Name: ________________________________

Student Number: ________________________________

FINAL EXAM DECEMBER 2001

CIV 420F - Construction Engineering

Department of Civil Engineering
Faculty of Applied Science and Engineering
University of Toronto

Examiner: B. McCabe

Exam Type C: Approved Aid Sheet Only

If you do not understand a question, state reasonable assumptions and continue with the problem.

Examiner's Report	
1.	/7
2.	/30
3.	/18
4.	/25
5.	/20
Total	/100

Question 1 **Definitions [7 marks]**

a) Dental concrete

b) AN/FO

c) Air Track

d) Fly rock

e) Cascade generation system

f) Stiff leg derrick

g) Echelon paving

Question 2 **Describe the differences** **[30 marks]**

a) **[5]** Cable strands vs. solid bars for tie-backs

Cable strands	Solid bars

b) **[5]** Fixed costs vs. Variable costs

Fixed costs	Variable costs

c) **[5]** Cofferdam vs. Caisson wall

Cofferdam	Caisson wall

d) **[5]** Critical path method vs. Line of balance

Critical path method (CPM)	Line of balance (LOB)

e) **[5]** Type 1 vs. Type 3 Asbestos Removal

Type 1	Type 3

f) **[5]** RAP vs. Riprap

RAP	Riprap

Question 3 Short Answers [18 marks]

a) **[3]** Why were articulated rock trucks used instead of fixed body trucks at the High Falls project?

b) **[3]** Why are caisson walls not used as the building foundation in Toronto?

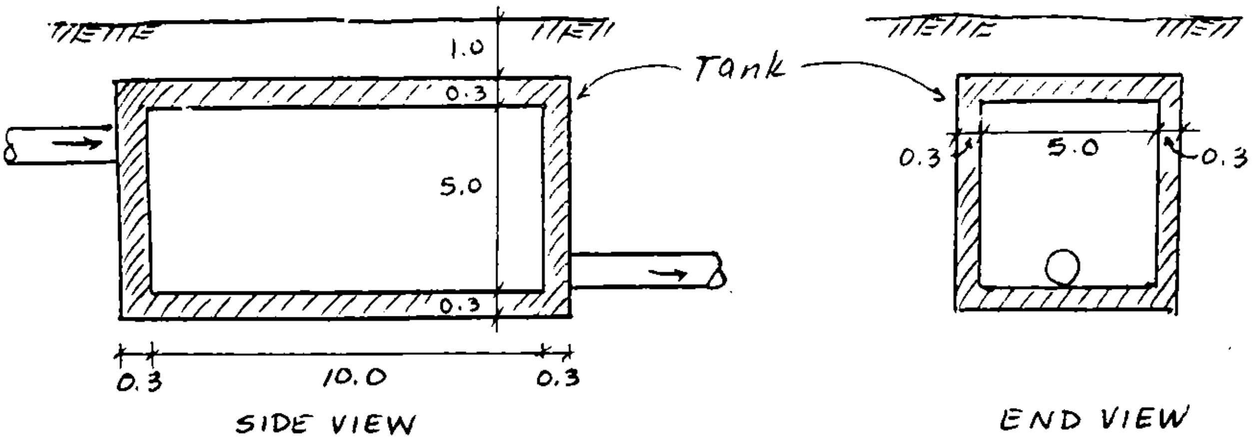
c) **[3]** Describe 3 methods for bracing excavation walls.

d) **[3]** Briefly describe 3 methods for dewatering an excavation.

e) **[6]** Discuss three major considerations when planning a construction project in Northwest Territories.

Question 4 **Formwork Analysis [25 marks]**

You have to build an underground tank in a vacant block of land, as shown below. The soil is undisturbed, dry packed earth.



a) [5]

i) What is the volume you must excavate to build the tank safely?

ii) Using the 315B Excavator and its largest bucket, how long will it take to excavate?

b) **[10]** You noticed that some gang forms are stacked in the materials yard. You are hoping that you can use them for the walls of the tank to reduce costs. The forms are:

- plywood: 20.5 mm, 7 ply
- studs: 38mm x 140mm at 350mm centres

Can you use them? Show why or why not.

c) **[5]** How will you construct the top of the tank?

d) **[5]** Why are different equations used to calculate Pmax? Why don't we just use the fluid pressure?

