Hand Calculation

Problem Statement:
Determine if 2 x 10 at 24in OC wood joist framing is safe and meet all the required demands

Joist size: 2 x 10

Joist width	$b := 1.5\ in$
Joist depth	$d := 9.25\ in$
Centroidal distance	$y_c := 4.625\ in$
Moment of inertia	$I_x := 98.932\ in^4$
Span	$L := 12.5\ ft$
Spacing	$S := 24\ in$ OC
Dead load (including self-weight)	$D_L := 25\ psf$
Live load	$LL := 30\ psf$
Total load deflection limit	L/240
Live load deflection limit	L/360
Wood Modulus Strength	$E := 1600\ ksi$

Compression flange fully braced by roof wood sheathing
Assume $C_b := 1.0$
Wood species: Douglas Fir-Larch (North)
Wood grade: No.1/No.2
Use NDS 2018 for the various reference design values
Design Method: ASD
Solution:
ANALYSIS (Step 1 to Step 4)
Step 1: Calculate Linear Load

$W_{DL} := D_L \cdot S = 50\ plf$ $\quad W_{DL} = 0.05\ klf$

$W_{LL} := LL \cdot S = 60\ plf$ $\quad W_{LL} = 0.06\ klf$

Step 2: Calculate Applied Moment

$$M_{DL} := \frac{W_{DL} \cdot L^2}{8} = 976.56\ lbf \cdot ft \qquad M_{DL} = 0.98\ kip \cdot ft$$

$$M_{LL} := \frac{W_{LL} \cdot L^2}{8} = 1171.88\ lbf \cdot ft \qquad M_{LL} = 1.17\ kip \cdot ft$$

Total applied moment is

$M_a := M_{DL} + M_{LL} = 2148.44\ lbf \cdot ft$ $\quad M_a = 2.15\ kip \cdot ft$

Step 3: Calculate Applied Bending Stress

Elastic section modulus, $S_x := \frac{I_x}{y_c} = 21.39\ in^3$

Applied bending stress is

$f_b := \frac{M_a}{S_x} = 1205.25\ psi$

Step 4: Calculate Applied Shear Stress

$V_{DL} := \frac{W_{DL} \cdot L}{2} = 312.5\ lbf$ $V_{DL} = 0.313\ kip$

$V_{LL} := \frac{W_{LL} \cdot L}{2} = 375\ lbf$ $V_{LL} = 0.375\ kip$

Total applied shear force is

$V_a := V_{DL} + V_{LL} = 687.5\ lbf$ $V_a = 0.69\ kip$

Total applied shear stress is

$f_v := \frac{3 \cdot V_a}{2 \cdot b \cdot d} = 74.32\ psi$

DESIGN CHECKS (Step 5 to Step 7)

Step 5: Calculate Bending Stress Capacity

Allowable bending stress	$F_b := 850\ psi$	
Load duration factor	$C_D := 1.25$	(Load with 7 days duration)
Wet use factor	$C_M := 1.0$	
Temperature factor	$C_T := 1.0$	
Beam lateral stability factor	$C_L := 1.0$	
Size factor	$C_F := 1.1$	
Flat use factor	$C_{FU} := 1.0$	
Repetitive member factor	$C_r := 1.15$	
Incising factor	$C_i := 1.0$	(Member is not pressure tested)

Adjusted allowable bending stress capacity is
$F'_b := F_b \cdot C_D \cdot C_M \cdot C_T \cdot C_L \cdot C_F \cdot C_{FU} \cdot C_r \cdot C_i = 1344.06\ psi$

Step 6: Calculate Shear Stress Capacity

Allowable shear stress $F_v := 180\ psi$

Adjusted allowable shear stress capacity is
$F'_v := F_v \cdot C_D \cdot C_M \cdot C_T \cdot C_i = 225$ *psi*

Step 7: Demand to Capacity Ratio (DCR) Check

- Bending stress check:

Calculated from step 3 and step 5
Applied bending stress, $f_b = 1205.25$ *psi*
Adjusted bending stress capacity, $F'_b = 1344.06$ *psi*

$DCR_{bending} := \frac{f_b}{F'_b} = 0.897$ < 1.0 **PASS** ✔

- Shear stress check:

Calculated from step 4 to step 6
Total applied shear stress, $f_v = 74.324$ *psi*
Adjusted shear stress capacity, $F'_v = 225$ *psi*

$DCR_{shear} := \frac{f_v}{F'_v} = 0.33$ < 1.0 **PASS** ✔

- Short-term Deflection check:

Calculated from step 1
Linear live load, $W_{LL} = 0.06$ *klf*
Linear dead load, $W_{DL} = 0.05$ *klf*
Total linear load, $W_{TL} := W_{LL} + W_{DL} = 0.11$ *klf*

Total load deflection limit is $\frac{L}{240} = 0.625$ *in*

Actual total load deflection is:

$\Delta_{TL} := \frac{5 \, W_{TL} \cdot L^4}{384 \cdot E \cdot I_x} = 0.382$ *in* < 0.625 in **PASS** ✔

Live load deflection limit is $\frac{L}{360} = 0.417$ *in*

Actual live load deflection is:

$\Delta_{LL} := \frac{5 \cdot W_{LL} \cdot L^4}{384 \cdot E \cdot I_x} = 0.208$ *in* < 0.417 in **PASS** ✔

Important note: ENERCALC does not calculate long term deflection due to creep. The user shall perform this calculation manually as needed. See below for the long term deflection hand calculation.

Long-term Deflection (Creep)

The framing member is considered to be seasoned lumber, hence $K_{cr} := 1.5$ (See NDS for more info about other values for Kcr)

Immediate deflection due to dead load is:

$$\Delta_{DL} := \frac{5 \cdot W_{DL} \cdot L^4}{384 \cdot E \cdot I_x} = 0.174 \ in$$

Creep deflection due to dead load is :

$$\Delta_{creep} := K_{cr} \cdot \Delta_{DL} = 0.26 \ in$$

Total long term deflection is:

$$\Delta_{Total\_Long} := \Delta_{creep} + \Delta_{LL} = 0.468 \ in$$

See the following ENERCALC printed calc report for comparison

ENERCALC

Project Title: Wood Beam Module
Engineer: ENERCALC Engr. Div.
Project ID: ENERCALC
Project Descr: Verification Example

Wood Beam

Project File: Wood Beam.ec6

DESCRIPTION: Wood Joist

Code References

Governing Code : IBC 2021
Referenced Design Standard(s) : NDS 2018
Load Combination Set : IBC 2018

Material Properties

Analysis Method : Allowable Stress Design
Load Combination : IBC 2018

Wood Species : Douglas Fir-Larch (North)
Wood Grade : No. 1/No. 2

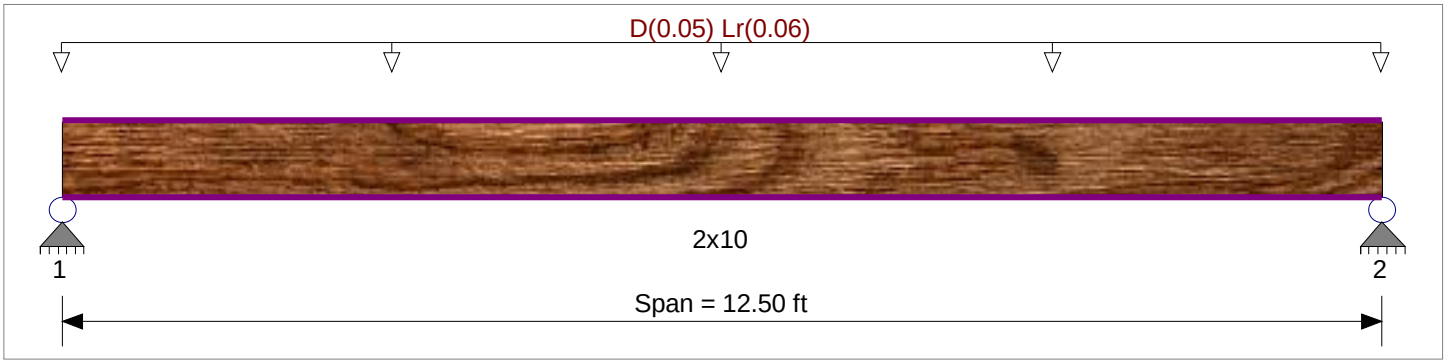
Beam Bracing : Beam is Fully Braced against lateral-torsional buckling

