ARCH 331: Practice Quiz 4

Note: No aids are allowed for part 1. One side of a letter sized paper with notes is allowed during part 2, along with a silent, ***non-programmable*** *calculator. There are reference charts for part 2, shown on pages 2-6.*

<u>Clearly show your work and answer.</u>

Part 1) *Worth 5 points* *(conceptual questions)*

Part 2) *Worth 45 points*

(NOTE: The loading type and sizes <u>can and will</u> be changed for the quiz with respect to the beam diagrams and formulas provided. The support condition, section, ***and bracing*** *for the column <u>can and will</u> be changed.)*

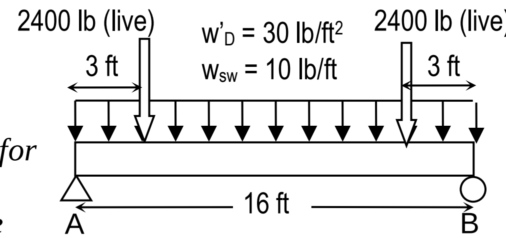


Figure 4a.

Sawn timber beams (like shown in Figure 4a) spaced 4 ft on center are needed to span 16 ft and support a roof having 30 lb/ft^2 of dead load and two 2400 lb seven-day roof live loads at 3 feet from each end. The beam is simply supported and fully braced. Idaho White Pine will be used and has the following tabular design values for bending for single member uses and modulus of elasticity:

F_b = 1150 psi, F_v = 65 psi, E = 1.4 x 10^6 psi

a) Including a self weight of 10 lb/ft, design the most economical member for strength (no consideration of serviceability).

A 6 m tall, 125 mm x 200 mm (metric) glu-lam column (Figure 4b) is braced in the weak axis (y-y) at 3.2 m from the base. The ends can be considered to be pinned. The timber has the following tabular design values:

F_c = 13.8 MPa, E = 12,400 MPa:

b) If the column is to support 180 kN, is it adequate for Allowable Stress Design assuming a two month snow load duration? (A = 25.0 x 10^{-3} m^2).

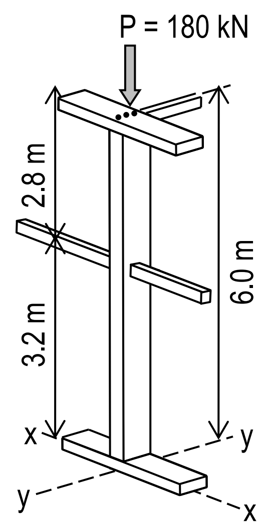


Figure 4b.

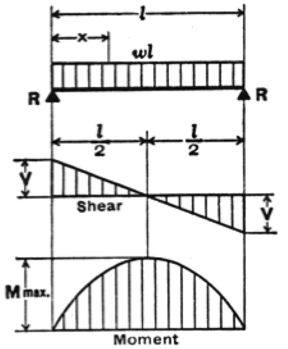
Answers – <u>Not provided on actual quiz!</u>

a) $S_{req'd} \geq 94.83$ in^3, $A_{req'd} \geq 63.5$in^2
b) $P_{allowable}$ = 136 kN ∴ No Good (P$_{weak}$= 182.9 kN weak direction)

Disclaimer: Answers have NOT been painstakingly researched.

REFERENCE CHARTS FOR QUIZ 4

1. SIMPLE BEAM—UNIFORMLY DISTRIBUTED LOAD



Total Equiv. Uniform Load . . . . $= wl$

R = V . . . . $= \frac{wl}{2}$

V_x . . . . $= w\left(\frac{l}{2} - x\right)$

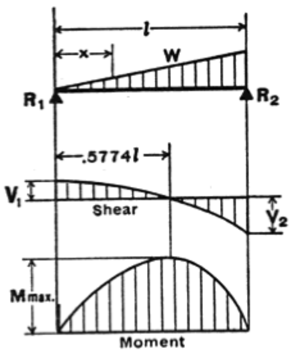
M max. (at center) . . . . . $= \frac{wl^2}{8}$

