THE PAPUA NEW GUINEA UNIVERSITY OF TECHNOLOGY

DEPARTMENT OF CIVIL ENGINEERING – 4TH YEAR DEGREE

FIRST SEMESTER EXAMINATION - 2023

CE 413 – DESIGN OF TIMBER STRUCTURES

DATE: FRIDAY, 5TH JUNE 2023 – 12:50 P.M

VENUE: HLT, TIME ALLOWED: 2 HOURS

INFORMATION FOR CANDIDATES

1. You have 10 minutes to read the paper before the examination starts. You must **not** begin writing during this time.
2. **There are FIVE (5) Questions in this paper. Answer any 4 Questions.**
3. Use only ink. Do not use pencils for writing except for drawings and sketches.
4. Only Calculator is allowed in the examination room. MOBILE PHONE is not allowed (**Switch your Mobile Phones OFF**). Notes and textbooks are not allowed.
5. Start each question on a new page and show all your calculations in the answer book provided. No other material will be accepted.
6. **Write your NAME and Student Id NUMBER clearly on the front page. Do it now.**
7. **Marking Scheme:** All Questions carry equal marks.

QUESTION 1 [10 marks] SLO2

a) Follow and indicate the Load/Force path of the on the cantilevered truss (**Fig. 1**) through the members and eventually to the foundation or support. Indicate the response path of the truss members and supports by arrows on the diagram. (5 marks)

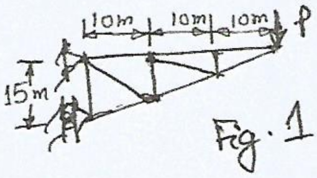


Fig. 1

SLO 4

a) Design glue-laminated column and sawn timber composite column to carry permanent axial compression of 40kN. The unsupported length of the column is 6 m. The column is pinned at both ends. (5 marks)

QUESTION 2 [10 marks] SLO5

The Plan and sectional view of a timber structure is shown in Fig. 2. Design the upper ridge beam . The following information are given: i) The beam is simply supported at 5.5 m spacing.

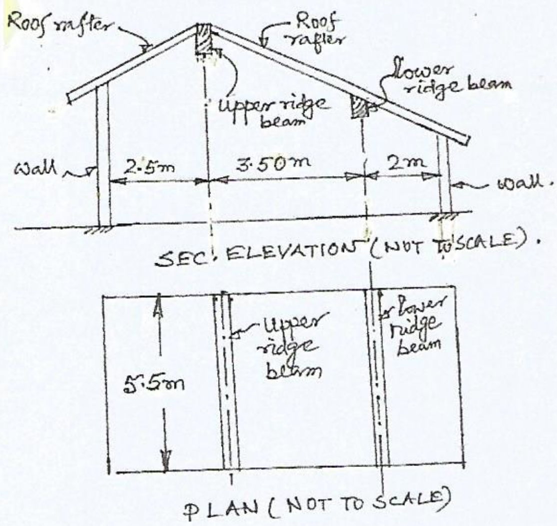


Fig. 2. PLAN AND SEC. ELEVATION OF A BUILDING.

Given Data:
Dead Load = 0.8kN/m^2
Live load = 1.0 kN/m^2
Self weight = 10% of the the dead load and live load

Species : Kamarere
Stress grade= select grade
Condition: Dry

a) Design only for dead and live load combination. (10 marks)

OR

Design a simply supported beam of span 6 metres subjected to a uniformly distributed dead and live loads of 2.25 kN/m and 6.75 kN/m respectively considering both strength and serviceability limit states. (10 marks)

QUESTION 3 [10 marks] SLO 6

Select a sawn timber member to carry a permanent axial compressive load of 18 kN with an effective length ($k_{10}L$) of 1.5m and a bending moment about X-X axis of 300 Nm. The relevant documents for design bending strengths for permanent loading, Figures with Basic allowable load on sawn timber columns for buckling in X-X direction and Y-Y direction are attached with this question paper. (6 marks)

TOPIC 6

What is MP 9 of Standards New Zealand? Write on the approvals of three categories through which the fire performance of building materials (like timber) may be achieved. (4 marks)

QUESTION 4 [10 marks] SLO 7

a) Show nail spacing for Radiata Pine schematically for at least two types of joints. Represent a schematic diagram of steel nail on plate inducing stresses perpendicular to the grain. (6 marks)
b) What is epoxied steel rod connection? (2 marks)
c) What do you understand by the term nail gun? (2 marks)

