UNIVERSITY OF RUHUNA

Faculty of Engineering

Semester 5 Examination in Engineering: March 2022

Module Number: CE5251 **Module Name: Design of Timber and Masonry Structures**

[Three Hours]

[Answer **all questions,** marks are given as indicated]

Note: (1) Code of practice BS EN 1995-1-1: 2004+A1:2008 and BS EN 1996-1-1: 2005 are provided separately, (2) Appendix A includes characteristic strength and other material properties that may be used for the designs.

Q1. A rack in a store has a steel-timber connection as shown in Figure Q1. It is used to transfer permanent load of 30kN and short-term variable load of 80kN in the parallel direction to the timber grain. In this joint, 10mm thick steel plate is inserted into the 200mm x 100mm sized C30 timber member and fixed it with four number of 12mm bolts. The bolt spacing is marked on the figure and the 13mm diameter holes are used to apply bolts. You may assume the exposure conditions of service class 1. Your answer should include all references to the Code of Practice provided.

(a) Check the adequacy of the timber member in resisting the designed tensile stresses under both the permanent and short-term conditions.
(Note: Partial safety factor for the permanent load $\gamma_G = 1.35$, variable load $\gamma_Q = 1.5$)

[6.0 Marks]

(b) Check whether the provided bolt spacing in the Figure Q1 is complying with the BS EN 1995-1-1 requirements.

[4.0 Marks]

(c) Determine the largest short term design force that can be transmitted through this connection by means of bolts. Is this joint safe under the loads applied in the connection. You may consider

- Characteristics tensile strength of bolts $f_{u,k} = 800 Nmm^{-2}$
- Characteristics timber density $\rho_k = 380 kgm^{-3}$
- Disregard the rope effects (i.e. characteristics axial withdrawal capacity of fasteners $F_{ax,Rk} = 0$)

[8.0 Marks]

(d) What do you mean by seasoning of timber? Described the consequences of the use of un-seasoned timber for the structural applications.

[2.0 Marks]

Q2. Figure Q2 shows an 80mm x 200mm purling of a roof with 18^0 degree slope. This purlin is rested simply support way on two main beams placed at 5m spacing. It was observed that the permanent UDL load and short-term variable UDL load on this purlin are 0.4kN/m and 0.6kN/m, respectively. It is required to check the adequacy of the purlin against the applied design bending moment. You may assume the exposure conditions of service class 1. Your answer should include all references to the Code of Practice provided.

(a) Determine the applied design bending moment
(Note: Partial safety factor for the permanent load $\gamma_G = 1.35$, variable load $\gamma_Q = 1.5$)

[2.0 Marks]

(b)

i. Determine the design bending moment component with respect to y-axis (M_y) and z-axis (M_z).

ii. Determine the design bending stress component with respect to y-axis (σ_{myd}) and z-axis (σ_{mzd})

[5.0 Marks]

(c) If the strength class C24 timber has been used for the purlin, determined its design strength (f_{myd}, f_{mzd}).

[3.0 Marks]

(d) Check the adequacy of the purlin against the applied design bending moment.

[5.0 Marks]

Q3. (a) Explain how would you obtain the effective height of a load-bearing masonry wall with a concrete slab at the top. Mention any exceptions to the general rule with the same end conditions.

[4.0 Marks]

(b) Why it is necessary to protect masonry wall exposed from rain? Identify three approaches generally used in construction to protect masonry against rain.

[3.0 Marks]

(c) In designing the type of mortar plays a part in strength of the masonry. Discuss in detail the other functionalities and purpose of mortar usage in masonry construction.

[3.0 Marks]

Q4. An outdoor masonry parapet wall has been proposed around the playground area of a well-known school within the Colombo city limits.
Figure Q4 shows the cross-section of a 3.2 m high wall constructed from clay bricks of standard format size having a declared air-dried mean compressive strength of 30 N/mm^2 laid in a 1:6 mortar. You may assume that the execution control Class II, and manufacturing control Category II for clay bricks.

(a) Briefly explain what is meant by "the Characteristic Compressive Strength of Masonry".

[2.0 Marks]

(b) Calculate the Characteristic Compressive Strength of Masonry for the given scenario, assuming "enhanced resistance" to lateral loading.