M_x . . . . $= \frac{wx}{2}(l - x)$

Δmax. (at center) . . . . . $= \frac{5wl^4}{384EI}$

Δx . . . . $= \frac{wx}{24EI}(l^3 - 2lx^2 + x^3)$

2. SIMPLE BEAM—LOAD INCREASING UNIFORMLY TO ONE END



Total Equiv. Uniform Load . . . . $= \frac{16W}{9\sqrt{3}} = 1.0264W$

$R_1 = V_1$ . . . . $= \frac{W}{3}$

$R_2 = V_2$ max. . . . . $= \frac{2W}{3}$

V_x . . . . $= \frac{W}{3} - \frac{Wx^2}{l^2}$

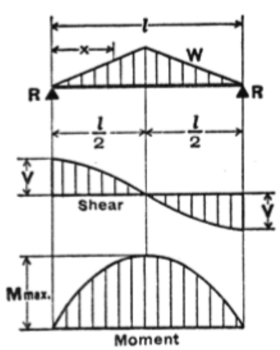
M max. $\left(\text{at } x = \frac{l}{\sqrt{3}} = .5774l\right)$ . . $= \frac{2Wl}{9\sqrt{3}} = .1283\ Wl$

M_x . . . . $= \frac{Wx}{3l^2}(l^2 - x^2)$

Δmax. $\left(\text{at } x = l\sqrt{1 - \sqrt{\frac{8}{15}}} = .5193l\right) = .01304 \frac{Wl^3}{EI}$

Δx . . . . $= \frac{Wx}{180EIl^2}(3x^4 - 10l^2x^2 + 7l^4)$

3. SIMPLE BEAM—LOAD INCREASING UNIFORMLY TO CENTER



Total Equiv. Uniform Load . . . . $= \frac{4W}{3}$

R = V . . . . $= \frac{W}{2}$

V_x $\left(\text{when } x < \frac{l}{2}\right)$ . . . . $= \frac{W}{2l^2}(l^2 - 4x^2)$

M max. (at center) . . . . $= \frac{Wl}{6}$

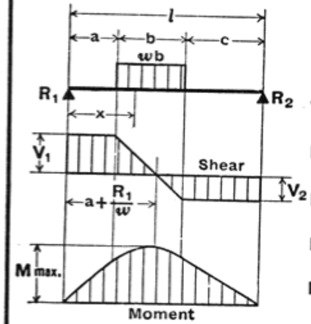
M_x $\left(\text{when } x < \frac{l}{2}\right)$ . . . . $= Wx\left(\frac{1}{2} - \frac{2x^2}{3l^2}\right)$

Δmax. (at center) . . . . $= \frac{Wl^3}{60EI}$

Δx $\left(\text{when } x < \frac{l}{2}\right)$ . . . . $= \frac{Wx}{480EIl^2}(5l^2 - 4x^2)^2$

$W = \frac{wl}{2}$

4. SIMPLE BEAM—UNIFORM LOAD PARTIALLY DISTRIBUTED



$R_1 = V_1$ (max. when a < c) . . . $= \frac{wb}{2l}(2c + b)$

$R_2 = V_2$ (max. when a > c) . . . $= \frac{wb}{2l}(2a + b)$

V_x (when x > a and < (a + b)) . $= R_1 - w(x - a)$

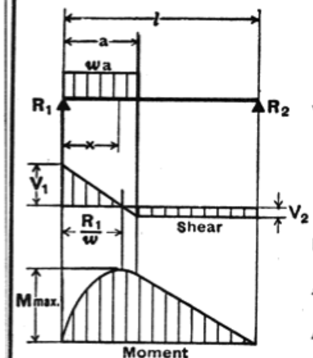
M max. $\left(\text{at } x = a + \frac{R_1}{w}\right)$ . . . . $= R_1\left(a + \frac{R_1}{2w}\right)$

M_x (when x < a) . . . . . . $= R_1x$

M_x (when x > a and < (a + b)) . $= R_1x - \frac{w}{2}(x - a)^2$

M_x (when x > (a + b)) . . . . $= R_2(l - x)$

5. SIMPLE BEAM—UNIFORM LOAD PARTIALLY DISTRIBUTED AT ONE END



$R_1 = V_1$ max. . . . . $= \frac{wa}{2l}(2l - a)$

$R_2 = V_2$ . . . . $= \frac{wa^2}{2l}$

V_x (when x < a) . . . . . . $= R_1 - wx$

M max. $\left(\text{at } x = \frac{R_1}{w}\right)$ . . . . . . $= \frac{R_1^2}{2w}$

