 100	3⅛ min. or more.	100	3⅝ min. or more.	See par. 500-M-4.	3 min. 3¾ or more	1⅞ min. 2⅝ or more.
3⅜	3⅜ min. 5½ or more	66.7 100	3⅜ min. or more.	100	3⅜ min. 5⅝ or more	66.7 100	3⅜ min. 6¾ or more	75 100	3⅞ min. or more.	100	3⅞ min. or more.	See par. 500-M-4.	4 min. 5 or more	2¼ min. 3¼ or more
4	4 min. 7 or more	66.7 100	4 min. or more.	100	4 min. 7 or more	66.7 100	4 min. 8 or more	75 100	4½ min. or more.	100	4½ min. or more.	See par. 500-M-4.	4⅝ min. 5¾ or more	2¾ min. 3⅝ or more.



DIMENSIONS IN INCHES

	2"	2⅝"	3⅜"	4"
Toothed ring:				
Diameter	2	2⅝	3⅜	4
Thickness of metal	.061	.061	.061	.061
Depth	.94	.94	.94	.94
Depth of slot (minimum)	.25	.25	.25	.25
Bolt hole:				
Diameter (maximum)	9/16	11/16	13/16	15/16

	2"	2⅝"	3⅜"	4"
Washers, minimum:				
Round, cast or malleable iron (diameter)	2	2¼	3	3½
Square plate:				
Length of side	2	2½	3	3½
Thickness	3/16	¼	¼	¼
Projected area:				
Portion of one ring within member (sq. in.)	.94	1.23	1.59	1.83

TABLE No. 10.—*Allowable loads for one CLAW-PLATE unit and bolt in single shear*

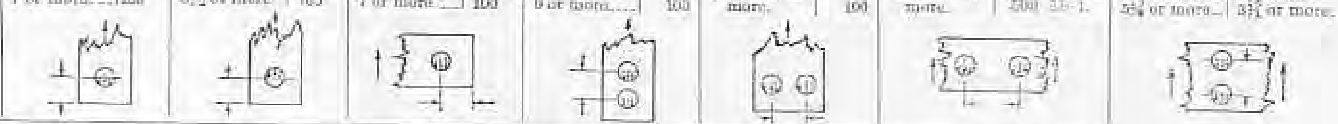
[Loads tabulated below are for wood side plates [1]]

Claw-plate diam.	Bolt diam.	Number of faces of a piece containing connectors on same bolt	Thickness (net) of lumber	Loaded parallel to grain (0°): Edge distance	Loaded parallel to grain (0°): Allowable load per connector unit and bolt for— Group A woods	Group B woods	Group C woods	Group D woods	Loaded perpendicular to grain (90°): Edge distance: Unloaded-edge-distance (edge opposite loaded edge)	Loaded-edge-distance (edge toward which connector load acts)	Loaded perpendicular to grain (90°): Allowable load per connector unit and bolt for— Group A woods	Group B woods	Group C woods	Group D woods
Inches	*Inches*		*Inches*	*Inches*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Inches*	*Inches*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
2⅝	½	1	1⅝ min. and thicker	1¾ min. or more	3,690	3,050	3,450	3,150	1¾ min. or more	1¾ min. 2¾ or more	2,740 3,260	2,370 2,815	2,005 2,375	1,715 2,035
		2	2 min.	1¾ min. or more	2,460	2,430	2,300	2,100	1¾ min. or more	1¾ min. 2¾ or more	1,830 2,170	1,580 1,880	1,330 1,585	1,143 1,355
			2⅝ and thicker	1¾ min. or more	3,690	3,650	3,450	3,150	1¾ min. or more	1¾ min. 2¾ or more	2,740 3,260	2,370 2,815	2,005 2,375	1,715 2,035
3⅛	½	1	1⅝ min. and thicker	2¼ min. or more	4,795	4,610	4,380	4,070	2¼ min. or more	2¼ min. 3¼ or more	3,450 4,100	2,980 3,540	2,515 2,990	2,170 2,580
		2	2 min.	2¼ min. or more	3,200	3,070	2,920	2,710	2¼ min. or more	2¼ min. 3¼ or more	2,300 2,730	1,985 2,365	1,675 1,990	1,445 1,715
			2½	2¼ min. or more	4,195	4,030	3,835	3,560	2¼ min. or more	2¼ min. 3¼ or more	3,020 3,590	2,610 3,095	2,200 2,610	1,900 2,255
			3 and thicker	2¼ min. or more	4,795	4,610	4,380	4,070	2¼ min. or more	2¼ min. 3¼ or more	3,450 4,100	2,980 3,540	2,515 2,990	2,170 2,580
4	¾	1	1⅝ min.	2¾ min. or more	5,995	5,730	5,230	4,840	2¾ min. or more	2¾ min. 3¾ or more	3,780 4,535	3,275 3,930	2,760 3,310	2,370 2,815
			2 and thicker	2¾ min. or more	6,745	6,500	5,940	5,460	2¾ min. or more	2¾ min. 3¾ or more	4,250 5,100	3,685 4,420	3,110 3,730	2,670 3,205
		2	2 min.	2¾ min. or more	4,405	4,330	3,960	3,630	2¾ min. or more	2¾ min. 3¾ or more	2,830 3,400	2,455 2,945	2,070 2,485	1,780 2,135
			2½	2¾ min. or more	5,430	5,240	4,790	4,385	2¾ min. or more	2¾ min. 3¾ or more	3,425 4,110	2,970 3,565	2,500 3,005	2,150 2,580
			3	2¾ min. or more	5,995	5,730	5,230	4,840	2¾ min. or more	2¾ min. 3¾ or more	3,780 4,535	3,275 3,930	2,760 3,310	2,370 2,815
			3⅝ and thicker	2¾ min. or more	6,745	6,500	5,940	5,450	2¾ min. or more	2¾ min. 3¾ or more	4,250 5,100	3,685 4,420	3,110 3,730	2,670 3,205

[1] Tabulated values also apply for metal side plates, except that for 3⅛-inch claw-plates the tabulated parallel to grain (not perpendicular) values for Groups A, B, and C, shall be [in]creased 11, 11, and 5 percent, respectively, and for 4-inch claw-plates, 18, 11, and 5 percent, respectively.

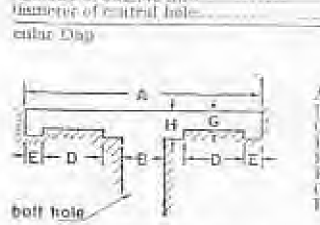
END DISTANCES AND SPACINGS FOR CLAW-PLATES AND PERCENTAGES OF TABULATED LOADS TO USE

Claw-plate diam. (inches)	End distance: Loaded parallel to grain (0°): Tension member (end toward which connector load acts): Tension end distance (inches)	Percentage of tabulated loads	Compression member (unloaded end): Compression end distance (inches)	Percentage of tabulated loads	Loaded perpendicular to grain (90°): End distance (inches)	Percentage of tabulated loads	Spacing—center to center of connectors: Loaded parallel to grain (0°): Spacing parallel to grain: Spacing (inches)	Percentage of tabulated loads	Spacing perpendicular to grain: Spacing (inches)	Percentage of tabulated loads	Loaded perpendicular to grain (90°): Spacing parallel to grain: Spacing (inches)	Percentage of tabulated loads	Spacing perpendicular to grain: For spacing in inches of—	Use 100 percent of load given for loaded-edge-distance of
2⅝	2¾ min. 5⅝ or more	62.5 100	2¾ min. 4¼ or more	62.5 100	2¾ min. 3⅜ or more	62.5 100	3 min. 7 or more	75 100	3⅛ min. or more	100	3⅛ min. or more	See par. [illegible]	3⅛ min. 4 or more	1¾ min. 2¾ or more
3⅛	3 min. 6¾ or more	62.5 100	3 min. 4¾ or more	62.5 100	3 min. 6½ or more	62.5 100	3½ min. 7¾ or more	75 100	3⅝ min. or more	100	3⅝ min. or more	See par. [illegible]	3⅝ min. 5½ or more	2¼ min. 3¼ or more
4	3½ min. 7 or more	62.5 100	3½ min. 5½ or more	62.5 100	3½ min. 7 or more	62.5 100	4½ min. 9 or more	75 100	4½ min. or more	100	4½ min. or more	See par. [illegible]	4½ min. 5⅝ or more	2¾ min. 3¾ or more



DIMENSIONS IN INCHES

w plates: Type:	2⅝" Male	2⅝" Female	3⅛" Male	3⅛" Female	4" Male	4" Female
Diameter	2⅝	2⅝	3⅛	3⅛	4	4
Depth of plate and teeth	.75	.75	.75	.75	.75	.75
Depth of outside hub	.37		.37		.37	
Diameter of outside hub	.87		.97		1.22	
Diameter of central hole	.53	.91	.53	.90	.78	*1.25
Circular Dap						
A	2.64	2.64	3.16	3.16	4.07	4.07
B	1.12	1.12	1.14	1.14	1.55	1.55
C	9/16	15/16	9/16	15/16	1 1/16	1¼
D	.52	.62	.76	.76	1.01	1.01
E	.25	.25	.25	.25	.25	.25
F	.38	.35	.38	.53	.38	.38
G	.22	.22	.22	.22	.26	.28
H	.42	.42	.42	.42	.35	.35
Steel straps or shapes for use with claw plates: Standard thickness	⅜	⅜	⅜	⅜	⅜	⅜
Minimum thickness (washers must be used to take up difference in hub depth of male claw plate)	¼	¼	¼	¼	¼	¼



	2⅝" Male	2⅝" Female	3⅛" Male	3⅛" Female	4" Male	4" Female
Bolt hole: Diameter in straps or plates	17/32	25/32	17/32	25/32	13/16	1 1/16
Diameter in timber:—when male plates or a combination of male and female are used	9/16		9/16		13/16	
—when female plates are used without male plates		13/16		13/16		1 1/16
Bolt diameter:—when male plates are used singly, or male and female used in combination	½		½		¾	
—when female plates are used without male plates		¾		¾		1
Washers (minimum): Timber-to-timber connections: Round, cast or malleable iron diameter	2½	3½	2½	3½	3	4½
Square plates: Length of side	2	3	2	3	3	4
Thickness	3/16	¼	3/16	¼	¼	¼
Timber-to-steel connections, round, wrought iron: Diameter	2	2	2	2	4	4
Thickness	5/32	5/32	5/32	5/32	11/64	11/64
Projected area: Portion of one claw plate within member (square inches)	1.07	1.07	2.34	2.34	3	3

*When used without male plate, and with 1⅛" bolt, ream hole to 1 3/16 inches.

CONNECTOR JOINTS

TABLE No. 11.—*Allowable loads for one* SHEAR-PLATE *unit and bolt in single shear*

[Loads tabulated below are for wood side plates. Also see notes below]

Shear-plate diam.	Bolt diam.	Number of faces of a piece containing connectors on same bolt	Thickness (net) of lumber	Loaded parallel to grain (0°): Edge distance	Allowable load per connector unit and bolt for— Group A woods	Group B woods	Group C woods	Group D woods	Loaded perpendicular to grain (90°): Edge distance: Unloaded-edge-distance (edge opposite loaded edge)	Loaded-edge-distance (edge toward which connector load acts)	Allowable load per connector unit and bolt for— Group A woods	Group B woods	Group C woods	Group D woods
Inches	*Inches*		*Inches*	*Inches*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Inches*	*Inches*	*Pounds*	*Pounds*	*Pounds*	*Pound*
2⅝	¾	1	1⅝ min. and thicker	1¾ min. or more	3, 175	3, 155	2, 629	2, 267	1¾ min. or more	1¾ min. 2¾ or more	2, 135 2, 576	1, 830 2, 208	1, 525 1, 840	1, 31 1, 58
		2	1⅝ min.	1¾ min. or more	2, 863	2, 454	2, 045	1, 764	1¾ min. or more	1¾ min. 2¾ or more	1, 661 2, 003	1, 423 1, 717	1, 186 1, 430	1, 02 1, 23
			2	1¾ min. or more	3, 175	2, 980	2, 483	2, 142	1¾ min. or more	1¾ min. 2¾ or more	2, 016 2, 434	1, 728 2, 086	1, 440 1, 738	1, 24 1, 49
			2⅝ and thicker	1¾ min. or more	3, 175	3, 155	2, 629	2, 267	1¾ min. or more	1¾ min. 2¾ or more	2, 135 2, 576	1, 830 2, 208	1, 525 1, 840	1, 31 1, 58
4	¾	1	1⅝ min.	2¾ min. or more	5, 184	4, 443	3, 703	3, 193	2¾ min. or more	2¾ min. 3¾ or more	3, 006 3, 629	2, 577 3, 111	2, 147 2, 592	1, 85 2, 23
			1¾ and thicker	2¾ min. or more	5, 300	4, 761	3, 967	3, 421	2¾ min. or more	2¾ min. 3¾ or more	3, 221 3, 888	2, 761 3, 333	2, 301 2, 777	1, 98 2, 39
		2	1¾ min.	2¾ min. or more	3, 703	3, 174	2, 645	2, 281	2¾ min. or more	2¾ min. 3¾ or more	2, 147 2, 592	1, 840 2, 222	1, 534 1, 851	1, 3 1, 5
			2	2¾ min. or more	4, 130	3, 540	2, 950	2, 544	2¾ min. or more	2¾ min. 3¾ or more	2, 395 2, 891	2, 053 2, 478	1, 711 2, 065	1, 4 1, 7
			2½	2¾ min. or more	4, 842	4, 150	3, 459	2, 983	2¾ min. or more	2¾ min. 3¾ or more	2, 808 3, 390	2, 407 2, 906	2, 006 2, 421	1, 7 2, 0
			3	2¾ min. or more	5, 269	4, 516	3, 764	3, 246	2¾ min. or more	2¾ min. 3¾ or more	3, 056 3, 689	2, 619 3, 162	2, 183 2, 635	1, 8 2, 2
			3⅝ and thicker	2¾ min. or more	5, 300	4, 761	3, 967	3, 421	2¾ min. or more	2¾ min. 3¾ or more	3, 221 3, 888	2, 761 3, 333	2, 301 2, 777	1, 9 2, 3
4	⅞	1	1⅝ min.	2¾ min. or more	5, 184	4, 443	3, 703	3, 193	2¾ min. or more	2¾ min. 3¾ or more	3, 006 3, 629	2, 677 3, 111	2, 147 2, 592	1, 8 2, 2
			1¾ and thicker	2¾ min. or more	5, 554	4, 761	3, 967	3, 421	2¾ min. or more	2¾ min. 3¾ or more	3, 221 3, 888	2, 761 3, 333	2, 301 2, 777	1, 9 2, 3
		2	1¾ min.	2¾ min. or more	3, 703	3, 174	2, 645	2, 281	2¾ min. or more	2¾ min. 3¾ or more	2, 147 2, 592	1, 840 2, 222	1, 534 1, 851	1, 3 1, 5
			2	2¾ min. or more	4, 130	3, 540	2, 950	2, 544	2¾ min. or more	2¾ min. 3¾ or more	2, 395 2, 891	2, 053 2, 478	1, 711 2, 065	1, 4 1, 7
			2½	2¾ min. or more	4, 842	4, 150	3, 459	2, 983	2¾ min. or more	2¾ min. 3¾ or more	2, 808 3, 390	2, 407 2, 906	2, 006 2, 421	1, 7 2, 0
			3	2¾ min. or more	5, 269	4, 516	3, 764	3, 246	2¾ min. or more	2¾ min. 3¾ or more	3, 056 3, 689	2, 619 3, 162	2, 183 2, 635	1, 8 2, 2
			3⅝ and thicker	2¾ min. or more	5, 554	4, 761	3, 967	3, 421	2¾ min. or more	2¾ min. 3¾ or more	3, 221 3, 888	2, 761 3, 333	2, 301 2, 777	1, 9 2, 3

NOTES

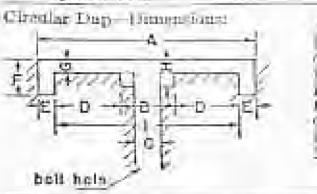
1. Tabulated loads shall apply for metal side plates except that for 4-inch shear plates, tabulated parallel-to-grain values (not perpendicular) for wood side plates for Groups A, B, and C woods shall be increased 18, 11, and 5 percent, respectively, but shall not exceed limitations in notes 2 and 3.
2. For the 2⅝-inch shear plate with ¾-inch bolt, the allowable loads for loading other than wind shall not exceed 3,175 pounds for parallel-to-grain loading or 2,900 pounds for perpendicular-to-grain loading. The allowable wind loads shall not exceed 3,475 pounds for parallel-to-grain loading and 2,900 pounds for perpendicular-to-grain loading.
3. For 4-inch shear plate with bolt, the allowable loads for loading other than wind shall not exceed 5,300 pounds for parallel-to-grain or perpendicular-to-grain loading when used with a ¾-inch bolt, and 7,200 pounds for parallel-to-grain loading or 6,500 pounds for perpendicular-to-grain loading when a ⅞-inch bolt is used. The allowable wind loads shall not exceed 6,650 pounds for parallel-to-grain loading and 5,775 pounds for perpendicular-to-grain loading when used with a ¾-inch bolt or 7,775 pounds for parallel-to-grain loading and 8,700 pounds for perpendicular-to-grain loading when used with a ⅞-inch bolt.