Fb +	850.0 psi
Fb -	850.0 psi
Fc - Prll	1,400.0 psi
Fc - Perp	625.0 psi
Fv	180.0 psi
Ft	500.0 psi

E : Modulus of Elasticity

Ebend- xx	1,600.0 ksi
Eminbend - xx	580.0 ksi
Density	30.590 pcf

Repetitive Member Stress Increase



Applied Loads

Service loads entered. Load Factors will be applied for calculations.

Beam self weight NOT internally calculated and added
Uniform Load : D = 0.0250, Lr = 0.030 ksf, Tributary Width = 2.0 ft

DESIGN SUMMARY

Design OK

Maximum Bending Stress Ratio	=	**0.897** : 1	Maximum Shear Stress Ratio	=	**0.330** : 1
Section used for this span		**2x10**	Section used for this span		**2x10**
fb: Actual	=	1,205.26 psi	fv: Actual	=	74.32 psi
F'b	=	1,344.06 psi	F'v	=	225.00 psi
Load Combination		+D+Lr	Load Combination		+D+Lr
Location of maximum on span	=	6.250 ft	Location of maximum on span	=	0.000 ft
Span # where maximum occurs	=	Span # 1	Span # where maximum occurs	=	Span # 1

Maximum Deflection

Max Downward Transient Deflection	0.209 in	Ratio =	716	>=360	Span: 1 : Lr Only
Max Upward Transient Deflection	0 in	Ratio =	0	>=360	n/a
Max Downward Total Deflection	0.384 in	Ratio =	390	>=180	Span: 1 : +D+Lr
Max Upward Total Deflection	0 in	Ratio =	0	>=180	n/a

Maximum Forces & Stresses for Load Combinations

Load Combination / Segment Length	Span #	Max Stress Ratios M	V	CD	CM	C_t	CLx	C_F	Cfu	C_i	C_r	Moment Values M	fb	F'b	Shear Values V	fv	F'v
D Only														0.0	0.00	0.0	0.0
Length = 12.50 ft	1	0.566	0.209	0.90	1.00	1.00	1.00	1.100	1.00	1.00	1.15	0.98	547.8	967.7	0.31	33.8	162.0
+D+Lr					1.00	1.00	1.00	1.100	1.00	1.00	1.15			0.0	0.00	0.0	0.0
Length = 12.50 ft	1	0.897	0.330	1.25	1.00	1.00	1.00	1.100	1.00	1.00	1.15	2.15	1,205.3	1,344.1	0.69	74.3	225.0
+D+0.750Lr					1.00	1.00	1.00	1.100	1.00	1.00	1.15			0.0	0.00	0.0	0.0
Length = 12.50 ft	1	0.774	0.285	1.25	1.00	1.00	1.00	1.100	1.00	1.00	1.15	1.86	1,040.9	1,344.1	0.59	64.2	225.0
+0.60D					1.00	1.00	1.00	1.100	1.00	1.00	1.15			0.0	0.00	0.0	0.0
Length = 12.50 ft	1	0.191	0.070	1.60	1.00	1.00	1.00	1.100	1.00	1.00	1.15	0.59	328.7	1,720.4	0.19	20.3	288.0