Question 5 Tunnelling [20 marks]

The City currently maintains a ferry for people, vehicles, supplies, fuel etc to access the Toronto City Centre Airport on Toronto's Ward Island. It is expensive to run, especially during the winter, when they have to call the icebreakers in to keep the path clear. They have decided to build a tunnel across the gap so that the ferry could be decommissioned, vehicles could go through the tunnel, and pleasure boats in Toronto Harbour will be able to pass into the lake unencumbered. The gap between the 2 pieces of land is 100 metres. Aside from airport buildings, there is an old 7 story masonry structure about 100 metres from the proposed path.

a) **[5]** What are the most important five factors in this specific case?

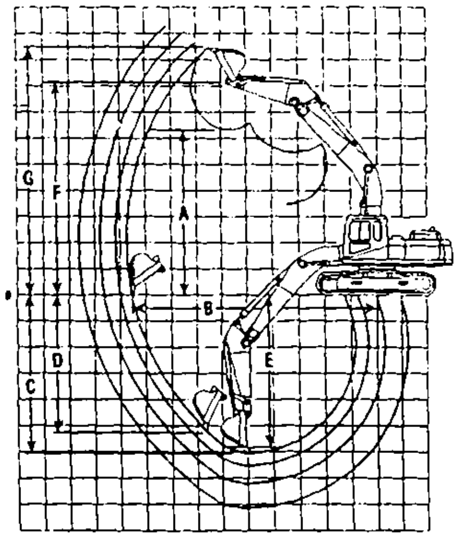
b) **[5]** What method of tunnelling would you use? Why?

c) **[5]** A tunneling operation produces muck at a rate of $51 m^3$ per hour. The conveyor system can carry a cross-sectional area of muck of $0.1\ m^2$. What speed must the conveyor move in *metres per minute*? If the conveyor is not capable of moving this fast, what practical options do you have?

d) **[5]** One year after completion of the tunnel, the owner of the masonry building wants to tear the building down and build a new condominium complex. If you are the demolition contractor, describe in point form the process you will use to demolish the building. What are your concerns?

Excavators | Range Dimensions

- 315B
- 315B L
- France Sourced



One-Piece Boom Digging Envelope

- Standard shoes and undercarriage

KEY:

- **A** Maximum loading height of bucket with teeth
- **B** Maximum reach at ground level
- **C** Maximum digging depth
- **D** Maximum vertical wall
- **E** Maximum depth of cut for 2.44 m (8'0") level bottom (straight clean up)
- **F** Maximum bucket hinge pin height
- **G** Maximum height, to bucket teeth at highest arc

France Sourced — **315B L**

Stick	1.85 m	6'1"	2.25 m	7'5"	2.6 m	8'6"	3.1 m	10'2"
	m	ft	m	ft	m	ft	m	ft
A	6.05	19'11"	6.07	19'11"	6.43	21'1"	6.27	20'7"
B	7.92	25'11"	8.21	26'11"	8.62	28'3"	8.90	29'2"
C	5.18	17'0"	5.58	18'3"	5.93	19'5"	6.43	21'1"
D	3.89	12'9"	4.03	13'3"	4.86	15'11"	4.68	15'4"
E	4.87	16'0"	5.27	17'3"	5.69	18'8"	6.13	20'1"
F	7.28	23'11"	7.30	23'11"	7.66	25'1"	7.50	24'7"
G	8.49	27'10"	8.51	27'11"	8.89	29'2"	8.69	28'6"

Cycle Time Estimating Chart

Model		307B	311B	312B, 312B L	315B, 315B L	317B L, 317B LN	318B L, 318B LN	320B	322B	325B	330B	345B*	350	375
Bucket Size L		280	450	520	520	520	800	800	1000	1100	1400		1900	2800
(yd³)		0.37	0.59	0.68	0.68	0.68	1.05	1.05	1.31	1.44	1.83		2.5	3.66
Soil Type		← Packed Earth →						← Hard Clay →						
Digging Depth	(m)	1.5	1.5	1.8	3.0	3.0	3.0	2.3	3.2	3.2	3.4		4.2	5.2
	(ft)	5	5	6	10	10	10	8	10	10	11		14	17
Load Bucket	(min)	0.08	0.07	0.07	0.10	0.10	0.09	0.09	0.09	0.09	0.09		0.10	0.11
Swing Loaded	(min)	0.05	0.06	0.06	0.04	0.04	0.06	0.06	0.06	0.06	0.07		0.09	0.10
Dump Bucket	(min)	0.03	0.03	0.03	0.02	0.02	0.04	0.03	0.04	0.04	0.04		0.04	0.04
Swing Empty	(min)	0.06	0.05	0.05	0.05	0.05	0.06	0.05	0.06	0.06	0.07		0.07	0.09
Total Cycle Time	(min)	0.22	0.21	0.21	0.21	0.21	0.25	0.23	0.25	0.25	0.27		0.30	0.34

*Information not available at time of printing.