END DISTANCE AND SPACINGS FOR SHEAR-PLATES AND PERCENTAGES OF TABULATED LOADS TO USE

Shear-plate diam. (inches)	End distance: Loaded parallel to grain (0°): Tension member (end toward which connector load acts): Tension end distance (inches)	Percentage of tabulated loads	Compression member (unloaded end): Compression end distance (inches)	Percentage of tabulated loads	Loaded perpendicular to grain (90°): End distance (inches)	Percentage of tabulated loads	Spacing—center to center of connectors: Loaded parallel to grain (0°): Spacing parallel to grain: Spacing (inches)	Percentage of tabulated loads	Spacing perpendicular to grain: Spacing (inches)	Percentage of tabulated loads	Loaded perpendicular to grain (90°): Spacing parallel to grain: Spacing (inches)	Percentage of tabulated loads	Spacing perpendicular to grain: For spacing in inches of—	Use 100 percent of load given for loaded-edge distance of—
2⅝	2¾ min. 5½ or more	62.5 100	2½ min. 4 or more	62.5 100	2¾ min. 5½ or more	62.5 100	3½ min. 6¾ or more	75 100	3½ min. or more.	100	3½ min. or more.	See par. 500-M-1.	3½ min. 4¼ or more	1¾ min. 2¾ or more
4	3½ min. 7 or more	62.5 100	3¼ min. 5½ or more	62.5 100	3½ min. 7 or more	62.5 100	4½ min. 9 or more	75 100	5 min. or more.	100	5 min. or more.	See par. 500-M-1.	5 min. 6 or more	2¾ min. 3¾ or more

DIMENSIONS IN INCHES

	2⅝"	4"	4"
Shear-plates: Material	Pressed steel.	Malleable iron.	Malleable iron.
Diameter of plate	2.62	4.02	4.02
Diameter of bolt hole	.81	.81	.94
Thickness of plate	.172	.20	.20
Depth of flange	.42	.62	.62
Circular Dap—Dimensions: [illegible]	2.65	4.03	4.03
[illegible]		1.55	1.55
[illegible]	13/16	[illegible]	[illegible]
[illegible]		0.97	.97
[illegible]	.19	.27	.27
[illegible]	.40	.64	.64
[illegible]	.23	.35	.22
[illegible]		.50	.50
[illegible]	2.27	2.40	3.49



	2⅝"	4"	4"
Steel strap or shapes for use with shear-plates (minimum thickness):			
Plates on one face of strap or shape	[illegible]	[illegible]	
Plates opposite on both faces of strap or shapes	[illegible]	[illegible]	
Hole diameter in straps or shapes for bolts	[illegible]	[illegible]	[illegible]
Bolt hole—Diameter in timber	[illegible]	[illegible]	[illegible]
Washers, standard: Round, cast or malleable iron, diameter	3	3	
Round, wrought iron, minimum: Diameter	2	2	
Thickness	[illegible]	[illegible]	[illegible]
Square plate: Length of side	3	3	
Thickness	¼	¼	
Projected area: Portion of one shear plate within member, square inches	[illegible]	[illegible]	[illegible]

PART VI. BOLTED JOINTS

For bolted joints using stress-grade lumber and the bolts defined herein, the provisions of Part VI and the tabulated allowable bolt loads herein apply.

600—BASIC DESIGN CONSIDERATIONS AND LIMITATIONS

600–A. Type of Load

600–A–1. Tabulated allowable bolt loads are the maximum for permanent loading, i. e., long time loading whether dead or live. Pertinent modifications of stresses and provisions of paragraphs 200, 201, 202, 203, and 204 for lumber except as otherwise provided in Part VI apply likewise to the tabulated bolt loads given in Part VI.

600–B. Number of Bolts

600–B–1. Tabulated loads are for ONE common bolt in double shear in a 3-member joint.

600–B–2. Loads for more than one bolt, each of the same or miscellaneous sizes, are the sum of the loads permitted for each bolt. Spacings, end distances and edge distances shall be sufficient to develop the full strength of each bolt.

600–C. Quality of Bolts

600–C–1. Tabulated loads are for common bolts with a yield point of approximately 45,000 pounds per square inch.

600–C–2. Where high strength bolts are used, higher allowable loads are permissible in some cases as noted in reference No. 9, Appendix G. For high-strength bolts, allowable bolt loads given herein shall be modified proportionately, using basic provisions of the reference for guidance.

600–D. Species of Lumber

600–D–1. Tabulated loads apply to species as given in Table No. 12.

600–D–2. For proportionate loads for other species, see reference No. 9, Appendix G.

600–E. Grade of Lumber

600–E–1. Tabulated loads apply to species irrespective of grade of lumber used.

600–F. Condition of Lumber

600–F–1. Tabulated loads are for bolts in lumber seasoned to a moisture content approximately equal to that to which it will eventually come in service.

600–F–2. For lumber installed unseasoned and which becomes seasoned in place, allowable bolt loads shall be one-third of the tabulated loads.

600–F–3. For lumber partially seasoned when fabricated, proportional intermediate values may be used.

600–G. Exposure to Weather

600–G–1. Tabulated loads apply for joints used indoors or in a location "always dry."

600–G–2. When joints are to be exposed to weather, 75 percent, and where always wet, 67 percent of the tabulated loads apply.

600–H. Bolt Holes

600–H–1. Bolt holes of a diameter permitting bolts to be driven easily and careful centering of holes in main members and splice plates are assumed.

600–H–2. Tight fit requiring forcible driving of bolts is not recommended.

600–I. Nuts

600–I–1. Loosening of nuts, resulting from any shrinkage, is assumed and allowed for in the tabulated bolt loads.

600–I–2. Tabulated bolt loads shall apply for tight nuts also.

600–J. Side Members—Materials

600–J–1. Tabulated bolt loads are for side members of wood. Bearing thrust on side plates is assumed to be parallel to fibers.

600–J–2. When wood splice plates are used, the allowable load perpendicular-to-grain shall not exceed the load parallel-to-grain for any given size and quality of timbers.

600–J–3. When steel plates are used for side members, the tabulated loads for parallel-to-grain loading shall be increased by 25 percent but no increase shall be made for perpendicular-to-grain loads. Steel plates shall be of ample strength.

600–K. Side Members—Dimensions

600–K–1. Tabulated loads apply when side members of wood are each one-half the thickness of main member. (Fig. 15.)

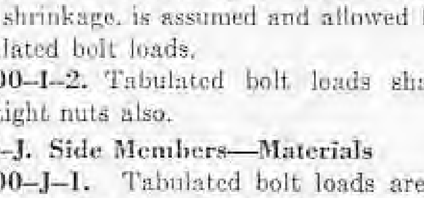


FIGURE 15.

600–K–2. If side members are thicker than one-half the thickness of the main member, no increase in tabulated loads is permissible. (Fig. 16.)

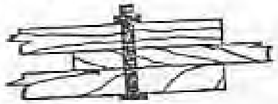


FIGURE 16.

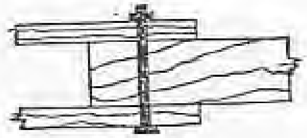


FIGURE 17.

600–K–3. When the side members are less than one-half the thickness of the main member, the tabulated loads indicated for a main member which is twice the thickness of thinnest side members used shall apply. For example, with 2-inch side members and a 10-inch center member, the tabulated loads for a 4-inch center member shall be used. (Fig. 17.)

600–L. Number of Members in Joint

600–L–1. Tabulated loads are for a joint consisting of three members (double shear). Length of bolt (l) is measured in the main member (i. e., thickness of the piece). (Fig. 18.)

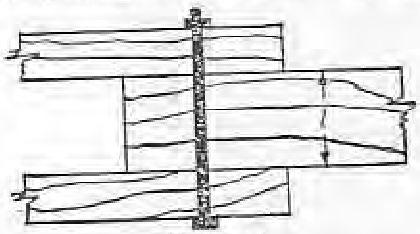


FIGURE 18.

600–L–2. When a joint consists of two members (single shear) of equal thickness, one-half the tabulated load for a piece twice the thickness of one of the members shall apply. (Fig. 19.)

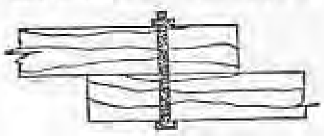


FIGURE 19.

600–L–3. When members of a two-member joint are of unequal thickness, one-half the tabulated load for a piece twice the thickness of the thinner member shall apply. (Fig. 20.)

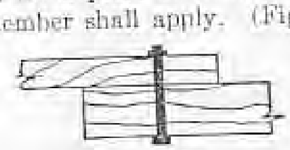


FIGURE 20.

600–L–4. For multiple-member joints other than two or three members, of which the pieces are of equal thickness, the allowable load shall vary as the number of shear planes involved; the allowable load for each shear plane shall be equal to one-half the tabulated load for a piece the thickness of the member involved. Thus, when a joint consists of four members of equal thickness, one and one-half times the tabulated load for a piece the thickness of one of the members shall apply. (Fig. 21.)

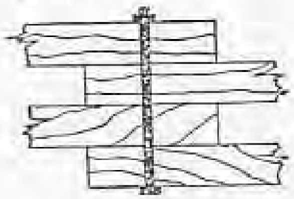


FIGURE 21.

600–M. Load at an Angle with Axis of Bolt (Fig. 22.)

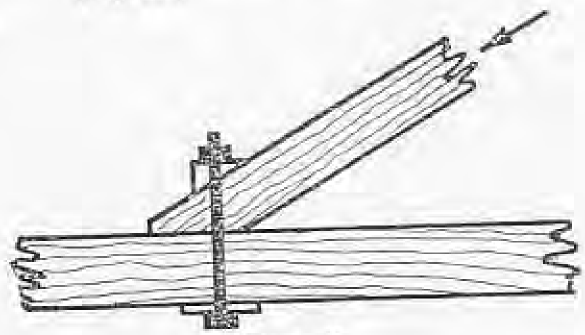


FIGURE 22.

600–M–1. Tabulated loads are for loading acting perpendicular-to-axis of bolt.

600–M–2. If the load in a two-member joint acts at an angle with the axis of a bolt, the allowable load component acting at 90° with the bolt axis shall be equal to one-half the tabulated load for a bolt twice the length of the bolt length in the thinner piece. Ample bearing area under washers or plates shall be provided to resist the load component acting parallel to the axis of the bolt.

600–N. Loads Neither Parallel nor Perpendicular to Grain. (Fig. 23.)

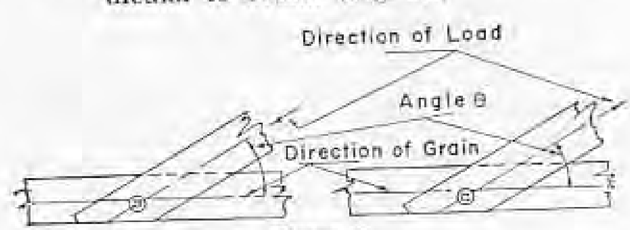


FIGURE 23.

600–N–1. Allowable bolt loads acting in a direction inclined to grain shall be determined from the Hankinson formula which for total bolt loads, may be stated as follows:

$$N=\frac{PQ}{P\sin^2\theta+Q\cos^2\theta}$$

in which

N=allowable load per bolt in a direction at inclination θ with the direction of the grain,

P=allowable load per bolt in compression parallel to grain,

Q=allowable load per bolt in compression perpendicular to grain,

θ=angle between the direction of the load and the direction of the grain.

For tabulated values of $\sin^2\theta$ and $\cos^2\theta$, and graphical solution of Hankinson formula, see Appendix C.

601—PLACEMENT OF BOLTS IN JOINT. (Fig. 24.)

601–A. *l/d* of Bolt

601–A–1. l/d of bolt is the ratio of its length, l, in main member, to its diameter, d.

601–B. Critical Section

601–B–1. The critical section is that section of the member, taken at right angles to the direction of the load, which gives the maximum stress in the member based on the net area remaining after reducing it for bolt holes at that section.

601–B–2. For parallel to grain loading, net tension area remaining at critical section must equal at least 80 percent of total area in bearing under all bolts at the joint in the particular timber in question for softwoods, and 100 percent for hardwoods, for designs under paragraph 600-F-1, and 33 percent and 42 percent, respectively, for those under paragraph 600-F-2. For partial seasoning, proportional intermediate areas may be used.

601–C. Row of Bolts

601–C–1. "*Row of Bolts*" means a number of bolts placed in a line parallel to the direction of the load when parallel or perpendicular to grain.

601–D. Spacing

601–D–1. All spacings and distances given are measured from center of bolt.

601–E. Spacing of Bolts in a Row

601–E–1. ***For parallel-to-grain loading,*** the minimum spacing is 4 times bolt diameter d.

601–E–2. ***For perpendicular-to-grain loading:***

(a) If design load approaches bolt bearing capacity of side members, space same as parallel-to-grain.

(b) If design load is less than bolt bearing capacity of side members, spacing may be reduced.

601–F. Spacing Between Rows of Bolts

601–F–1. ***For parallel-to-grain loading,*** the spacing across the grain between rows of bolts is controlled by net section as provided in paragraph 601-B-2.

601–F–2. ***For perpendicular-to-grain loading,*** the spacing shall be at least $2\frac{1}{2}$ times bolt diameter for l/d ratio of 2, and 5 times bolt diameter for l/d ratios of 6 or more. For ratios between 2 and 5, the spacing shall be obtained by straight line interpolation.