Wood Beam

Project File: Wood Beam.ec6

DESCRIPTION: Wood Joist

Overall Maximum Deflections

Span	Load Combination	Max. "-" Defl	Location in Span	Load Combination	Max. "+" Defl	Location in Span
1	+D+Lr	0.3840	6.296		0.0000	0.000

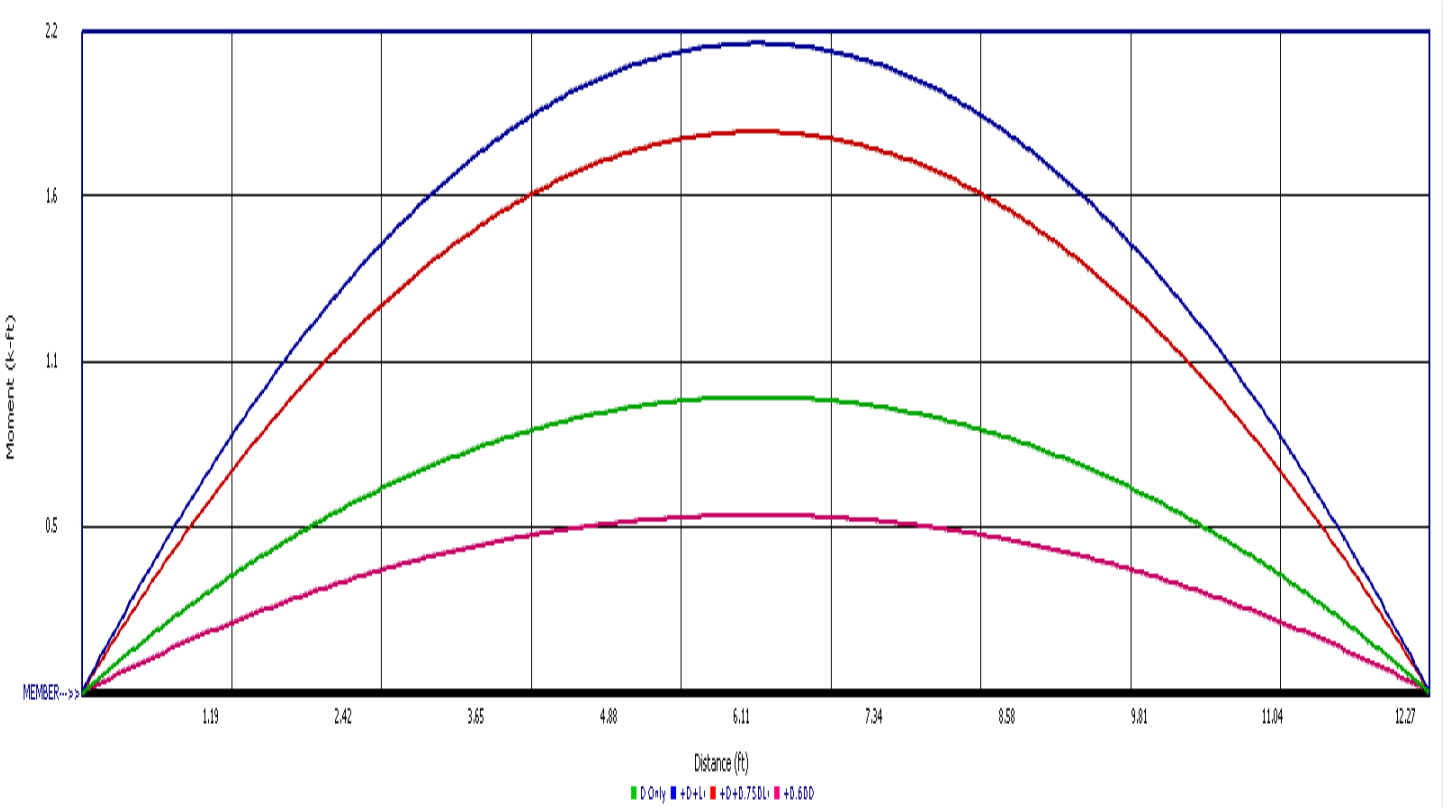
Maximum Deflections for Load Combinations

