National Exams December 2010

**04-Agric-B2, Structural Design for 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.
   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.

1. You have been asked to produce a mix design for concrete intended for the construction of a 0.3 m thick wall of a liquid manure tank below a swine barn. Most of the wall will be below grade after backfilling The pigs are kept in pens on a slatted floor covering the liquid manure tank below. The structural design of the manure tank wall calls for a concrete with a 28-day strength of 25 MPa. Discuss the various factors you will consider in the design of the mix with particular attention to water/cement ratio, cement content, aggregates, admixtures. (20 marks)
2. Analyze the beam in Fig. 1 for reactions, shears and bending moments. Draw shear force and a bending moment diagrams; include values. (15 marks). What is the mathematical relationship between shear forces and bending moments. (5 marks).
3. The cylindrical reinforced concrete wall of an above-ground liquid manure tank is 4.5 m high, 50.0 m inside diameter. There is no overflow outlet below the top of the wall. Assuming that liquid manure has a density 1.02 times that of water, show a design pressure diagram on the tank wall. (5 marks). Assuming that the factored internal pressure causes a maximum circumferential tension (factored) in the wall of 1125 kN/m some 3 m below the top of the wall, what wall reinforcement would you suggest at that point neglecting small vertical bending moments (see Table 1 for reinforcing sizes and spacings). Provide a sketch. Use reinforcement with a yield strength of 400 MPa. The strength reduction factor is 0.85 (10 marks). How thick would you make the wall, and why. (5 marks).
4. Determine the forces in members 1-2, 2-3 and 2-6 of the truss in Fig. 2. Indicate compression (negative) or tension (positive). (20 marks).
5. Design the size and shape of a suitable footing for a concrete retaining wall that is 0.3 m thick and 4.0 m high, measured from the top of the footing. The soil behind the retaining wall is level and has little or no surcharge load behind the wall. The soil in front of the retaining wall is 1.0 m above the top of the footing, so the difference in soil level is 3.0 m. The angle of internal friction of the soil may be taken as $30^{\circ}$, its mass density 1800 kg/$m^3$. The soil is well-drained. You may assume that the wall can move sufficiently for active soil pressures to develop. The ultimate bearing capacity of the sandy soil at footing level is 900 kPa. (20 marks).

6. A lintel over a 4.0 m wide door opening inside an agricultural building, a machine storage shed in Ontario,is to be made of sawn timber. The horizontal lintel is supported at each end by 140 x 140 mm posts. The timber lintel has to carry a factored live load of 5.0 kN/m and a factored dead load of 2.5 kN/m. Design a suitable sawn timber lintel using #1 grade S-P-F lumber. See Table 2 (CSA Standard O86.1-94 Table 5.3.1C) for specified strength and Table 3 (O86.1-94 Tables 5.4.4 and 5.4.5) for strength modification factors. The systems factor $K_H$ may be taken as 1.0, the size factor depend on the selected size of timber. You may assume standard live load duration, dry service load conditions and you may also assume that the lintel will not be treated with preservatives. (20 marks).

7. A storage structure on a farm in Southern Ontario is supported by structural steel frames shaped roughly as shown in Fig.3. Discuss briefly the various loads that should be considered in the design of each structural steel frame 5 marks). Further discuss, given the various loads, how you would analyze the frame to obtain design bending moments, shear forces and axial loads. 10 marks). Finally, given that the stored materials will cause high relative humidity inside the building, make recommendations on wall and roof materials, finishes and various measures to minimize corrosion. (5 marks).