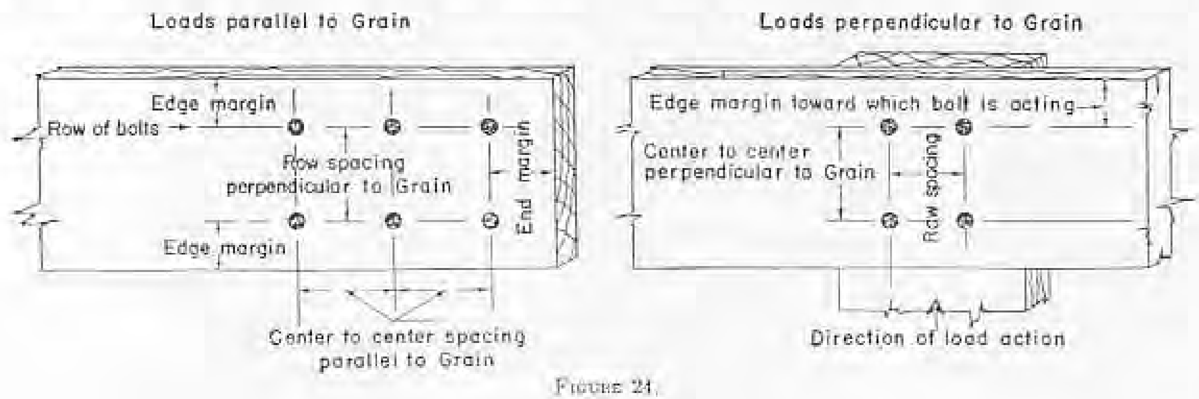


FIGURE 24.

601–G. End Distance

601–G–1. ***"End Distance"*** is the distance from the end of a bolted timber to the center of the bolt hole nearest the end.

601–G–2. ***For parallel-to-grain loading,*** the end distance shall be:

(a) In tension, 7 times the bolt diameter for softwoods and 5 times for hardwoods.

(b) In compression, 4 times the bolt diameter.

601–G–3. ***For perpendicular-to-grain loading,*** when members abut at a joint, the strength of the joint shall be evaluated not only for the bolt load but also as a notched beam, considering the notch to extend from the lower side of the beam to the center of the bolt nearest the bottom. (For notched beams, see paragraph 400-D.)

601–H. Edge Distance

601–H–1. ***"Edge Distance"*** is the distance from the edge of the timber to the center of the nearest bolt hole.

601–H–2. ***For parallel-to-grain loading in tension or compression,*** the edge distance shall be at least $1\frac{1}{2}$ times the bolt diameter, except that for l/d ratios more than 6, use one-half the distance between rows of bolts.

601–H–3. ***For perpendicular-to-grain loading,*** the edge distance nearest the edge toward which load is acting shall be at least 4 times the bolt diameter.

601–I. Staggered Bolts

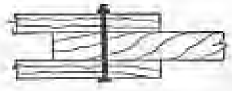
601–I–1. ***For parallel-to-grain loading*** with staggered bolts, special precaution shall be taken to provide sufficient area at the critical section. Adjacent staggered bolts shall be considered as being placed at the critical section.

601–I–2. ***For perpendicular-to-grain loading,*** if design load for main member is less than bolt bearing capacity of side timbers, staggering may be employed.

601–J. Bolting for Loads at Angle to Grain

601–J–1. It is virtually impossible to set up general rules regarding the alignment, spacing, and distances of bolts to cover all possible directions of applied load. Uniform stress in main members and a uniform distribution of load to all bolts, however, require that the gravity axis of the members shall pass through the center of resistance of the bolt groups.

TABLE No. 12.—*Allowable load in pounds on one bolt loaded at both ends (double shear)* for following species*



Length of bolt in main member	Diameter of bolt		Projected area of bolt	Cypress, tidewater red; Douglas fir, (coast and inland); larch, western; pine, southern longleaf and shortleaf; redwood; tamarack		Cedar, western red; cedar, Alaska, Port Orford; Douglas fir, (Rocky Mountain); hemlock, west coast; pine, Norway		Cedar, northern and southern white; fir, balsam, commercial white; hemlock, eastern; pine, northern white, Idaho white, ponderosa, sugar; spruce, red, Sitka, white, Engelmann		Ash, commercial white; beech; birch, sweet and yellow; elm, rock; hickory, true and pecan; maple, hard; oak, commercial red and white		Maple, soft; elm, soft; gum, black, red, tupelo; sycamore		Ash, black, brown; aspen and large toothed aspen; basswood; birch, paper; chestnut; cottonwood, eastern and western; yellow poplar	
				Parallel to grain	Perpendicular to grain	Parallel to grain	Perpendicular to grain	Parallel to grain	Perpendicular to grain	Parallel to grain	Perpendicular to grain	Parallel to grain	Perpendicular to grain	Parallel to grain	Perpendicular to grain
l	d	l/d	$A=l\times d$	P	Q	P	Q	P	Q	P	Q	P	Q	P	Q
Inches	*Inches*		*Sq. in.*												
1⅝	½	3.3	0.8125	1,000	460	780	320	620	240	1,140	660	940	410	720	290
	⅝	2.6	1.0156	1,260	500	970	370	780	280	1,460	740	1,180	470	900	320
	¾	2.2	1.2188	1,520	560	1,180	410	940	310	1,750	830	1,400	520	1,080	360
	⅞	1.9	1.4219	1,780	620	1,370	460	1,090	340	2,050	910	1,630	560	1,260	400
	1	1.6	1.625	2,030	680	1,560	490	1,250	370	2,340	1,000	1,870	620	1,440	430
2	½	4.0	1.00	1,150	550	940	410	770	300	1,330	800	1,130	500	890	350
	⅝	3.2	1.25	1,540	620	1,200	460	960	340	1,780	910	1,440	580	1,100	400
	¾	2.7	1.50	1,860	700	1,440	490	1,150	380	2,150	1,020	1,730	640	1,330	430
	⅞	2.3	1.75	2,180	770	1,680	560	1,340	420	2,520	1,120	2,020	700	1,560	490
	1	2.0	2.00	2,500	840	1,920	610	1,540	460	2,880	1,220	2,300	770	1,780	530
2⅝	½	5.3	1.3125	1,250	720	1,070	530	940	400	1,440	1,060	1,270	660	1,060	470
	⅝	4.2	1.6406	1,850	830	1,510	600	1,250	440	2,140	1,200	1,820	740	1,440	530
	¾	3.5	1.9688	2,380	910	1,870	670	1,510	500	2,740	1,330	2,300	830	1,750	590
	⅞	3.0	2.2969	2,830	1,010	2,210	730	1,760	550	3,280	1,460	2,640	910	2,040	650
	1	2.6	2.625	3,260	1,100	2,520	800	2,020	600	3,770	1,600	3,020	1,000	2,330	700
3	½	6.0	1.50	1,260	830	1,090	600	980	460	1,450	1,160	1,310	760	1,140	530
	⅝	4.8	1.875	1,940	940	1,630	680	1,390	520	2,210	1,370	1,960	850	1,610	600
	¾	4.0	2.25	2,590	1,070	2,100	770	1,720	580	3,000	1,520	2,620	950	1,990	670
	⅞	3.4	2.625	3,100	1,160	2,510	840	2,020	620	3,670	1,680	3,010	1,040	2,330	730
	1	3.0	3.00	3,710	1,260	2,880	910	2,300	680	4,270	1,820	3,460	1,140	2,660	800
3⅝	½	7.3	1.8125	1,260	960	1,090	720	980	550	1,450	1,220	1,310	880	1,140	640
	⅝	5.8	2.2656	1,970	1,140	1,700	830	1,540	620	2,270	1,610	2,040	1,030	1,780	720
	¾	4.8	2.7188	2,810	1,260	2,360	940	2,020	700	3,240	1,840	2,830	1,150	2,330	800
	⅞	4.1	3.1719	3,620	1,390	2,950	1,010	2,420	760	4,180	2,030	3,540	1,270	2,800	890
	1	3.6	3.625	4,340	1,520	3,440	1,100	2,780	820	5,020	2,210	4,140	1,380	3,220	960
4	½	8.0	2.00	1,260	970	1,090	770	980	600	1,450	1,210	1,310	890	1,140	710
	⅝	6.4	2.50	1,970	1,250	1,700	910	1,540	680	2,270	1,700	2,050	1,140	1,790	790
	¾	5.3	3.00	2,830	1,390	2,440	1,020	2,150	770	3,260	2,020	2,920	1,270	2,460	890
	⅞	4.6	3.50	3,730	1,540	3,120	1,120	2,620	840	4,310	2,230	3,740	1,390	3,020	980
	1	4.0	4.00	4,620	1,680	3,740	1,220	3,060	910	5,330	2,440	4,490	1,520	3,530	1,070
4½	½	9.0	2.25	1,260	950	1,090	780	980	650	1,450	1,180	1,310	880	1,140	760
	⅝	7.2	2.8125	1,970	1,360	1,700	1,030	1,540	770	2,270	1,730	2,050	1,240	1,790	900
	¾	6.0	3.375	2,830	1,570	2,460	1,140	2,220	850	3,260	2,210	2,940	1,430	2,570	1,000
	⅞	5.1	3.9375	3,850	1,730	3,290	1,260	2,870	950	4,450	2,520	3,950	1,570	3,310	1,100
	1	4.5	4.50	4,870	1,580	4,060	1,370	3,380	1,030	5,630	2,750	4,860	1,720	3,910	1,200
	1⅛	4.0	5.0625	5,840	2,050	4,720	1,490	3,860	1,120	6,740	2,990	5,680	1,870	4,490	1,310
5	½	10.0	2.50	1,260	940	1,090	770	980	650	1,450	1,120	1,310	850	1,140	760
	⅝	8.0	3.125	1,970	1,380	1,700	1,030	1,540	850	2,270	1,700	2,050	1,250	1,790	1,000
	¾	6.7	3.75	2,830	1,730	2,460	1,270	2,220	950	3,260	2,280	2,940	1,500	2,570	1,100
	⅞	5.7	4.375	3,850	1,920	3,250	1,390	3,010	1,040	4,450	2,740	4,010	1,750	3,470	1,220
	1	5.0	5.00	4,900	2,100	4,240	1,520	3,660	1,140	5,760	3,050	5,090	1,910	4,240	1,330
	1⅛	4.4	5.625	6,180	2,280	5,110	1,660	4,250	1,250	7,180	3,320	6,130	2,080	4,920	1,450
5½	⅝	8.8	3.4375	1,970	1,360	1,700	1,120	1,540	900	2,270	1,670	2,050	1,240	1,790	1,060
	¾	7.3	4.125	2,830	1,910	2,460	1,390	2,220	1,040	3,260	2,340	2,940	1,660	2,570	1,220
	⅞	6.3	4.8125	3,850	2,110	3,350	1,540	3,010	1,150	4,450	2,800	4,010	1,920	3,480	1,340
	1	5.5	5.50	5,020	2,300	4,340	1,680	3,800	1,260	5,780	3,320	5,210	2,100	4,460	1,460
	1⅛	4.9	6.1875	6,290	2,510	5,320	1,820	4,500	1,370	7,250	3,650	6,370	2,280	6,280	1,600
6	⅝	9.6	3.75	1,970	1,330	1,700	1,100	1,540	910	2,270	1,620	2,050	1,210	1,790	1,070
	¾	8.0	4.50	2,830	1,850	2,460	1,460	2,220	1,140	3,260	2,290	2,940	1,650	2,570	1,330
	⅞	6.9	5.25	3,850	2,260	3,350	1,680	3,010	1,260	4,450	2,950	4,010	2,050	3,480	1,460
	1	6.0	6.00	5,030	2,520	4,370	1,820	3,950	1,370	5,810	3,520	5,240	2,280	4,560	1,600
	1⅛	5.3	6.75	6,400	2,740	5,470	1,900	4,840	1,490	7,340	3,990	6,380	2,500	5,590	1,740
6½	⅝	10.4	4.0625	1,970	1,300	1,700	1,070	1,540	900	2,270	1,540	2,050	1,180	1,790	1,080
	¾	8.7	4.875	2,830	1,820	2,460	1,490	2,220	1,260	3,260	2,220	2,940	1,660	2,570	1,390
	⅞	7.4	5.6875	3,850	2,300	3,350	1,800	3,010	1,370	4,450	2,980	4,010	2,150	3,480	1,580
	1	6.5	6.50	5,030	2,700	4,370	1,980	3,950	1,490	5,610	3,650	5,210	2,400	4,560	1,730
	1⅛	5.8	7.3125	6,400	2,960	6,300	2,160	4,940	1,620	7,340	4,210	6,600	2,700	5,710	1,880
7	⅝	11.2	4.375	1,970	1,270	1,700	1,050	1,540	800	2,270	1,510	2,050	1,150	1,790	1,030
	¾	9.3	5.25	2,830	1,800	2,460	1,480	2,220	1,220	3,260	2,200	2,940	1,630	2,570	1,430
	⅞	8.0	6.125	3,850	2,300	3,350	1,880	3,010	1,460	4,450	2,940	4,010	2,150	3,480	1,720
	1	7.0	7.00	5,030	2,870	4,370	2,140	3,950	1,600	5,810	3,700	5,240	2,600	4,560	1,870
	1⅛	6.2	7.875	6,400	3,190	5,560	2,330	5,000	1,740	7,350	4,430	6,660	2,900	5,760	2,040
7½	⅝	12.0	4.6875	1,970	1,220	1,700	1,040	1,540	880	2,270	1,460	2,050	1,120	1,790	780
	¾	10.0	5.625	2,830	1,760	2,460	1,440	2,220	1,210	3,260	2,110	2,940	1,610	2,570	1,420
	⅞	8.6	6.5625	3,850	2,340	3,350	1,910	3,010	1,540	4,450	2,900	4,010	2,120	3,480	1,700
	1	7.5	7.50	5,030	2,920	4,370	2,270	3,950	1,720	5,810	3,710	5,240	2,650	4,500	2,000
	1⅛	6.7	8.4375	6,400	3,400	5,560	2,500	5,000	1,870	7,340	4,300	6,600	3,080	5,790	2,150
8	⅝	12.8	5.00	1,970	1,150	1,700	1,030	1,540	800	2,270	1,390	2,050	1,070	1,790	1,010
	¾	10.7	6.00	2,830	1,730	2,460	1,430	2,220	1,200	3,260	2,040	2,940	1,610	2,570	1,400
	⅞	9.1	7.00	3,850	2,330	3,350	1,900	3,010	1,570	4,450	2,860	4,010	2,120	3,480	1,910
	1	8.0	8.00	5,030	2,950	4,370	2,340	3,950	1,820	5,810	3,650	5,240	2,690	4,560	2,110
	1⅛	7.1	9.00	6,400	3,530	5,560	2,650	5,000	1,990	7,340	4,540	6,660	3,220	5,760	2,330
	1¼	6.4	10.00	7,860	3,920	6,840	2,550	6,170	2,140	9,070	5,330	8,200	3,550	7,130	2,590
9½	¾	12.7	7.125	2,830	1,570	2,450	1,370	2,220	1,150	3,260	1,980	2,940	1,520	2,570	1,740
	⅞	10.9	8.3125	3,850	2,200	3,350	1,810	3,010	1,520	4,450	2,590	4,010	1,990	3,480	1,790
	1	9.5	9.50	5,030	2,860	4,370	2,300	3,950	1,940	5,810	3,470	5,240	2,500	4,560	2,280
	1⅛	8.4	10.6875	6,400	3,640	5,560	2,930	5,000	2,330	7,340	4,460	6,660	3,300	5,760	2,710
	1¼	7.6	11.875	7,860	4,310	6,840	3,340	6,170	2,540	9,070	5,410	8,200	3,920	7,130	2,960
10	⅞	11.4	8.75	3,850	2,160	3,350	1,800	3,010	1,520	4,450	2,570	4,010	1,970	3,480	1,780
	1	10.0	10.00	5,030	2,810	4,370	2,330	3,950	1,940	5,810	3,360	5,240	2,640	4,560	2,270
	1⅛	8.9	11.25	6,400	3,560	5,560	2,920	5,000	2,360	7,340	4,380	6,600	3,240	5,700	2,760
	1¼	8.0	12.50	7,590	4,330	6,840	3,420	6,170	2,680	9,070	5,340	8,200	3,940	7,130	3,120
11½	1	11.5	11.50	5,030	2,690	4,370	2,230	3,950	1,910	5,810	3,200	5,240	2,450	4,500	2,250
	1⅛	10.2	12.9375	6,400	3,460	5,560	2,830	5,000	2,380	7,340	4,100	6,660	3,140	5,760	2,770
	1¼	9.2	14.375	7,800	4,290	6,840	3,460	6,170	2,840	9,070	5,170	8,200	3,840	7,130	3,320
12	1	12.0	12.00	5,030	2,620	4,370	2,220	3,950	1,880	5,810	3,110	5,210	2,380	4,560	2,200
	1⅛	10.7	13.50	6,400	3,380	5,560	2,750	5,000	2,350	7,340	4,020	6,660	3,070	5,760	2,740
	1¼	9.6	15.00	7,560	4,150	6,840	3,450	6,170	2,900	9,070	5,040	8,200	3,780	7,130	3,340

*Three (3) member joint.

