WEST COAST LUMBER INSPECTION BUREAU

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COMPARING MACHINE STRESS RATED AND VISUALLY GRADED LUMBER IN WALLS AND COLUMNS

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West Coast Lumber Inspection Bureau

Technical Report

Comparing MSR and Visually Graded Lumber When Used in Walls

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INTRODUCTION

There are two grading systems by which structural lumber is produced under West Coast Lumber Inspection Bureau's Standard Grading Rules No. 17, visually graded and Mechanically Stressed Rated (MSR) lumber. Both offer an assortment of grades with distinct mechanical properties. These sets of properties do not match up directly across the two grading systems, thus requiring some comparison when specifying structural lumber.

Under the American Lumber Standard Committee (ALSC), approved rules-writing agencies assign stress lumber grades six design properties: bending (F_b), tensile-parallel to grain (F_t), compression parallel-to-grain (F_c//), shear (F_v), and compression perpendicular-to-grain strength (F_{cz}), plus the modulus of elasticity (MOE), an index of stiffness. These properties let designers determine which lumber grade to specify for a given application. A listing of these unadjusted single-member properties is shown in Table 1 for selected grades.

The purpose of this paper is to show that even though a particular MSR lumber grade might have a lower MOE mean value than a visual grade, it may perform as well in a column or wall application as a visual grade. As an example, MSR 1350f-1.3E has an assigned mean MOE that is 400,000 psi lower than No. 1 Douglas fir [1,300,000 psi for the 1350f-1.3E compared to 1,700,000 for the No. 1 Douglas fir]. At first glance it would appear that since the average grade stiffness is lower for the 1350f-1.3E grade than the No. 1, there would be a tendency for column buckling to occur under a lower load. However, the 1350f-1.3E grade actually has an adjusted compressive strength that is slightly higher than the No. 1 grade. This is due to higher adjustment factors assigned MSR in the 1991 National Design Specification (NDS) column formula.

An MSR grade with a mean MOE lower than a visual grade's mean MOE may still perform as well in a column or wall application. The comparative performance will depend upon the loading. In some cases, the load may be only in compression; in many other cases some lateral load, such as wind, must be considered. Further analysis is needed to determine what MSR grade would be an appropriate alternate under these conditions.

This note illustrates, through typical loading situations, how MSR grades compare with visual grades. Actual design applications must be assessed by the design engineer.

DIFFERENCES BETWEEN MSR AND VISUALLY GRADED LUMBER

Specification of a lumber grade for an end-use is based on the previously mentioned properties (Table 1). Comparisons between grades from different grading systems, such as MSR and visual, often can be made on the basis of these tabulated properties. A significant exception to this involves performance of a column, such as a wall stud. When this type of end-use is anticipated, additional comparisons are required.

Column performance is a function of the grade F_c//, MOE, the variability of MOE, the column geometry (R_Q/d) and load assumptions. Initially, this discussion will address a simple column with no lateral load.

The mean MOE and MOE variability determines the resistance of a column to buckling. When comparing MSR with visual grades, it is important to note that MSR lumber has enhanced resistance to buckling, relative to visual lumber, because of tighter control of MOE in the MSR process. This is reflected in an adjusted compression-parallel strength (F_c'), the property used to determine the design load capacity of the column. Table 2 shows the calculated F_c' for various MSR and visual grades at a wall height of 96".

The variation in MOE is described by the Coefficient of Variation (COV). The lower the COV, the tighter a grade population is clustered around the mean MOE. Currently, the assumed COV for design in the NDS and Uniform Building Code is 11% for MSR and 25% for visually graded lumber. The different Euler buckling coefficients, K_{CE}, used in determining the effective column strength, F_c', reflect the differences in COV. K_{CE} for visual grades is 0.3; for MSR, 0.418.

The low COV for stiffness is due to the grading process which measures the stiffness of each piece. The stiffness COV of MSR lumber can be controlled by adjusting the grading machine settings for each grade. MSR grades also have limited visual restrictions, while visual grades, as the name indicates, are based solely on visual limitations.

In the MSR process, the lumber is also visually graded once it has passed through the nondestructive grading machine. The purpose of visually grading is to limit certain strength-reducing characteristics, primarily edge knots. Certified lumber graders examine each piece for characteristics as specified in the appropriate grade rule book.