QUESTION 5 [Answer any 5 questions 2 x 5=10 marks] SLO 1 & SLO 8

a. Differentiate between strength and serviceability limit states of timber. (2 marks)
b. Differentiate between micro and macro characteristics of timber. (2 marks)
c. What is the relation between the effective length and effective length factor in the analysis of timber structural member subject to compression in limit state method of design? (2 marks)
d. Define a beam-column. (2 marks)
e. What do you understand by the nominal and actual size of timber? (2 marks)
f. Write two primary objectives of seasoning of timber (2 marks)
g. What is the difference between live loads and wind loads? (2 marks)

compressive stress, using:

$$P = \phi k_1 k_8 b d f_c$$

where f_c is the characteristic stress in compression parallel to grain.

k_1 is the duration of load factor
k_8 is the slenderness factor

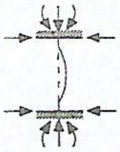
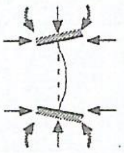
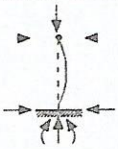
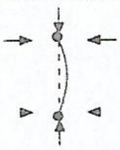
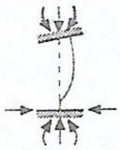
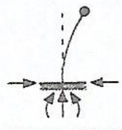
Grade and moisture content

The characteristic design stress f_c is dependant on the grade and moisture content of the timber. NZS 3603 provides for either green or dry timber. Dry values are used in most designs as it is assumed that maximum design load is not likely to occur in the first few months of service life of a structure, so members installed green will be dry before peak loads occur. Characteristic stresses in compression are given in Chapter 10 for various species, grades and moisture content.

Duration of load factor k_1

Calculation of the design strength of a column includes the duration of load factor k_1. Values of k_1 are given in Table 2.4 of NZS 3603, or in Chapter 10.

Figure 12.3. Effective length factor k_{10}

Condition of end restraint	Deflected shape of member	K_{10}
Restrained at both Ends in position and direction		0.7
Each end held in position and substantially restrained against rotation (by two bolts)		0.75
One end fixed in position and direction and the other restrained in position only		0.85
Restrained at both ends in position only		1.0
Restrained at one end in position and direction, and at the other partially restrained in direction but not in position		1.5
Restrained at one end in position and direction but not restrained in either position or direction at the other end		2.0

Parallel support factor k_4

Where two or more sawn timber members are connected in such a way that they resist applied loads together, then design strengths can be increased to recognise the load sharing that occurs. The design strengths can be multiplied by the "parallel support factor" k_4 from Table 2.7 of NZS 3603. This factor can be applied to bending, tension and short compression members. It should not be applied to slender compression members because load carrying capacity depends on stiffness rather than material strength.

Effective length factor k_{10}

The stability of axially loaded compression members depends on the degree of end restraint. For members which are not pinned at both ends, the effective length is given by $k_{10}L$ where L is the length of the member and k_{10} is an effective length factor given in Figure 12.3.

A k_{10} factor of 1.0 is normally used unless end rotational restraint can be confidently relied on. The adequacy of lateral restraints can be checked against the requirements of NZS 3603 Appendix B if necessary.

Column Design

Columns should be designed so that:

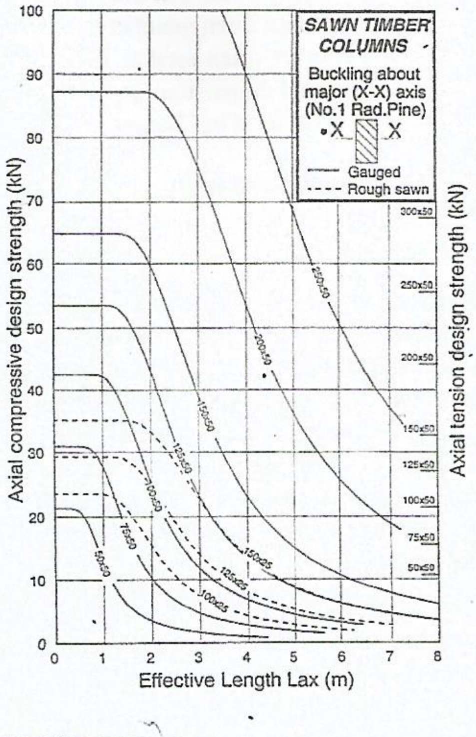
$$P^* \leq P_x \text{ and } \qquad P^* \leq P_y$$