PART VII. LAG SCREW JOINTS

For machine (cut) thread lag screw (lag bolt) joints using stress-grade lumber and the lag screws defined herein, the provisions of Part VII and the tabulated values herein apply.

700—PROVISIONS APPLICABLE TO BOTH WITHDRAWAL AND LATERAL RESISTANCE

700–A. Type of Load

700–A–1. Allowable loads for lag screws given in Part VII are the maximum for permanent loading, i. e., long-time loading whether dead or live. Pertinent modifications of stresses and provisions of paragraphs 200, 201, 202, 203 and 204 for lumber except as otherwise provided in Part VII apply likewise to loads for lag screws given in Part VII.

700–B. Number of Lag Screws

700–B–1. Loads given are for one lag screw either in withdrawal or in lateral resistance in single shear in a two member joint.

700–B–2. Loads for more than one lag screw, each of the same or miscellaneous sizes, are the sum of the loads permitted for each lag screw provided that spacings, end distances, and edge distances are sufficient to develop the full strength of each lag screw.

700–C. Quality of Lag Screw

700–C–1. The following allowable loads are based on lag screws of metal having a yield point of 45,000 pounds per square inch and a tensile strength of 77,000 pounds per square inch.

700–C–2. For other metal, the values herein may be adjusted in proportion to the tensile strength of the metal for maximum allowable loads in withdrawal (paragraph 701-A) and in proportion to square roots of the yield point stresses of the metal for allowable loads in lateral resistance.

700–D. Species of Lumber

700–D–1. The method of determining allowable loads for lag screws in the various species is indicated by formulas and provisions and tabulated values herein.

700–E. Grade of Lumber

700–E–1. The allowable loads for lag screws in a given species apply to all grades of that species.

700–F. Condition of Lumber

700–F–1. The allowable loads given are for lag screws in lumber seasoned to a moisture content approximately equal to that to which it will eventually come in service.

700–F–2. For lumber installed unseasoned and which becomes seasoned in place, the allowable lag screw loads shall be one-third of those given.

700–F–3. For lumber partially seasoned when fabricated, proportional intermediate loads may be used.

700–G. Exposure to Weather

700–G–1. Allowable loads given herein apply for joints used indoors or in a location "always dry."

700–G–2. Where joints are to be exposed to weather, 75 percent, and where always wet, 67 percent of these allowable loads apply.

700–H. Lead Holes

700–H–1. Lead holes shall be prebored as follows:

(a) The lead hole for the shank shall have the same diameter as the shank and the same depth as the length of unthreaded shank.

(b) The lead hole for the threaded portion shall have a diameter equal to 65 percent to 85 percent of the shank diameter in oak, 60 percent to 75 percent in Douglas fir and southern pine, and 40 percent to 70 percent in redwood and northern white pine and a length equal to at least the length of the threaded portion. The larger figure in each range shall apply to screws of the greater diameters. For other species the diameter shall be determined from the foregoing percentages by proportions based on the relative specific gravities of the species.

(c) Lead holes slightly larger than those specified in paragraphs 700-H-1-(a) and (b) shall be used with lag screws of excessive length.

700–I. Insertion

700–I–1. The threaded portion of the screw shall be inserted in its lead hole by turning with a wrench, not by driving with a hammer.

700–I–2. Soap or other lubricant shall be used on the screws, particularly with the denser species, to facilitate insertion and prevent damage to screw.

700–J. Penetration of Threaded Portion of Lag Screw

700–J–1. In determining the penetration of threaded portion of lag screw into a member, the reduced portion (threaded or gimlet point) shall not be considered as part of the threaded portion. For dimensions of standard lag screws, see Table No. 13.

701—WITHDRAWAL RESISTANCE

701–A. Tensile Strength of Lag Screw

701–A–1. In determining withdrawal resistance, the allowable tensile strength of lag bolt at net (root) section shall not be exceeded. Penetration of threaded portion of about 7 times the shank diameter in the denser species and 10 to 12 times the shank diameter in the softer species will develop approximately the ultimate tensile strength of the screw in axial withdrawal. (See par. 701-B.)

701–B. Allowable Withdrawal Load in Side Grain

701–B–1. The allowable load for lag screws in withdrawal from side grain with axis of the lag screw perpendicular to the fibers shall be determined from the formula:

$$p=1800D^{3/4}G^{3/2}$$

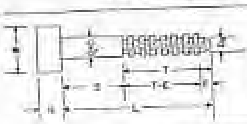
in which

p=allowable load per inch of penetration of threaded portion of lag screw

D=shank diameter of lag screw in inches (See Table No. 13)

G=specific gravity of oven dry wood (See Table No. 14)

TABLE No. 13.—*Dimensions of standard lag bolts or lag screws for wood—Cut thread, gimlet and cone point*



[All dimensions in inches]

D =Nominal diameter.
$D_S=D$=Diameter of shank.
D_R=Diameter at root of thread.
W =Width of bolt head across flats.
H =Height of bolt head.
L =Nominal length of bolt.
S =Length of shank.
T =Length of thread.
E =Length of tapered tip.
N =Number of threads per inch.

Nominal length of bolt (L) in inches*	Item	3/16	1/4	5/16	3/8	7/16	1/2	9/16	5/8	3/4	7/8	1	1 1/8	1 1/4
All lengths	$D_S=D$	0.190	0.250	0.3125	0.375	0.4375	0.500	0.5625	0.625	0.750	0.875	1.000	1.125	1.250
	D_R	.120	.173	.227	.265	.328	.371	.435	.471	.579	.683	.780	.887	1.012
	E	3/32	3/16	1/4	1/4	9/32	5/16	3/8	3/8	7/16	1/2	9/16	5/8	3/4
	H	9/64	11/64	13/64	1/4	19/64	21/64	3/8	27/64	1/2	19/32	43/64	3/4	27/32
	W	9/32	3/8	1/2	9/16	5/8	3/4	7/8	15/16	1 1/8	1 5/16	1 1/2	1 11/16	1 7/8
	N	11	10	9	7	7	6	6	5	4 1/2	4	3 1/2	3 1/4	3 1/4
1	S	1/4	1/4	1/4	1/4	1/4	1/4	----	----	----	----	----	----	----
	T	3/4	3/4	3/4	3/4	3/4	3/4	----	----	----	----	----	----	----
	$T-E$	21/32	9/16	1/2	1/2	15/32	7/16	----	----	----	----	----	----	----
1 1/2	S	3/8	3/8	3/8	3/8	3/8	3/8	----	----	----	----	----	----	----
	T	1 1/8	1 1/8	1 1/8	1 1/8	1 1/8	1 1/8	----	----	----	----	----	----	----
	$T-E$	1 1/32	15/16	7/8	7/8	27/32	13/16	----	----	----	----	----	----	----
2	S	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	----	----	----	----	----
	T	1 1/2	1 1/2	1 1/2	1 1/2	1 1/2	1 1/2	1 1/2	1 1/2	----	----	----	----	----
	$T-E$	1 13/32	1 5/16	1 1/4	1 1/4	1 7/32	1 3/16	1 1/8	1 1/8	----	----	----	----	----
2 1/2	S	1	1	7/8	7/8	3/4	3/4	3/4	3/4	----	----	----	----	----
	T	1 1/2	1 1/2	1 5/8	1 5/8	1 3/4	1 3/4	1 3/4	1 3/4	----	----	----	----	----
	$T-E$	1 13/32	1 5/16	1 3/8	1 3/8	1 15/32	1 7/16	1 3/8	1 3/8	----	----	----	----	----
3	S	1	1	1	1	1	1	1	1	1	1	1	----	----
	T	2	2	2	2	2	2	2	2	2	2	2	----	----
	$T-E$	1 29/32	1 13/16	1 3/4	1 3/4	1 23/32	1 11/16	1 5/8	1 5/8	1 9/16	1 1/2	1 7/16	----	----
4	S	1 1/2	1 1/2	1 1/2	1 1/2	1 1/2	1 1/2	1 1/2	1 1/2	1 1/2	1 1/2	1 1/2	1 1/2	1 1/2
	T	2 1/2	2 1/2	2 1/2	2 1/2	2 1/2	2 1/2	2 1/2	2 1/2	2 1/2	2 1/2	2 1/2	2 1/2	2 1/2
	$T-E$	2 13/32	2 5/16	2 1/4	2 1/4	2 7/32	2 3/16	2 1/8	2 1/8	2 1/16	2	1 15/16	1 7/8	1 3/4
5	S	2	2	2	2	2	2	2	2	2	2	2	2	2
	T	3	3	3	3	3	3	3	3	3	3	3	3	3
	$T-E$	2 29/32	2 13/16	2 3/4	2 3/4	2 23/32	2 11/16	2 5/8	2 5/8	2 9/16	2 1/2	2 7/16	2 3/8	2 1/4
6	S	2 1/2	2 1/2	2 1/2	2 1/2	2 1/2	2 1/2	2 1/2	2 1/2	2 1/2	2 1/2	2 1/2	2 1/2	2 1/2
	T	3 1/2	3 1/2	3 1/2	3 1/2	3 1/2	3 1/2	3 1/2	3 1/2	3 1/2	3 1/2	3 1/2	3 1/2	3 1/2
	$T-E$	3 13/32	3 5/16	3 1/4	3 1/4	3 7/32	3 3/16	3 1/8	3 1/8	3 1/16	3	2 15/16	2 7/8	2 3/4
7	S	3	3	3	3	3	3	3	3	3	3	3	3	3
	T	4	4	4	4	4	4	4	4	4	4	4	4	4
	$T-E$	3 29/32	3 13/16	3 3/4	3 3/4	3 23/32	3 11/16	3 5/8	3 5/8	3 9/16	3 1/2	3 7/16	3 3/8	3 1/4
8	S	3 1/2	3 1/2	3 1/2	3 1/2	3 1/2	3 1/2	3 1/2	3 1/2	3 1/2	3 1/2	3 1/2	3 1/2	3 1/2
	T	4 1/2	4 1/2	4 1/2	4 1/2	4 1/2	4 1/2	4 1/2	4 1/2	4 1/2	4 1/2	4 1/2	4 1/2	4 1/2
	$T-E$	4 13/32	4 5/16	4 1/4	4 1/4	4 7/32	4 3/16	4 1/8	4 1/8	4 1/16	4	3 15/16	3 7/8	3 3/4
9	S	4	4	4	4	4	4	4	4	4	4	4	4	4
	T	5	5	5	5	5	5	5	5	5	5	5	5	5
	$T-E$	4 29/32	4 13/16	4 3/4	4 3/4	4 23/32	4 11/16	4 5/8	4 5/8	4 9/16	4 1/2	4 7/16	4 3/8	4 1/4
10	S	4 3/4	4 3/4	4 3/4	4 3/4	4 3/4	4 3/4	4 3/4	4 3/4	4 3/4	4 3/4	4 3/4	4 3/4	4 3/4
	T	5 1/4	5 1/4	5 1/4	5 1/4	5 1/4	5 1/4	5 1/4	5 1/4	5 1/4	5 1/4	5 1/4	5 1/4	5 1/4
	$T-E$	5 5/32	5 1/16	5	5	4 31/32	4 15/16	4 7/8	4 7/8	4 13/16	4 3/4	4 11/16	4 5/8	4 1/2
11	S	5 1/2	5 1/2	5 1/2	5 1/2	5 1/2	5 1/2	5 1/2	5 1/2	5 1/2	5 1/2	5 1/2	5 1/2	5 1/2
	T	5 1/2	5 1/2	5 1/2	5 1/2	5 1/2	5 1/2	5 1/2	5 1/2	5 1/2	5 1/2	5 1/2	5 1/2	5 1/2
	$T-E$	5 13/32	5 5/16	5 1/4	5 1/4	5 7/32	5 3/16	5 1/8	5 1/8	5 1/16	5	4 15/16	4 7/8	4 3/4
12	S	6	6	6	6	6	6	6	6	6	6	6	6	6
	T	6	6	6	6	6	6	6	6	6	6	6	6	6
	$T-E$	5 29/32	5 13/16	5 3/4	5 3/4	5 23/32	5 11/16	5 5/8	5 5/8	5 9/16	5 1/2	5 7/16	5 3/8	5 1/4

*Length of thread (T) on intervening bolt lengths is the same as that of the next shorter bolt length listed. The length of thread (T) on standard bolt lengths (L) in excess of 12 inches is equal to 1/2 the bolt length (L/2).

701–C. Allowable Withdrawal Load in End Grain

701–C–1. If possible, the design shall be such that lag screws are not loaded in withdrawal from end grain of wood. When this condition cannot be avoided, the allowable load in withdrawal from end grain shall not be taken as more than three-fourths of that for withdrawal from side grain.

TABLE No. 14.—*Specific gravity of commercially important species of wood based on oven dry weight and volume*

Species	Specific gravity	Species	Specific gravity
Alder, red	0.43	Gum, red	.53
Ash, black	.53	Gum, tupelo	.52
Ash, white	.64	Hackberry	.56
Aspen	.40	Hemlock, eastern	.43
Basswood	.40	Hemlock, western	.44
Birch, yellow	.66	Hickory	.72
Buckeye, yellow	.38	Larch, western	.59
Butternut	.40	Locust, black	.71
Cedar, northern white	.32	Madrone	.69
Cedar, Port Orford	.44	Magnolia, evergreen	.53
Cedar, western red	.34	Maple, hard	.68
Cherry, black	.53	Maple, soft	.51
Chestnut	.45	Oak	.68
Cottonwood, eastern	.43	Pine, northern white	.37
Cucumber, magnolia	.52	Pine, ponderosa	.42
Cypress, southern	.48	Pine, southern yellow	.58
Douglas fir	.51	Poplar	.43
Elm, American	.55	Redwood	.39
Elm, rock	.66	Spruce	.39
Fir, commercial white	.42	Sycamore	.54
Gum, black	.55	Tamarack	.56
		Walnut, black	.56
		Willow, black	.41

702—LATERAL RESISTANCE

702–A. Thickness of Wood Side Piece

702–A–1. The allowable loads for lateral resistance of lag screws given in paragraph 702-E are for wood side members having a thickness equal to 3.5 times the shank diameter.

702–A–2. For other ratios of thickness of side piece to shank diameter, the percentages given in Table No. 15 shall be applied to the allowable loads for lateral resistance obtained from the formulas in Table No. 17.