Visually graded lumber is separated into various structural grades by a certified lumber grader who examines each piece and assigns a grade based on natural characteristics (knots, slope of grain, splits, etc.) and manufacturing imperfections.

Most of the mechanical properties of visually graded dimension lumber are based on the results of the In-Grade program that was conducted in North America from 1977 to 1985. The program included testing over 70,000 pieces of graded lumber to determine the MOE, F_b, F_t, and F_c//. The data from this program was used to determine new allowable property values that were published in Standard Grading Rules No. 17.

The mechanical properties of MSR lumber are based on laboratory tests, and on qualification and quality control tests at mills. In order to grade stamp MSR lumber, a mill must have each proposed grade pass the required qualification tests. Once a grade has been approved, the mill must perform daily quality control for each grade (and each size) it produces. A mill must also have a written quality control program that is approved by the grading agency. MSR lumber was first introduced commercially in 1963.

Both MSR and visual grading systems conform with ALSC policies and are recognized by the National Grading Rule Committee in accordance with the United States Department of Commerce Voluntary Product Standard, PS 20-70.

SIMPLE COLUMN DESIGN IN THE 1991 NDS

The design of simple columns (no lateral load) is covered in Sections 3.6 and 3.7 of the 1991 Edition of the NDS. In order to determine a column's carrying capacity, such as in a wall, the effective column strength, F_c', must be calculated. The 1991 NDS specifies adjustment factors that are applied to the grade rule-listed F_c// in order to calculate the F_c'. These factors account for load duration, temperature, wet service, size, and column stability. The designer must choose which are appropriate to use.

A major element in the calculation of F_c' is the column stability factor, C_p. The C_p is a function of the MOE, the Euler buckling coefficient, the column geometry, and the F_c//, as well as the design factors noted above*. As F_c' is calculated for both visual and MSR grades, there is a relative gain for MSR. This gain has been provided in versions of the

*For this case of a sheathed wall, R_Q is taken as the length of the framing (in this case, wall height is assumed equal to framing height); d is the width of the lumber (e.g., 3.5 inches for a 2x4).

NDS starting with the 1973 edition. The different variability levels of MOE for MSR and visually graded lumber were first recognized in the 1977 NDS.

Table 2 illustrates F_c' values for visual and MSR grades of two species groups, Douglas fir and HEM-FIR, both 2x4 and 2x6. The gains in F_c' for MSR relative to visually graded lumber are due to a higher stability factor for such materials having a stiffness COV less than or equal to 11%. As an illustration, Table 3 shows the C_p and F_c' for two grades, 1350f-1.3E MSR and No. 1 (Douglas Fir and HEM-FIR), when varying the column height.

EXAMPLE FOR 8' WALL HEIGHT

For the purpose of an example, a column effective length was set at 96 inches, and 2 x 4 and 2 x 6 lumber was used. When lateral support, such as sheathing, is applied along the 2" direction, the C_p is calculated for the width, 3.5" or 5.5" in this case. The R_Q/d values for the 2x4 and 2x6 are 27.43 and 17.45, respectively.

The difference in the calculated F_c' can be shown by comparing the results obtained from two sizes and grades; 2x4 and 2x6 No. 1 (Douglas fir) visual and 1350f-1.3E MSR. The mechanical properties and calculated C_p factors for a load duration factor of 1.00 are as follows:

Property	Douglas fir No. 1 (2x4)	Douglas fir No. 1 (2x6)	All species 1350f-1.3E
F_b, psi	1,500	1,300	1,350
F_t, psi	1,010	875	750
F_c//, psi	1,725	1,650	1,600
MOE, 10^6 psi	1.7	1.7	1.3
C_p	0.365	0.707	0.727 (2x6) 0.399 (2x4)

If the remaining adjustment factors (wet service and temperature) are set equal to 1.0, the F_c' will be:

	2x4		2x6	
Property	D.fir No. 1	All species 1350f-1.3E	D.fir No. 1	All species 1350f-1.3E
F_c', psi	608	638	1128	1163

Note: A framing height of 96" yields an R_Q/d of 64 in the plane of the wall, the 2" direction. The 1991 NDS and 1991 Uniform Building Code (UBC) limit the R_Q/d ratio to 50; therefore, an unsupported 2x4 column would not be allowed in this application. Lateral support by sheathing restricts the buckling calculation to the depth of the member, in this case the 3.5" and 5.5" widths.