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Excavators | Bucket Specifications

Model	Bucket Type	Bucket Bite Width		Bucket Tip Radius		Heaped Capacity		Bucket Weight With Teeth	
		mm	in	mm	in	L	yd³	kg	lb
315B/315B L	General Purpose	610	24.0	1340	53.0	380	0.50	419	924
		760	30.0	1340	53.0	500	0.65	471	1038
		914	36.0	1340	53.0	610	0.80	517	1140
		1067	42.0	1340	53.0	690	0.90	566	1248
		1219	48.0	1340	53.0	840	1.10	609	1343

WEIGHT* OF MATERIALS	LOOSE kg/m³	LOOSE lb/yd³	BANK kg/m³	BANK lb/yd³	LOAD FACTORS
Basalt	1960	3300	2970	5000	.67
Bauxite, Kaolin	1420	2400	1900	3200	.75
Caliche	1250	2100	2260	3800	.55
Carnotite, uranium ore	1630	2750	2200	3700	.74
Cinders	560	950	860	1450	.66
Clay — Natural bed	1660	2800	2020	3400	.82
Dry	1480	2500	1840	3100	.81
Wet	1660	2800	2080	3500	.80
Clay & gravel — Dry	1420	2400	1660	2800	.85
Wet	1540	2600	1840	3100	.85
Coal — Anthracite, Raw	1190	2000	1600	2700	.74
Washed	1100	1850			.74
Ash, Bituminous Coal	530-650	900-1100	590-890	1000-1500	.93
Bituminous, Raw	950	1600	1280	2150	.74
Washed	830	1400			.74
Decomposed rock —					
75% Rock, 25% Earth	1960	3300	2790	4700	.70
50% Rock, 50% Earth	1720	2900	2280	3850	.75
25% Rock, 75% Earth	1570	2650	1960	3300	.80
Earth — Dry packed	1510	2550	1900	3200	.80
Wet excavated	1600	2700	2020	3400	.79
Loam	1250	2100	1540	2600	.81
Granite — Broken	1660	2800	2730	4600	.61
Gravel — Pitrun	1930	3250	2170	3650	.89
Dry	1510	2550	1690	2850	.89
Dry 6-50 mm (1/4"-2")	1690	2850	1900	3200	.89
Wet 6-50 mm (1/4"-2")	2020	3400	2260	3800	.89
Gypsum — Broken	1810	3050	3170	5350	.57
Crushed	1600	2700	2790	4700	.57
Hematite, iron ore, high grade	1810-2450	4000-5400	2130-2900	4700-6400	.85
Limestone — Broken	1540	2600	2610	4400	.59
Crushed	1540	2600	—	—	—
Magnetite, iron ore	2790	4700	3260	5500	.85
Pyrite, iron ore	2580	4350	3030	5100	.85
Sand — Dry, loose	1420	2400	1600	2700	.89
Damp	1690	2850	1900	3200	.89
Wet	1840	3100	2080	3500	.89
Sand & clay — Loose	1600	2700	2020	3400	.79
Compacted	2400	4050			
Sand & gravel — Dry	1720	2900	1930	3250	.89
Wet	2020	3400	2230	3750	.91
Sandstone	1510	2550	2520	4250	.60
Shale	1250	2100	1660	2800	.75
Slag — Broken	1750	2950	2940	4950	.60
Snow — Dry	130	220			
Wet	520	860			
Stone — Crushed	1600	2700	2670	4500	.60
Taconite	1630-1900	3600-4200	2360-2700	5200-6100	.58
Top Soil	950	1600	1370	2300	.70
Taprock — Broken	1750	2950	2610	4400	.67
Wood Chips**	—	—	—	—	—

*Varies with moisture content, grain size, degree of compaction, etc. Tests must be made to determine exact material characteristics.
**Weights of commercially important wood species can be found in the last pages of the Logging & Forest Products section. To obtain wood weights use the following equations: lb/yd³ = (lb/ft³) × .4 × 27
kg/m³ = (kg/m³) × .4

