National Exams December 2017

04-Agric-B2
Structural Design of Agricultural, Biosystems and Food Industries

3 hours duration

NOTES:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.

2. This is an OPEN BOOK EXAM.
   Any non-communicating calculator is permitted.

3. FIVE (5) questions constitute a complete exam paper.
   Question 1 to be answered by all candidates plus 4 of the following 5 questions. The first five questions as they appear in the answer book will be marked.

4. Each question is of equal value.

5. Some questions require an answer in essay format. Clarity and organization of the answer are important. Provide sketches to illustrate the answer where applicable.

Question 1 (Mandatory question):
Define the following terms and explain their relationship to the structural design of agricultural structures; use examples to illustrate your answer. (20 marks, 2 each definition)

a) Importance factor
b) Load combinations
c) Factored loads
d) Factored resistance
e) Low human occupancy
f) Slope factor
g) Hoop stress
h) Uplift
i) Lateral force resisting system
j) Type HS cement

The drawing below (Figure 1) is illustrative of a typical loose animal housing barn with below slab manure storage facility. This schematic drawing applies to questions 2 through 6.

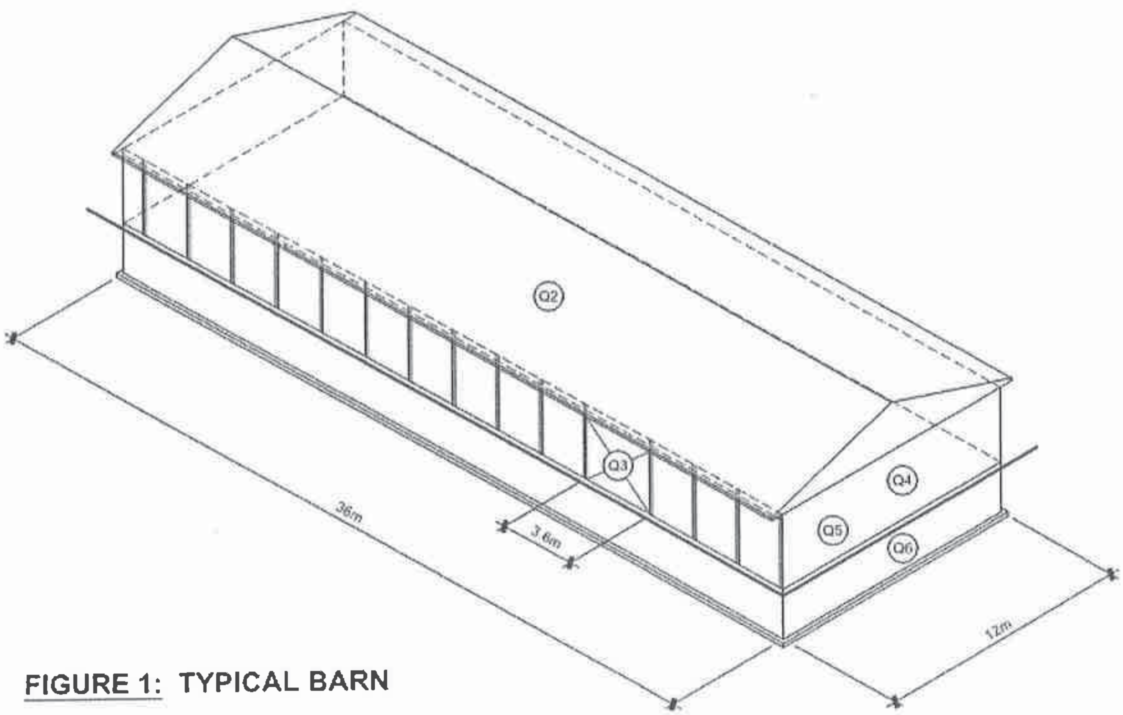


FIGURE 1: TYPICAL BARN

Answer 4 of the following 5 questions:

Question 2:

a) Determine the factored reactions at bearing location 1 and 5 (5 marks)
b) Determine the member axial forces in members 1-2, 2-3, 2-8 and 7-8 for the truss illustrated in Figure 2 (15 marks).