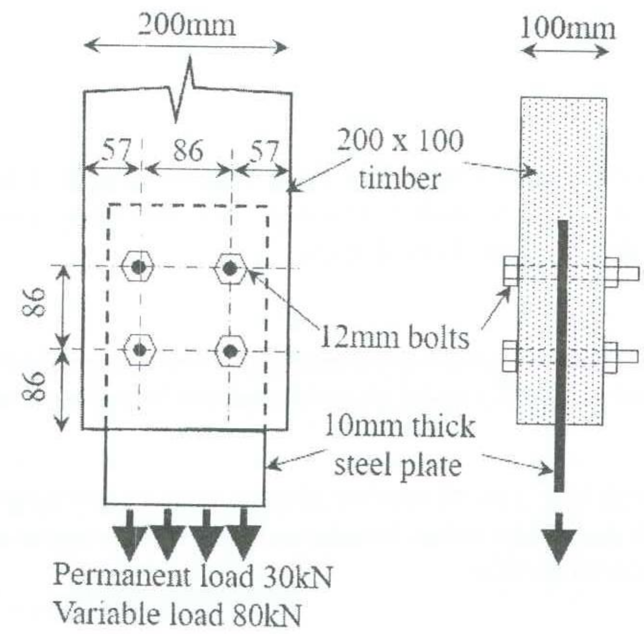
[3.0 Marks]

(c) Estimate the ultimate load bearing capacity of the wall. State clearly any assumptions you make in the process. Your answer should clearly show the slenderness ratio, and capacity reduction factor.

[8.0 Marks]

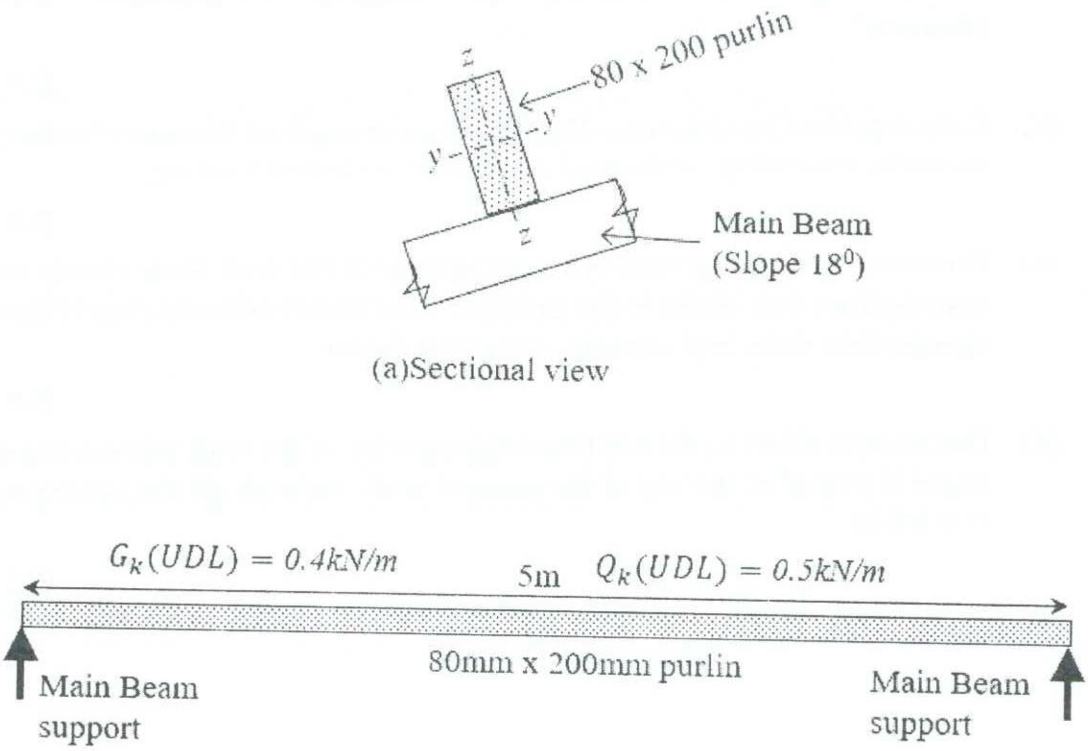
(d) Discuss the effect to the load bearing capacity of the wall when a concrete tie beam is placed at the top of the parapet wall. Indicate all the assumptions you make.

[2.0 Marks]