Load Combination	Span	Max. Downward Defl	Location in Span	Max. Upward Defl	Location in Span
D Only	1	0.1745 in	6.296 ft	0.0000 in	0.000 ft
+D+Lr	1	0.3840 in	6.296 ft	0.0000 in	0.000 ft
+D+0.750Lr	1	0.3316 in	6.296 ft	0.0000 in	0.000 ft
+0.60D	1	0.1047 in	6.296 ft	0.0000 in	0.000 ft
Lr Only	1	0.2094 in	6.296 ft	0.0000 in	0.000 ft

Vertical Reactions

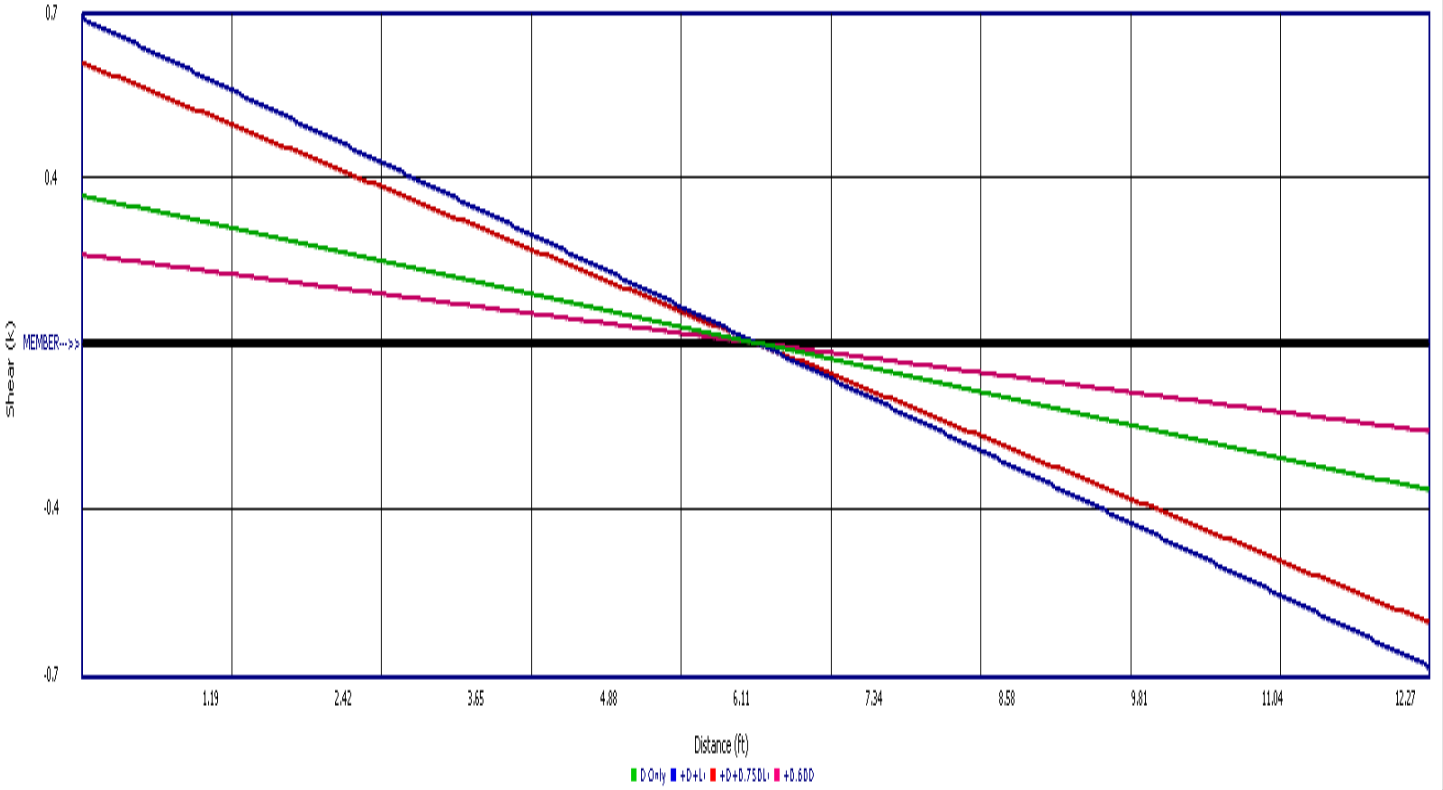
Support notation : Far left is #1 Values in KIPS