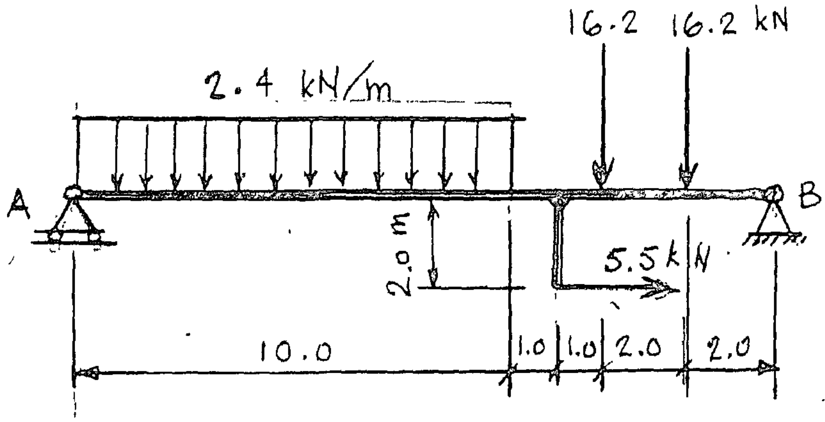


Figure 1 for question 2
All dimensions in m

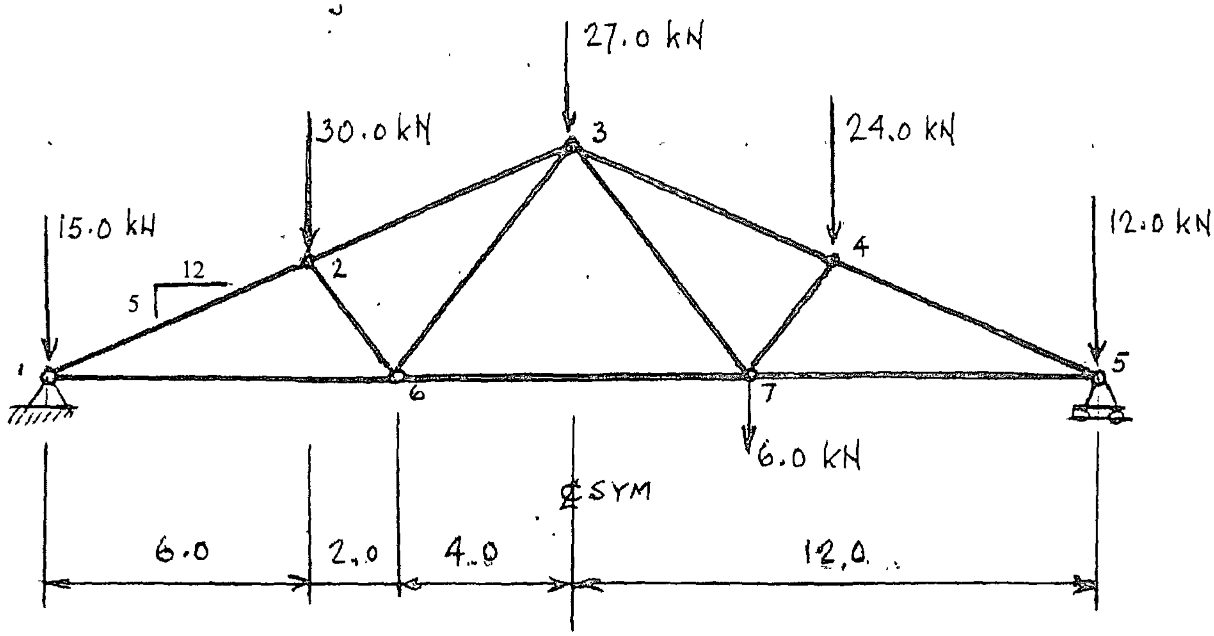


Figure 2 for question 4
All dimensions in m

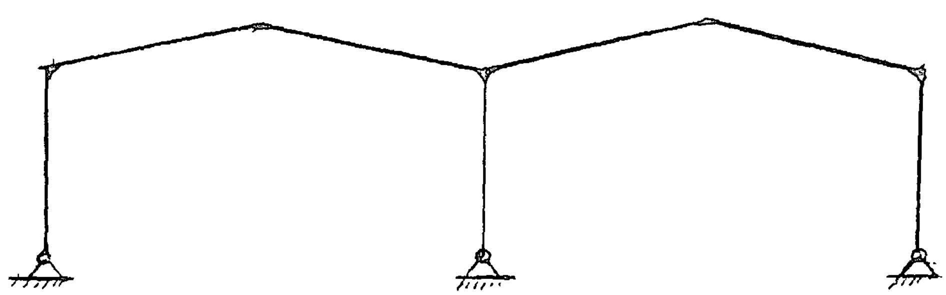

Figure 3 for question 7

Table 1 for Question 3

**Table 5.10 Area of Reinforcing Steel ($A_s$ $mm^2$) Per One Metre Strip**

| Bar Spacing mm | Bar Size (No.) | | | | | |
|---|---|---|---|---|---|---|
| | 10 | 15 | 20 | 25 | 30 | 35 |
| 50 | 2000 | 4000 | 6000 | 10000 | 14000 | 20000 |
| 80 | 1250 | 2500 | 3750 | 6250 | 8750 | 12500 |
| 100 | 1000 | 2000 | 3000 | 5000 | 7000 | 10000 |
| 120 | 833 | 1667 | 2500 | 4167 | 5833 | 8333 |
| 150 | 667 | 1333 | 2000 | 3333 | 4667 | 6667 |
| 180 | 556 | 1111 | 1667 | 2778 | 3889 | 5556 |
| 200 | 500 | 1000 | 1500 | 2500 | 3500 | 5000 |
| 220 | 455 | 909 | 1364 | 2273 | 3182 | 4545 |
| 240 | 417 | 833 | 1250 | 2083 | 2917 | 4167 |
| 250 | 400 | 800 | 1200 | 2000 | 2800 | 4000 |
| 260 | 385 | 769 | 1154 | 1923 | 2692 | 3846 |
| 280 | 357 | 714 | 1071 | 1786 | 2500 | 3571 |
| 300 | 333 | 667 | 1000 | 1667 | 2333 | 3333 |
| 320 | 313 | 625 | 938 | 1563 | 2188 | 3125 |
| 340 | 294 | 588 | 882 | 1471 | 2059 | 2941 |
| 360 | 278 | 556 | 833 | 1389 | 1944 | 2778 |
| 380 | 263 | 526 | 789 | 1316 | 1842 | 2632 |
