MACHINE STRESS-RATED LUMBER: QUALITY CONTROL, AVAILABILITY, SPECIFYING, CODE ACCEPTABILITY

MSR LUMBER-equation format

What is MSR Lumber?

Machine Stress-Rated Lumber (MSR) is dimension lumber that has been evaluated by mechanical stress-rating equipment. The stress-rating equipment measures the stiffness of the material and sorts it into various modulus of elasticity (E) classes.

Research has shown that a direct relationship exists between the bending stiffness of a piece of lumber, its bending strength or modulus of rupture (MOR), and its ultimate tensile strength (UTS).

Since the only way to determine strength values is to actually break the piece, the next best thing is to measure the stiffness, compute the modulus of elasticity (E), and then predict the strength values.

MSR lumber is distinguished from visually stress-graded lumber in that each piece is nondestructively evaluated for bending stiffness and sorted into modulus of elasticity classes.

Following this "E" sorting, each piece must also meet certain visual requirements and daily quality control test procedures for both bending (F_b) and modulus of elasticity (E).

Voluntary Procedures

Because there is a direct relationship between specific gravity values and MSR lumber grades (with higher-strength grades having higher specific gravity values), some MSR lumber producers provide additional daily quality control for specific gravity (SG) and/or tension (F_t), in addition to the mandatory F_b and E testing.

When these additional levels of quality control are provided, the producer may include the appropriate F_t, SG, and specific gravity-related compression perpendicular to grain ($F_{c\perp}$) and horizontal shear (F_v) values on the grade stamp, in addition to F_b and E. MSR producers providing one or more of these additional levels of quality control may choose to limit the number of grades which are subject to F_t and SG testing.

Quality Control

In addition to requiring conformance to the *Western Lumber Grading Rules* for machine rated lumber, the Association and the producers assume the following additional areas of responsibility for quality control:

WWPA

- Certification of machines
- Calibration of test equipment
- Plant use regulations
- Quality inspections
- Product appearance considerations

Producer

- Adherence to WWPA procedures
- Strength level checks every shift
- Constant visual quality checks
- "E" level checks every shift
- Maintenance of detailed test records
- Specific gravity and/or tension level checks every shift, when additional procedures are implemented

Code Acceptability

MSR lumber produced under an approved grading agency's certification and quality control procedures is accepted by regulatory agencies and all major building codes.

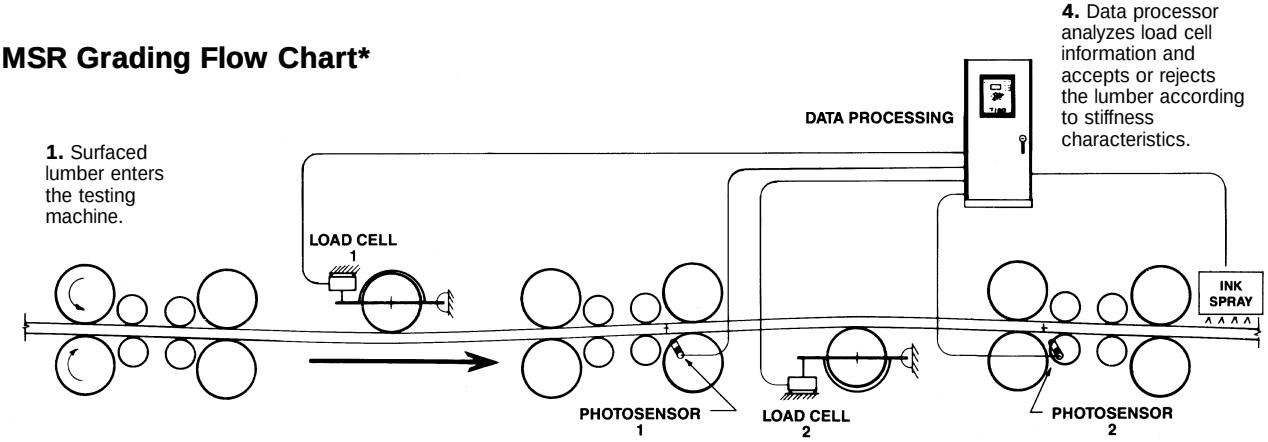
How to Specify MSR

Specifying machine stress-rated lumber is simple because it is generally marketed by strength and stiffness values, F_b and E.