TABLE No. 15.—*Percentages of allowable loads for ratio of thickness of side member to shank diameter*

Ratio of thickness of side member to shank diameter of lag screw	Percentage of the allowable load for a ratio of 3.5	Ratio of thickness of side member to shank diameter of lag screw	Percentage of the allowable load for a ratio of 3.5
2.0	62	4.5	113
2.5	77.5	5.0	118
3.0	93	5.5	121
3.5	100	6.0	122
4.0	107	6.5	122.5

702–B. Steel Side Piece

702–B–1. Where steel plates rather than wood side pieces are used, the allowable loads given by the formulas for parallel-to-grain loading (paragraph 702-E) may be increased by 25 percent but no increase shall be made in the allowable loads for perpendicular-to-grain loading.

702–B–2. The stresses induced in the steel plate and at bearing of lag bolt on plate shall not exceed the allowable stresses for the metal used.

702–C. Penetration of Shank in Side and Main Members

702–C–1. The allowable loads given in paragraph 702-E are for the condition where the junction of the unthreaded shank and threaded portion of lag screw is at the plane of contact of the side and main member.

702–C–2. When the shank penetrates into the main member, the following percentage loads apply:

TABLE No. 16.—*Percentages of allowable loads for ratio of penetration of shank into main member to shank diameter*

Ratio of penetration of shank into main member to shank diameter	Percentage of allowable load for zero penetration	Ratio of penetration of shank into main member to shank diameter	Percentage of allowable load for zero penetration
0.0	100	4.5	135
0.5	104	5.0	136
1.0	108	5.5	137
1.5	112.5	6.0	138
2.0	117	6.5	138.5
2.5	122	7.0	139
3.0	126.5	7.5	139
3.5	130.5	8.0	139
4.0	133	8.5	139

702–C–3. When the portion of the shank and threaded portion of the lag screw is within the side member, the allowable load shall be determined from the actual penetration of shank by interpolation between the allowable load given in paragraph 702-C-1 for complete penetration of side member and 80 percent of that load for no penetration (thread extended to head of screw).

702–D. Depth of Penetration of Threaded Portion in the Main Member

702–D–1. The formulas in paragraph 702-E for determining allowable loads for lateral resistance are based on a minimum penetration of the threaded portion of the lag screw into the main member of 11 times the shank diameter for Group 1 woods (the softer woods) to 7 times for Group 4 woods (the harder woods), when the ratio of thickness of side member to shank diameter is 3.5 and the length of the shank is equal to the thickness of the side member.

702–D–2. Higher ratios of thickness of side member to shank diameter (up to about 7 to 1 and in excess of 3.5, paragraph 702-A-2) and greater ratios of penetration of shank into main member to shank diameter (up to a ratio of about 7 to 1, paragraph 702-C-2) require greater depths of penetration into main member to develop the percentage loads given in Table No. 15 of paragraph 702-A-2 and Table No. 16 of paragraph 702-C-2. The required penetration of threaded portion into main member shall be obtained through multiplication of the standard penetration by a fraction having the square root of the product of the two percentage loads as the numerator and 100 percent as the denominator. If the product of the two percentages is less than 100 percent, due to the use of thin side members, or of side members thicker than the length of shank, or of both, the required depth of penetration of threaded portion into main member shall be obtained by direct proportion of the percentage product to 100 percent for standard penetration, but shall not be less than 5 times the shank diameter.

If the above required penetration of threaded portion into main member cannot be obtained, the allowable loads given in paragraph 702-E shall be reduced in direct proportion of the actual penetration to the required penetration, but, if greater penetration than required is used, the allowable loads shall not be increased.

702–E. Allowable Loads for Lateral Resistance When the Loads Act Parallel to Grain and Lag Screw Is Inserted in Side Grain

702–E–1. Allowable loads for lateral resistance when the loads act parallel to grain, lag screw is inserted perpendicular to the fiber (i. e., in side grain of main member), and a wood side piece is used, shall be determined from the formulas in Table No. 17 for the species under consideration.

702–E–2. For adjustment of loads for metal instead of wood side pieces, see paragraph 702-B.

702–F. Allowable Loads for Lateral Resistance When the Loads Act Perpendicular to Grain and Lag Screw Is Inserted in Side Grain

702–F–1. Allowable loads for lateral resistance when the loads act perpendicular to grain, lag screw is inserted perpendicular to the fibers (i. e., in side grain of main member), and wood side piece is used, shall be determined by multiplying the allowable loads for lateral resistance parallel to grain for wood side plates by the factors from Tables No. 18 and No. 19 for the species used.

TABLE No. 17.—*Equations for computing allowable lateral loads parallel-to-grain for lag screws screwed into side grain*

Group	Species of wood	Equation
1	Cedar, northern and southern white Fir, balsam and commercial white Hemlock, eastern Pine, ponderosa, sugar, northern white and western white Spruce, Engelmann, red, Sitka and white	$P=1800D^2$
2	Aspen and largetooth aspen Basswood Cedar, Alaska, Port Orford and western red Chestnut Cottonwood, black and eastern Cypress, southern Douglas fir (Rocky Mountain type) Hemlock, western Pine, Norway Redwood Tamarack Yellow poplar	$P=2040D^2$
3	Ash, black Birch, paper Douglas fir (coast type) Elm (soft), American and (gray) slippery Gum, black, red and tupelo Larch, western Maple, (soft) red and silver Pine, southern yellow Sycamore	$P=2280D^2$
4	Ash, commercial white Beech Birch, sweet and yellow Elm, rock Hickory, true and pecan Maple (hard), black and sugar Oak, commercial red and white	$P=2640D^2$

P=Allowable load per lag screw in pounds.
D=Shank diameter of lag screw in inches.

TABLE No. 18.—*Factors for computing allowable lateral loads for perpendicular-to-grain loading of lag screw in side grain*

Lag screw diameter	Factor				
	Group 1	Group 2	Group 3	Group 4	Group 5
3/16	1.00	1.00	1.00	1.00	1.00
1/4	.94	1.00	1.00	.89	1.00
5/16	.82	.87	.89	.77	.91
3/8	.73	.78	.80	.69	.82
7/16	.67	.72	.74	.64	.76
1/2	.62	.67	.68	.59	.70
5/8	.57	.61	.62	.54	.64
3/4	.53	.56	.57	.50	.59
7/8	.50	.53	.54	.47	.56
1	.48	.51	.52	.45	.53

TABLE No. 19.—*Grouping of species for use with table No. 18*

Group	Species of wood
1	Ash, black Aspen and largetooth aspen Basswood Birch, paper Butternut Cedar, northern and southern Chestnut Cottonwood, black and eastern Fir, balsam and commercial white Hemlock, eastern Pine, lodgepole, ponderosa, sugar, northern white and western white Poplar, yellow Spruce, Engelmann, red, Sitka and white
2	Cedar, Alaska, incense, Port Orford and western red Douglas fir (Rocky Mountain region) Hemlock, western Pine, Norway
3	Cedar, eastern red Cypress, southern Douglas fir (coast region) Larch, western Pine, southern yellow Redwood Tamarack
4	Alder, red Elm, American and slippery Gum, black, red and tupelo Hackberry Magnolia, cucumber and evergreen Maple, bigleaf, and red and silver (soft) Sugarberry Sycamore
5	Ash, commercial white and Oregon Beech Birch, sweet and yellow Cherry, black Elm, rock Hickory, true and pecan Locust, black Locust, honey Maple (hard), black and sugar Oak, commercial red and white Walnut, black

702–F–2. The allowable loads for lateral resistance when the loads act perpendicular to grain are the same for both METAL and WOOD side pieces.

702–G. Allowable Loads for Lateral Resistance When the Loads Act at Angles Other Than 0° and 90° With the Grain and the Lag Screw Is Inserted in Side Grain

702–G–1. When the load acts at an angle other than 0° and 90° with the grain, the lag screw is inserted perpendicular to the fiber (i. e., in side grain of main member), and either wood or metal side piece is used, the allowable loads for lag screws under lateral loading shall be determined from the Hankinson formula.

702–G–2. For Hankinson formula, see paragraph 600-N and Appendix C.

702–H. Allowable Loads for Lateral Resistance When the Loads Act Perpendicular to the Grain and the Lag Screw Is Inserted in End Grain

702–H–1. Allowable loads for lateral resistance when the loads act perpendicular to grain and the lag screw is inserted parallel to the fibers (i. e., in the end grain of the main member) shall be two-thirds of those for lateral resistance when the loads act perpendicular to the grain, the lag screw is inserted perpendicular to the grain (i. e., in the side grain of the main member) and a wood side piece is used.

703—PLACEMENT OF LAG SCREWS IN JOINT

703–A. The spacings, end distances, edge distances and net section for lag screw joints shall be the same as for joints with bolts of a diameter equal to the shank diameter of the lag screw used. See paragraph 601.

PART VIII. NAIL, SPIKE, DRIFTPIN, AND WOOD SCREW JOINTS

800—NAILED JOINTS

For nailed joints using stress-grade lumber and the nails defined herein, the provisions of paragraph 800 and the tabulated allowable nail loads herein apply.

800–A. General Provisions

800–A–1. The following provisions (except par. 800-A-2) apply to common wire nails.

800–A–2. For nails other than common wire nails, allowable loads herein for common wire nails may be adjusted by proportion in accordance with the provisions of reference No. 2, Appendix G.

800–A–3. When more than one nail is used in a nailed joint, the total allowable load in withdrawal or lateral resistance is the sum of the allowable loads for the individual nails.

800–B. Type of Load

800–B–1. The allowable loads for nails given in paragraph 800 are the maximum for permanent loading, i. e., long-time loading whether dead or live. Pertinent modifications of stresses and provisions of paragraphs 200, 201, 202, 203, and 204 for lumber except as otherwise provided in paragraph 800 apply likewise to the allowable nail loads in paragraph 800.

800–C. Withdrawal from Side Grain (See Table No. 20)

800–C–1. If possible, the structural design shall be such that nails are not loaded in withdrawal. When this condition cannot be avoided, the following provisions shall apply:

(a) For common wire nails, the allowable withdrawal load per inch of penetration of a nail driven in side grain (perpendicular to fibers) of main member of seasoned wood or unseasoned wood which will remain wet shall be:

(1) That given in Table No. 20 for species listed, or

(2) Determined from the following formula for species not tabulated:

$$p=1{,}380\ G^{5/2}D$$

in which

p=allowable load PER INCH of penetration,

G=specific gravity of oven dry wood (see Table No. 14, Part VII),

D=diameter of nail in inches.

(b) When driven in unseasoned wood which will season subsequently under load, the allowable load from side grain shall be one-fourth of that given in paragraph 800-C-1-(a).

800–D. Withdrawal from End Grain

800–D–1. The structural design shall be such that nails are not loaded in withdrawal from end grain of wood.

TABLE No. 20.—*Allowable loads for common wire* NAILS IN WITHDRAWAL *from side grain*

Nail data:										
Pennyweight	6	8	10	12	16	20	30	40	50	60
Length (inches)	2	2½	3	3¼	3½	4	4½	5	5½	6
Diameter (inches)	0.113	0.131	0.148	0.148	0.162	0.192	0.207	0.225	0.244	0.263
	Allowable load in pounds per inch of penetration in main member									
Species:										
Birch, yellow and sweet	61	72	80	80	89	104	113	122	133	144
Douglas fir	29	34	38	38	42	49	53	58	62	67
Maple, sugar	60	68	78	78	85	101	109	119	128	138
Oak, red and white	61	72	80	80	89	104	113	122	133	144
Pine, longleaf	41	47	54	54	56	60	66	71	77	83
Pine, northern white	16	18	20	20	23	26	29	31	34	36
Pine, ponderosa	18	20	23	23	25	30	32	36	38	42
Pine, shortleaf	34	38	43	43	46	49	53	58	62	68
Redwood	18	20	23	23	25	30	32	36	38	42
Spruce, Sitka	17	20	23	23	25	30	32	35	37	41

800–E. Lateral Resistance of Nails Driven in Side Grain of Wood

800–E–1. The allowable LOAD PER COMMON WIRE NAIL in lateral resistance when driven in side grain (perpendicular to fibers) of seasoned wood with the load applied in any lateral direction shall be determined from the formulas in Table No. 21. These loads apply only for conditions where the side piece and main member have approximately the same density and where the nail penetrates in the main member a minimum distance equal to two-thirds of its length in softwoods and one-half in hardwods.

TABLE No. 21.—*Allowable loads for common wire* NAILS IN LATERAL RESISTANCE *when driven in side grain*

Equation for computing allowable lateral load for common wire nails driven perpendicular to the grain of wood in seasoned lumber expressed in pounds per nail.

Species	Equation
Aspen and largetooth aspen Basswood Butternut Cedar, northern and southern white Chestnut Cottonwood, black and eastern Fir, balsam and commercial white Hemlock, eastern Pine, lodgepole, ponderosa, sugar, northern white, and western white Poplar, yellow Spruce, Engelmann, red, Sitka, and white	$P=1{,}080\ D^{3/2}$
Cedar, Alaska, incense, Port Orford, and western red Cedar, eastern red Cypress, southern Douglas fir (Rocky Mountain region) Hemlock, western Pine, Norway Redwood Tamarack	$P=1{,}350\ D^{3/2}$
Alder, red Ash, black Birch, paper Elm, American and slippery Gum, black, red, and tupelo Hackberry Magnolia, cucumber Magnolia, evergreen Maple, bigleaf Maple (soft), red and silver Sugarberry Sycamore	$P=1{,}500\ D^{3/2}$
Douglas fir (coast region) Larch, western Pine, southern yellow	$P=1{,}650\ D^{3/2}$
Ash, commercial white Ash, Oregon Beech Birch, sweet and yellow Cherry, black Elm, rock Hickory, true and pecan Locust, honey and black Maple (hard), black and sugar Oak, commercial red and white Walnut, black	$P=2{,}040\ D^{3/2}$

P=Allowable load per nail in pounds.
D=Diameter of nail in inches.

800–E–2. For nails driven into side grain of unseasoned wood which will remain wet or will be loaded before seasoning, the allowable load per nail in lateral resistance shall be three-fourths of that given in paragraph 800-E-1.

800–E–3. Where metal side plates are used, the allowable load per nail given in paragraph 800-E-1 may be increased by 25 percent.

800–F. Lateral Resistance of Nails Driven in End Grain of Wood

800–F–1. The allowable LOAD PER NAIL in lateral resistance for a common wire nail driven in the end grain (parallel to fibers) shall be two-thirds of that given for nails in paragraph 800-E.

800–G. Spacing of Nails

800–G–1. The end distance, edge distances, and spacings of nails shall be such as to avoid unusual splitting of the wood.

801—SPIKED JOINTS

For spiked joints using stress-grade lumber and the spikes defined herein, the provisions of paragraph 801 and the tabulated allowable spike loads herein apply.

801–A. General Provisions

801–A–1. The following provisions (except par. 801-A-2) apply to common wire spikes with diamond or chisel points.

801–A–2. For boat spikes which are square in cross section allowable loads given in reference No. 2, Appendix G, shall be adjusted in proportion to values given herein for common wire spikes.

801–A–3. When more than one spike is used in a spiked joint, the total allowable load in withdrawal or lateral resistance is the sum of the allowable loads for the individual spikes.

801–B. Type of Load

801–B–1. The allowable loads for spikes given in paragraph 801 are the maximum for permanent loading, i. e., long-time loading whether dead or live. Pertinent modifications of stresses and provisions of paragraphs 200, 201, 202, 203, and 204 for lumber except as otherwise provided in paragraph 801 apply likewise to the allowable spike loads in paragraph 801.