| 400 | 250 | 500 | 750 | 1250 | 1750 | 2500 |
| 420 | 238 | 476 | 714 | 1190 | 1667 | 2381 |
| 440 | 227 | 455 | 682 | 1136 | 1591 | 2273 |
| 460 | 217 | 435 | 652 | 1087 | 1522 | 2174 |

Table 2 for Question 6



## Table 5.3.1C
## Specified Strengths and Modulus of Elasticity for Beam and Stringer Grades (MPa) *

| Species identification | Grade | Bending at extreme fibre | Longitudinal shear | Compression | | Tension parallel to grain | Modulus of elasticity | |
|---|---|---|---|---|---|---|---|---|
| | | | | Parallel to grain | Perpendicular to grain | | | |
| | | $f_b$ | $f_v$ | $f_c$ | $f_{cp}$ | $f_t$ | E | $E_{05}$ |
| D Fir-L | SS | 19.5 | | 13.2 | | 10.0 | 12 000 | 8 000 |
| | No. 1 | 15.8 | 0.9 | 11.0 | 7.0 | 7.0 | 12 000 | 8 000 |
| | No 2 | 9.0 | | 7.2 | | 3.3 | 9 500 | 6 000 |
| Hem-Fir | SS | 14.5 | | 10.8 | | 7.4 | 10 000 | 7 000 |
| | No. 1 | 11.7 | 0.7 | 9.0 | 4.6 | 5.2 | 10 000 | 7 000 |
| | No. 2 | 6.7 | | 5.9 | | 2.4 | 8 000 | 5 500 |
| S-P-F | SS | 13.6 | | 9.5 | | 7.0 | 8 500 | 6 000 |
| | No. 1 | 11.0 | 0.7 | 7.9 | 5.3 | 4.9 | 8 500 | 6 000 |
| | No. 2 | 6.3 | | 5.2 | | 2.3 | 6 500 | 4 500 |
| Northern | SS | 12.8 | | 7.2 | | 6.5 | 8 000 | 5 500 |
| | No. 1 | 10.8 | 0.6 | 6.0 | 3.5 | 4.6 | 8 000 | 5 500 |
| | No. 2 | 5.9 | | 3.9 | | 2.2 | 6 000 | 4 000 |