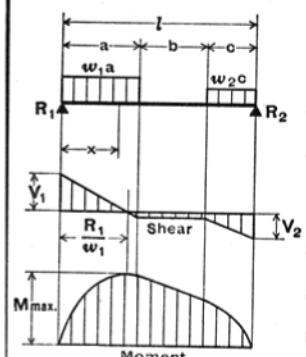
M_x (when x < a) . . . . . . $= R_1x - \frac{wx^2}{2}$

M_x (when x > a) . . . . . . $= R_2(l - x)$

Δx (when x < a) . . . . . . $= \frac{wx}{24EIl}\left(a^2(2l - a)^2 - 2ax^2(2l - a) + lx^3\right)$

Δx (when x > a) . . . . . . $= \frac{wa^2(l - x)}{24EIl}(4xl - 2x^2 - a^2)$

6. SIMPLE BEAM—UNIFORM LOAD PARTIALLY DISTRIBUTED AT EACH END



$R_1 = V_1$ . . . . $= \frac{w_1a(2l - a) + w_2c^2}{2l}$

$R_2 = V_2$ . . . . $= \frac{w_2c(2l - c) + w_1a^2}{2l}$

V_x (when x < a) . . . . . . $= R_1 - w_1x$

V_x (when x > a and < (a + b)) . $= R_1 - w_1a$

V_x (when x > (a + b)) . . . . $= R_2 - w_2(l - x)$

M max. $\left(\text{at } x = \frac{R_1}{w_1} \text{ when } R_1 < w_1a\right)$. $= \frac{R_1^2}{2w_1}$

M max. $\left(\text{at } x = l - \frac{R_2}{w_2} \text{ when } R_2 < w_2c\right) = \frac{R_2^2}{2w_2}$

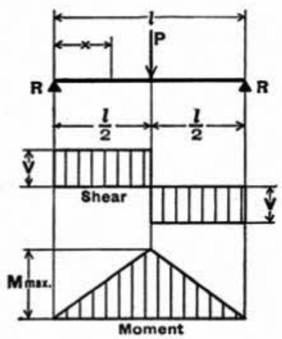
M_x (when x < a) . . . . . . $= R_1x - \frac{w_1x^2}{2}$

M_x (when x > a and < (a + b)) . $= R_1x - \frac{w_1a}{2}(2x - a)$

M_x (when x > (a + b)) . . . . $= R_2(l - x) - \frac{w_2(l - x)^2}{2}$

REFERENCE CHARTS FOR QUIZ 4

7. SIMPLE BEAM—CONCENTRATED LOAD AT CENTER



Total Equiv. Uniform Load . . . . . . = $2P$

$R = V$ . . . . = $\frac{P}{2}$

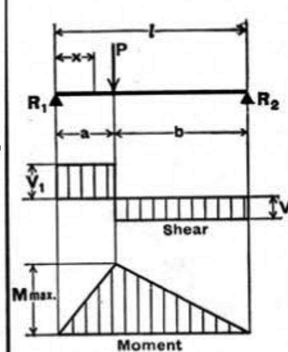
M max. (at point of load) . . . . . . = $\frac{Pl}{4}$

M_x (when $x < \frac{l}{2}$) . . . . . . = $\frac{Px}{2}$

Δmax. (at point of load) . . . . . . = $\frac{Pl^3}{48EI}$

Δx (when $x < \frac{l}{2}$) . . . . . . = $\frac{Px}{48EI}(3l^2 - 4x^2)$

8. SIMPLE BEAM—CONCENTRATED LOAD AT ANY POINT



Total Equiv. Uniform Load . . . . . . = $\frac{8\,Pab}{l^2}$

$R_1 = V_1$ (max. when $a < b$) . . . . = $\frac{Pb}{l}$

$R_2 = V_2$ (max. when $a > b$) . . . . = $\frac{Pa}{l}$

M max. (at point of load) . . . . = $\frac{Pab}{l}$

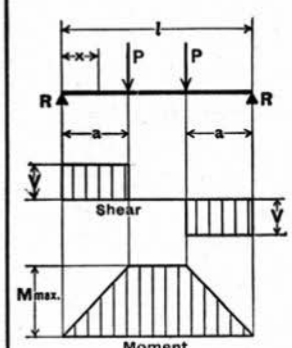
M_x (when $x < a$) . . . . = $\frac{Pbx}{l}$