801–C. Withdrawal from Side Grain

801–C–1. If possible, the structural design shall be such that spikes are not loaded in withdrawal. When this condition cannot be avoided, the following provisions shall apply:

TABLE No. 22.—*Allowable loads for common wire* SPIKES IN WITHDRAWAL *from side grain*

Spike data:										
Pennyweight	10	12	16	20	30	40	50	60	----	----
Length (inches)	3	3¼	3½	4	4½	5	5½	6	7	8–12
Diameter	0.192	0.192	0.207	0.225	0.244	0.263	0.283	0.283	5/16	3/8
	Allowable load in pounds per inch of penetration in main member									
Species:										
Birch, yellow and white	104	104	112	123	133	144	155	155	171	205
Douglas fir	49	49	53	58	63	68	73	73	80	96
Maple, sugar	101	101	109	118	128	138	149	164	164	197
Oak, red and white	104	104	112	123	133	144	155	155	171	205
Pine, longleaf	60	60	65	71	77	83	89	89	99	116
Pine, northern white	26	26	29	31	33	36	39	39	43	52
Pine, ponderosa	30	30	32	35	38	41	44	44	49	59
Pine, shortleaf	49	49	53	58	63	68	73	73	81	97
Redwood	30	30	32	35	38	41	44	44	49	59
Spruce, Sitka	30	30	32	35	37	40	43	43	48	58

(a) For common wire spikes, the allowable withdrawal load per inch of penetration of spike driven in side grain (perpendicular to fibers) of seasoned wood or unseasoned wood which will remain wet shall be:

(1) That given in Table No. 22, or

(2) Determined from formula in paragraph 800-C-1-(a)-(2) for species not tabulated in Table No. 22.

(b) When driven in unseasoned wood which will season subsequently under load, the allowable withdrawal load shall be one-fourth of that given in paragraph 801-C-1-(a).

801–D. Withdrawal from End Grain

801–D–1. The structural design shall be such that spikes are not loaded in withdrawal from end grain of wood.

801–E. Lateral Resistance of Spikes Driven in Side Grain

801–E–1. The allowable LOAD PER COMMON WIRE SPIKE in lateral resistance when driven in side grain (perpendicular to fibers) of seasoned wood with the load applied in any direction shall be determined from the formulas in Table No. 21. The loads apply only for conditions where the side piece and main member have approximately the same density and where the spike penetrates in the main member a minimum distance equal to two-thirds of its length in softwoods and one-half its length in hardwoods.

801–E–2. For spikes driven in side grain of unseasoned wood which will remain wet or will be loaded before seasoning, the allowable load per common wire spike in lateral resistance shall be three-fourths of that given in paragraph 801-E-1.

801–F. Lateral Resistance of Spikes Driven in End Grain of Wood

801–F–1. The allowable LOAD PER SPIKE in lateral resistance of a common wire spike driven in end grain (parallel to fibers) shall be two-thirds of that for spikes driven in side grain given in paragraph 801-E.

801–G. Spacing of Spikes

801–G–1. The end distance, edge distances, and spacings of spikes shall be such as to avoid unusual splitting of wood.

802—DRIFTPIN JOINTS

802–A. Withdrawal of Driftpins or Driftbolts from Side Grain

802–A–1. The ULTIMATE withdrawal load per linear inch of penetration of a round drift bolt or pin from side grain when driven into a prebored hole having a diameter one-eighth inch less than that of the bolt diameter shall be determined from the formula:

$$p = 6{,}000\ G^2 D$$

in which

p=ULTIMATE withdrawal LOAD PER LINEAR INCH OF PENETRATION.

G=specific gravity of oven-dry wood. (See Table No. 14.)

D=diameter of driftbolt in inches.

802–A–2. The allowable load per linear inch of penetration shall be determined by dividing the ultimate withdrawal load given in paragraph 802-A-1 by a factor of safety which is consistent with the character of the work. A factor of five is suggested for general use.

802–B. Lateral Resistance of Driftbolts

802–B–1. The allowable load in lateral resistance for a driftbolt or pin driven in the side grain of wood shall not exceed, and ordinarily shall be taken as less than, that for a common bolt of the same diameter. When possible, additional penetration of pin into members shall be provided in lieu of the washers, head, and nut on a common bolt.

803—WOOD SCREW JOINTS

For wood screw joints with stress-grade lumber and the wood screws defined herein, the provisions of paragraph 803 and the tabulated values herein apply.

803–A. Type of Load

803–A–1. Allowable loads for wood screws given in paragraph 803 are the maximum for permanent loading, i. e., long time loading whether dead or live. Pertinent modifications of stresses and provisions of paragraphs 200, 201, 202, 203, and 204 for lumber except as otherwise provided in paragraph 803 apply likewise to loads for wood screws given in paragraph 803.

803–B. Number of Wood Screws

803–B–1. Loads given are for ONE wood screw either in withdrawal or in lateral resistance in a TWO member joint.

803–B–2. Loads for more than one wood screw each of the same or miscellaneous sizes are the sum of the loads permitted for each wood screw, provided that spacings, end distances, and edge distances are sufficient to develop the full strength of each wood screw.

803–C. Quality of Wood Screws

803–C–1. The allowable loads herein are for any wood screw of sufficient strength to cause failure in the wood rather than the metal.

803–D. Species of Lumber

803–D–1. The method of determining allowable loads for wood screws in the various species is indicated by formulas and provisions and tabulated values herein.

803–E. Grade of Lumber

803–E–1. The allowable loads for wood screws in a given species apply to all grades of that species.

803–F. Condition of Lumber

803–F–1. The allowable loads given in paragraph 803 are for wood screws in seasoned lumber.

803–G. Exposure to Weather

803–G–1. Tabulated loads apply for joints used indoors or in a location "always dry."

803–G–2. When joints are to be exposed to weather, 75 percent, and when always wet, 67 percent of the tabulated loads apply.

803–H. Lead Holes

803–H–1. Lead holes shall be prebored as follows:

(a) For Withdrawal Resistance:

(1) For hardwoods, the lead hole shall have a diameter of about 90 percent the root diameter of the wood screw.

(2) For conifers, the lead hole shall have a diameter of about 70 percent of the root diameter of the wood screw.

(b) For Lateral Resistance:

(1) For hardwoods, such as oak, the part of the lead hole receiving the shank shall have about the same diameter as the shank, and that receiving the threaded portion shall have about the same diameter as the root of the thread.

(2) For conifers such as southern pine and Douglas fir, the part of the hole receiving the shank shall be about seven-eighths the diameter of the shank and that for the threaded portion shall be about seven-eighths the diameter of the screw at the root of the thread.

803–I. Insertion

803–I–1. The screw shall be inserted in its lead hole by turning with a screw driver or other tool, not by driving with a hammer.

803–I–2. Soap or other lubricant may be used on the screws to facilitate insertion and to prevent damage to screw.

803–J. Penetration of Wood Screws in Main Member

803–J–1. For Withdrawal Resistance:

(a) The depth of penetration into member receiving the point shall not be less than two-thirds the length of the screw.

803–J–2. For Lateral Resistance:

(a) The length of screw in main member shall be approximately seven times the shank diameter.

(b) If the depth of penetration is less than seven times the diameter of the shank, the allowable load for lateral resistance shall be reduced in proportion to the length of penetration, but a length of penetration of less than four times the shank diameter shall not be used.

803–K. Withdrawal Resistance of Wood Screws

803–K–1. If possible, the structural design shall be such that wood screws are not loaded in withdrawal. When this condition cannot be avoided, the following provisions shall apply:

(a) Tensile strength of wood screw:

(1) In determining the allowable withdrawal resistance from paragraph 803-K-1-(b), the allowable tensile strength of wood screw at net (root) section shall not be exceeded.

(b) Withdrawal from side grain:

(1) The allowable load in withdrawal from side grain with axis of the wood screw perpendicular to the fibers shall be determined from the formula:

$$p=2{,}040\ G^2D$$

in which

p=the allowable load per inch of total length of screw (two-thirds of screw length shall be in member receiving point),

G=specific gravity of oven dry wood (See Table No. 14),

D=diameter of the screw in inches.

(2) The preceding equation is applicable to the wood screw lengths and gages given in Table No. 23.

TABLE No. 23.—*Screw-lengths and gage limits.*

Screw length	Gage limits	Screw length	Gage limits
½	1–6	2	7–16
¾	2–11	2½	9–18
1	3–12	3	12–20
1½	5–14		

(3) Allowable loads for other wood screw lengths and gages may be adjusted proportionately to those herein in accordance with reference No. 2, Appendix G.

(c) Withdrawal from end grain:

(1) The structural design shall be such that wood screws are not loaded in withdrawal from end grain of wood.

803–L. Lateral Resistance of Wood Screws

803–L–1. Thickness of wood side piece.

(a) See paragraph 803-J-2.

803–L–2. Steel side piece.

(a) Where steel side plates rather than wood side pieces are used, the allowable load for wood screws in lateral resistance of any angle of load to grain may be increased by 25 percent.

803–L–3. Depth of penetration of threaded portion in main member.

(a) See paragraph 803-J-2.

803–L–4. Penetration of shank in side and main members.

(a) See paragraph 803-J-2.

803–L–5. Allowable loads for lateral resistance with wood screws in side grain.

(a) The allowable loads for lateral resistance to any angle of load to grain when the wood screw is inserted perpendicular to the fibers (i. e., in side grain of main member) and a wood side piece is used, shall be determined from the formula in Table No. 24 for the species under consideration.

803–L–6. Allowable loads for lateral resistance when loads act perpendicular to the grain and the wood screw is inserted in end grain.

(a) The allowable loads for lateral resistance when the loads act perpendicular to grain and the wood screw is inserted parallel to the fibers (i. e., in the end grain of the main member) shall be two-thirds of those for lateral resistance given in paragraph 803-L-5.

803–M. Placement of Wood Screws in Joints

803–M–1. Spacings, end distances, and edge distances for wood screw joints shall be such as to prevent unusual splitting.

TABLE No. 24—*Allowable loads in* LATERAL RESISTANCE FOR WOOD SCREWS *in side grain*

Species	Equation
Ash, commercial white	$P=4{,}800\ D^2$
Ash, Oregon	
Beech	
Birch, sweet and yellow	
Cherry, black	
Elm, rock	
Hickory, true and pecan	
Honey, locust	
Locust, black	
Maple (hard), black and sugar	
Oak, commercial red and white	
Walnut, black	
Douglas fir (coast region)	$P=3{,}960\ D^2$
Larch, western	
Pine, southern yellow	
Alder, red	$P=3{,}480\ D^2$
Ash, black	
Birch, paper	
Elm, American and slippery	
Gum, black, red and tupelo	
Hackberry	
Magnolia, cucumber	
Magnolia, evergreen	
Maple, bigleaf	
Maple (soft), red and silver	
Sugarberry	
Sycamore	
Cedar, Alaska, incense, Port Orford and western red	$P=3{,}240\ D^2$
Cedar, eastern red	
Cypress, southern	
Douglas fir (Rocky Mountain region)	
Hemlock, western	
Pine, Norway	
Redwood	
Tamarack	
Aspen and largetooth aspen	$P=2{,}520\ D^2$
Basswood	
Butternut	
Cedar, northern and southern white	
Chestnut	
Cottonwood, black and eastern	
Fir, balsam and commercial white	
Hemlock, eastern	
Pine, lodgepole, ponderosa, sugar, northern white and western white	
Poplar, yellow	
Spruce, Engelmann, red, Sitka and white	

P = Allowable load per screw in pounds.
D = Shank diameter of screw in inches.

PART IX. GLUED LAMINATED STRUCTURAL MEMBERS

In the design and construction of the glued laminated structural members of lumber defined in Part X, the provisions of Part IX apply.

)—GENERAL PROVISIONS

900–A. Except as otherwise provided in Part X, pertinent provisions of Parts I, II, III, and IV hall apply to glued laminated members.

900–B. The term "glued laminated structural nembers" as used herein refers only to those glued aminated structural members in which the grain f all laminations of a member is approximately arallel.

900–C. The glue line between laminations shall e assumed to be as strong as the wood itself proided that all the requirements of Part IX are ulfilled.

900–D. Strength shall be calculated on the basis f net dimensions of wood in a member, i. e., voids etween pieces of lumber used shall not be conidered part of the section.

900–E. Sections other than rectangular shall be designed in accordance with the procedures in references 2 and 10, Appendix G, and Appendix D, but the design shall be based on allowable unit stresses given herein.

1—WORKMANSHIP

901–A. The construction of laminated members shall be in accordance with good practices and under the supervision of properly qualified personnel.

901–B. Gluing practices shall take into consideration the characteristics and limitations of the specific glue used and shall conform to good practices as to preparation of wood surfaces for gluing, control of temperature and moisture content of materials, mixing and spreading of glue, maintenance of adequate pressures, assembly time within life of glue, and compatibility of the glue with any other wood treatments employed. See references 10 and 11, Appendix G.

)2—ALLOWABLE UNIT STRESSES FOR LAMINATED MEMBERS

902–A. For a member built of laminations consisting of seasoned stress-grades of Joist and Plank or seasoned boards graded on Joist and Plank grading rules:

902–A–1. *Flexure*—The allowable unit stresses in flexure shall be equal to the allowable unit stresses in extreme fiber in bending, given for the corresponding Joist and Plank grades in Table No. 1.

902–A–2. *Compression Parallel to Grain*—The allowable unit stresses for compression parallel to grain shall be the value in Table No. 1 for the grade and species increased by 50 percent except that 90 percent of the values in column A in Table 25 shall not be exceeded.

902–A–3. *Flexure and Compression Combined*—Allowable unit stresses for combined bending and compression shall be determined from the formulas in paragraph 403-B.

902–A–4. *Shear*—The allowable unit shearing stress given in Column B in Table 25 apply to all grades of a given species and density.

TABLE No. 25.

Species	A Lbs. sq. in.	B Lbs. sq. in.
Ash, white	2,200	200
Beech	2,400	200
Birch	2,400	200
Chestnut	1,600	145
Cypress, southern	2,200	160
Cypress, tidewater	2,200	160
Douglas fir, all regions, dense	2,575	170
Douglas fir, coast region, close grained	2,350	145
Douglas fir, coast region	2,200	145
Douglas fir, inland region, close grained	2,225	145
Douglas fir, inland region	2,075	145
Elm, rock	2,400	200
Elm, soft	1,600	160
Gum, black and red	1,600	160
Hemlock, eastern	1,400	110
Hemlock, western	1,800	120
Hickory	3,000	225
Larch, dense	2,575	185
Larch, close grained	2,350	160
Larch	2,200	160
Maple, hard	2,400	200
Oak, red and white	2,000	200
Pecan	3,000	225
Pine, Norway	1,600	135
Pine, southern longleaf	2,575	205
Pine, southern shortleaf, dense	2,575	205
Pine, southern shortleaf	2,200	175
Poplar, yellow	1,600	130
Redwood, close grained	2,125	110
Redwood	2,000	110
Spruce, eastern	1,600	135
Tupelo	1,600	160

902–A–5. *Tension Perpendicular to Grain*—The allowable unit stress in tension perpendicular to grain shall not exceed 2½ percent of the allowable bending stress for softwoods nor 4 percent for hardwoods. See Table No. 1.

902–B. Allowable unit stresses for laminated members composed of material 2 inches or less in thickness conforming to standard commercial grades or special grading may be determined by applying the principles used in reference 3, Appendix G, (assuming the values in columns 2, 3, 4, and 5 of Table No. 8 therein to be increased by 20 percent). The stresses so determined for combined bending and compression and for compression parallel to grain shall be used for bending and for longitudinal compression, respectively, the bending stress being modified for curvature in accordance with paragraph 905-A. The stress for combined bending and compression shall then be governed by paragraph 403-B.