WALL DESIGN WITH COMBINED VERTICAL COMPRESSION & LATERAL LOADS

Wall design with combined vertical and lateral loads is a more complex situation in which it is necessary to incorporate allowable bending stress, F_b, in addition to the factors previously discussed. The governing design equation, NDS eq. 3.9.3, has two terms in this case and their sum must be less than or equal to unity.

$$(f_c/F_c')^2 + f_b/F_b'(1-f_c/F_{CE}) \# 1 \qquad \text{NDS eq. 3.9.3}$$

f_c and f_b are wall framing compression and bending stresses respectively. F_c' and F_b' are corresponding allowable stresses. F_{CE} is the Euler column stress on the basis of member depth parallel to the lateral load direction. An additional constraint given with this equation requires that $f_c < F_{CE}$. It is assumed that attached wall sheathing prevents buckling in the plane of the wall.

Where uplift due to wind is an important design consideration, the wall design may also require addressing combined tension and bending forces (NDS Section 3.9). This report is limited to combined vertical compression and lateral loads.

As previously noted, both F_{CE} and F_c' are influenced by variational control in MOE thus using higher adjustment factors for MSR. F_c' is also influenced by the applicable load duration factor for both MSR and visually graded lumber. F_b' is adjusted for load duration and by a repetitive member factor if the wall framing are suitably sheathed and spacing is 24" o.c. or less.

As in the simpler case presented earlier, the relative performance of MSR and visually rated lumber for a specific application cannot be judged only on the basis of tabulated allowable values; NDS eq. 3.9.3 must be applied. An example comparison of an MSR and visual grade is given in complete detail in the Appendix.

Some regulatory jurisdictions require that deflection of the wall framing under lateral load be limited to a value such as R/240. If the framing stays within this limit at design lateral load, vertical load may be applied until NDS eq. 3.9.3 reaches its limit. It should be noted that the MOE used in the lateral deflection calculations is the tabulated average value and contemporary practice gives no recognition of the more controlled bending stiffness of MSR members.

In either case, deflection limit or not, NDS eq. 3.9.3 can be set equal to one and solved for the maximum axial stress, f_c, that can accompany the bending stress, f_b, produced by the lateral load. This leads to determination of a maximum vertical wall load for given cases of framing grade, wall height, lateral load, load duration and spacing. Comparison of the maximum vertical load capacities leads to case-by-case determination of which MSR grades can be substituted for visual grades. Table 4, 5 and 6 give the results of such comparisons for given sheathed wall cases in which R/240 deflection limitations were also imposed.

CONCLUSION

Piece by piece measurement and control of MOE in MSR lumber gives a design advantage in compression members. This enables MSR lumber having a lower tabulated average MOE value to substitute for visually graded lumber with higher tabulated averages. For example, cases are found where MSR 1350f-1.3E lumber will perform as well or better than No. 1 Douglas fir which has a tabulated MOE of 1.7 million psi.

Matching cases for substitution of MSR are not simply identifiable from tables of allowable lumber property values. It is necessary to process case situations through the required design equations to establish equivalence. The 1991 National Design Specification provides the basis for examination under compressive and combined compressive and bending loads.

In common applications of interior walls with a 5 psf lateral load and of exterior walls with snow or with wind and a R/240 deflection criteria, many MSR grades are shown to be inter-changeable with visual grades. In all uses examined, Douglas fir 1650f-1.5E MSR will perform equal to Douglas fir visual grade #1 & Btr. Other grade level substitutions may be even more appropriate and efficient.

ENGINEERING AIDS

To assist in making a comparison between grades for wall framing, the WCLIB has available a tabulation of size-adjusted allowable properties for both visual and MSR grades of lumber and standardized forms for calculating the interaction equation following NDS 1991. These standardized forms are also available on disc for PC compatible.