Δmax. (at $x = \sqrt{\frac{a(a+2b)}{3}}$ when $a > b$) = $\frac{Pab(a+2b)\sqrt{3a(a+2b)}}{27\,EI\,l}$

Δa (at point of load) . . . . = $\frac{Pa^2b^2}{3EI\,l}$

Δx (when $x < a$) . . . . = $\frac{Pbx}{6EI\,l}(l^2 - b^2 - x^2)$

9. SIMPLE BEAM—TWO EQUAL CONCENTRATED LOADS SYMMETRICALLY PLACED



Total Equiv. Uniform Load . . . . . . = $\frac{8\,Pa}{l}$

$R = V$ . . . . = P

M max. (between loads) . . . . . . = Pa

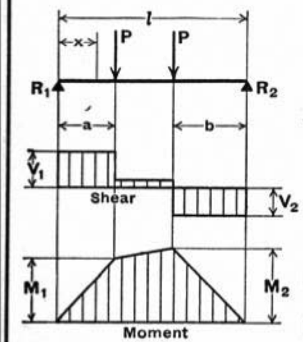
M_x (when $x < a$) . . . . . . = Px

Δmax. (at center) . . . . = $\frac{Pa}{24EI}(3l^2 - 4a^2)$

Δx (when $x < a$) . . . . = $\frac{Px}{6EI}(3la - 3a^2 - x^2)$

Δx (when $x > a$ and $< (l - a)$) . . = $\frac{Pa}{6EI}(3lx - 3x^2 - a^2)$

10. SIMPLE BEAM—TWO EQUAL CONCENTRATED LOADS UNSYMMETRICALLY PLACED



$R_1 = V_1$ (max. when $a < b$) . . . . = $\frac{P}{l}(l - a + b)$

$R_2 = V_2$ (max. when $a > b$) . . . . = $\frac{P}{l}(l - b + a)$

V_x (when $x > a$ and $< (l - b)$) . . = $\frac{P}{l}(b - a)$

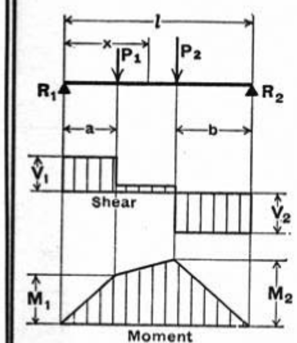
M_1 (max. when $a > b$) . . . . = R_1a

M_2 (max. when $a < b$) . . . . = R_2b

M_x (when $x < a$) . . . . = R_1x

M_x (when $x > a$ and $< (l - b)$) . . = $R_1x - P(x - a)$

11. SIMPLE BEAM—TWO UNEQUAL CONCENTRATED LOADS UNSYMMETRICALLY PLACED



$R_1 = V_1$ . . . . = $\frac{P_1(l - a) + P_2b}{l}$

$R_2 = V_2$ . . . . = $\frac{P_1a + P_2(l - b)}{l}$

V_x (when $x > a$ and $< (l - b)$) . . = $R_1 - P_1$

M_1 (max. when $R_1 < P_1$) . . . = R_1a

M_2 (max. when $R_2 < P_2$) . . . = R_2b

M_x (when $x < a$) . . . . . . = R_1x

M_x (when $x > a$ and $< (l - b)$) . . = $R_1x - P_1(x - a)$

REFERENCE CHARTS FOR QUIZ 4

Section Properties of Dimension Western Lumber Sizes

Nominal Size ($b \times h$) (in.)	Surfaced Dry Size (actual) (in.)	Nominal Size ($b \times h$) (mm)	Surfaced Dry Size (actual) (mm)	Area $A = (b) \times (h)$ (in.^{2})	Area $A = bh$ $\times 10^3$mm^2	Section Modulus $S = bh^2/6$ (in.^{3})	Section Modulus $S = bh^2/6$ $\times 10^3$ mm^3	Moment of Inertia $I = bh^3/12$ (in.^{4})	Moment of Inertia $I = bh^3/12$ $\times 10^6$ mm^4
2×2	1.5×1.5	50×50	38×38	2.25	1.44	0.56	9.12	0.42	0.17
2×3	1.5×2.5	50×75	38×64	3.75	2.43	1.56	25.9	1.95	0.83