where

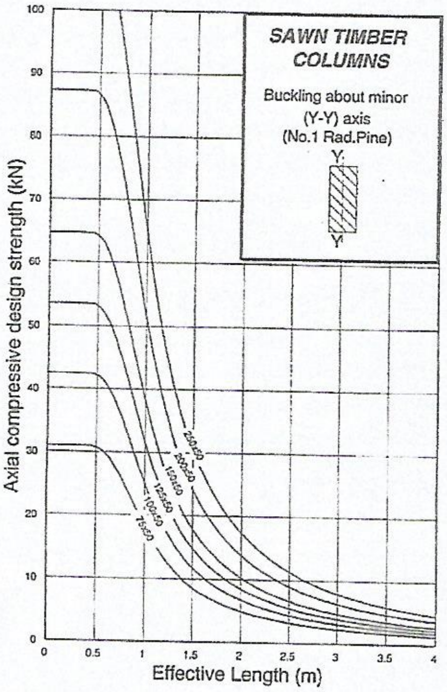
P* is the applied axial load and

P_x and P_y are the design strengths, considering buckling about the X-X and Y-Y axes respectively.

Figure 12.4. Basic allowable load on sawn timber columns considering buckling in the Y-Y direction



gure 12.5. Basic allowable load on sawn timber columns nsidering buckling in the X-X direction.



Sawn timber columns

Design strengths for some common sizes of short columns are given in Tables 10.17 and 10.18.

Figures 12.4 and 12.5 show the axial compressive design strengths plotted against effective length for a range of standard timber sizes, for buckling about the major (X-X) and minor (Y-Y) axes respectively. Dry No.1 Framing grade radiata pine ($f_c = 20.9$ MPa) has been used, assuming permanent load duration (k_1=0.6). The charts have been prepared for ex 50 mm thick gauged members and 25 mm thick rough sawn members. (Rough sawn 25 mm thick members are often used as T-stiffeners in trusses). The assumed dimensions and section properties are the same as those used in Chapter 10.

Glue-laminated columns

Design strengths for some common sizes of short glulam columns are given in Table 10.19.

The same stability considerations apply to glue laminated timber columns as for columns of sawn timber. However no adjustment to the call sizes is needed for shrinkage or gauging. Figures 12.6 and 12.7 show the design compression strengths plotted against effective length for a range of glue laminated columns for buckling about the major (X-X) and minor (Y-Y) axes respectively. Dry No.1 Framing grade radiata pine ($f_c = 20.9$ MPa) has been used, assuming permanent load duration (k_1=0.6).

As with sawn timber, Figures 12.6 and 12.7 have the same design strengths on the left hand edge where strength is determined only by short column behaviour.

Composite columns

Composite columns may be fabricated by joining two or more individual members together by glue, nails, nail-plates, screws, bolts or other structural connectors. The column members may be in contact and continuously connected over the full length, or spaced apart and connected through packing pieces. The design of spaced columns was covered in the 1990 edition of NZS 3603, but is not in the current (1993) edition. See Further Reading for information on design of spaced and composite columns.

Figure 12.6. Basic allowable load on glulam columns considering buckling in Y-Y direction.