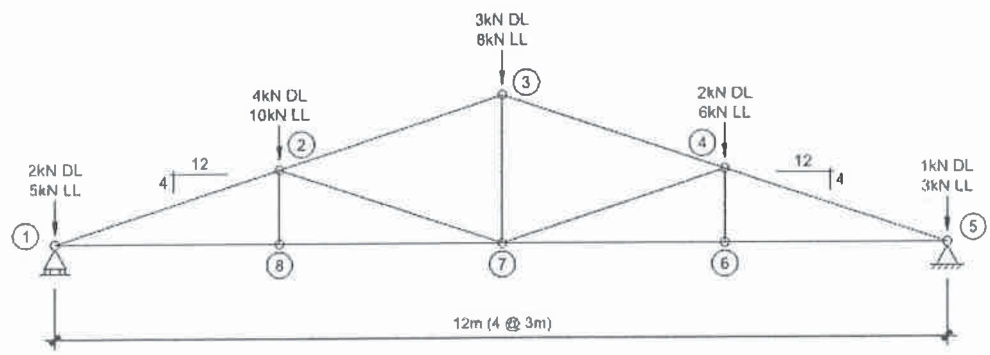


FIGURE 2: TRUSS ELEVATION

Question 3:
A lintel over a 3.6m wide side wall doors is to be made from built up (multi-ply) 38x286 [2x12] SPF No.1 members supported by 140x140 [6x6] wood posts. As illustrated below, the applied truss loads are applied at 1.2m on centre and it can be assumed that the truss load over a post is applied directly to the post.

a) Using the attached CSA Standard O86-09 Table 6.3.1A for specified strength, design the required timber lintel B1. For the purpose of this design, the strength modification factors may be all taken as 1.0. (10 marks)
b) Using the attached CSA Standard O86-09 Table 6.3.1D for specified strength, verify that the 140x140 timber post P1 is structurally adequate assuming that the stress ratio from wind induced bending is 32%. For the purpose of this design, the strength modification factor Kzc may be taken as 1.14 and Kc as 0.70. (10 marks)

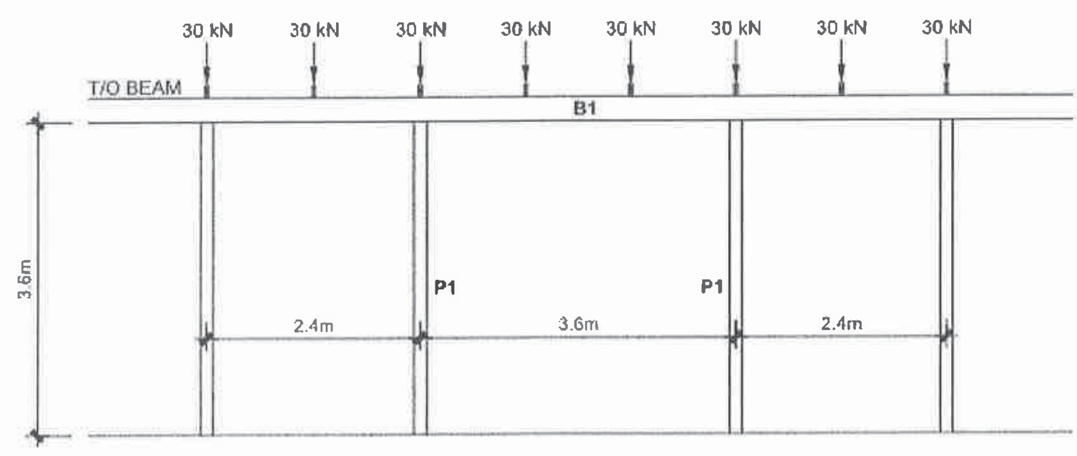


FIGURE 3: SIDE WALL BEAM / POST ELEVATIONS

Question 4:

a) Based on the barn illustrated in Figure 1, discuss three lateral force resisting systems available to address wind forces. For each, describe the method for determining the magnitude of the lateral load to be resisted by the force resisting elements. (10 marks)

b) Assuming that the wind lateral force resisting system is based on a diaphragm roof transferring the lateral load to the barn endwall, design and detail a plywood shearwall system. For the purpose of this question, assume that a total factored wind lateral load of 16 KN is to be resisted at each end wall – refer to Figure 4. (10 marks)

