UTHM
Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2014/2015

COURSE NAME	:	ADVANCED STRUCTURAL TIMBER DESIGN
COURSE CODE	:	BFK 40303
PROGRAMME	:	BACHELOR OF CIVIL ENGINEERING WITH HONOURS
EXAMINATION DATE	:	JUNE / JULY 2015
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER **ALL** QUESTIONS IN PART A AND **ONE (1)** QUESTION FROM PART B

THIS QUESTION PAPER CONSISTS OF **SEVEN (7)** PAGES

PART A: ANSWER ALL QUESTIONS

Q1 A GL18 grade 90 × 630 glued laminated timber (glulam) section has been proposed as a column to support a 40 m span Duo-pitch Pratt truss. The on-plan permanent and variable actions on the truss are 3 kN/m and 4.5 kN/m, respectively. The truss is connected to the narrow face of the column while laminated veneer lumber (LVL) tie beams are connected to the wide face at mid-height and full height of the column. The purpose of the tie beams is to provide out of plane stability to the whole column-truss frame. The full height of the column is 6 m. All connections including column to base are pinned type.

Number of laminations	=	14
Charateristic bending strength, f_b	=	50 N/mm^2
Charateristic compression parallel strength, f_c	=	50 N/mm^2
Modification factors:		
Parallel support system, k_6	=	1.30
Size factor, k_{24}	=	0.88

Combined actions inequalities:

$$N_c^*/\phi N_{ncx} + M_x^*/\phi M_{nx} < 1$$
$$N_c^*/\phi N_{ncy} + (M_x^*/\phi M_{nx})^2 < 1$$

(a) Check the axial capacity of the proposed section in the major axis.
(10 marks)

(b) Check the axial capacity of the proposed section in the minor axis.
(10 marks)

(c) Check the capacity of the proposed section under combined axial and bending actions in both the major and minor axes by considering a nominal bending moment resulting from the design axial load. To quantify the nominal bending moment, the design axial load shall be assumed to act at 100 mm distance from the narrow face of the proposed section.
(20 marks)

Q2 A three storey commercial building requires a building system that provides open floor space with minimum number of columns in the middle. Timber-concrete composite (TCC) floor system spanning 8 m has been proposed. The TCC floor is made of 63 × 400 laminated veneer lumber (LVL) joists spaced at 600 mm centres with 65 mm thick normal weight concrete slab. The composite action between the timber and concrete interlayers is provided by rectangular notched cut into the LVL and reinforced by coach screws. These notches are positioned along the length of the LVL joist such that the effective spacing, s_{eff} is 375 mm.

Imposed load	=	3	kN/m^2
Permanent load for finishes and services	=	1	kN/m^2
Density of concrete	=	24	kN/m^3

Mass of HySpan LVL 63 × 400	=	15.6	kg/m
Young's modulus of LVL	=	13.2	GPa
Young's modulus of concrete	=	30	GPa
Connection stiffness for SLS, K_{SLS}	=	297000 N/mm	

Characteristic strengths:			
LVL tensile	=	33	N/mm^2
LVL bending	=	48	N/mm^2
LVL shear	=	5.3	N/mm^2
LVL compression perpendicular to grain	=	12	N/mm^2
LVL compression parallel to the grain	=	45	N/mm^2
Modification factors:			
Size factor, k_{24}	=	0.95	

Gamma coefficient for concrete, $$\gamma_c = \frac{1}{1+\dfrac{\pi^2 E_c A_c s_{ef}}{K_{SLS} l^2}}$$

Distance between local to global centroid for LVL, a_t = 188 mm
Distance between local to global centroid for concrete, a_c = 66 mm
Effective flexural stiffness, $(EI)_{ef} = E_c I_c + E_t I_t + \gamma_c E_c A_c a_c^2 + E_t A_t a_t^2$

(a) For the design of one strip of TCC floor under ultimate limit state, determine the maximum demand bending moment and shear force.
(10 marks)

(b) As a result of the composite action, the demand on the LVL for axial tensile is 113.6 kN, bending moment is 8.25 kNm, shear stress is 1.13 N/mm^2 and compressive stress perpendicular to grain due to bearing at support is 2.00 N/mm^2. Check the capacity of the LVL for each given demand.
(10 marks)

(c) Verify the short-term deflection of the proposed TCC floor for only variable action and for vibration under serviceability limit state condition.
(20 marks)

PART B: ANSWER ONE QUESTION ONLY

Q3 An opening of 4.8 m wide requires a lintel beam to support a load bearing wall above the opening. The wall load inclusive self weight is 3.0 kN/m. Check the adequacy of a 90 mm × 300 mm Nelson Pine LVL11 Dry beam for the lintel construction. The required verifications are bending, shear and short-term deflection.

Nelson Pine LVL Young's Modulus:

LVL13	=	13.2	GPa
LVL11	=	11.0	GPa
LVL bending	=	38	N/mm^2
LVL shear	=	5.0	N/mm^2

Size factor, k_{24} modification for bending strength:

LVL 240 mm deep	=	0.86
LVL 300 mm deep	=	0.83
LVL 360 mm deep	=	0.80

(a) Bending verification.

