LAST NAME (PRINT): ______________________________

FIRST NAMES (PRINT): ______________________________

STUDENT NUMBER: ______________________________

UNIVERSITY OF TORONTO
FACULTY OF APPLIED SCIENCE AND ENGINEERING
FINAL EXAMINATION, DECEMBER 2001

CIV 424F – FOUNDATIONS AND EARTHWORKS

Exam Type: Type A (Closed Book, No Exam Aids; Approved Calculators)

Examiner: Cameran Mirza, P. Eng.

- There are six questions of equal value (partial values for parts of questions are shown with each part).
- Answer Question 5 and any three others of your choosing. Indicate with an X, in the table below, the three elective questions you wish to have graded.
- If you have not indicated with an X in the table below which three elective questions you wish to have graded, then only Questions 1, 2, 3, and 5 will be graded.
- Where required, draw neat free-hand sketches. Show scales. Label each axis.
- Show all calculations. Indicate SI units against calculated values to check dimensional compatibility.

Question No. and No. of Parts	**Value**	**Pages**	**Questions to be graded (indicate with an X)**	**Grade**
1, in 3 parts	25	2-3		
2, in 2 parts	25	4-5		
3, in 3 parts	25	6-7		
4, in 2 parts	25	8-9		
5, in 4 parts	25	10-11	X	
6, in 2 parts	25	12-13		
Total				

Question 1. (In 3 parts, Total Value = 25 Marks)

A high rise apartment building will be constructed within a completely dewatered 11 m deep rectangular excavation. The soil for the entire depth of excavation is a stiff fissured glacial clay. Its properties throughout the plan area and depth of excavation are: $\gamma = 21.4$ kN/m^3; $\phi' = 24°$; $c' = 15$ kN/m^2. In order to protect surrounding buildings and infrastructure, the vertical long walls of the excavation will be supported with soldier piles and timber lagging. The soldier piles will be installed at 3.5 m c.c spacing. Steel I-beam walers will be welded to the soldier H-piles at depths of 3.0 m and 7.0 m below the ground surface.

The excavation bracing will consist of upper level 450 mm dia. steel pipe struts spanning the width of the excavation, and lower level steel I-beam rakers, inclined at 45°, anchored into concrete block footings in the excavation base. The horizontal pipe struts and inclined I-beam rakers will be provided at each soldier H-pile location, and pre-stressed by jacking.

(1.i) 8 Marks

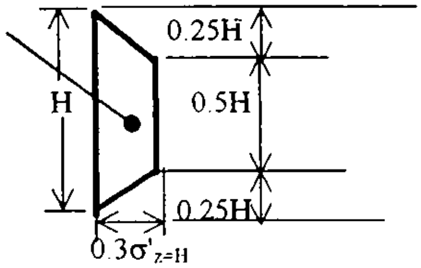
Sketch a partial plan and elevation or cross-section of the excavation shoring scheme described above.

Plan View (Partial)

Elevation or Cross-Section View

(1.ii) 14 Marks
What jacking load in kN will achieve 80 % of the pre-stressing load in a pipe strut?