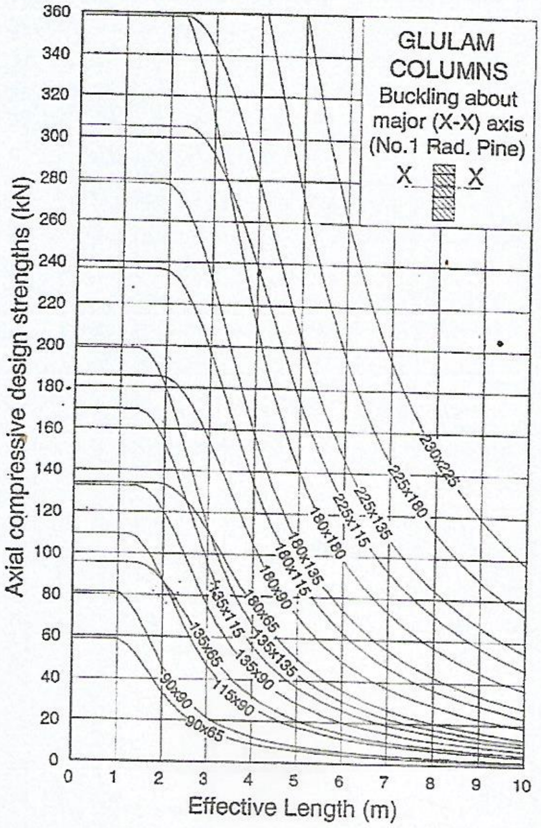


Table 11.5 No. 1 Framing grade glulam beams

Breadth b (mm)	65	65	65	65	65	65	65
Depth d (mm)	180	225	270	315	360	405	450
No. of laminations	4	5	6	7	8	9	10
Area A (mm^{2}x10^3)	11.7	14.6	17.6	20.5	23.4	26.3	29.3
Z (mm^{3}x10^6)	0.351	0.548	0.790	1.07	1.40	1.78	2.19
I (mm^{4}x10^6)	31.6	61.7	107	169	253	360	494
Weight kN/m	0.059	0.073	0.088	0.102	0.117	0.132	0.146

	Uniformly distributed factored design loads in kN/m limited by:													
Span (m)	stress	defl	stress	defl	stress	defl	stress	defl	stress	defl	stress	defl	stress	defl
2.00	8.66	9.70												
2.25	6.84	6.82	10.8	13.3										
2.50	5.54	4.97	8.76	9.70										
2.75	4.58	3.73	7.24	7.29	10.5	12.6								
3.00	3.85	2.88	6.09	5.62	8.80	9.70								
3.25	3.28	2.26	5.19	4.42	7.50	7.63	10.2	12.1						
3.50	2.83	1.81	4.47	3.54	6.47	6.11	8.81	9.70						
3.75	2.46	1.47	3.90	2.88	5.63	4.97	7.67	7.89	10.0	11.8				
4.0	2.17	1.21	3.42	2.37	4.95	4.09	6.74	6.50	8.79	9.70				
4.5	1.71	0.85	2.70	1.66	3.91	2.88	5.33	4.57	6.95	6.82	8.77	9.70		
5.0	1.39	0.62	2.19	1.21	3.17	2.10	4.32	3.33	5.63	4.97	7.10	7.07	8.73	9.70
5.5			1.81	0.91	2.62	1.57	3.57	2.50	4.65	3.73	5.87	5.32	7.22	7.29
6.0			1.52	0.70	2.20	1.21	3.00	1.93	3.91	2.88	4.93	4.09	6.07	5.62
6.5			1.30	0.55	1.87	0.95	2.55	1.52	3.33	2.26	4.20	3.22	5.17	4.42
7.0					1.62	0.76	2.20	1.21	2.87	1.81	3.62	2.58	4.46	3.54
7.5					1.41	0.62	1.92	0.99	2.50	1.47	3.16	2.10	3.88	2.88
8.0					1.24	0.51	1.69	0.81	2.20	1.21	2.77	1.73	3.41	2.37
8.5							1.49	0.68	1.95	1.01	2.46	1.44	3.02	1.98
9.0							1.33	0.57	1.74	0.85	2.19	1.21	2.70	1.66
9.5							1.20	0.49	1.56	0.72	1.97	1.03	2.42	1.41
10.0									1.41	0.62	1.78	0.88	2.18	1.21
11.0											1.47	0.66	1.80	0.91
12.0											1.23	0.51	1.52	0.70
13.0													1.29	0.55
14.0													1.11	0.44

Check the stress-limited loads against the combination 1.2G & 1.6Q for ultimate strength.
Characteristic bending stress $f_b = 17.7$ MPa. Strength reduction factor $\phi = 0.8$.
Load duration factor $k_1 = 0.8$. Shear and bearing strengths are not included in this table.

Deflection-limited loads apply to GL 8 grade.
Stress-limited loads should be calculated separately for GL grades.

Check the deflection-limited loads against the combination $G + \psi_s Q$ for short term deflections or $k_2 (G + \psi_l Q)$ for long term deflections, where k_2 is from Table 10.6 and ψ is from NZS 4203.
Deflection limit used in table is L/250 = 0.004L. Modulus of elasticity = 8000 MPa.