(7 marks)

(b) Shear verification.

(6 marks)

(c) Short-term deflection verification.

(7 marks)

Q4 The same lintel beam in **Q3** was burnt in a fire accident. The fire department was able to put out the fire within a good time frame of 30 minutes. You are appointed as a structural engineer to perform an on-site forensic investigation. Produce a calculation sheet in the order required below to show whether the existing fired lintel beam can be used again or needs to be replaced. Only bending strength verification is sufficient for the decision to be made.

Depth of charring, t_c	=	vC
Charring rate, v	=	0.65 mm/min
Fire period, C	=	30 minutes
Four sided charring properties:		
Charred section modulus, Z_r	=	$\frac{1}{6}(d-2t_c)[(b-2t_c)(d-2t_c)-2.58t_c^2]$

(a) Remaining cross section (b × d) after the fire has been put out.

(5 marks)

(b) Section modulus after the fire has been put out.

(5 marks)

(c) Bending verification and final decision on the re-use of the existing lintel beam after fire.

(10 marks)

- END OF QUESTION-

FINAL EXAMINATION

SEMESTER/SESSION : SEMESTER II 2014/2015 PROGRAM : 4BFF
COURSE NAME : ADVANCED STRUCTURALTIMBER DESIGN COURSE CODE : BFK 40303

Table 15.1 Load combintations

Load	Load Combination
Dead load only (permanent)	1.35*G*
Dead and live load (medium)	1.2*G* & 1.5*Q*
Gravity plus downward wind load	1.2*G* & $\psi_c Q$ & W_u
Gavity plus upward wind load	0.9*G* & W_u
Earthquake load combination	G & $\psi_c Q$ & E_u
Snow load combination	1.2*G* & $\psi_c Q$ & S_u

G is gravity load
Q is live load
W_u is wind load
E_u is seismic load, and
S_u is snow load

Table 15.3 Strength reduction factor for design of timber members and connections

	ϕ
Timber, poles and glulam,	0.8
Nails in lateral loading	0.8
Toothed metal plate connection	0.8
Other types of fasteners	0.7
Plywood and LVL	0.9
Actions derived from the strength of ductile elements under large displacements	1.0
Design for fire resistance	1.0

Table 15.2 ψ factors used for load combinations

Imposed action	Short-term factor (ψ_s)	Long-term factor (ψ_l)	Combination factor (ψ_c)
Distributed imposed actions, Q			
Floors for residential, domestic, office or retail use.	0.7	0.4	0.4
Floors for storage	1.0	0.6	0.6
Roofs	0.7	0.0	0.0
Concentrated imposed actions, Q			
Residential & domestic floors	1.0	0.4	0.4
Other floors	0.7	0.6	0.6
Roofs	1.0	0.0	0.0

Table 2.4 – Duration of load factor, k_1 for strength

Duration of load	Examples	k_1
Permanent	Dead and live loads that are essentially permanent such as stores (including water tanks and the like), library stacks, fixed plant, soil pressures.	0.60
Medium	Snow loads, live loads, crowd loadings, concrete formwork, vehicle, pedestrian and cattle loadings.	0.80
Brief	Wind, earthquake, impact, erection and maintenance loadings, pile driving	1.00

FINAL EXAMINATION

SEMESTER/SESSION : SEMESTER II 2014/2015 PROGRAM : 4BFF
COURSE NAME : ADVANCED STRUCTURALTIMBER DESIGN COURSE CODE : BFK 40303

Table 2.5 – Duration of load factor, k_2 for deflection

Duration of load	Moisture content at time of loading	k_2	
		For bending, compression or shear	For tension
12 months or more	25 % or more	3.0	1.5
12 months or more	18 % or less	2.0	1.0
2 weeks or less	Any	1.0	1.0

Table 2.6 – Bearing area factor, k_3

Length of bearing surface (mm)	10	25	50	75	100	150
k_3	1.90	1.60	1.30	1.15	1.06	1.00

Table 2.7 – Parallel support factor k_4 or k_6

Number of elements	2	3	4	5	6	7	8	9	10 or more
k_4 or k_6	1.14	1.20	1.24	1.26	1.28	1.30	1.31	1.32	1.33