2×4	1.5×3.5	50×100	38×89	5.25	3.38	3.06	50.2	5.36	2.23
2×6	1.5×5.5	50×150	38×140	8.25	5.32	7.58	124	20.80	8.69
2×8	1.5×7.25	50×200	38×184	10.88	6.99	13.14	214	47.63	19.7
2×10	1.5×9.25	50×250	38×235	13.88	8.93	21.39	350	98.93	41.1
2×12	1.5×11.25	50×300	38×286	16.88	10.87	31.64	518	177.98	74.1
3×3	2.5×2.5	75×75	64×64	6.25	4.10	2.60	43.7	3.26	1.40
3×4	2.5×3.5	75×100	64×89	8.75	5.70	5.10	84.5	8.93	3.76
3×6	2.5×5.5	75×150	64×140	13.75	8.96	12.60	209	34.66	14.6
3×8	2.5×7.25	75×200	64×184	18.12	11.78	21.90	361	79.39	33.2
3×10	2.5×9.25	75×250	64×235	23.12	15.04	35.65	589	164.89	69.2
3×12	2.5×11.25	75×300	64×286	28.12	18.30	52.73	872	296.63	124.7
4×4	3.5×3.5	100×100	89×89	12.25	7.92	7.15	118	12.51	5.23
4×6	3.5×5.5	100×150	89×140	19.25	12.5	17.65	292	48.53	20.4
4×8	3.5×7.25	100×200	89×184	25.38	16.4	30.66	502	111.15	46.2
4×10	3.5×9.25	100×250	89×235	32.38	20.9	49.91	819	230.84	96.3
4×12	3.5×11.25	100×300	89×286	39.38	25.4	73.83	1213	415.28	174
4×14	3.5×13.25	100×350	89×335	46.38	29.8	102.41	1664	678.48	279
6×6	5.5×5.5	150×150	140×140	30.25	19.6	27.7	457	76.3	32.0
6×8	5.5×7.5	150×200	140×191	41.25	26.7	51.6	851	193.4	81.3
6×10	5.5×9.5	150×250	140×241	52.25	33.7	82.7	1355	393.0	163
6×12	5.5×11.5	150×300	140×292	63.25	40.9	121.2	1989	697.1	290
6×14	5.5×13.5	150×350	140×343	74.25	48.0	167.1	2745	1127.7	471
8×8	7.5×7.5	200×200	191×191	56.25	36.5	70.3	1161	263.7	111
8×10	7.5×9.5	200×250	191×241	71.25	46.0	112.8	1849	535.9	223
8×12	7.5×11.5	200×300	191×292	86.25	55.8	165.3	2714	950.6	396
8×14	7.5×13.5	200×350	191×343	101.25	65.5	227.8	3745	1537.7	642
8×16	7.5×15.5	200×400	191×394	116.25	75.2	300.3	4942	2327.4	974
10×10	9.5×9.5	250×250	241×241	90.25	58.1	142.9	2333	678.8	281
10×12	9.5×11.5	250×300	241×292	109.25	70.4	209.4	3425	1204.0	500
10×14	9.5×13.5	250×350	241×343	128.25	82.7	288.6	4726	1947.8	810
10×16	9.5×15.5	250×400	241×394	147.25	95.0	380.4	6235	2948.1	1228
12×12	11.5×11.5	300×300	292×292	132.25	85.3	253.5	4150	1457.5	606
12×14	11.5×13.5	300×350	292×343	155.25	100	349.3	5726	2357.9	982
12×16	11.5×15.5	300×400	292×394	178.25	115	460.5	7555	3568.7	1488
12×18	11.5×17.5	300×450	292×445	201.25	130	587.0	9637	5136.1	2144

REFERENCE CHARTS FOR QUIZ 4

Table 14 Column Stability Factor C_p.