When ordering, specify lumber gradestamped MSR or Machine Rated and list the F_b and corresponding E values.

The only time it is necessary to specify a particular species is when design criteria require a horizontal shear (F_v), specific gravity (SG), or compression perpendicular to grain ($F_{c\perp}$) value associated

MSR Grading Flow Chart*



1. Surfaced lumber enters the testing machine.

2. Mechanical rollers exert bending stress in two directions.

3. Electronic load cells measure resistance to bending and send information to data processing unit.

4. Data processor analyzes load cell information and accepts or rejects the lumber according to stiffness characteristics.

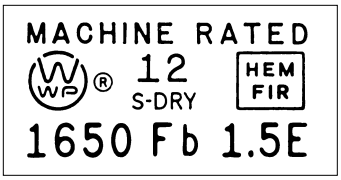
5. Each piece automatically identified with appropriate symbol.

***Continuous Lumber Tester (CLT) Mechanical Schematic**

with a specific species, or when design criteria call for higher specific gravity (and related $F_{c\perp}$ and F_v values) resulting from additional specific gravity quality control.

Grade Stamp Facsimiles

All MSR lumber must be grade-stamped by an American Lumber Standard-approved agency. The grade stamp must include a product designation such as "MSR" or "MACHINE RATED", the registered trademark of the grading agency, the mill number or name, moisture content designation, species designation, and the F_b and E rating. F_t, SG, $F_{c\perp}$ and F_v values may only appear when appropriate additional quality control processes are implemented. The following grade stamp facsimiles are examples only, the exact format may vary as a result of stamping equipment requirements.



Typical MSR Stamp

MSR Stamp with Additional Quality Control

MSR Design Values

Design values are in pounds per square inch. When designing with MSR lumber, the appropriate adjustments in Tables B-G must be applied to the numbers in Table A.

F_b: For any given value of F_b, the average modulus of elasticity (E), may vary depending on species, timber source and other variables. The E value included in the F_b-E grade designations in Table A are those usually associated with each F_b level. Grade stamps may show higher or lower E values (in increments of 100,000 psi), if machine rating indicates the assignment is appropriate. When an E value varies from the designated F_b level in the table, the tabulated F_b, F_t and F_c values associated with the designated F_b value are applicable.

Flatwise Use: The tabulated F_b values are applicable to lumber loaded on edge. When loaded flatwise, refer to Table F, page 4.

$F_{c\perp}$ and F_v: Design values for compression perpendicular to grain ($F_{c\perp}$), and horizontal shear (F_v), are the same as assigned to visually graded lumber of the appropriate species. These average $F_{c\perp}$ and F_v values for Western Lumber are shown in Table 1, for your convenience, followed by explanations of deriving $F_{c\perp}$ and F_v when specific gravity is tested and quality controlled (Tables 1A and 1B).

(Refer to the *WWPA Product Use Manual*, *WWPA Size-Adjusted Values* or the *Western Lumber Grading Rules* for complete design value information on visually-graded lumber.)

DESIGN VALUES — **TABLE A**
MACHINE STRESS-RATED LUMBER
2″ and less in thickness, 2″ and wider
Use with appropriate Adjustments in Tables B through G

Grade Designation	Extreme Fiber Stress in Bending F_b Single	Modulus of Elasticity E	Tension Parallel to Grain F_t	Compression Parallel to Grain F_c
2850 Fb-2.3E	2850	2,300,000	2300	2150
2700 Fb-2.2E	2700	2,200,000	2150	2100
2550 Fb-2.1E	2550	2,100,000	2050	2025
2400 Fb-2.0E	2400	2,000,000	1925	1975
2250 Fb-1.9E	2250	1,900,000	1750	1925
2100 Fb-1.8E	2100	1,800,000	1575	1875
1950 Fb-1.7E	1950	1,700,000	1375	1800
1800 Fb-1.6E	1800	1,600,000	1175	1750
1650 Fb-1.5E	1650	1,500,000	1020	1700
1500 Fb-1.4E	1500	1,400,000	900	1650
1450 Fb-1.3E	1450	1,300,000	800	1625
1350 Fb-1.3E	1350	1,300,000	750	1600
1200 Fb-1.2E	1200	1,200,000	600	1400
900 Fb-1.0E	900	1,000,000	350	1050