$$k_5 = 1 + (k_4 - 1)\left(1 - \frac{2s}{L_B}\right) \qquad \text{(Eq. 2.5)}$$

but not less than 1.00

where

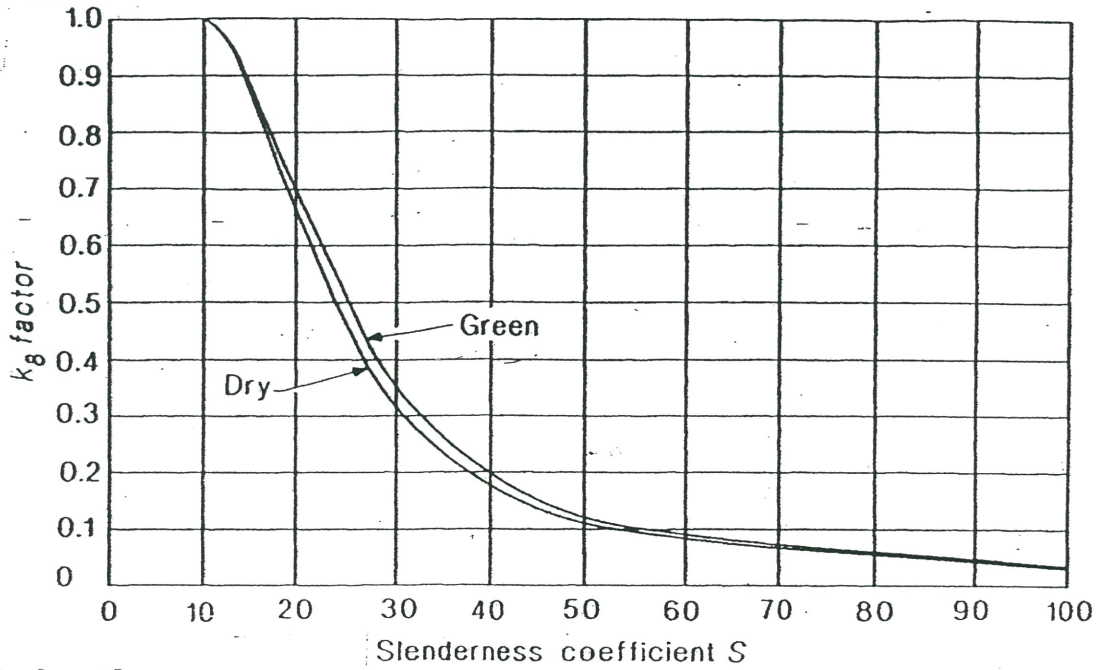
k_4 = the value obtained from 2.9.1 that would be applicable if the main beams were fastened together to act as a parallel support system

s = the centre-to-centre spacing of the supporting members

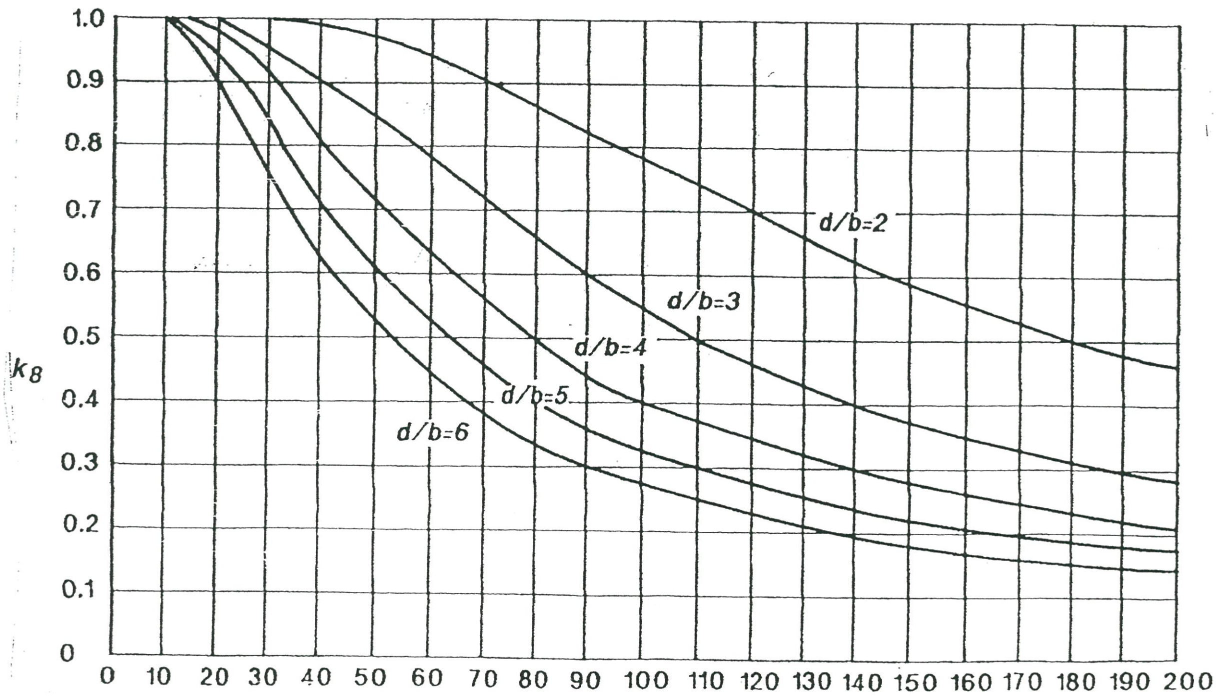
L_B = the span of the supporting members.

FINAL EXAMINATION

SEMESTER/SESSION : SEMESTER II 2014/2015 PROGRAM : 4BFF
COURSE NAME : ADVANCED STRUCTURAL TIMBER DESIGN COURSE CODE : BFK 40303



k_8 for columns



k_8 for beams, dry timber

Length - breadth ratio L_{ay}/b