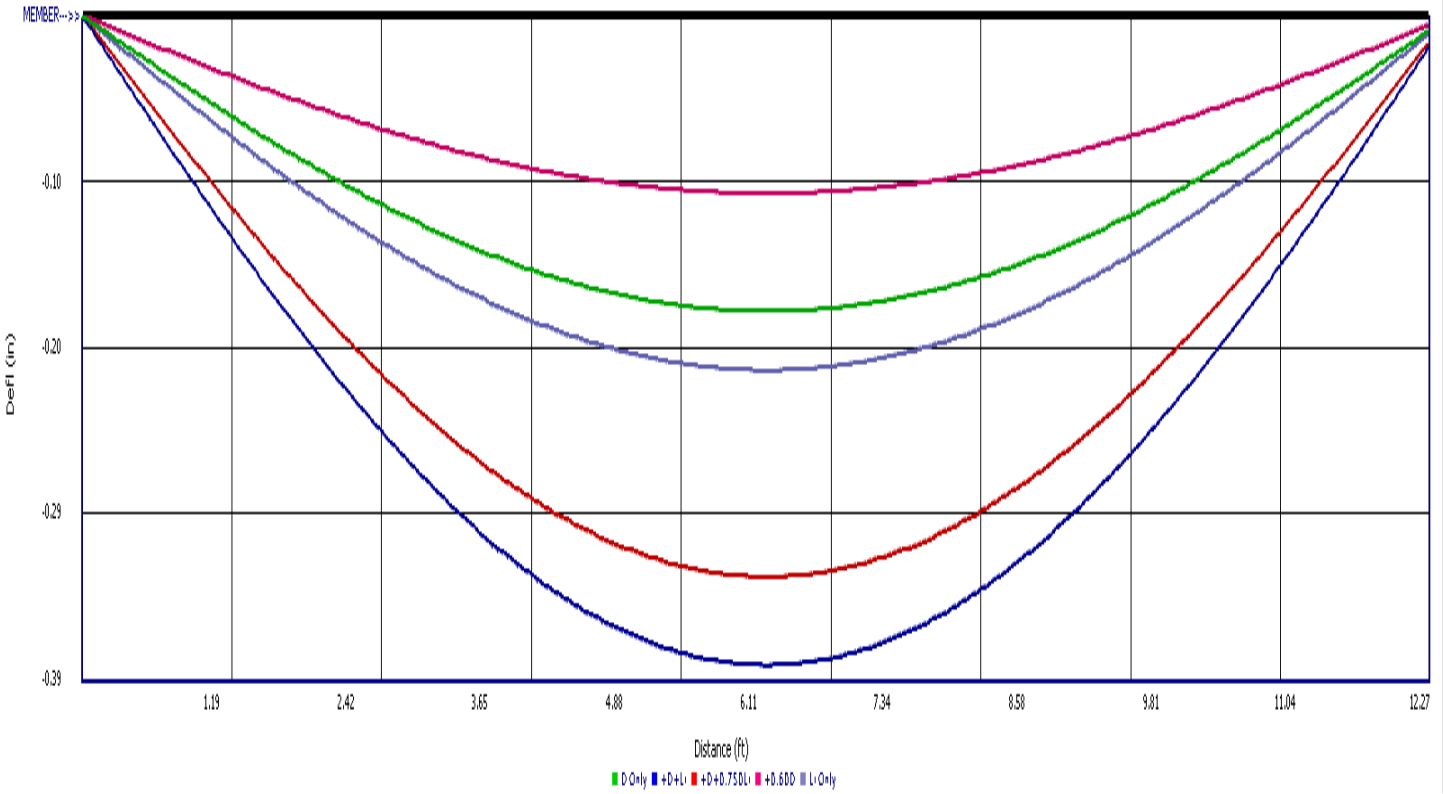
Load Combination	Support 1	Support 2
Max Upward from all Load Conditions	0.688	0.688
Max Upward from Load Combinations	0.688	0.688
Max Upward from Load Cases	0.375	0.375
D Only	0.313	0.313
+D+Lr	0.688	0.688
+D+0.750Lr	0.594	0.594
+0.60D	0.188	0.188
Lr Only	0.375	0.375



