UNIVERSITY OF RUHUNA

Faculty of Engineering

Semester 5 Examination in Engineering: May 2023

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

[Three Hours]

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

Notes: (1) Codes 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 strengths and other material properties.

Q1. Answer the following questions:

(a) What is the meaning of "seasonal defects" in timber?

[1.0 Mark]

(b) Explain the distinctions between "softwood" and "hardwood".

[2.0 Marks]

(c) Describe the two physical properties that influence the strength of the timber.

[2.0 Marks]

(d) Figure Q1 shows the timber column (solid section) with a cross section of 150 mm x 250 mm, a strength class of C30. It is subjected to service class 1 exposure condition. It is used to transfer the characteristic permanent compressive action of 12 kN and the characteristic variable medium-term compressive action of 16 kN. The loads are applied 20 mm eccentrically from the Y-Y axis and 25 mm from the X-X axis. The height of the column (L) is 4 m. The effective lengths of the column (L_e) are L and $0.85L$ about X-X and Y-Y axis, respectively. The slenderness ratio $\lambda = L_e/i$, where $i-$ radius of gyration, $i=\sqrt{I/A}$, $I-$Second moment of area, $A-$ cross-sectional area. You may consider the partial safety factor for the permanent load $\gamma_G = 1.35$, and the variable load $\gamma_Q = 1.5$. You may assume any missing information and clearly state it.

i) Calculate compressive stress and bending stress.

[2.0 Marks]

ii) Calculate bending and compressive strength.

[3.0 Marks]

iii) Check the adequacy for the combined effect of axial compression and bending.

[5.0 Marks]

Q2. Two 35 mm x 115 mm side members are connected to 65 mm x 115 mm timber member as shown in Figure Q2. The connection is functioning in exposure condition of service class 2. Four numbers of 3.35 mm diameter smooth round nails 60 mm long without pre-drilling are driven in the members. The spacing of the nails is shown in Figure Q2. The nails have a tensile strength of 600 N/mm^2. The characteristic density of the timber is 340 kg/m^3. The joint is subjected to a characteristic permanent action of 2.5 kN and a characteristic medium-term variable action of 3 kN and all timber is strength class C24. You may consider the partial safety factor for the permanent load $\gamma_G = 1.35$, and the variable load $\gamma_Q = 1.5$. You may assume any missing information and clearly state it.

(a) Does this connection single or double shear?

[2.0 Marks]

(b) Check the adequacy of the bolt spacing and point side penetration for nails.

[4.0 Marks]

(c) Check the adequacy of the timber member in resisting the designed tensile stresses under both the permanent and medium-term conditions.

[6.0 Marks]

(d) Check the adequacy of the lateral load-carrying capacity of the connection for the medium-term conditions. (disregard the rope effects)

[8.0 Marks]

Q3. (a) Briefly explain what is meant by "the Characteristic Compressive Strength of Masonry". How do you determine the above?

[4.0 Marks]

(b) Eurocode 6 part 2 specifies the "protective procedures to be implemented during construction" so that damages to the newly constructed masonry can be prevented. Briefly discuss three procedures.

[3.0 Marks]

(c) Satisfactory adhesion is required to achieve the design strength of masonry. Discuss the control measures of cement mortar use in construction of masonry structures.

[3.0 Marks]

Q4. Cavity wall AB of length 6m supports the RC slab as shown in Figure Q4. The inner leaf is built using solid concrete blocks of size 440 mm x 100 mm x 215 mm, faced with plaster, and the outer leaf using standard clay bricks. The self-weight of the blocks and plaster can be taken as 2.2 kN/m^2. The reinforced concrete roof slab is subjected to a dead load of 5.0 kN/m^2 and imposed load of 1.5 kN/m^2. You may assume Class 1 execution control, and Category II manufacturing control of concrete blocks.

(a) State clearly the assumptions you make in designing the cavity wall.

[1.0 Marks]

(b) Calculate the ultimate design load in kN/m.

[3.0 Marks]

(c) Calculate the slenderness ratio (SR) of the wall. You may assume that E values of the both leaves are approximately the same.

[2.0 Marks]

(d) Determine the Capacity Reduction Factor and the characteristic compressive strength of masonry (f_k). You may assume that the modulus of elasticity of masonry, $E = 1000\ f_k$.

[7.0 Marks]

(e) Provide clearly the specifications for the above cavity wall. You may assume that the Conditioning Factor =1.0, and Shape Factor = 1.38.