REFERENCES

American Forest and Paper Association (AFPA). 1991. National Design Specification for Wood Construction. Washington, D.C.
[originally issued by the National Forest Products Association, dated 1991a]

International Conference of Building Officials (ICBO). 1991. Uniform Building Code. Whittier, CA.

West Coast Lumber Inspection Bureau (WCLIB). 1991. Allowable Property Values for Western Softwood Species. Portland, OR.

West Coast Lumber Inspection Bureau (WCLIB). 1991. Standard Grading Rules No. 17. Portland, OR.

TABLE 1
SINGLE MEMBER PROPERTIES
OF SELECTED GRADE OF DOUGLAS FIR AND HEM-FIR*

MSR GRADES

All Species All Sizes	MOE 10^6 psi	Extreme Fiber In Bending psi, F_b	Tension Parallel to Grain psi, F_t	Compression Parallel to Grain psi, F_c//
2100-1.8	1.8	2100	1575	1875
1800-1.6	1.6	1800	1175	1750
1650-1.6	1.6	1650	1175	1700
1650-1.5	1.5	1650	1020	1700
1500-1.4	1.4	1500	900	1650
1350-1.3	1.3	1350	750	1600
1250-1.4	1.4	1250	800	1475
1200-1.2	1.2	1200	600	1400

VISUAL GRADES

D.Fir 2x4				
Sel. Str.	1.9	2175	1500	1955
1 & Btr.	1.8	1725	1160	1725
No. 1	1.7	1500	1010	1665
No. 2	1.6	1310	860	1495
Stud	1.4	740	495	865
D.Fir 2x6				
Sel. Str.	1.9	1885	1300	1870
1 & Btr.	1.8	1495	1005	1650
No. 1	1.7	1300	875	1595
No. 2	1.6	1135	745	1430
Stud	1.4	675	450	825
Hem-Fir 2x4				
Sel. Str.	1.6	2100	1350	1725
1 & Btr.	1.5	1575	1050	1550
No. 1	1.5	1425	900	1495
No. 2	1.3	1275	750	1435
Stud	1.2	740	440	840
Hem-Fir 2x6				
Sel. Str.	1.6	1820	1170	1650
1 & Btr.	1.5	1365	910	1485
No. 1	1.5	1235	780	1430
No. 2	1.3	1105	650	1375
Stud	1.2	675	400	800

*WCLIB, Rules 17. For shear and compression perpendicular-to-grain see Rules 17 para. 200 for visual grades, para. 206 for MSR.

FRAMING MEMBER SIZE

	NOMINAL Depth(d)	ACTUAL, INCHES* Thickness(b)
2x4	3.5	1.5
2x6	5.5	1.5

*Dry Size

Form 1-11-93

TABLE 2

F_c' OF SELECTED MSR AND VISUAL LUMBER GRADES

MSR GRADE ALL SPECIES	MOE 10^6 psi	2x4 F_c' psi	2x6 F_c' psi
2100-1.8	1.8	857	1,457
1800-1.6	1.6	768	1,335
1650-1.6	1.6	765	1,310
1650-1.5	1.5	726	1,280
1500-1.4	1.4	681	1,223
1350-1.3	1.3	638	1,163
1250-1.4	1.4	668	1,141
1200-1.2	1.2	584	1,042

SPECIES: DOUGLAS FIR

VISUAL GRADE	MOE 10^6 psi	2x4 F_c' psi	2x6 F_c' psi
Sel Str	1.9	684	1,292
1 & Btr	1.8	642	1,180
No. 1	1.7	608	1,128
No. 2	1.6	568	1,034

SPECIES: HEM-FIR

VISUAL GRADE	MOE 10^6 psi	2x4 F_c' psi	2x6 F_c' psi
Sel Str	1.6	579	1,113
1 & Btr	1.5	540	1,023
No. 1	1.5	538	1,004
No. 2	1.3	472	915

NOTES: Wall height is 96" (framing height is 96")
Lateral support in the plane of the wall.
The load duration factor is 1.0.