REPETITIVE MEMBER FACTOR (C_r) — TABLE B
Apply to Size-adjusted F_b

Where 2″ to 4″ thick lumber is used repetitively, such as for joists, studs, rafters, and decking, the pieces side by side share the load and the strength of the entire assembly is enhanced. Therefore, where three or more members are adjacent or are not more than 24″ on center and are joined by floor, roof, or other load distributing elements, the F_b value can be increased 1.15 for repetitive member use.

Repetitive Member Use
$F_b \times 1.15 F_b$

HORIZONTAL SHEAR ADJUSTMENT (C_H) — TABLE C

Apply to F_V Values

Horizontal shear values published in Table 1 are based upon the maximum degree of shake, check, or split that might develop in a piece. When the actual size of these characteristics is known, the following adjustments may be taken.

2″ Thick Lumber

For convenience, the table below may be used to determine horizontal shear values for any grade of 2″ thick lumber in any species when the length of split or check is known and any increase in them is not anticipated.

3″ and Thicker Lumber

Horizontal shear values for 3″ and thicker lumber also are established as if a piece were split full length. When specific lengths of splits are known and any increase in them is not anticipated, the following adjustments may be applied.

When length of split on wide face is:	Multiply Tabulated F_V value by:	When length of split on narrow face is:	Multiply Tabulated F_V value by:
No split	2.00	No split	2.00
1/2 of wide face	1.67	1/2 of narrow face	1.67
3/4 of wide face	1.50	3/4 of narrow face	1.50
1 of wide face	1.33	1 of narrow face	1.33
1 1/2 or more of wide face	1.00	1 1/2 or more of narrow face	1.00

ADJUSTMENTS FOR COMPRESSION PERPENDICULAR TO GRAIN ($C_{C\perp}$) — TABLE D

For Deformation Basis of 0.02″
Apply to $F_{C\perp}$ Values

Design values for compression perpendicular to grain ($F_{C\perp}$) are established in accordance with the procedures set forth in ASTM Standards D 2555 and D 245. ASTM procedures consider deformation under bearing loads as a serviceability limit state comparable to bending deflection because bearing loads rarely cause structural failures. Therefore, ASTM procedures for determining compression perpendicular to grain values are based on a deformation of 0.04″ and are considered adequate for most classes of structures. Where more stringent measures need to be taken in design, the following formula permits the designer to adjust design values to a more conservative deformation basis of 0.02″:

$$Y_{02} = 0.73\, Y_{04} + 5.60$$

Example:

Douglas Fir-Larch: Y_{04} = 625 psi

Y_{02} = 0.73 (625) + 5.60 = 462 psi

AVERAGE MEAN-BASED $F_{C\perp}$ AND F_V DESIGN VALUES FOR WESTERN DIMENSION LUMBER — TABLE 1

2” to 4” thick by 2” & wider
Assigned to MSR lumber and/or visually graded lumber (effective from 9/91)

Species Grouping	Compression Perpendicular to Grain $F_{C\perp}$	Horizontal Shear F_V
Douglas Fir-Larch	625	95
Douglas Fir-South	520	90
MSR Engelmann Spruce-Lodgepole Pine		
1650 Fb & higher	555	85
1500 Fb & lower	375	70
Hem-Fir	405	75
Spruce-Pine-Fir (South)	335	70
Western Woods	335	70

DERIVING COMPRESSION PERPENDICULAR TO GRAIN VALUE ($F_{C\perp}$) — TABLE 1A

For MSR lumber subjected to specific gravity (SG) testing and quality control

When a grade of MSR lumber is qualified by testing and daily quality control for specific gravity (SG), the allowable compression perpendicular to grain ($F_{C\perp}$) value may be calculated (rather than drawn from published tables). When the SG value is included in the grade stamp, the $F_{C\perp}$ may be calculated by the following research-based formula which is approved by the American Lumber Standard Board of Review and provided in the *Western Lumber Grading Rules*.

$F_{C\perp}$ = (225.4 x SG) - 480

$F_{C\perp}$ values, determined by the above equation, will be based on a 0.04-inch deformation limit and are for the design of most structures.