Apparent Earth Pressure
Stiff Fissured Clay



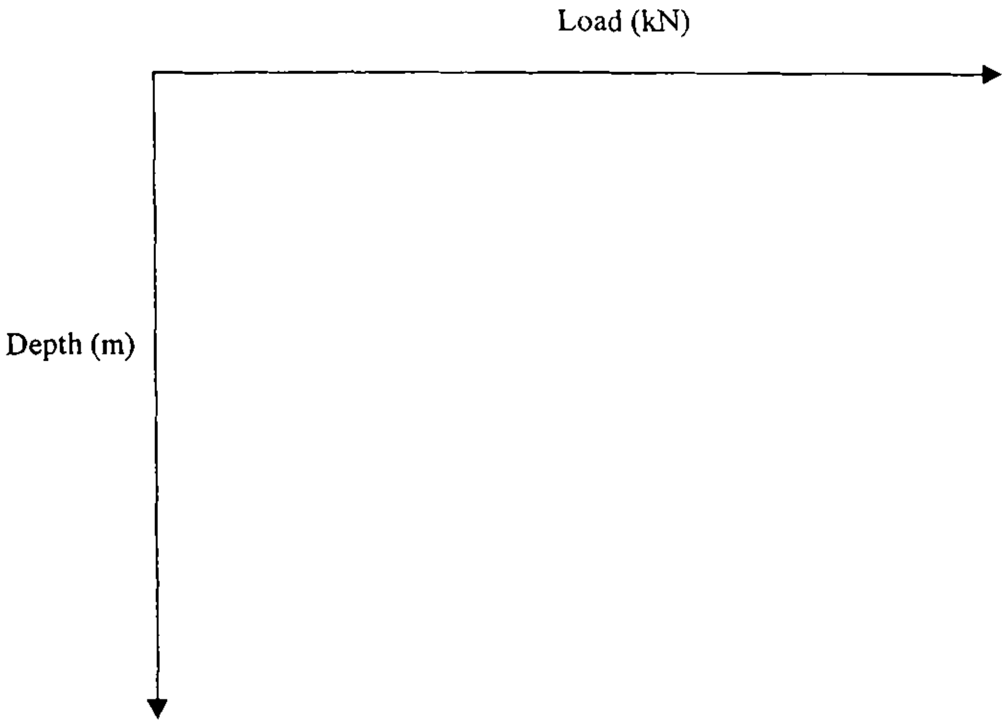
Jacking Load = ___________ kN

(1.iii) 3 Marks
If the lower ends of opposing rakers are 4 m apart at the level of the base of the excavation, what is the width of the excavation? Ignore bracing/shoring member sizes.

Width of Excavation = _______ m

Question 2. (In 2 parts, Total Value = 25 Marks)

(2.i) 8 Marks
In pile design, what is the significance of the neutral plane? Illustrate your answer with a sketch.

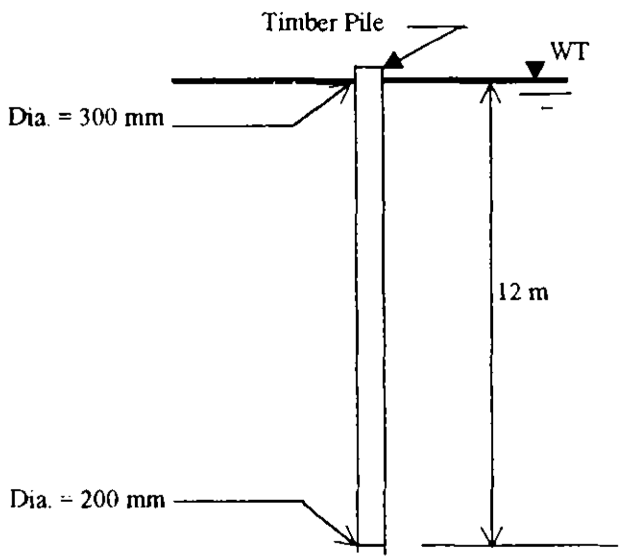


(2.ii) 17 Marks

A timber pile (toe diameter = 200 mm; diameter at ground line = 300 mm), will be driven to an embedment depth of 12 m through a silty clay soil (γ_{sat} = 17.8 kN/m^3) which extends from ground surface down to a depth in excess of 20 m. The undrained shear strength of the silty clay is 40 kN/m^2 at the surface. The c_u/σ'_v ratio is 0.25 (i.e., c_u increases with increasing depth in the ratio indicated). The prevailing groundwater level is at the ground surface.

<u>Given</u>: N_t = 9, and α = 0.7 (at all depths in the silty clay).

<u>Required</u>: The ultimate capacity of the timber pile. $Q_{ult} = R_s + R_t$. <u>Consider the pile taper in your calculations</u>!



Q_{ult} (single timber pile) = ________ kN

Question 3. (In 3 parts, Total Value = 25 Marks)

A 4.5 m high concrete gravity retaining wall has a base width of 2.5 m and a top width of 0.5 m. The back of the wall is vertical. From ground surface up to a height of 2.5 m the horizontal backfill consists of a well drained sand & gravel with $\phi' = 36^\circ$ and $\gamma = 22.0\ kN/m^3$. The remainder of the backfill consists of a uniform sand with $\phi' = 30^\circ$ and $\gamma = 19.0\ kN/m^3$. The backfill surface is horizontal and level with the top of the wall. There is no fill in front of the wall and no surcharge on the backfill. The wall base is founded on the surface of a slightly cohesive soil with the following properties: $\phi' = 28^\circ$; $c' = 5.0\ kN/m^2$; $\gamma = 19.0\ kN/m^3$.

Assume $\delta = 0.75\phi'$, $\gamma_{concr.} = 24.0\ kN/m^3$ and a water table 10 m below the wall footing.