TABLE 3

COMPARISON OF F_c' AND C_p FOR
SELECTED MSR AND VISUAL LUMBER GRADES

WALL HEIGHT ft.	1350f-1.3E MSR C_p	1350f-1.3E MSR F_c' psi	No. 1 D. FIR C_p	No. 1 D. FIR F_c' psi	No. 1 HEM-FIR C_p	No. 1 HEM-FIR F_c' psi
2x6, WITH LATERAL SUPPORT						
8	0.727	1,163	0.707	1,128	0.702	1,004
10	0.566	905	0.543	866	0.537	767
12	0.430	689	0.410	653	0.404	578
14	0.331	530	0.314	501	0.310	443
16	0.260	417	0.246	393	0.243	347
2x4, WITH LATERAL SUPPORT						
8	0.399	638	0.365	608	0.360	538
10	0.269	431	0.244	407	0.241	360
12	0.192	306	0.173	289	0.171	255
14	0.143	228	0.129	215	0.127	190

NOTES: Lateral support applied in the plane of the wall.
The column stability factor, C_p, was determined by Eq. 3.7-1, 1991 NDS. Wall framing is taken equal to the wall height.
The load duration factor is 1.0.

TABLE 4

MSR SUBSTITUTES FOR LISTED VISUAL GRADES FOR
INTERIOR WALL APPLICATIONS*

VISUAL GRADES		MINIMUM MSR GRADE - ALL SPECIES		
		2" X 6" LUMBER - 24" OC		
		WALL HEIGHT		
SPECIES	GRADE	8'	10'	12'
Douglas Fir	Select Structural	1650f-1.6E	1650f-1.5E	1650f-1.5E
	No. 1 & Better	1500f-1.4E	1250f-1.4E	1250f-1.4E
	No. 1	1250f-1.4E	1250f-1.4E	1250f-1.4E
	No. 2	1200f-1.2E	1200f-1.2E	1200f-1.2E
HEM-FIR	Select Structural	1250f-1.4E	1250f-1.4E	1250f-1.4E
	No. 1 & Better	1200f-1.2E	1200f-1.2E	1200f-1.2E
	No. 1	1200f-1.2E	1200f-1.2E	1200f-1.2E
	No. 2	1200f-1.2E	1200f-1.2E	1200f-1.2E
		2" X 4" LUMBER - 16" OC		
Douglas Fir	Select Structural	1650f-1.5E	1650f-1.5E	1650f-1.5E
	No. 1 & Better	1500f-1.4E	1500f-1.4E	1500f-1.4E
	No. 1	1350f-1.3E	1350f-1.3E	1350f-1.3E
	No. 2	1200f-1.2E	1200f-1.2E	1350f-1.3E
HEM-FIR	Select Structural	1350f-1.3E	1350f-1.3E	1500f-1.4E
	No. 1 & Better	1200f-1.2E	1200f-1.2E	1350f-1.3E
	No. 1	1200f-1.2E	1200f-1.2E	1200f-1.2E
	No. 2	1200f-1.2E	1200f-1.2E	1200f-1.2E

*This table applies to 8' to 12' wall heights with sheathing or other lateral support in the plane of the wall. The load duration factor is 1.00. A lateral load of 5 psf is assumed. Lateral deflection is limited to R/240. Wall framing is equal to wall height.

[Note: This table was prepared by calculating the maximum vertical wall load for each of the visual grades shown in the GRADE column. Similar calculations were carried out for MSR grades. A case-by-case comparison was made to determine the minimum MSR grade that would equal or exceed the maximum vertical load capacity of each visual grade.]