TABLE 2.2.1
BASIC WORKING STRESSES AND STIFFNESS FOR STRUCTURAL TIMBER (MPa)

Basic Stress					Short duration modulus of elasticity (1) E	Short duration modulus of rigidity G
Stress Grade	Bending F'b	Tension parallel to grain F't	Shear in beams F's	Compression parallel to grain F'c		
F34	34.5	20.7	2.45	26.0	21500	1430
F27	27.5	16.5	2.05	20.5	18500	1230
F22	22.0	13.2	1.70	16.5	16000	1070
F17	17.0	10.2	1.45	13.0	14000	930
F14	14.0	8.4	1.25	10.5	12000	800
F11	11.0	6.6	1.05	8.3	10500	700
F8	8.6	5.2	0.85	6.6	9100	610
F7	6.9	4.1	0.70	5.2	7900	530
F5	5.5	3.3	0.60	4.1	6900	460
F4	4.3	2.6	0.50	3.3	6100	410
F3	3.4	2.0	0.45	2.6	5200	350
F2	2.8	1.7	0.35	2.1	4500	300

(1) modulus of elasticity includes an allowance for shear deformation

TABLE 2.2.2
BASIC WORKING STRESSES (MPa) FOR COMPRESSION PERPENDICULAR TO GRAIN AND SHEAR AT JOINTS

Strength Group		Compression perpendicular to grain F'p	Shear at joints details F'sj
Green	Seasoned		
	SD1	10.4	4.15
	SD2	9.0	3.45
	SD3	7.8	2.95
S1	SD4	6.6	2.45
S2	SD5	5.2	2.05
S3	SD6	4.1	1.70
S4	SD7	3.3	1.45
S5	SD8	2.6	1.25
S6		2.1	1.05
S7		1.7	0.85

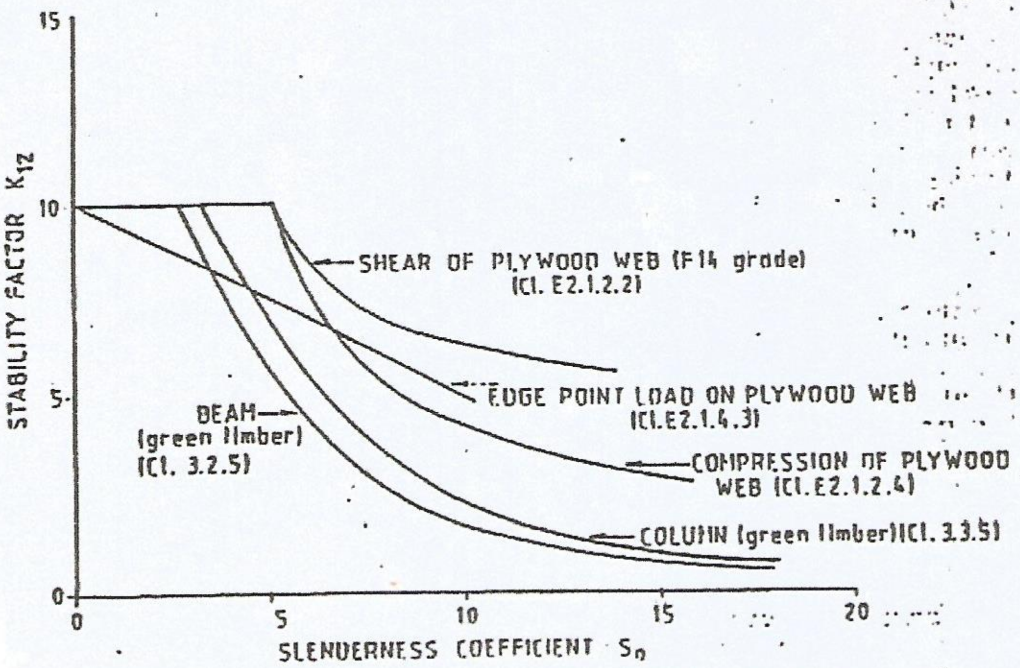


Fig: 2.4.7 EXAMPLES OF STABILITY FACTORS

(Dead Load Only)