SWELL — VOIDS — LOAD FACTORS

SWELL (%)	VOIDS (%)	LOAD FACTOR
5	4.8	.952
10	9.1	.909
15	13.0	.870
20	16.7	.833
25	20.0	.800
30	23.1	.769
35	25.9	.741
40	28.6	.714
45	31.0	.690
50	33.3	.667
55	35.5	.645
60	37.5	.625
65	39.4	.606
70	41.2	.588
75	42.9	.571
80	44.4	.556
85	45.9	.541
90	47.4	.526
95	48.7	.513
100	50.0	.500

BUCKET FILL FACTORS

Loose Material	Fill Factor
Mixed Moist Aggregates	95-100%
Uniform Aggregates up to 3 mm (1/8")	95-100
3 mm-9 mm (1/8"-3/8")	90-95
12 mm-20 mm (1/2"-3/4")	85-90
24 mm (1") and over	85-90
Blasted Rock	
Well Blasted	80-95%
Average Blasted	75-90
Poorly Blasted	60-75
Other	
Rock Dirt Mixtures	100-120%
Moist Loam	100-110
Soil, Boulders, Roots	80-100
Cemented Materials	85-95

NOTE: Loader bucket fill factors are affected by bucket penetration, breako force, rackback angle, bucket profile and ground engaging tools such bucket teeth or bolt-on replaceable cutting edges.

NOTE: For bucket fill factors for hydraulic excavators, see bucket payloads [illegible]

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Table 7.3.A.
Douglas Fir Plywood
Specified Strength Capacities for Standard Constructions of Regular Grades of Unsanded Douglas Fir Plywood

Nominal plywood thickness	Number of plies	Bending m_p		Tension t_p		Compression p_p		Shear-through-thickness v_p	Planar shear bending v_{pb}		Planar shear in-plane force v_{pf}	
		Orientation of applied force relative to face grain										
		0°	90°	0°	90°	0°	90°	0° & 90°	0°	90°	0°	90°
mm		$\left(\frac{N \cdot mm}{mm}\right)$	$\left(\frac{N \cdot mm}{mm}\right)$	N/mm	N/mm	N/mm	N/mm	N/mm	N/mm	N/mm	MPa	MPa
7.5	3	180	38	97	23	130	40	20	3.7	1.3	0.72	0.72
9.5	3	280	59	97	28	130	50	24	3.9	1.4	0.55	0.72
12.5	4	420	130	97	65	130	96	30	6.6	2.8	0.55	0.72
12.5	5	560	200	130	71	170	79	30	7.2	3.7	0.72	0.72
15.5	4	740	230	150	72	200	130	39	6.5	3.6	0.55	0.72
15.5	5	770	280	130	71	170	79	36	9.4	4.9	0.72	0.72
18.5	5	1300	460	200	110	260	120	45	11.0	5.7	0.72	0.72
18.5	6	900	440	160	71	210	79	43	9.1	5.4	0.55	0.55
18.5	7	1100	450	160	110	210	120	43	9.7	7.1	0.72	0.72
20.5	6	1200	740	180	130	230	160	47	10.0	5.6	0.55	0.55
20.5	6	1100	550	170	71	220	79	47	10.0	6.5	0.55	0.55
20.5	7	1200	560	160	110	210	120	47	11.0	8.5	0.72	0.72

Notes:

(1) *Specified strength in bearing (normal to plane of piles)* $q_p = 3.9$ MPa

(2) *Dry service conditions*

(3) *Standard term duration of load*

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Table 7.3.B.
Douglas Fir Plywood
Specified Stiffnesses and Rigidities for Standard Constructions of Regular Grades of Unsanded Douglas Fir Plywood

Nominal plywood thickness	Number of plies	Bending stiffness $B_b = EI$		Axial stiffness in tension or compression $B_a = EA$		Shear-through-thickness rigidity B_v
		Orientation of applied force relative to face grain				
		0°	90°	0°	90°	0° & 90°
mm	plies	$\frac{(N \cdot mm^2)}{mm}$	$\frac{(N \cdot mm^2)}{mm}$	N/mm	N/mm	N/mm
7.5	3	440 000	17 000	70 000	24 000	3 900
9.5	3	840 000	33 000	70 000	30 000	4 600
12.5	4	1 700 000	190 000	70 000	67 000	5 800
12.5	5	1 700 000	350 000	94 000	47 000	5 800
15.5	4	3 700 000	430 000	110 000	75 000	7 600
15.5	5	3 000 000	630 000	95 000	47 000	7 000
18.5	5	6 000 000	1 300 000	140 000	73 000	8 600
18.5	6	4 600 000	1 300 000	120 000	47 000	8 200
18.5	7	4 900 000	1 300 000	120 000	71 000	8 200
20.5	5	6 300 000	2 600 000	130 000	89 000	9 100
20.5	6	5 900 000	1 900 000	130 000	47 000	9 000
20.5	7	6 200 000	2 000 000	120 000	71 000	9 000

