UNIVERSITY OF RUHUNA

Faculty of Engineering

Semester 5 Examination in Engineering: December 2020

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 that may be used for the designs.

Q1. Faculty of Engineering, University of Ruhuna is planned to design a suitable pedestrian bridge made of timber sections to connect administration building and nearby road towards the Engineering Library. It is expected to have a small open cafeteria side of the bridge as well.

(a) Discuss suitability to use timber sections for such construction and identify methods to improve the durability of the timber sections.

[3.0 Marks]

(b) Timber columns of strength class C16 with square cross section of size 100 x 100 mm is restrained at both ends in position but not in direction about either axis are used as intermediate supporting members. The actual height of a column is 3.75 m. Determine the design axial load that the column can support. You may clearly state appropriate Service Class condition and Load duration for the above bridge.

[8.0 Marks]

(c) It is identified that one of the corner columns in the cafeteria side is subjected to eccentric loading condition. Determine the adequacy of the similar size of column subjected to a load of 10 kN applied 35 mm eccentric to its axis. Also, determine the adequacy of the same column for lateral torsional buckling.

[8.0 Marks]

(d) Discuss methods to improve overall structural stability of the timber pedestrian bridge when it's exposed to unexpected static and dynamic loading conditions.

[6.0 Marks]

Q2. (a) What are the factors affecting the strength properties of timber sections? Briefly discuss effect of each factor on the strength of timber section.

[4.0 Marks]

(b) Determine the following values for the timber material of *D35*. Clearly show relevant equations, table numbers and clause numbers used in the calculation.

i) Grade stresses of compression perpendicular to the grain direction, modulus of elasticity perpendicular to the grain direction and shear modulus of the member.

[3.0 Marks]

ii) Modulus of elasticity perpendicular to the grain direction.

[2.0 Marks]

(c) Table Q2.1 shows typical information for three types of unknown timber materials. These sections are proposed to be used as lateral beams of the container storage facility in a very remote area in Galle district. Which of the timber specie would you select for the timber elements of the lateral beams? Justify your selection with all possible reasons.

Table Q2.1 Details of Timber Materials

Species	Cost of treated timber (per m length)	Colour	Natural Durability	Ease of treatment at the site	Self-weight	Availability at the area
TA-1	Rs. 275/=	Dark Brown	High	Difficult	High	Scare
TA-2	Rs. 125/=	Dark Brown	Medium	Moderate	Medium	Plentiful
TA-3	Rs. 75/=	Light Brown	Medium	Easy	Low	Plentiful

[6.0 Marks]

(d) Discuss four different structural forms of timber roof trusses.

[4.0 Marks]

(e) What are the methods of timber preservative treatment available in Sri Lanka? Discuss their suitability for different applications in the construction industry.

[3.0 Marks]

(f) Explain briefly why timber should be seasoned prior to use in structures.

[3.0 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.

[5.0 Marks]

(b) Briefly explain when you would use masonry walls stiffened by piers. Diagrams and equations to support your explanation may be necessary.

[5.0 Marks]

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

[5.0 Marks]

(d) 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.

[5.0 Marks]

Q4. An indoor gymnasium which consists of three badminton courts has been proposed to be built for Faculty of Engineering, University of Ruhuna. You have been asked to design the masonry walls. The rough sketch is shown in Figure Q4. 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 that the conditioning factor of 1.0, shape factor of 1.32, execution control Class 1, and manufacturing control Category II for concrete blocks.

(a) How would you idealize an external cavity wall? Explain briefly the assumptions you would make.

[2.0 Marks]

(b) Calculate the following:

i) Ultimate design load for external cavity wall

[3.0 Marks]

ii) Ultimate design load for internal single-leaf wall

[3.0 Marks]

(c) Design the external cavity wall consisting of a 102.5 mm thick brick outer leaf, a 390x190x100 solid concrete block inner leaf with a cavity of 75mm. State clearly any assumptions you make in the process of designing the wall.

[12.0 Marks]

(d) Check whether the internal single-leaf load-bearing block wall with the same specifications (as (c) above) is adequate to support the design loads. Indicate all the assumptions you make.