Wood Beam

DESCRIPTION: Wood Joist





Wood Beam

DESCRIPTION: Wood Joist

Beam Span Moments & Shears at Incremental Locations

Load Type/ Combination	Span Location (ft)	Span ID	Shear (k)	Moment (ft-k)
D Only	0.00	Span 1	0.313	0.000
D Only	1.28	Span 1	0.249	0.358
D Only	2.55	Span 1	0.185	0.635
D Only	3.83	Span 1	0.121	0.830
D Only	5.11	Span 1	0.057	0.944
D Only	6.39	Span 1	-0.007	0.976
D Only	7.66	Span 1	-0.071	0.927
D Only	8.94	Span 1	-0.135	0.795
D Only	10.22	Span 1	-0.198	0.583
D Only	11.50	Span 1	-0.262	0.288
+D+Lr	0.00	Span 1	0.688	0.000
+D+Lr	1.28	Span 1	0.547	0.788
+D+Lr	2.55	Span 1	0.406	1.397
+D+Lr	3.83	Span 1	0.266	1.827
+D+Lr	5.11	Span 1	0.125	2.077
+D+Lr	6.39	Span 1	-0.015	2.147
+D+Lr	7.66	Span 1	-0.156	2.038
+D+Lr	8.94	Span 1	-0.296	1.750
+D+Lr	10.22	Span 1	-0.437	1.282
+D+Lr	11.50	Span 1	-0.577	0.635
+D+0.750Lr	0.00	Span 1	0.594	0.000
+D+0.750Lr	1.28	Span 1	0.472	0.681
+D+0.750Lr	2.55	Span 1	0.351	1.207
+D+0.750Lr	3.83	Span 1	0.230	1.578
+D+0.750Lr	5.11	Span 1	0.108	1.794
+D+0.750Lr	6.39	Span 1	-0.013	1.855
+D+0.750Lr	7.66	Span 1	-0.134	1.760
+D+0.750Lr	8.94	Span 1	-0.256	1.511
+D+0.750Lr	10.22	Span 1	-0.377	1.107
+D+0.750Lr	11.50	Span 1	-0.498	0.548
+0.60D	0.00	Span 1	0.188	0.000
+0.60D	1.28	Span 1	0.149	0.215
+0.60D	2.55	Span 1	0.111	0.381
+0.60D	3.83	Span 1	0.073	0.498
+0.60D	5.11	Span 1	0.034	0.566
+0.60D	6.39	Span 1	-0.004	0.586
+0.60D	7.66	Span 1	-0.042	0.556
+0.60D	8.94	Span 1	-0.081	0.477
+0.60D	10.22	Span 1	-0.119	0.350
+0.60D	11.50	Span 1	-0.157	0.173