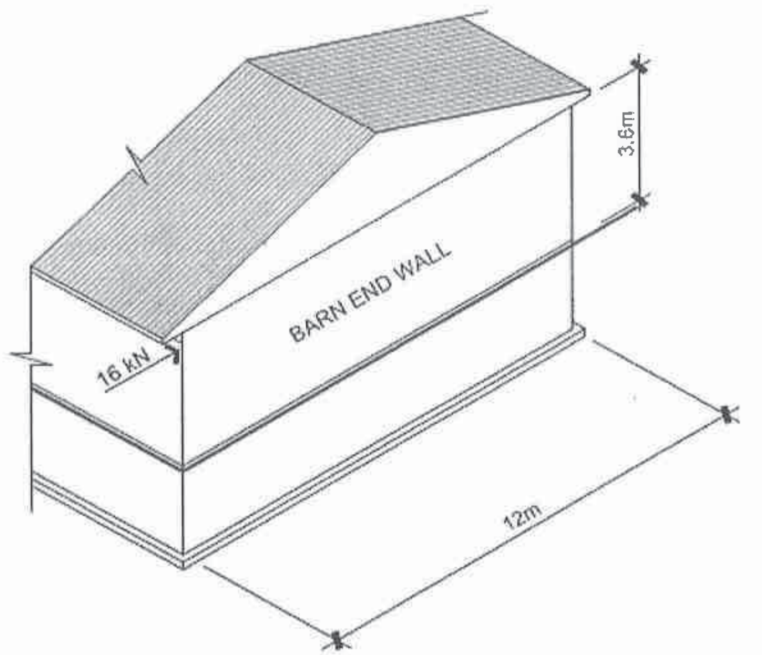


FIGURE 4: BARN END WALL ELEVATION

Question 5:
The barn floor consists of a reinforced concrete slab supported by the below-ground concrete liquid manure tank complete with interior raceway walls installed at 3.6m on centre. Design a typical middle span (of a 10 span continuous slab) to support a specified live load of 5.0 kPa (loose animal housing) and a superimposed dead load of 2.0 kPa. See attached reinforcement ratios. Provide a sketch illustrating the required concrete slab thickness, reinforcing steel, connection details and indicate the required concrete specifications. (20 marks)

Question 6:
The below-floor rectangular concrete manure storage tank is 12m wide, 36m long and 2.4m deep. The exterior of the tank will be backfilled after construction. The tank is designed to safely store 240 days of liquid manure.

a) Discuss the loads applied on the manure tank structure and the appropriate design considerations (10 marks)
b) Manure storage is a very corrosive environment. Discuss the concrete design requirements including cement types, cement content, water/cement ration, aggregates, admixtures, concrete cover, and curing required to provide a durable storage facility. (10 marks)