SPECIES	(1) LOCATION	MOISTURE CONDITION	(2) STRENGTH GROUP	JOINT GROUP	STRESS GRADE					
					SAWN TIMBER			(4) POLE TIMBER	(5) DESIGN DENSITY kg/m^3	(6) DURABILITY CLASS
					SELECT STRUCTURE	STANDARD STRUCTURE	COMMON BUILDING			
GARO GARO	1,2,5, 7,10	Green Seasoned	S4 SD3	J2 JD2	F14 F27	F11 F22	F8 F17	F17	1100 800	2
GORDONIA	4,5	Green Seasoned	S5 SD5	J3 JD3	F11 F17	F8 F14	F7 F11	F14	1100 700	4
GUM, WATER	General	Green Seasoned	S4 SD3	J3 JD3	F14 F27	F11 F22	F8 F17	F17	1100 750	3
HARDWOOD, YELLOW	1,7,10	Green Seasoned	S2 SD2	J3 JD3	F22 F34	F17 F27	F14 F22	F27	1100 800	3
HERITIERA	Coastal	Green Seasoned	S3 SD2	J2 JD2	F17 F34	F14 F27	F11 F22	F22	1100 850	4
HOPEA, HEAVY	3,4,5, 9	Green Seasoned	S1 SD1	J1 JD2	F27 F34	F22 F34	F17 F27	F34	1100 1000	2
HOPEA, LIGHT	1,3,4, 5,7,8,9	Green Seasoned	S2 SD3	J3 JD3	F22 F27	F17 F22	F14 F17	F27	1100 750	2
KAMARERE	10	Green Seasoned	S4 SD4	J3 JD3	F14 F22	F11 F17	F8 F14	F17	1100 700	3
KANDIS	General	Green Seasoned	S3 SD3	J2 JD2	F17 F27	F14 F22	F11 F17	F22	1100 850	3
KAPIAK	General	Green Seasoned	S7 SD8	J5 JD5	F7 F8	F5 F7	F4 F5	F8	1100 450	4
KEMPAS, PNG	3,7	Green Seasoned	S3 SD3	J2 JD2	F17 F27	F14 F22	F11 F17	F22	1100 900	3
KISO	1,2,5, 10	Green Seasoned	S5 SD6	J4 JD4	F11 F14	F8 F11	F7 F8	F14	1100 600	4
KWILA	1,2	Green Seasoned	S2 SD3	J2 JD2	F22 F27	F17 F22	F14 F17	F27	1100 850	2
LABULA	10	Green Seasoned	S6 SD6	J5 JD5	F8 F14	F7 F11	F5 F8	F11	1100 450	4
LITSEA	10	Green Seasoned	S7 SD7	J4 JD4	F7 F11	F5 F8	F4 F7	F8	1100 550	4

TIMBER SIZES AND PROPERTIES (SAWN SIZES)

Studs and Joists

Nominal Dimensions mm	Actual Dim. mm	Sect. Area x 10^3 mm^2	Z x 10^3 mm^3	I x 10^6 mm^6
75 x 40	69 x 37	2.55	29.4	1.01
100 x 40	94 x 37	3.48	54.5	2.56
75 x 50	69 x 47	3.24	37.3	1.29
100 x 50	94 x 47	4.42	69.2	3.25
125 x 50	119 x 47	5.59	110.9	6.60
150 x 50	144 x 47	6.77	162.	11.70
200 x 50	194 x 47	9.12	295.	28.60
250 x 50	244 x 47	11.47	466.	56.90
300 x 50	294 x 47	13.82	677.	99.53

Bearers and Posts

Nominal Dimensions mm	Actual Dim. mm	Sect. Area x 10^3 mm^2	Z x 10^3 mm^3	I x 10^6 mm^6
100 x 75	94 x 69	6.49	101.6	4.78
125 x 75	119 x 69	8.21	162.9	9.69
150 x 75	144 x 69	9.94	238.5	17.17
100 x 100	94 x 94	8.84	138.4	6.51
125 x 125	119 x 119	14.16	280.9	16.71
150 x 150	144 x 144	20.74	497.7	35.83

Beams

Nominal Dimensions mm	Actual Dim. mm	Sect. Area x 10^3 mm^2	Z x 10^3 mm^3	I x 10^6 mm^6
200 x 75	194 x 69	13.34	432.8	41.98
200 x 100	194 x 94	18.24	589.6	57.19
250 x 75	244 x 69	16.83	781.3	83.53
250 x 100	244 x 94	22.94	932.7	113. 8
300 x 75	294 x 69	20.29	994.0	146. 1
300 x 100	294 x 94	27.64	135.4	199. 1
350 x 100	344 x 94	32.34	185.4	318.9
350 x 125	344 x 119	40.94	234.5	403.7
350 x 150	344 x 144	49.54	284.0	488.5
400 x 100	394 x 94	37.04	243.2	479.1
400 x 125	394 x 119	46.89	307.9	606.5
400 x 150	394 x 144	56.74	372.6	734.0

Figure 12.7. Basic allowable load on glulam columns considering buckling in X-X direction.