Beam Span Deflections at Incremental Locations

Load Type/ Combination	Span Location (ft)	Span ID	Deflection (in)
Overall MAXimum Envelope	0.00	Span 1	0.000
Overall MAXimum Envelope	1.28	Span 1	0.122
Overall MAXimum Envelope	2.55	Span 1	0.231
Overall MAXimum Envelope	3.83	Span 1	0.316
Overall MAXimum Envelope	5.11	Span 1	0.368
Overall MAXimum Envelope	6.39	Span 1	0.384
Overall MAXimum Envelope	7.66	Span 1	0.361
Overall MAXimum Envelope	8.94	Span 1	0.303
Overall MAXimum Envelope	10.22	Span 1	0.213
Overall MAXimum Envelope	11.50	Span 1	0.101
Overall MAXimum Envelope	12.50	Span 1	0.004
D Only	0.00	Span 1	0.000
D Only	1.28	Span 1	0.056
D Only	2.55	Span 1	0.105
D Only	3.83	Span 1	0.144
D Only	5.11	Span 1	0.167
D Only	6.39	Span 1	0.174
D Only	7.66	Span 1	0.164
D Only	8.94	Span 1	0.138
D Only	10.22	Span 1	0.097
D Only	11.50	Span 1	0.046

Wood Beam

DESCRIPTION: Wood Joist

Beam Span Deflections at Incremental Locations

Load Type/ Combination	Span Location (ft)	Span ID	Deflection (in)
D Only	12.50	Span 1	0.002
+D+Lr	0.00	Span 1	0.000
+D+Lr	1.28	Span 1	0.122
+D+Lr	2.55	Span 1	0.231
+D+Lr	3.83	Span 1	0.316
+D+Lr	5.11	Span 1	0.368
+D+Lr	6.39	Span 1	0.384
+D+Lr	7.66	Span 1	0.361
+D+Lr	8.94	Span 1	0.303
+D+Lr	10.22	Span 1	0.213
+D+Lr	11.50	Span 1	0.101
+D+Lr	12.50	Span 1	0.004
+D+0.750Lr	0.00	Span 1	0.000
+D+0.750Lr	1.28	Span 1	0.106
+D+0.750Lr	2.55	Span 1	0.200
+D+0.750Lr	3.83	Span 1	0.273
+D+0.750Lr	5.11	Span 1	0.318
+D+0.750Lr	6.39	Span 1	0.331
+D+0.750Lr	7.66	Span 1	0.312
+D+0.750Lr	8.94	Span 1	0.262
+D+0.750Lr	10.22	Span 1	0.184
+D+0.750Lr	11.50	Span 1	0.087
+D+0.750Lr	12.50	Span 1	0.004
+0.60D	0.00	Span 1	0.000
+0.60D	1.28	Span 1	0.033
+0.60D	2.55	Span 1	0.063
+0.60D	3.83	Span 1	0.086
+0.60D	5.11	Span 1	0.100
+0.60D	6.39	Span 1	0.105
+0.60D	7.66	Span 1	0.099
+0.60D	8.94	Span 1	0.083
+0.60D	10.22	Span 1	0.058
+0.60D	11.50	Span 1	0.028
+0.60D	12.50	Span 1	0.001
Lr Only	0.00	Span 1	0.000
Lr Only	1.28	Span 1	0.067
Lr Only	2.55	Span 1	0.126
Lr Only	3.83	Span 1	0.172
Lr Only	5.11	Span 1	0.201
Lr Only	6.39	Span 1	0.209
Lr Only	7.66	Span 1	0.197
Lr Only	8.94	Span 1	0.165
Lr Only	10.22	Span 1	0.116
Lr Only	11.50	Span 1	0.055
Lr Only	12.50	Span 1	0.002