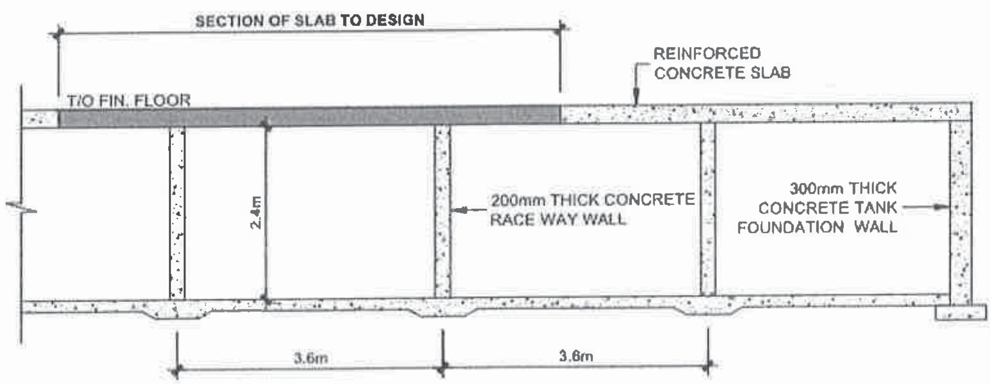


FIGURE 5: **SECTION OF MANURE STORAGE TANK**

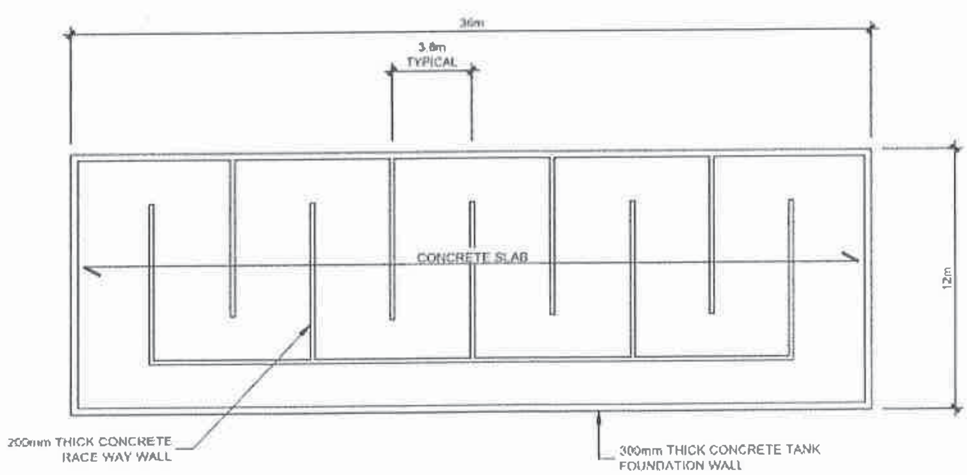


FIGURE 6: **PLAN OF MANURE TANK**

Table 6.3.1A
Specified strengths and modulus of elasticity for structural joist and plank, structural light framing, and stud grade categories of lumber, MPa

Species identification	Grade	Bending at extreme fibre, f_b	Longitudinal shear, f_v	Compression: Parallel to grain, f_c	Compression: Perpendicular to grain, f_{cp}	Tension parallel to grain, f_t	Modulus of elasticity: E	Modulus of elasticity: E_{05}
D Fir-L	SS	16.5		19.0		10.6	12 500	8 500
	No. 1/No. 2	10.0	1.9	14.0	7.0	5.8	11 000	7 000
	No. 3/Stud	4.6		7.3		2.1	10 000	5 500
Hem-Fir	SS	16.0		17.6		9.7	12 000	8 500
	No. 1/No. 2	11.0	1.6	14.8	4.6	6.2	11 000	7 500
	No. 3/Stud	7.0		9.2		3.2	10 000	6 000
Spruce-Pine-Fir	SS	16.5		14.5		8.6	10 500	7 500
	No. 1/No. 2	11.8	1.5	11.5	5.3	5.5	9 500	6 500
	No. 3/Stud	7.0		9.0		3.2	9 000	5 500
Northern	SS	10.6		13.0		6.2	7 500	5 500
	No. 1/No. 2	7.6	1.3	10.4	3.5	4.0	7 000	5 000
	No. 3/Stud	4.5		5.2		2.0	6 500	4 000

Note: *Tabulated values are based on the following standard conditions:*
(a) 286 mm larger dimension;
(b) dry service conditions; and
(c) standard-term duration of load.

Table 6.3.1D
Specified strengths and modulus of elasticity for post and timber grades, MPa

Species identification	Grade	Bending at extreme fibre, f_b	Longitudinal shear, f_v	Compression: Parallel to grain, f_c	Compression: Perpendicular to grain, f_{cp}	Tension parallel to grain, f_t	Modulus of elasticity: E	Modulus of elasticity: E_{05}
D Fir-L	SS	18.3	1.5	13.8	7.0	10.7	12 000	8 000
	No. 1	13.8		12.2		8.1	10 500	6 500
	No. 2	6.0		7.5		3.8	9 500	6 000
Hem-Fir	SS	13.6	1.2	11.3	4.6	7.9	10 000	7 000
	No. 1	10.2		10.0		6.0	9 000	6 000
	No. 2	4.5		6.1		2.8	8 000	5 500
Spruce-Pine-Fir	SS	12.7	1.2	9.9	5.3	7.4	8 500	6 000
	No. 1	9.6		8.7		5.6	7 500	5 000
	No. 2	4.2		5.4		2.6	6 500	4 500
Northern	SS	12.0	1.0	7.5	3.5	7.0	8 000	5 500
	No. 1	9.0		6.7		5.3	7 000	5 000
	No. 2	3.9		4.1		2.5	6 000	4 000

Notes:

(1) *Posts and timbers have a smaller dimension of at least 114 mm, with a larger dimension not more than 51 mm greater than the smaller dimension.*

(2) *Posts and timbers graded to beam and stringer rules may be assigned beam and stringer strength.*