902–C. If all laminations within one-tenth of the depth (parallel to applied load) of the member from the outer face of each outer lamination of a member in bending are selected so that the knots do not exceed one-half the size of the maximum knot permitted in the Joist and Plank grade used elsewhere in the laminated member, the allowable unit stress in extreme fiber in bending for the next higher grade in Table No. 1 shall apply. This provision is to be applied only within the group of grades designated by footnote 7 to Table No. 1 as including density requrements or within the group of grades not so designated.

902–D. When the material in the middle three-fifths of the depth (parallel to applied load) of cross-section in a laminated beam or arch stressed principally in bending is but one grade lower than that in the upper and lower fifths of the depth, the allowable unit stresses in bending for the higher grade in the outer fifths shall apply. This provision shall be applied to dense and nondense grades as in the preceding paragraph.

902–E. For laminated members designed and constructed in accordance with the provisions of reference 10, Appendix G, the allowable stresses shall be those recommended in reference 10 (except that the numerical values in columns 2, 3, 4, and 5 of Table No. 24 therein shall be increased by 20 percent). Modification of the increased values shall be made in accordance with that in paragraph 902-A.

902–F. When stress grade lumber is resawn, it shall be regraded and the allowable unit stresses for the resulting grades shall apply thereto. Only those pieces meeting the stress requirements of the member shall be used.

902–G. For a member in bending, in that portion of a laminated member which is stressed up to or more than two-thirds of its allowable stress, the end joints in laminations shall be scarfed.

903—LUMBER

903–A. At time of gluing, the moisture content of all laminations in a member shall be uniform and as close as is practical to the moisture content at which the member will be in service.

903–B. All surfaces to be glued shall be surfaced flat to as smooth a finish as possible (approaching a machine polished surface, but not sanded) after seasoning to the appropriate moisture content.

903–C. Surfaces to be glued shall be flat, clean and free from oil and dust. Material shall be free from warp which will prevent surfaces of adjacent laminations from being brought into intimate contact which will assure a proper thickness and uniform spread of glue. In curved portions of members material shall be free from warp, knots or knot holes which will prevent bending of laminations to uniform curvature.

903–D. Before assembling, lumber shall be so sorted that the material in all laminations of an individual member shall be either flat grain (angle of annual ring with wide face of less than 45°) or edge grain (angle of annual ring with wide face of 45° or more).

904—GLUES AND GLUING (See references 10 and 11, Appendix G)

904–A. Glue shall be of a quality which will develop the full strength of the wood used.

904–B. Only glue which will provide adequate strength under conditions of service and for the expected service life of the structure shall be used.

904–C. Good glue bond shall be made over the entire surface to be glued.

905—CURVED LAMINATED MEMBERS

905–A. For the curved portion of laminated members, the allowable unit stress in bending shall be modified by multiplication by the following factor:

$$1-2{,}000\left(\frac{t}{R}\right)^2$$

in which

t=thickness of lamination in inches,

R=radius of curvature in inches,

and t/R should not exceed 1/100 and preferably not 1/150.

No curvature factor shall be applied to stress in a straight portion of a member regardless of curvature elsewhere.

905–B. No defects shall be permitted that interfere with bending to the required curvature without localized irregularities in the curvature or that interfere with bringing laminations into intimate contact.

905–C. For portions of members in which the laminations are curved to a radius of less than 150 times the thickness of lamination, the slope of grain in the laminations within one-tenth the depth of the member from the outer face of each outer lamination shall not exceed 1 in 15.

905–D. There shall be no end joints in laminations where the radius of curvature is 150 times the thickness of lamination or less. End joints in laminations where the radius of curvature is between 150 and 250 times the thickness of lamination shall be scarfed. Scarf joints are recommended for greater curvatures.

906—JOINTS

906–A. The slope of scarfed joints where laminations are fully stressed shall not be steeper than permitted for slope of grain in the grade of lumber used, except that a slope of scarf flatter than 1 to 12 shall not be required for straight members or curved members where the radius of curvature exceeds 150 times the thickness of lamination.

The slope of scarf shall be in the same general direction as slope of grain.

906–B. If there are end joints in the two exterior laminations they shall be scarfed.

906–C. In members curved to a radius less than 250 t in the portion of laminations stressed to more than 60 percent of allowable working stress, scarfed joints shall be glued, the glue set, and the laminations then dressed to a uniform thickness before they are finally assembled into the member.

906–D. In adjacent laminations and in corresponding laminations located symmetrically with respect to the tension and compression faces of a member, the scarfed end joints of the laminations shall be staggered longitudinally by at least 24 times the thickness of a lamination and butt end joints by at least 40 times (measured center to center of joints).

906–E. For wide members, a lamination may consist of two or more pieces of lumber placed side by side to form the full width of lamination provided that all longitudinal joints in adjacent laminations are staggered at least 1½ inches laterally and preferably more. In width, top and bottom face laminations of the member shall be of one piece or pieces glued together edgewise with excess glue removed from surfaces prior to final assembly into the member.

906–F. For laminations consisting of two or more pieces in width the sum of the widths (parallel to width of lamination) of scarfed or butted end joints in any three adjacent laminations at any given cross-section shall not exceed the overall width of one lamination.

906–G. When stepped-scarf end joints are used, the slope of scarf in fully stressed laminations shall not be steeper than for other scarf joints and any reduction in the effective cross section of the lamination caused by the step shall be taken into consideration in the design.

906–H. A laminated member with scarfed joints properly made and placed shall be designed as a solid member.

906–I. When butt end joints are used, they shall not be assumed to transfer load from one side of the end joint to the other side of the end joint within the same lamination, i. e., the load shall be assumed to be transferred to and carried by the adjacent laminations rather than by the lamination in which the butt joint occurs.

906–J. When laminations are glued over tapered pieces, the taper shall not exceed a slope of 1 in 12.

906–K. The minimum practicable number of end joints of laminations shall occur at any given cross-section of a member. There shall not be more than one end joint in any three successive laminations at a given cross-section where highly stressed.

APPENDIX A

LATERAL DISTRIBUTION OF A CONCENTRATED LOAD

A. Lateral Distribution of a Concentrated Load for Moment

The lateral distribution of a concentrated load for computing bending moment may be determined by the following method (see reference 19, Appendix G):

When a concentrated load at the center of the beam span is distributed to adjacent parallel beams by a wood (plank or laminated strip) or concrete floor slab, the load on the beam nearest the point of application shall be determined by multiplying the load by the following factors:

Kind of floor:	*Load on Critical beam***
2-inch wood	S/4.0
4-inch wood	S/4.5
6-inch wood	S/5.0
Concrete, structurally designed	S/6.0

*S=average spacing of beams in feet.

*In case *S* exceeds the denominator of the factor the load on the two adjacent beams shall be the reactions of the load, with the assumption that the floor slab between the beams acts as a simple beam.

**For more than one traffic lane, see additional data in reference 19, Appendix G.

B. Lateral Distribution of a Concentrated Load for Shear

When the load distribution for moment at the center of a beam is known or assumed to correspond to specific values in the first two columns of Table No. A-1, the distribution to adjacent parallel beams when loaded at or near the quarter point, i. e., the approximate point of maximum shear (see par. 400–D–2–(c)–(3)), shall be assumed to be the corresponding values in the last two columns of Table No. A-1.

TABLE No. A-1—*Distribution in terms of proportion of total load*

Load applied at center of span		Load applied at ¼ point of span	
Center beam	Distribution to side beams	Center beam	Distribution to side beams
1.00	0	1.00	0
.90	.10	.94	.06
.80	.20	.87	.13
.70	.30	.79	.21
.60	.40	.69	.31
.50	.50	.58	.42
.40	.60	.44	.56
.33	.67	.33	.67

APPENDIX B

FORMULAS FOR WOOD COLUMNS WITH SIDE LOADS AND ECCENTRICITY

A. General

The following information is provided for use when more accurate calculation of the maximum direct compression load that can be put upon an eccentrically loaded column or one with a side load is desired.

The most accurate of all the column formulas for the critical load on a long, originally straight, centrally loaded column of uniform cross section is the Euler formula, and for long columns with an eccentric application of load is the secant formula.

The inaccuracies of these formulas are too small to be detected by the ordinary methods of testing such columns and are much smaller than the inaccuracy of calculating the stiffness of wooden beams neglecting the distortions due to shear.

The formulas here presented can be made to have an accuracy fairly comparable to that for the Euler column, but in their simplified form they do not pretend to such accuracy; however, they do have an accuracy well within an acceptable range for most engineering purposes (reference 18, Appendix G).

B. Assumptions

The following assumptions have been made in arriving at the following simplified equations, but normally they change the results but little:

1. The stresses which cause a given deflection as a sinusoidal curve are the same as those for a beam with a uniform side load.

2. For a single concentrated side load the stress under the load can be used, regardless of the position of the load with reference to the length of the column.

3. The stress to use with a system of side loads is the maximum stress due to the system. (With large side loads near each end some slight error on the side of overload will occur.)

4. The equations can be used for solving for P/A with rectangular wood columns with an l/d ratio of 20 or more, provided that for the column between $l/d=20$ and $l/d=K$, that is, when the Euler formula begins to apply, the c is the stress for a centrally loaded column of intermediate length, using the Forest Products Laboratory fourth power parabolic formula.

5. For columns with an l/d ratio of 11 or less, the stress due to deflection of the column may be neglected.

6. Between l/d ratios of 11 and 20 the stress may be assumed to vary as a straight line.

C. Notation

P/A=direct compressive stress in pounds per square inch induced by axial load.

M/S=flexural stress in pounds per square inch induced by side loads.

c=the allowable unit stress in compression parallel to the grain in pounds per square inch that would be permitted for the column if axial compressive stress only existed; that is, the allowable unit stress for the l/d of the column under consideration.

f=the allowable unit stress in flexure in pounds per square inch that would be permitted if flexural stress only existed.

e=eccentricity in inches.

l=length of column in inches.

d=side in inches of a rectangular column, measured in the direction of the side loads.

z=ratio of flexural stress induced by side loads to compressive stress induced by axial end load,

$$\text{i. e., } \frac{M/S}{P/A}$$

D. Formulas

The following formulas, which are for pin-end columns of rectangular cross sections, apply when a member is subjected to both axial compression and moment (from eccentricity or side loads). (For design data on columns loaded axially only, see paragraph 401.) The formulas given are for determining the maximum permissible unit load or stress, P/A or M/S, which is permissible under the conditions of combined loading, i. e., the P/A and M/S induced by loading shall not exceed the values therefor obtained from the formulas. The two or three formulas in any one of the following groups are identical except for the arrangement of the terms and, therefore, any one within the group may be used for the specific condition indicated. The formula to be used is selected on the basis of the ease with which the values desired can be computed from the formula through insertion therein of known or assumed values.

1. Columns having an l/d ratio of 11 or less:

(a) End and Side Loads:

$$\frac{M/S}{f}+\frac{P/A}{c}=1$$

or

$$P/A=\frac{c(f-M/S)}{f}$$

or

$$M/S=\frac{f(c-P/A)}{c}$$

(b) Eccentric Load:

$$\frac{c\left(\frac{6e}{d}\right)}{f+c\left(\frac{6e}{d}\right)}+\frac{P/A}{c}=1$$

or

$$P/A=\frac{cf}{f+c\left(\frac{6e}{d}\right)}$$

(c) Side Load Proportional to End Load:

(A load carried by a chord member of a truss causes an end load in the member which has a proportional relation to the side load causing it.)

$$\frac{z(P/A)}{f}+\frac{P/A}{c}=1$$

or

$$P/A=\frac{cf}{f+zc}$$

or

$$M/S=z(P/A)$$

(d) Combined End Load, Side Loads, and Eccentricity:

$$\frac{M/S+(P/A)\left(\frac{6e}{d}\right)+z(P/A)}{f}+\frac{P/A}{c}=1$$

or

$$P/A=\frac{c(f-M/S)}{f+c\left(\frac{6e}{d}+z\right)}$$

2. Columns having an l/d ratio between $l/d=11$ and $l/d=20$:

Assume that the stress induced by loads varies as a straight line between that for a column having an l/d ratio of 11 and for one having an l/d ratio of 20.

3. Columns having an l/d ratio of 20 or more:

(a) End and Side Loads:

$$\frac{M/S}{f-P/A}+\frac{P/A}{c}=1$$

or

$$P/A=\frac{f+c}{2}-\sqrt{\left(\frac{f+c}{2}\right)^2-c(f-M/S)}$$

or

$$M/S=\frac{(f-P/A)(c-P/A)}{c}$$

(b) Eccentric Load:

$$\frac{c\left(\frac{15e}{2d}\right)}{f-P/A+c\left(\frac{15e}{2d}\right)}+\frac{P/A}{c}=1$$

or

$$P/A=\frac{f+c\left(1+\frac{15e}{2d}\right)}{2}-\sqrt{\left[\frac{f+c\left(1+\frac{15e}{2d}\right)}{2}\right]^2-cf}$$

(c) Side Load Proportional to End Load:

$$\frac{z(P/A)}{f-P/A}+\frac{P/A}{c}=1$$

or

$$P/A=\frac{f+c(1+z)}{2}-\sqrt{\left(\frac{f+c(1+z)}{2}\right)^2-cf}$$

or

$$M/S=z(P/A)$$

(d) Combined End Load, Side Loads, and Eccentricity:

$$\frac{M/S+(P/A)\left(\frac{15e}{2d}\right)+z(P/A)}{f-P/A}+\frac{P/A}{c}=1$$

or

$$P/A=\frac{f+c\left(1+\frac{15e}{2d}+z\right)}{2}-\sqrt{\left[\frac{f+c\left(1+\frac{15e}{2d}+z\right)}{2}\right]^2-c(f-M/S)}$$

E. Columns with Side Brackets

An exact solution of the stresses in a column with end and bracket loads is difficult. The following simple rule for determining loads to be used in the combined loading formulas is safe, and for brackets in the upper quarter of the height of a column is sufficiently accurate.

Instead of using the bracket load P in its actual position, add to the end load on the column an axial end load P equal to the load on the bracket and calculate the bending stress from an assumed side load P', concentrated at the center of the length of the column and determined as follows (See Fig. B-1):

$$P'=3\times\frac{l'}{l}\times\frac{a}{l}P=\frac{3a\,l'\,P}{l^2}$$

in which

P=actual load in pounds on bracket,

P'=assumed horizontal side load in pounds assumed to be placed at center of height of column,

a=horizontal distance in inches from load on bracket to center of column,

l=total length of column in inches,

l'=distance in inches measured vertically from point of application of load on bracket to farther end of column.

Use P' to determine the induced unit flexural stress M/S, as if the column were a beam with a concentrated load P' at midlength. Then combine these stresses with those from other loads and apply the appropriate combined stress formulas previously given under paragraph D of this Appendix.

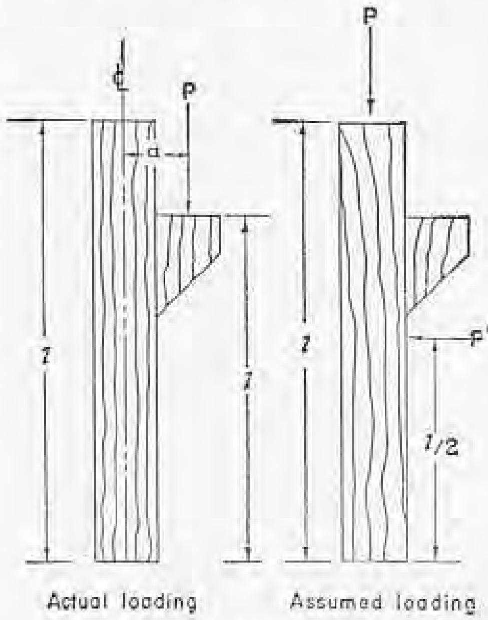


Figure B-1

APPENDIX C

SOLUTION OF HANKINSON FORMULA

A. The allowable unit stresses in compression for lumber and allowable loads for connectors, bolts, and lag screws at an angle of load to grain between 0° and 90° are obtained from the Hankinson formula given in figure C–1.