"C_p" $F_c' = C_p \cdot F_c^*$ $F_{CE} = \frac{.30\,E}{(l/d)^2}$ for sawed posts $F_{CE} = \frac{.418\,E}{(l/d)^2}$ for glu-lam posts

$\frac{F_{CE}}{F_C^*}$	Sawed C_p	Glu-Lam C_p	$\frac{F_{CE}}{F_C^*}$	Sawed C_p	Glu-Lam C_p	$\frac{F_{CE}}{F_C^*}$	Sawed C_p	Glu-Lam C_p	$\frac{F_{CE}}{F_C^*}$	Sawed C_p	Glu-Lam C_p
0.00	0.000	0.000	0.40	0.360	0.377	0.80	0.610	0.667	1.20	0.750	0.822
0.01	0.010	0.010	0.41	0.367	0.386	0.81	0.614	0.672	1.22	0.755	0.826
0.02	0.020	0.020	0.42	0.375	0.394	0.82	0.619	0.678	1.24	0.760	0.831
0.03	0.030	0.030	0.43	0.383	0.403	0.83	0.623	0.683	1.26	0.764	0.836
0.04	0.040	0.040	0.44	0.390	0.411	0.84	0.628	0.688	1.28	0.769	0.840
0.05	0.049	0.050	0.45	0.398	0.420	0.85	0.632	0.693	1.30	0.773	0.844
0.06	0.059	0.060	0.46	0.405	0.428	0.86	0.637	0.698	1.32	0.777	0.848
0.07	0.069	0.069	0.47	0.412	0.436	0.87	0.641	0.703	1.34	0.781	0.852
0.08	0.079	0.079	0.48	0.419	0.444	0.88	0.645	0.708	1.36	0.785	0.855
0.09	0.088	0.089	0.49	0.427	0.453	0.89	0.649	0.713	1.38	0.789	0.859
0.10	0.098	0.099	0.50	0.434	0.461	0.90	0.653	0.718	1.40	0.793	0.862
0.11	0.107	0.109	0.51	0.441	0.469	0.91	0.658	0.722	1.42	0.796	0.865
0.12	0.117	0.118	0.52	0.448	0.477	0.92	0.661	0.727	1.44	0.800	0.868
0.13	0.126	0.128	0.53	0.454	0.484	0.93	0.665	0.731	1.46	0.803	0.871
0.14	0.136	0.138	0.54	0.461	0.492	0.94	0.669	0.735	1.48	0.807	0.874
0.15	0.145	0.147	0.55	0.468	0.500	0.95	0.673	0.740	1.50	0.810	0.877
0.16	0.154	0.157	0.56	0.474	0.508	0.96	0.677	0.744	1.52	0.813	0.879
0.17	0.164	0.167	0.57	0.481	0.515	0.97	0.680	0.748	1.54	0.816	0.882
0.18	0.173	0.176	0.58	0.487	0.523	0.98	0.684	0.752	1.56	0.819	0.884
0.19	0.182	0.186	0.59	0.494	0.530	0.99	0.688	0.756	1.58	0.822	0.887
0.20	0.191	0.195	0.60	0.500	0.538	1.00	0.691	0.760	1.60	0.825	0.889
0.21	0.200	0.205	0.61	0.506	0.545	1.01	0.694	0.764	1.62	0.827	0.891
0.22	0.209	0.214	0.62	0.512	0.552	1.02	0.698	0.767	1.64	0.830	0.893
0.23	0.218	0.224	0.63	0.518	0.559	1.03	0.701	0.771	1.66	0.832	0.895
0.24	0.227	0.233	0.64	0.524	0.566	1.04	0.704	0.774	1.68	0.835	0.897
0.25	0.235	0.242	0.65	0.530	0.573	1.05	0.708	0.778	1.70	0.837	0.899
0.26	0.244	0.252	0.66	0.536	0.580	1.06	0.711	0.781	1.72	0.840	0.901
0.27	0.253	0.261	0.67	0.542	0.587	1.07	0.714	0.784	1.74	0.842	0.903
0.28	0.261	0.270	0.68	0.548	0.593	1.08	0.717	0.788	1.76	0.844	0.904
0.29	0.270	0.279	0.69	0.553	0.600	1.09	0.720	0.791	1.78	0.846	0.906
0.30	0.278	0.288	0.70	0.559	0.607	1.10	0.723	0.794	1.80	0.849	0.908
0.31	0.287	0.297	0.71	0.564	0.613	1.11	0.726	0.797	1.82	0.851	0.909
0.32	0.295	0.306	0.72	0.569	0.619	1.12	0.729	0.800	1.84	0.853	0.911
0.33	0.304	0.315	0.73	0.575	0.626	1.13	0.731	0.803	1.86	0.855	0.912
0.34	0.312	0.324	0.74	0.580	0.632	1.14	0.734	0.806	1.88	0.857	0.914
0.35	0.320	0.333	0.75	0.585	0.638	1.15	0.737	0.809	1.90	0.858	0.915
0.36	0.328	0.342	0.76	0.590	0.644	1.16	0.740	0.811	1.92	0.860	0.916
0.37	0.336	0.351	0.77	0.595	0.650	1.17	0.742	0.814	1.94	0.862	0.918
0.38	0.344	0.360	0.78	0.600	0.655	1.18	0.745	0.817	1.96	0.864	0.919
0.39	0.352	0.368	0.79	0.605	0.661	1.19	0.747	0.819	1.98	0.868	0.920