Notes:

(1) *Dry service conditions*

(2) *Standard term duration of load*

Table 5.3.1.A.
Specified Strengths and Modulus of Elasticity (MPa)
for Structural Joists and Planks, Structural Light Framing
and Stud Grade Categories of Lumber.

Species Identification	Grade	Bending at Extreme Fibre f_b	Longitudinal Shear f_v	Compression Parallel to Grain f_c	Compression Perpendicular to f_{cp}	Tension Parallel to Grain f_t	Modulus of Elasticity MPa E	E_{05}
D.Fir-L	SS	16.5		19.0		10.6	12500	8500
	No.1/No.2	10.0	1.1	14.0	7.8	5.8	11000	7000
	No.3/Stud	4.6		4.6		2.1	10000	5500
Hem-Fir	SS	16.0		17.6		9.7	12000	8500
	No.1/No.2	11.0	0.9	14.8	4.6	6.2	11000	7500
	No.3/Stud	7.0		7.0		3.2	10000	6000
S-P-F	SS	16.5		14.5		8.6	10500	7500
	No.1/No.2	11.8	1.0	11.5	5.3	5.5	9500	6500
	No.3/Stud	7.0		7.0		3.2	9000	5500
Northern	SS	10.6		13.0		6.2	7500	5500
	No.1/No.2	7.6	0.9	10.4	4.0	4.0	7000	5000
	No.3/Stud	4.5		4.5		2.0	6500	4000

Note: *Tabulated values are based on the following standard conditions:*

286 mm larger dimension

Dry service conditions

Standard term duration of load

F4

Table 5.4.2.
Service Condition Factors, K_S

K_S	For specified strength in	Dry service conditions	Wet service conditions: Sawn lumber piling and poles of least dimension 89 mm or less	Wet service conditions: Sawn lumber piling and poles of least dimension Over 89 mm
K_{Sb}	Bending at extreme fibre	1.00	0.84	1.00
K_{Sv}	Longitudinal shear	1.00	0.96	1.00
K_{Sc}	Compression parallel to grain	1.00	0.69	0.91
K_{Scp}	Compression perpendicular to grain	1.00	0.67	0.67
K_{St}	Tension parallel to grain	1.00	0.84	1.00
K_{SE}	Modulus of elasticity	1.00	0.94	1.00

Table 5.4.3.
Treatment Factor, K_T

Product	Dry Service Conditions	Wet Service Conditions
Untreated lumber	1.00	1.00
Preservative treated, unincised lumber	1.00	1.00
Preservative treated, incised lumber of thickness 89 mm or less, for:		
(a) Modulus of elasticity	0.90	0.95
(b) Other properties	0.70	0.85
Fire-retardant treated lumber	0.90	0.90

Table 5.4.4.
System Factor, K_H

For specified strength in	Case 1*	Case 2** Visually Graded	Case 2** 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	1.00	1.00	1.00
All other properties	1.00	1.00	1.00	1.00

Notes:

* *See Clause 5.4.4.1 for conditions applying to Case 1*

** *See Clause 5.4.4.2 for conditions applying to Case 2*

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

Larger dimension (mm)	Bending and Shear K_{Zb}, K_{Zv}			Tension parallel to grain, K_{Zt}	Compression parallel to grain, K_{Zc}	All other properties
	Smaller dimension (mm)					
	38 to 64	89 to 100	114 or larger	All	All	All
38	1.7	-	-	1.5		1.0
64	1.7	-	-	1.5	Value	1.0
89	1.7	1.7	-	1.5	calculated	1.0
114	1.5	1.6	1.3	1.4	using	1.0
140	1.4	1.5	1.3	1.3	formula	1.0
184 to 190	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	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

Table 5.5.7.2.
Bearing Factor, K_B

Bearing length diameter (mm)	Modification factor
12.5 and less	1.75
25.0	1.38
38.0	1.25
50.0	1.19
75.0	1.13
100.0	1.10
150.0 or more	1.00