(3) *An approximate value for modulus of rigidity may be estimated at 0.065 times the modulus of elasticity.*

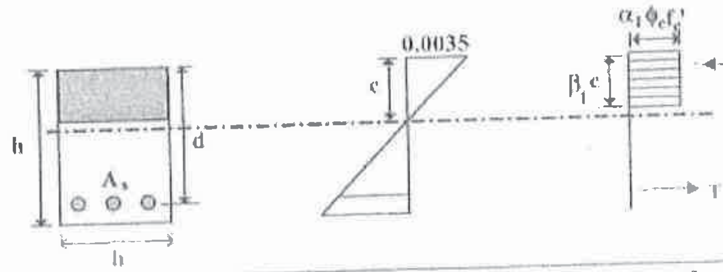
(4) *With sawn members thicker than 89 mm that season slowly, care should be exercised to avoid overloading in compression before appreciable seasoning of the outer fibre has taken place; otherwise, compression strengths for wet service conditions shall be used.*

(5) *Tabulated values are based on the following standard conditions:*
(a) 343 mm larger dimension for bending and shear and 292 mm larger dimension for tension and compression parallel to grain;
(b) dry service conditions; and
(c) standard-term duration of load.

(6) *The designer is strongly advised to check availability of species, grade, and sizes before specifying. See Clause A.6.2.1.2.*

Table 2.1 **Reinforcement ratio ρ (%) for rectangular sections with tension reinforcement f_y = 400 MPa**

$M_r = K_r b d^2 \times 10^{-6}$ kN.m; $K_r = \left[1 - \frac{\rho\phi_s f_y}{2\alpha_1\phi_c f'_c}\right]\rho\phi_s f_y$; $\rho = \frac{A_s}{bd}$



f'_c (MPa)	20	25	30	35	40	45	50	55	60
α_1 :	0.82	0.81	0.81	0.80	0.79	0.78	0.78	0.77	0.76
β_1 :	0.92	0.91	0.90	0.88	0.87	0.86	0.85	0.83	0.82
ρ_{bal} :	1.83	2.24	2.63	3.00	3.34	3.67	3.98	4.27	4.55
K_r					ρ (%)				
0.5	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
0.6	0 18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
0.7	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21
0.8	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24
0.9	0.28	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27
1.0	0.31	0.31	0.30	0.30	0.30	0.30	0.30	0.30	0.30
1.1	0.34	0.34	0.34	0.33	0.33	0.33	0.33	0.33	0.33
1.2	0.38	0.37	0.37	0.37	0.36	0.36	0.36	0.36	0.36
1.3	0.41	0.40	0.40	0.40	0.40	0.39	0.39	0.39	0.39
1.4	0.44	0.44	0.43	0.43	0.43	0.43	0.42	0.42	0.42
1.5	0.48	0.47	0.46	0.46	0.46	0.46	0.46	0.45	0.45
1.6	0.51	0.50	0.50	0.49	0.49	0.49	0.49	0.49	0.48
1.7	0.55	0.54	0.53	0.53	0.52	0.52	0.52	0.52	0.52
1.8	0.58	0.57	0.56	0.56	0.55	0.55	0.55	0.55	0.55
1.9	0.62	0.61	0.60	0.59	0.59	0.58	0.58	0.58	0.58
2.0	0.66	0.64	0.63	0.62	0.62	0.62	0.61	0.61	0.61
2.1	0.69	0.68	0.67	0.66	0.65	0.65	0.65	0.64	0.64
2.2	0.73	0.71	0.70	0.69	0.69	0.68	0.68	0 68	0.67
2.3	0.77	0.75	0.73	0.73	0.72	0.71	0.71	0.71	0.70
2.4	0.81	0.79	0.77	0.76	0.75	0.75	0.74	0.74	0.74
2.5	0.85	0.82	0.81	0.79	0.79	0.78	0.78	0.77	0.77
2.6	0.89	0.86	0.84	0.83	0.82	0.81	0.81	0.80	0.80
2.7	0.93	0.90	0.88	0.86	0.85	0.85	0.84	0.84	0.83
2.8	0.98	0.94	0.91	0.90	0.89	0.88	0.88	0.87	0.87
2.9	1.02	0.98	0.95	0.93	0.92	0.92	0.91	0.90	0.90