[2.0 Marks]

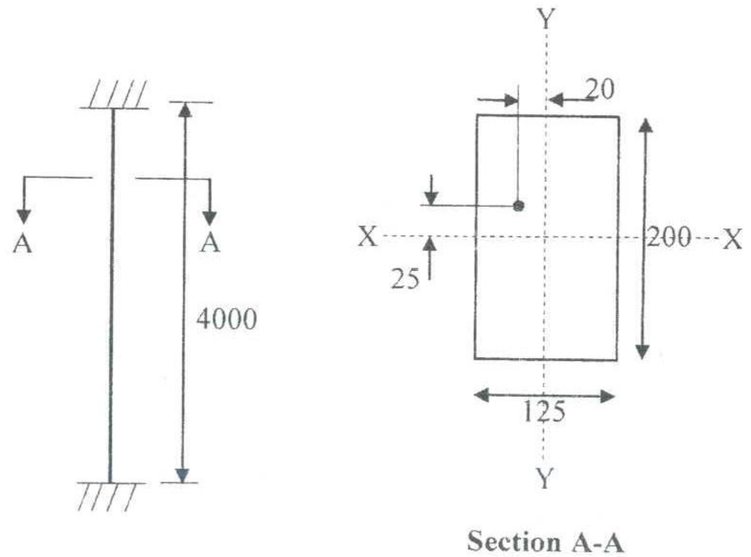

Figure Q1: Timber column (all dimensions are in mm).

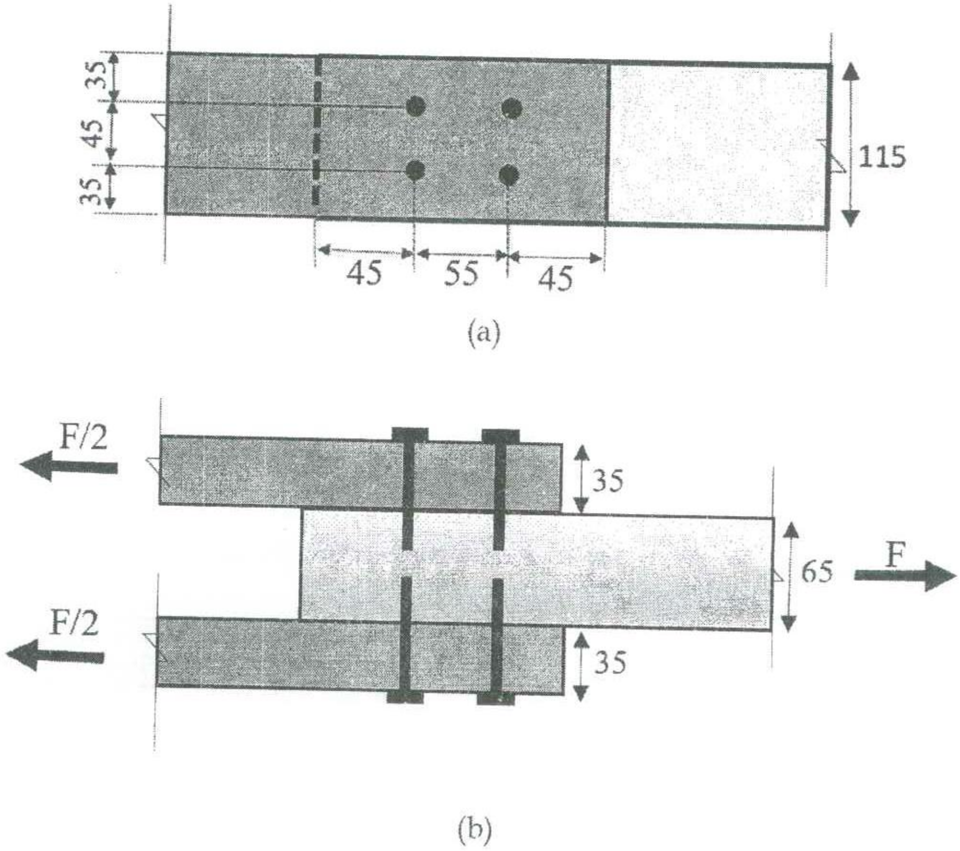

Figure Q2: (a) Plan and (b) Elevation view of the timber-to-timber connection (all dimensions are in mm).

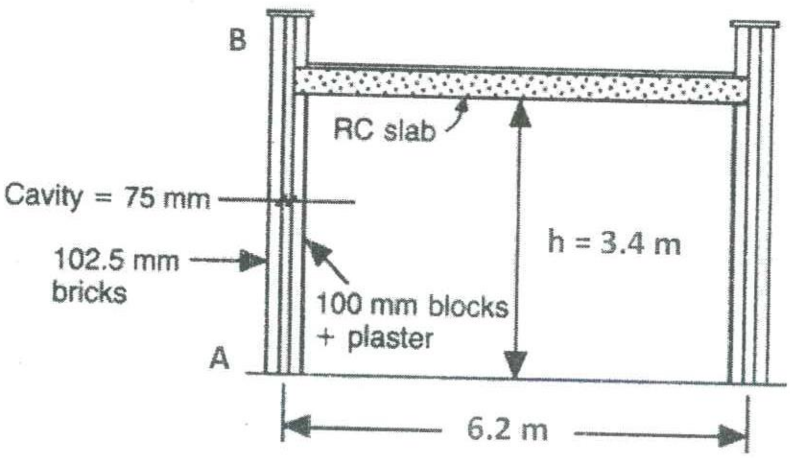

Figure Q4. Cross-section of cavity wall AB and the RC roof slab

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/mm²																			
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/mm²																			
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 perpendicular 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/m³																			
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