**Specified strengths for "Beams and Stringers" are based on loads applied to the narrow face. When "Beams and Stringers" are subject to loads applied to the wide face, the specified strength for bending at the extreme fibre and the specified modulus of elasticity shall be multiplied by the following factors:*

| | $f_b$ | E or $E_{05}$ |
|---|---|---|
| *Select Structural* | *0.88* | *1.00* |
| *No. 1 or No. 2* | *0.77* | *0.90* |

**Notes:**

(1) *"Beams and Stringers" have a smaller dimension of at least 114 mm, with a larger dimension more than 51 mm greater than the smaller dimension.*

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

(3) *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.*

(4) *Beam and stringer grades listed in this Table are not graded for continuity (see Clause 5.5.3).*

(5) *Tabulated values are based on the following standard conditions:*

*(a) 343 mm larger dimension for bending and shear, 292 mm larger dimension for tension and compression parallel to grain;*

*(b) dry service conditions;*

*(c) standard term duration of load.*

Table 3 for Question 6



**Table 5.4.4**
**System Factor, $K_H$**

| | | Case 2† | | |
|---|---|---|---|---|
| For specified strength in | Case 1* | Visually graded | MSR | Built-up beams |
| Bending | 1.10 | 1.40 | 1.20 | 1.10 |
| Longitudinal shear | 1.10 | 1.40 | 1.20 | 1.10 |
| Compression parallel to grain | 1.10 | 1.10 | 1.10 | 1.00 |
| Tension parallel to grain | 1.10 | N/A | N/A | 1.00 |
| All other properties | 1.00 | 1.00 | 1.00 | 1.00 |

*See Clause 5.4.4.1 for conditions applying to Case 1.
†See Clause 5.4.4.2 for conditions applying to Case 2.
N/A = not applicable

**Table 5.4.5**
**Size Factor, $K_Z$, for Visually Stress-Graded Lumber**

| | Bending and shear $K_{Zb}$, $K_{Zv}$ | | | Tension parallel to grain $K_{Zt}$ | Compression perpendicular to grain $K_{Zcp}$ | Compression parallel to grain $K_{Zc}$ | All other prope |
|---|---|---|---|---|---|---|---|
| | Smaller dimension (mm) | | | | | | |
| Larger dimension (mm) | 38 to 64 | 89 to 102 | 114 or more | All | All | All | All |
| 38 | 1.7 | — | — | 1.5 | | | 1.0 |
| 64 | 1.7 | — | — | 1.5 | See | Value | 1.0 |
| 89 | 1.7 | 1.7 | — | 1.5 | Clause | computed | 1.0 |
| 114 | 1.5 | 1.6 | 1.3 | 1.4 | 5.5.7.4 | using | 1.0 |
| 140 | 1.4 | 1.5 | 1.3 | 1.3 | | formula | 1.0 |
| 184 to 191 | 1.2 | 1.3 | 1.3 | 1.2 | | in | 1.0 |
| 235 to 241 | 1.1 | 1.2 | 1.2 | 1.1 | | Clause | 1.0 |
| 286 to 292 | 1.0 | 1.1 | 1.1 | 1.0 | | 5.5.6.2.2 | 1.0 |
| 337 to 343 | 0.9 | 1.0 | 1.0 | 0.9 | | | 1.0 |
| 387 or larger | 0.8 | 0.9 | 0.9 | 0.8 | | | 1.0 |

**Note:** *See Clause 5.4.5.4 for conditions applying to No. 1, No. 2, or No. 3 64 x 89 mm and 89 x mm members.*