B. The Hankinson formula is for the condition where the loaded surface is perpendicular to the direction of the load. See Fig. 7, paragraph 405.

C. Where the resultant force is at an angle other than 90° with the surface under consideration, the angle θ is the angle between the direction of grain and the direction of the force component which is perpendicular to the surface.

D. The bearing surface for a connector, bolt, or lag screw is assumed perpendicular to the force. See Fig. 23, paragraph 600–N.

E. For specific applications of the formula, see paragraphs 211–A, 212, 405, 500–N, 600–N, and 702–G.

F. The following table lists $\sin^2\theta$ and $\cos^2\theta$ for various angles of θ.

$\sin^2\theta$	θ	$\cos^2\theta$	$\sin^2\theta$	θ	$\cos^2\theta$
0.00000	0	1.00000	.58682	50	.41318
.00760	5	.99240	.67101	55	.32899
.03015	10	.96985	.75000	60	.25000
.06698	15	.93302	.82140	65	.17860
.11698	20	.88302	.88302	70	.11698
.17860	25	.82140	.93302	75	.06698
.25000	30	.75000	.96985	80	.03015
.32899	35	.67101	.99240	85	.00760
.41318	40	.58682	1.00000	90	.00000
.50000	45	.50000			

The Hankinson formula may be solved graphically through use of the following charts:

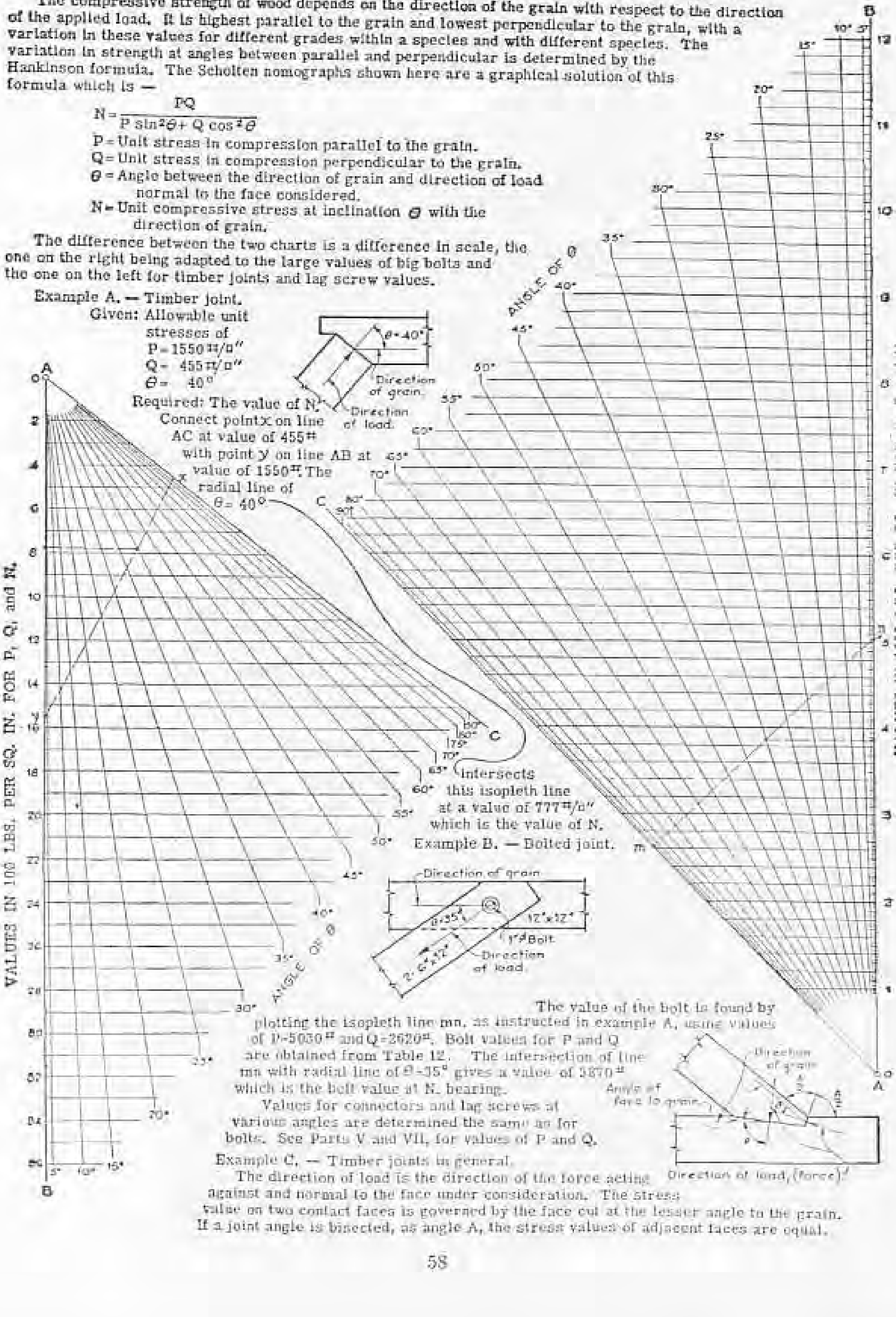
Fig. C-1. — BEARING STRENGTH OF WOOD AT ANGLES TO THE GRAIN (HANKINSON FORMULA)

The compressive strength of wood depends on the direction of the grain with respect to the direction of the applied load. It is highest parallel to the grain and lowest perpendicular to the grain, with a variation in these values for different grades within a species and with different species. The variation in strength at angles between parallel and perpendicular is determined by the Hankinson formula. The Scholten nomographs shown here are a graphical solution of this formula which is —

$$N = \frac{PQ}{P \sin^2\theta + Q \cos^2\theta}$$

P = Unit stress in compression parallel to the grain.
Q = Unit stress in compression perpendicular to the grain.
θ = Angle between the direction of grain and direction of load normal to the face considered.
N = Unit compressive stress at inclination θ with the direction of grain.

The difference between the two charts is a difference in scale, the one on the right being adapted to the large values of big bolts and the one on the left for timber joints and lag screw values.



Example A. — Timber joint.
Given: Allowable unit stresses of
P = 1550 #/□"
Q = 455 #/□"
θ = 40°
Required: The value of N.
Connect point x on line AC at value of 455# with point y on line AB at value of 1550#. The radial line of θ = 40° intersects this isopleth line at a value of 777#/□" which is the value of N.

Example B. — Bolted joint.
The value of the bolt is found by plotting the isopleth line mn, as instructed in example A, using values of P = 5030# and Q = 2620#. Bolt values for P and Q are obtained from Table 12. The intersection of line mn with radial line of θ = 35° gives a value of 3870# which is the bolt value at N. bearing.

Values for connectors and lag screws at various angles are determined the same as for bolts. See Parts V and VII, for values of P and Q.

Example C. — Timber joints in general.
The direction of load is the direction of the force acting against and normal to the face under consideration. The stress value on two contact faces is governed by the face cut at the lesser angle to the grain. If a joint angle is bisected, as angle A, the stress values of adjacent faces are equal.

APPENDIX D

DESIGN OF SECTIONS OTHER THAN RECTANGULAR

A. Form factor formulas for I and box sections and for deep rectangular beams are given in references 2 and 10, Appendix G.

B. In determining bending stresses for structural use, a form factor of .90 was used, corresponding to that of a beam approximately 12 inches in depth. In applying a form factor to standard bending stresses, therefore, the form factor or the bending stress should first be multiplied by 10/9.

C. To determine working stresses in bending and compression, and combinations thereof, for cross-sections other than rectangular, the following procedure should be followed (also see paragraphs 400-C, 401-G, 401-H and 900-E herein):

1. Bending

(a) The form factor for the section should be determined (page 153, reference 2).

(b) The section should be investigated for lateral buckling (page 159, reference 2).

The factor G in the formulas on page 161 may be taken as E/16 (see page 59, reference 2).

2. Compression

(a) For compression members use the Forest Products Laboratory formulas (paragraph 401 herein).

(b) For a section other than rectangular, the numerical value to be used for the least dimension in the column formulas is the least radius of gyration of the section multiplied by 3.46.

(The radius of gyration, r, is the square root of I/A, in which I is the moment of inertia and A is the area. The ratio of the least dimension of a rectangular column to its least radius of gyration is 3.46.)

(c) Investigate the section in question for wrinkling and twisting of outstanding flanges (page 165, reference 2), whether the Euler or fourth power parabola formula is used.

On page 167, reference 2, the "critical half wave length c" is referred to but not evaluated. It is determined by experiment, but its determination is not necessary in applying the formulas for wrinkling and twisting.

3. Combined Bending and Compression

Having determined the allowable working stresses in bending and compression, the allowable stress in combination may be determined by the formulas for wood columns with side loads and eccentricity given in Appendix B.

APPENDIX E

HORIZONTAL SHEAR IN CHECKED BEAMS

A. Shearing strength in a beam is a function of the shearing strength of the species and the extent of shake or checks. In a checked beam, however, there is a greater uniformity of distribution of shearing strength over the unchecked portion than in an unchecked beam, which explains why a checked beam will carry a load for which it would appear to be entirely inadequate from the standpoint of shear.

B. In addition to this, the Forest Products Laboratory of the United States Forest Service, located at Madison, Wisconsin, has determined that in a checked beam the upper and lower halves of the beam carry a large portion of the shear independently of that at the neutral axis, the proportion depending on the distance of the load from a support, varying inversely with the square of the distance, until, with a load close to the support almost the entire shear is carried by the upper and lower halves of the beam. The result is that with a concentrated or moving load the maximum end shear is not attained except when the load is at a distance of usually three or four times the depth of the beam from the support, and at this point approximately one-fifth still is carried by the upper and lower halves of the beam—"two-beam shear action" it is called by the Laboratory.

C. For design formulas, see paragraph 400-D herein.

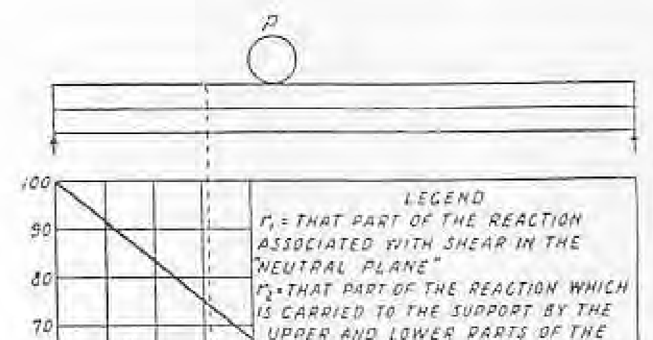


Fig. E-1. A graphical representation of the total single-beam, and two-beam reaction for a beam with a span-height ratio of 12. For a single concentrated load the ordinates to the straight line represent the total reaction; "a" the ordinate in the cross-hatched portion is the single-beam reaction, associated with shear in the neutral plane. The two-beam reaction is represented by "b", that part of the ordinate in the unshaded area. Placing the load at 3.1 times the height of the beam from the support gives the maximum single-beam reaction and is the point at which to place the load for greatest likelihood of failure by shear. For a uniform load over the entire span, the area under the straight line represents the total reaction, the cross-hatched area, the single-beam reaction, and the unshaded area that portion of the reaction which is carried to the support by two-beam action and is not associated with shear in the neutral plane.

APPENDIX F

RECOMMENDED CONSTRUCTION PRACTICES

. Care of Material

1. Lumber shall be so handled and covered as to revent marring, and moisture absorption from snow r rain.

. Foundations

1. Foundations shall be adequate to support the uilding or structure and any required loads, withut excessive or unequal settlement or uplift.

2. For permanent structures it is desirable:

(a) That foundations or piers be of concrete, masonry, wood with an approved preservative treatment, or the heartwood of a durable species;

(b) That the space under the floors of buildings without basements or cellars be ventilated through foundation walls by openings having a net area of not less than 2 square feet for each 25 linear feet of exterior wall;

(c) That a ventilating space of at least one-half inch, preferably more, be provided on sides, tops, and ends of wood members such as girders, beams, or other structural members where surrounded by masonry, or concrete;

(d) That basement and exterior posts of materials other than provided in paragraph B–2–(a) be placed on concrete, masonry or cast-iron base blocks or piers extending at least 2 inches above floor levels or 6 inches above the finished ground level.

(e) That, wherever there is need to take precautions against entry of termites from the ground into the structure, all debris, whether above or below the ground, shall be removed from around foundations and under the structure, and one or more of the following construction practices shall be followed:

(1) Extend foundations at least 12 inches and preferably 18 inches above ground under the building and provide a solid reinforced cement mortar cap 2 inches thick over foundations of unit or hollow block construction. If foundations can be readily inspected for termite shelter tubes, the exterior grade line may be a minimum of 6 inches from the sills or siding.

(2) Place metal termite shields of an approved design at the upper edges of all unit or block foundation walls and piers, and, if not on top, in the sides of all monolithic foundation walls and piers, and around all pipes entering buildings, except that the overhanging portion of the shield may be omitted on exterior surfaces and basement or cellar interiors, which are open to easy occasional inspection. Foundations not easily inspected shall have termite shields set at least 12 inches and preferably 18 inches above the ground.

(3) Where structural lumber is in contact with the soil, or is less than 12 inches from the ground and not protected by termite shields, except for the exterior 6-inch minimum clearance as noted in recommendation in paragraph B–2–(e)–(1), it shall be impregnated with an approved preservative or be the heartwood of a termite resistant species.

(4) Insulate outside steps from the soil by masonry foundations; also insulate steps from buildings or porches by metal shields.

C. Structural Design

1. Consideration shall be given in the design to the possible effect of cross grain dimensional changes which may occur in lumber fabricated or erected in a green condition, i. e., provisions shall be made in the design so that if dimensional changes caused by seasoning to moisture equilibrium occur, the structure will move as a whole, and the differential movement of similar parts and members meeting at joints will be a minimum.

2. When lumber is fabricated green and used in a dry location, application of end sealers to exposed end grain of material while wet is recommended. (See reference 42, Appendix G.)

D. Drainage

1. In exterior structures the design shall be such as to minimize pockets in which moisture can accumulate or adequate caps, drainage and drips shall be provided.

E. Camber

1. Adequate camber in trusses to give proper appearance and to counteract any deflection from

loading should be provided and for connector construction may be estimated from the formula:

$$\Delta = K_1 \frac{L^3}{H} + K_2 \frac{L^2}{H}$$

in which

Δ = recommended camber in inches at center of truss

L = span of truss in feet

H = height of truss in feet at center

K_1 = 0.000032 for any type of truss

K_2 = 0.0028 for flat and pitched trusses, or 0.00063 for bowstring trusses, i. e., trusses without splices in upper chord.

F. Erection

1. Provision shall be made to prevent the overstressing of members or joints during erection.

2. Bolted connections shall be snugged-up but not to the extent of crushing wood under washers.

G. Inspection

1. Provision shall be made for competent inspection of materials and workmanship.

H. Maintenance

1. There shall be competent inspection and tightening of bolts (see par. F-2) in joints of trusses and structural frames.

APPENDIX G

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