(continued)

REFERENCE CHARTS FOR QUIZ 4

Table 14 Column Stability Factor C_p. *(Continued)*

"C_p" $F_c' = C_p \cdot F_c^*$ $F_{CE} = \frac{.30\,E}{(l/d)^2}$ **for sawed posts** $F_{CE} = \frac{.418\,E}{(l/d)^2}$ **for glu-lam posts**

$\frac{F_{CE}}{F_C^*}$	Sawed C_p	Glu-Lam C_p	$\frac{F_{CE}}{F_C^*}$	Sawed C_p	Glu-Lam C_p	$\frac{F_{CE}}{F_C^*}$	Sawed C_p	Glu-Lam C_p	$\frac{F_{CE}}{F_C^*}$	Sawed C_p	Glu-Lam C_p
2.00	0.867	0.921	2.40	0.894	0.940	3.40	0.930	0.962	4.40	0.948	0.972
2.02	0.869	0.922	2.45	0.897	0.941	3.45	0.931	0.963	4.45	0.949	0.973
2.04	0.870	0.924	2.50	0.899	0.943	3.50	0.932	0.963	4.50	0.949	0.973
2.06	0.872	0.925	2.55	0.901	0.944	3.55	0.933	0.964	4.55	0.950	0.974
2.08	0.874	0.926	2.60	0.904	0.946	3.60	0.934	0.965	4.60	0.950	0.974
2.10	0.875	0.927	2.65	0.906	0.947	3.65	0.936	0.965	4.65	0.951	0.974
2.12	0.876	0.928	2.70	0.908	0.949	3.70	0.937	0.966	4.70	0.952	0.975
2.14	0.878	0.929	2.75	0.910	0.950	3.75	0.938	0.966	4.75	0.952	0.975
2.16	0.879	0.930	2.80	0.912	0.951	3.80	0.938	0.967	4.80	0.953	0.975
2.18	0.881	0.931	2.85	0.914	0.952	3.85	0.939	0.968	4.85	0.953	0.975
2.20	0.882	0.932	2.90	0.916	0.953	3.90	0.940	0.968	4.90	0.954	0.976
2.22	0.883	0.932	2.95	0.917	0.954	3.95	0.941	0.969	5.00	0.955	0.976
2.24	0.885	0.933	3.00	0.919	0.955	4.00	0.942	0.969	6.00	0.963	0.981
2.26	0.886	0.934	3.05	0.920	0.956	4.05	0.943	0.969	8.00	0.973	0.986
2.28	0.887	0.935	3.10	0.922	0.957	4.10	0.944	0.970	10.0	0.979	0.989
2.30	0.888	0.936	3.15	0.923	0.958	4.15	0.944	0.970	20.0	0.990	0.995
2.32	0.889	0.937	3.20	0.925	0.959	4.20	0.945	0.971	40.0	0.995	0.997
2.34	0.891	0.937	3.25	0.926	0.960	4.25	0.946	0.971	60.0	0.997	0.998
2.36	0.892	0.938	3.30	0.927	0.961	4.30	0.947	0.972	100.0	0.998	0.999
2.38	0.893	0.939	3.35	0.929	0.961	4.35	0.947	0.972	200.0	0.999	0.999

Table developed and permission for use granted by Professor Ed Lebert, Dept. of Architecture, University of Washington.

Table 10.3 Load duration factors.

C_D—Load Duration Adjustment	
Load Duration	**Factor**
Permanent	0.9
Ten years (normal load)	1.0
Two months (snow load)	1.15
Seven days (construction load)	1.25
One day	1.33
Ten minutes (Wind or EQ)	1.6
Impact	2.0