Examples of the resulting $F_{C\perp}$ (0.04) values for standard SG relationships would be as follows:

SG =.50
$F_{C\perp}$ = (2252.4 x .50) - 480
$F_{C\perp}$ = **645** psi (rounded from 646.2)

SG = .47
$F_{C\perp}$ = (2252.4 x .47) - 480
$F_{C\perp}$ = **580** psi (rounded from 578.6)

SG = .43
$F_{C\perp}$ = (2252.4 x .43) - 480
$F_{C\perp}$ = **490** psi (rounded from 488.5)

DERIVING HORIZONTAL SHEAR VALUE (F_V) — TABLE 1B

For MSR lumber subjected to specific gravity (SG) testing and quality control

When a grade of MSR lumber is qualified by testing and daily quality control for specific gravity (SG), the allowable horizontal shear (F_V) value may be calculated (rather than drawn from published tables). When the SG value is included in the grade stamp, the Fv may be calculated using the following research-based formula which is approved by the American Lumber Standard Board of Review and provided in the *Western Lumber Grading Rules*.

F_V = 20.6 + (136.08 x SG)

Once the F_V has been calculated, it is subject to the adjustments for wide and narrow face splits, as provided in Table C. Examples of resulting F_V values for standard SG relationships would be as follows:

SG =.50
F_V = 20.6 + (136.08 x .50)
F_V = **90** psi (rounded to nearest 5 from 88.6)

SG = .47
F_V = 20.6 + (136.08 x .47)
F_V = **85** psi (rounded from 84.6)

SG = .43
F_V = 20.6 + (136.08 x .43)
F_V = **80** psi (rounded from 79.1)

DURATION OF LOAD ADJUSTMENT (C_D) — TABLE E

Apply to Size-adjusted Values

Wood has the property of carrying substantially greater maximum loads for short durations than for long durations of loading. Tabulated design values apply to normal load duration. (Factors do not apply to MOE or $F_{c\perp}$)

Load Duration	Factor
Permanent	0.9
Ten Years (Normal Load)	1.0
Two Months (Snow Load)	1.15
Seven Day	1.25
One Day	1.33
Ten Minutes (Wind and Earthquake Loads)	1.6
Impact	2.0

Confirm load requirements with local codes. Refer to model building codes or the *National Design Specification* for high-temperature or fire retardant-treated adjustment factors.

FLAT USE FACTORS (C_{fu}) — TABLE F

Apply to Size-adjusted F_b

Nominal Width	Nominal Thickness	
	2″ & 3″	4″
2″ & 3″	1.00	—
4″	1.10	1.00
5″	1.10	1.05
6″	1.15	1.05
8″	1.15	1.05
10″ & wider	1.20	1.10

WET USE FACTORS (C_M) — TABLE G

Apply to Size-adjusted Values

The design values shown in the accompanying tables are for routine construction applications where the moisture content of the wood does not exceed 19%. When end use conditions are such that the moisture content of dimension lumber will exceed 19%, the Wet Use Adjustment Factors below are recommended.

	Property	Adjustment Factor
F_b	Extreme Fiber Stress in Bending	0.85*
F_t	Tension Parallel to Grain	1.0
F_c	Compression Parallel to Grain	0.8**
F_v	Horizontal Shear	0.97
$F_{c\perp}$	Compression Perpendicular to Grain	0.67
E	Modulus of Elasticity	0.9

*Wet Use Factor 1.0 for size-adjusted F_b not exceeding 1150 psi.

**Wet Use Factor 1.0 for size-adjusted F_c not exceeding 750 psi.

ADJUSTMENTS FOR MSR LUMBER — Checklist

- ☐ Repetitive Member Use Factor (C_r) — Table B
- ☐ Duration of Load (C_D) — Table E
- ☐ Horizontal Shear (C_H) — Table C
- ☐ Flat Use Factor (C_{fu}) — Table F
- ☐ Compression Perpendicular ($C_{c\perp}$) — Table D
- ☐ Wet Use Factor (C_M) (only when appropriate) — Table G

Additional Information

For additional information on MSR lumber contact WWPA's Quality Services or Technical Services divisions:

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