[10.0 Marks]

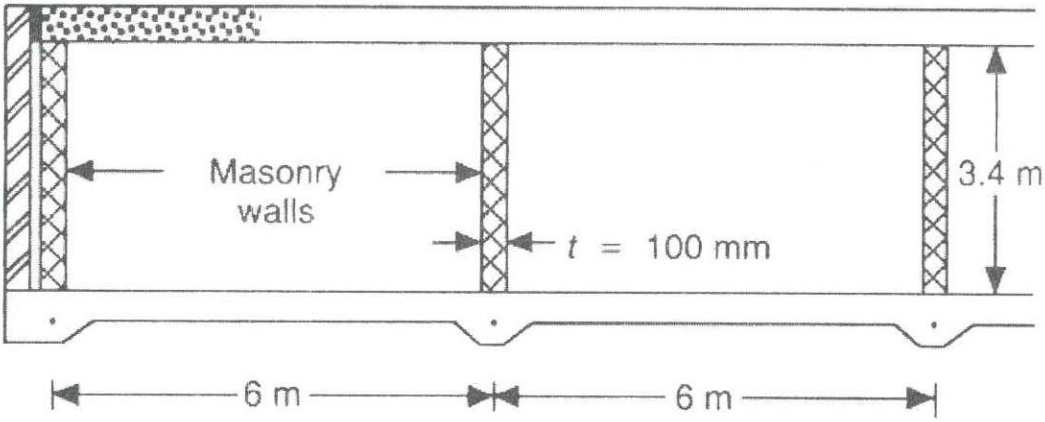

Figure Q4

APPENDIX A

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

Wood Class	Strength Properties (in N/mm²)						Stiffness properties (in kN/mm²)				Density (in kg/m³)	
	Bending	Tension Parallel	Tension Perpendicular	Compression Parallel	Compression Perpendicular	Shear	Mean modulus of elasticity parallel	5% modulus of elasticity parallel	Mean modulus of elasticity perpendicular	Mean shear modulus	Density (kg/m3)	Density (kg/m3)
	$f_{m,k}$	$f_{t,0,k}$	$f_{t,90,k}$	$f_{c,0,k}$	$f_{c,90,k}$	$f_{v,k}$	$E_{0,mean}$	$E_{0,05}$	$E_{90,mean}$	G_{mean}	ρ_k	ρ_{mean}
C14	14	8	0.4	16	2	3	7	4.7	0.23	0.44	290	350
C16	16	10	0.4	17	2.2	3.2	8	5.4	0.27	0.5	310	370
C18	18	11	0.4	18	2.2	3.4	9	6	0.3	0.56	320	380
C20	20	12	0.4	19	2.3	3.6	9.5	6.4	0.32	0.59	330	390
C22	22	13	0.4	20	2.4	3.8	10	6.7	0.33	0.63	340	410
C24	24	14	0.4	21	2.5	4	11	7.4	0.37	0.69	350	420
C27	27	16	0.4	22	2.6	4	11.5	7.7	0.38	0.72	370	450
C30	30	18	0.4	23	2.7	4	12	8	0.4	0.75	380	460
C35	35	21	0.4	25	2.8	4	13	8.7	0.43	0.81	400	480
C40	40	24	0.4	26	2.9	4	14	9.4	0.47	0.88	420	500
C45	45	27	0.4	27	3.1	4	15	10	0.5	0.94	440	520
C50	50	30	0.4	29	3.2	4	16	10.7	0.53	1	460	550
D18	18	11	0.6	18	7.5	3.4	9.5	8	0.63	0.59	475	570
D24	24	14	0.6	21	7.8	4	10	8.5	0.67	0.62	485	580
D30	30	18	0.6	23	8	4	11	9.2	0.73	0.69	530	640
D35	35	21	0.6	25	8.1	4	12	10.1	0.8	0.75	540	650
D40	40	24	0.6	26	8.3	4	13	10.9	0.86	0.81	550	660
D50	50	30	0.6	29	9.3	4	14	11.8	0.93	0.88	620	750
D60	60	36	0.6	32	10.5	4.5	17	14.3	1.13	1.06	700	840
D70	70	42	0.6	34	13.5	5	20	16.8	1.33	1.25	900	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