TABLE 5

MSR SUBSTITUTES FOR LISTED VISUAL GRADES IN
WALL APPLICATIONS UNDER A SNOW LOAD*

VISUAL GRADES		MINIMUM MSR GRADE - ALL SPECIES		
		2" X 6" LUMBER - 24" OC		
		WALL HEIGHT		
SPECIES	GRADE	8'	10'	12'
Douglas Fir	Select Structural	1650f-1.5E	1650f-1.5E	1500f-1.4E
	No. 1 & Better	1500f-1.4E	1250f-1.4E	1250f-1.4E
	No. 1	1250f-1.4E	1250f-1.4E	1250f-1.4E
	No. 2	1200f-1.2E	1200f-1.2E	1200f-1.2E
HEM-FIR	Select Structural	1250f-1.4E	1250f-1.4E	1200f-1.2E
	No. 1 & Better	1200f-1.2E	1200f-1.2E	1200f-1.2E
	No. 1	1200f-1.2E	1200f-1.2E	1200f-1.2E
	No. 2	1200f-1.2E	1200f-1.2E	1200f-1.2E
		2" X 4" LUMBER - 16" OC		
Douglas Fir	Select Structural	1500f-1.4E	1500f-1.4E	1500f-1.4E
	No. 1 & Better	1500f-1.4E	1350f-1.3E	1350f-1.3E
	No. 1	1350f-1.3E	1350f-1.3E	1350f-1.3E
	No. 2	1200f-1.2E	1200f-1.2E	1200f-1.2E
HEM-FIR	Select Structural	1200f-1.2E	1200f-1.2E	1200f-1.2E
	No. 1 & Better	1200f-1.2E	1200f-1.2E	1200f-1.2E
	No. 1	1200f-1.2E	1200f-1.2E	1200f-1.2E
	No. 2	1200f-1.2E	1200f-1.2E	1200f-1.2E

*This table applies to 8' to 12' wall heights with sheathing or other lateral support in the plane of the wall. A load duration factor of 1.15 is used for snow. No lateral load is applied. Wall framing is equal to wall height.

[Note: This table was prepared by calculating the maximum vertical wall load for each of the visual grades shown in the GRADE column. Similar calculations were carried out for MSR grades. A case-by-case comparison was made to determine the minimum MSR grade that would equal or exceed the maximum vertical load capacity of each visual grade.]

TABLE 6

MSR SUBSTITUTES FOR LISTED VISUAL GRADES IN
WALL APPLICATIONS UNDER COMBINATIONS OF
AXIAL LOAD AND WIND LOADS UP TO 20 PSF*

VISUAL GRADES — MINIMUM MSR GRADE - ALL SPECIES

2" X 6" LUMBER - 24" OC

		WALL HEIGHT		
SPECIES	GRADE	8'	10'	12'
Douglas Fir	Select Structural	1650f-1.5E	1650f-1.5E	1650f-1.5E
	No. 1 & Better	1500f-1.4E	1500f-1.4E	1650f-1.5E
	No. 1	1250f-1.4E	1250f-1.4E	1650f-1.5E
	No. 2	1200f-1.2E	1200f-1.2E	1650f-1.5E
HEM-FIR	Select Structural	1250f-1.4E	1250f-1.4E	1650f-1.5E
	No. 1 & Better	1200f-1.2E	1200f-1.2E	1650f-1.5E
	No. 1	1200f-1.2E	1200f-1.2E	1650f-1.5E
	No. 2	1200f-1.2E	1200f-1.2E	**

2" X 4" LUMBER - 16" OC

SPECIES	GRADE	8'	10'	12'
Douglas Fir	Select Structural	1800f-1.6E	**	**
	No. 1 & Better	1500f-1.4E	**	**
	No. 1	1350f-1.3E	**	**
	No. 2	1350f-1.3E	**	**
HEM-FIR	Select Structural	1500f-1.4E	**	**
	No. 1 & Better	1350f-1.3E	**	**
	No. 1	1200f-1.2E	**	**
	No. 2	1200f-1.2E	**	**

*This table applies to wall heights with sheathing or lateral support in the plane of the wall. A load duration factor of 1.6 for wind is used; a 20 psf wind load is applied; lateral deflection is limited to R/240. Wall framing is equal to wall height.

**Substitution is irrelevant since the visual grades shown exceed the R/240 deflection limit at 20 psf.

[Note: This table was prepared by calculating the maximum vertical wall load for each of the visual grades shown in the GRADE column. Similar calculations were carried out for MSR grades. A case-by-case comparison was made to determine the minimum MSR grade that would equal or exceed the maximum vertical load capacity of each visual grade.]

EXAMPLE COMPARISON OF MSR AND VISUAL GRADES
IN WALL FRAMING

The example wall is 10 ft. (120 in.) high with adequate sheathing and framing end fixation to provide full lateral support in bending.

The beam stability factor C_L = 1.0

Length of framing members for both compression and bending calculations is 4-1/2 inches less than overall wall height to allow for two upper plates and one lower plate.