(3.i) 5 Marks

Sketch the retaining wall, showing all dimensions, materials, and the earth pressure diagram.

Wall Cross-Section

Earth Pressure Diagram

Question 3. Calculation Table (make your own)

(3.ii) 8 Marks

Determine the factor of safety against sliding.

Factor of Safety Against Sliding along the Base = ______

(3.iii) 12 Marks

Sketch with values shown, or draw to a scale, the base contact pressure diagram for

$$q_{max,\ min} = [(\Sigma V/B)*(1 \pm 6e/B)]$$

q_{max} = __________ kN/m^2 q_{min} = __________ kN/m^2

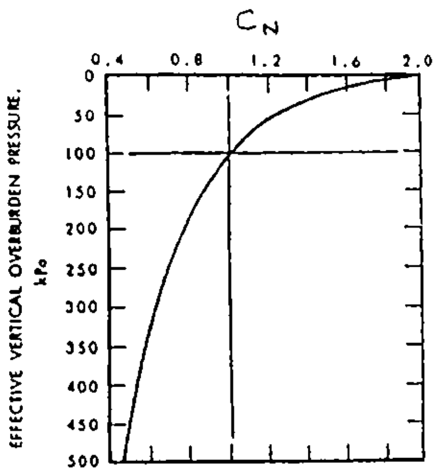
Question 4. (In 2 parts, Total Value = 25 Marks)

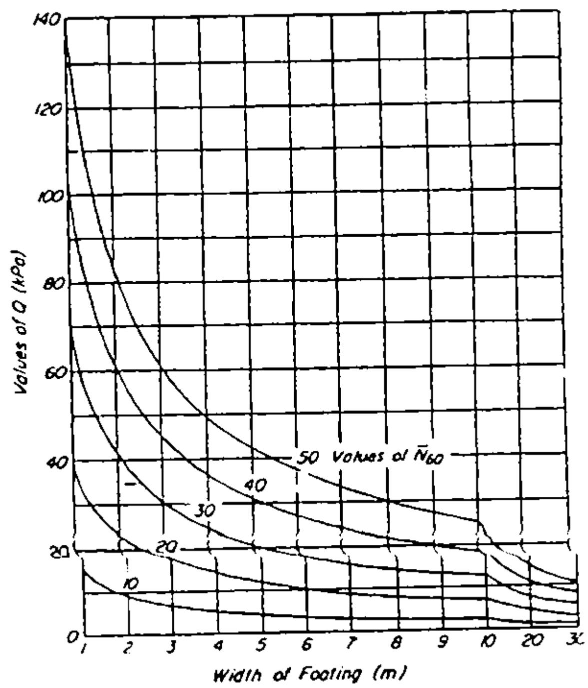
Given: A square footing (2 m x 2 m) founded at a depth of 1.5 below the surface of a 5 m thick sand deposit underlain by 3 m of clay over hard glacial till. The groundwater is located 0.5 m below the footing level. The unit weight of the sand is 18.8 kN/m^3. Standard Penetration Test "N" values in the sand are shown below.

Depth - m	N value (blows/0.3 m)	Description
0.5	10	Loose Brown Med. Sand
1.0	12	Compact Sand, Trace Silt
1.5	11	Compact Sand, Tr. Silt
2.0	20	Grey-Brown Sand. Groundwater @ 2 m.
3.0	30	Compact-Dense Grey Sand, occ. Gravel
4.5	28	Compact Sand, Tr. Silt & Gravel

(4.i) 10 Marks

Determine the allowable bearing capacity of the 2 m x 2 m footing so as to limit differential settlement in the sand to16 mm, using the Q chart of Terzaghi, Peck and Mesri given below.





q_{all} = ________ kN/m^2

(4.ii) 15 Marks
Calculate the long term settlement of the 2 m x 2 m square footing due to consolidation, if any, of the clay stratum, assuming a 2:1 (H:V) stress distribution with depth.