(a) Front view (b) Side view

Figure Q1. Plan and Elevation view of the steel-timber connection



(a)Sectional view

(b) Sketch of the purlin loading arrangement

Figure Q2. Loading on roof purlin

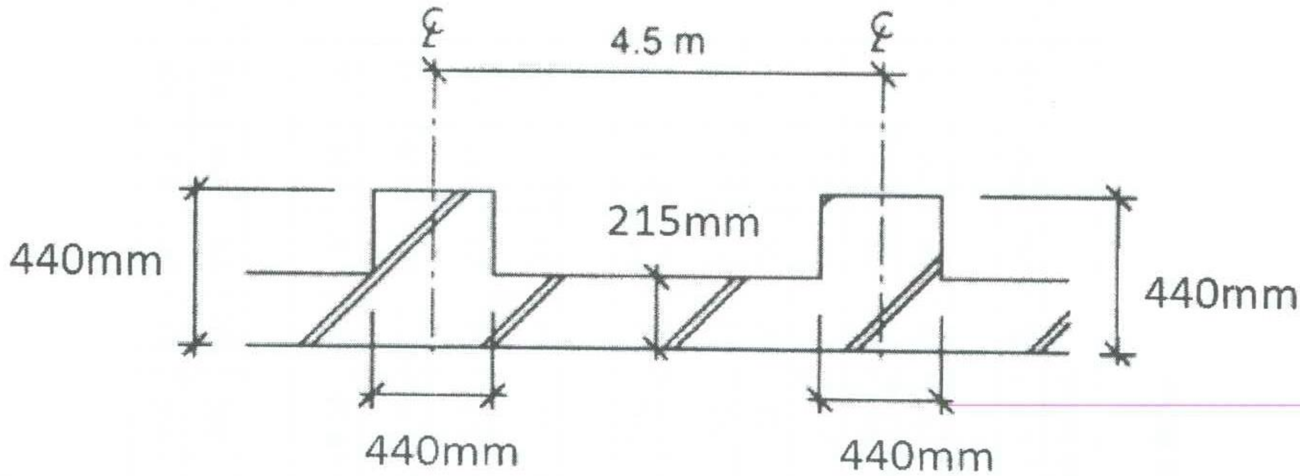


Figure Q4

APPENDIX A

Table A.1: Characteristic Values for Hardwood Timber (Extracted from EN 338:2009)

		Coniferous species and Poplar												Deciduous species					
		C14	C16	C18	C20	C22	C24	C27	C30	C35	C40	C45	C50	D30	D35	D40	D50	D60	D70
Strength properties in N/mm^2																			
Bending	$f_{m,k}$	14	16	18	20	22	24	27	30	35	40	45	50	30	35	40	50	60	70
Tension parallel to grain	$f_{t,0,k}$	8	10	11	12	13	14	16	18	21	24	27	30	18	21	24	30	36	42
Tension perpendicular to grain	$f_{t,90,k}$	0,4	0,5	0,5	0,5	0,5	0,5	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6
Compression parallel to grain	$f_{c,0,k}$	16	17	18	19	20	21	22	23	25	26	27	29	23	25	26	29	32	34
Compression perpendicular to grain	$f_{c,90,k}$	2,0	2,2	2,2	2,3	2,4	2,5	2,6	2,7	2,8	2,9	3,1	3,2	8,0	8,4	8,8	9,7	10,5	13,5
Shear	$f_{v,k}$	1,7	1,8	2,0	2,2	2,4	2,5	2,8	3,0	3,4	3,8	3,8	3,8	3,0	3,4	3,8	4,6	5,3	6,0
Stiffness properties in kN/mm^2																			
Mean value of modulus of elasticity parallel to grain	$E_{0,mean}$	7	8	9	9,5	10	11	11,5	12	13	14	15	16	10	10	11	14	17	20
5% value of modulus of elasticity parallel to grain	$E_{0,05}$	4,7	5,4	6,0	6,4	6,7	7,4	7,7	8,0	8,7	9,4	10,0	10,7	8,0	8,7	9,4	11,8	14,3	16,8
Mean value of modulus of elasticity pependicular to grain	$E_{90,mean}$	0,23	0,27	0,30	0,32	0,33	0,37	0,38	0,40	0,43	0,47	0,50	0,53	0,64	0,69	0,75	0,93	1,13	1,33
Mean value of shear modulus	G_{mean}	0,44	0,5	0,56	0,59	0,63	0,69	0,72	0,75	0,81	0,88	0,94	1,00	0,60	0,65	0,70	0,88	1,06	1,25
Density in kg/m^3																			
Density	ρ_k	290	310	320	330	340	350	370	380	400	420	440	460	530	560	590	650	700	900
Mean value of density	ρ_{mean}	350	370	380	390	410	420	450	460	480	500	520	550	640	670	700	780	840	1080

Table A.2: Partial factors for material properties for the ultimate limit state (γ_M)

	Class of execution control	
	1	*2*
When in a state of direct or flexural compression		
Unreinforced masonry made with:		
units of category I	2.3	2.7
units of category II	2.6	3.0
When in a state of flexural tension		
units of category I and II	2.3	2.7

Table A.3: Types of Mortar

Compressive strength class	*Prescribed mortars (proportion of materials by volume)*				*Mortar designation*
	Cement-lime-sand with or without air entrainment	*Cement-sand with or without air entrainment*	*Masonry cement[1]-sand*	*Masonry cement[2]-sand*	
M12	1:0 to 1/4:3	–	–	–	(i)
M6	1:1/2:4 to 4 1/2	1:3 to 4	1:2 1/2 to 3 1/2	1:3	(ii)
M4	1:1:5 to 6	1:5 to 6	1:4 to 5	1:3 1/2 to 4	(iii)
M2	1:2:8 to 9	1:7 to 8	1:5 1/2 to 6 1/2	1:4 1/2	(iv)

Notes:
[1]Masonry cement with organic filler other than lime
[2]Masonry cement with lime