L = 120 - 4.5 = 115.5 in

The wall is subjected to a vertical compression load of 2400f plf and a lateral wind load of 20 psf.

The load duration factor C_D = 1.6

Wall framing is nominal 2x6 spaced 24 in. o.c.

The bending repetitive member factor C_r = 1.15

Area A = (1.5)(5.5) = 8.25 in^2

Section modulus S = $(1.5)(5.5)^2/6$ = 7.563 in^3

Compression stress f_c = 2 (2400)/8.25 = 582 psi

Bending stress f_b = $WL^2/(8S)$ = $(20)(2/12)(115.5)^2/(8(7.563))$ = 735 psi

Allowable stresses are pre-adjusted for size.

Size factors C_F = 1.0

References given in parentheses at right in the calculations below relate to the 1991 National Design Specification.

COMPARISON

1350f-1.3E MSR 2x6	No. 1 Douglas fir 2x6
F_b = 1350 psi	F_b = 1300 psi

$F_c = 1600$ psi	$F_c = 1595$ psi
$E = 1{,}300{,}000$ psi	$E = 1{,}700{,}000$ psi

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COMPRESSION (NDS '91 3.6, 3.7)

$$F_c^* = F_c\, C_D\, C_F$$

$$F_{cE} = K_c E/(L/d)^2$$

$$C_p = \frac{1 + (F_{CE}/F_c^*)}{2c} - \text{r ‰} \quad \frac{1 + F_{CE}/F_c^*}{2c}\ ^2 - \frac{F_{CE}/F_c^*}{c} \;\_$$

$c = 0.8$

$$F_c' = F_c\, C_D\, C_F\, C_p$$

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$F_c^* = (1600)(1.6)(1.0) = 2560$ psi	$F_c^* = (1595)(1.6)(1.0) = 2552$
$K_{cE} = 0.418$ (NDS '91 3.7.1.5)	$K_{cE} = 0.3$ (NDS '91 3.7.1.5)
$F_{CE} = \frac{(0.418)(1{,}300{,}000)}{(115.5/5.5)^2} = 1232$ psi	$F_{CE} = \frac{(0.3)(1{,}700{,}000)}{(115.5/5.5)^2} = 1156$ psi
$C_p = \frac{1 + 1232/2560}{2\,(0.8)} -$	$C_p = \frac{1 + 1156/2552}{2\,(0.8)} -$
r‰ $\frac{1 + 1232/2560}{2\,(0.8)}\ ^2 - \frac{1232/2560}{0.8}$ _	r‰ $\frac{1 + 1156/2552}{2\,(0.8)}\ ^2 - \frac{1156/2552}{0.8}$ _
$= 0.4203$	$= 0.3997$
$F_c' = 1600(1.6)(1.0)(0.4203) = 1076$ psi	$F_c' = 1595(1.6)(1.0)(0.3997) = 1020$ psi
$f_c = 582 < 1076$ ok	$f_c = 582 < 1020$ ok

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Bending (NDS '91 3.3)

$$F_b' = F_b\, C_D\, C_L\, C_F\, C_r$$

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$F_b' = (1350)(1.6)(1.0)(1.0)(1.15)$ $= 2484$ psi	$F_b' = (1300)(1.6)(1.0)(1.0)(1.15)$ $= 2392$ psi
$f_b = 735 < 2484$ ok	$f_b = 735 < 2392$ ok
1350f-1.3E MSR 2X6	No. 1 Douglas fir 2x6

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COMBINED BENDING AND AXIAL COMPRESSION (NDS '91 3.9.2)

$$\left[\frac{f_c}{F_c'}\right]^2 + \frac{f_b}{F_b'\,(1 - f_c/F_{CE})} \leq 1.0$$

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$$\left[\frac{582}{1076}\right]^2 + \frac{735}{2484\,(1 - 582/1232)} =$$

$$0.293 + 0.561 = 0.854 \text{ ok}$$

$$\left[\frac{582}{1020}\right]^2 + \frac{735}{2393\,(1 - 582/1156)} =$$

$$0.326 + 0.619 = 0.945 \text{ ok}$$

CONCLUSION: 1350f-1.3E MSR is a more than satisfactory substitute for No. 1 Douglas fir in this application.