Clay Properties: $e_o = 1.2$; $\sigma'_c = 120$ kN/m^2; $c_v = 3.0$ m^2/yr; $c_c = 0.3$ $c_r = 0.02$

[Note: You are encouraged to solve this problem by sketching an hypothetical e-log p curve with a preconsolidation break, and using the slope values of c_c and c_r to determine Δe, remembering that $s_c = \Delta e * H/(1+e_o)$]

Settlement due to consolidation of clay stratum = ________ mm

Question 5. (In 4 parts, Total Value = 25 Marks)

Prior to this exam you were provided with a copy of a paper: "Winter effects on hydraulic conductivity of compacted clay", by Benson et al. (ASCE J. Geot. Eng., vol. 121:1:69-79, 1995). The paper describes a field experiment to study changes in hydraulic conductivity (Darcy k) due to freeze-thaw cycles in compacted clay fills, such as those that may be considered for landfill covers. The north portion of a 1.5 m thick compacted glacial clay till embankment was insulated against freezing whereas the south portion was left uninsulated. Ground temperatures were measured at several locations and depths within the test embankment by means of thermocouples. The thermocouples were placed in 25 mm diameter augered holes, backfilled with dry bentonite and auger cuttings and tamped with a 10 mm dia. rod. The researchers state that the insulated section did not freeze (according to temperature measurements). The uninsulated section is reported to have been frozen to a depth of 0.5 m (according to recorded ground temperatures). After several cycles of freeze-thaw the researchers took block and tube samples of the compacted clay fill from the insulated and uninsulated sections of the test embankment. These samples were then transported to a laboratory located a considerable distance away from the field site.

In field permeability tests the researchers found little difference in k values between the insulated and uninsulated sections. They concluded that owing to only 0.5 m of frost penetration in a 1.5 m thickness of the test embankment, the unfrozen soil controlled the field permeability.

Considerable difference in hydraulic conductivity was observed in laboratory tests. The hydraulic conductivity of block samples was significantly higher than that of tube samples.

(5.i) 6 Marks – Describe briefly the purpose of the research.

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(5.ii) 6 Marks – In your opinion, were the field temperature measurements reliable, and if not, why not?

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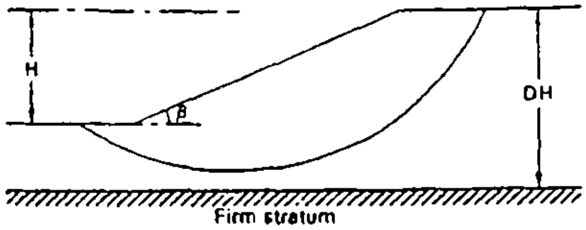
(5.iii) 8 Marks – The test embankment was compacted at an average moisture content of 13.9 per cent, corresponding to an average dry unit weight of 18.8 kN/m^3. The researchers indicate that the average degree of saturation (S_r) of the test embankment was 88 %, assuming G_s = 2.75. Corroborate the researchers' value of S_r with your own calculations.

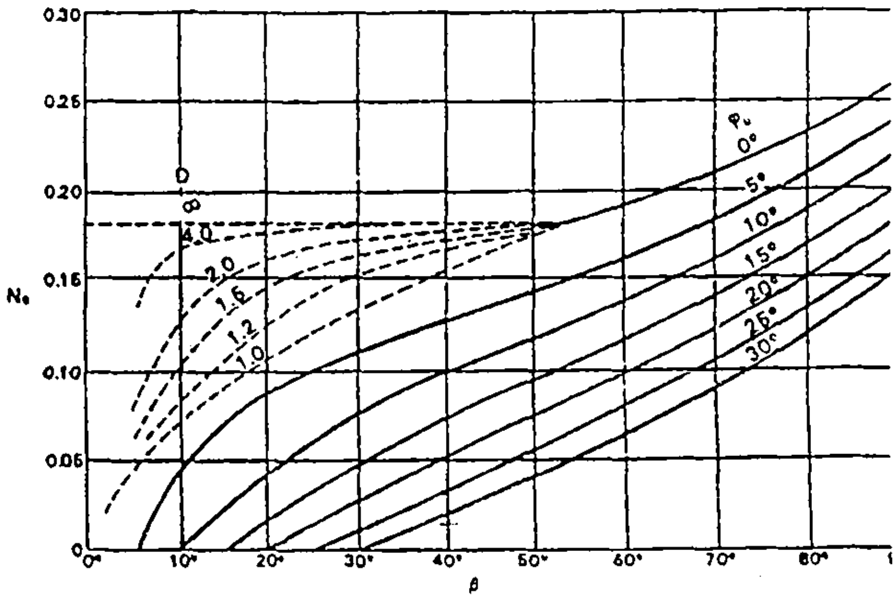
(5.iv) 5 Marks – The laboratory measured hydraulic conductivity of block samples was generally higher than that of comparable tube samples. Suggest some probable and plausible causes for the difference.

Question 6. (In 2 parts, Total Value = 25 Marks).

(6.i) 10 Marks

A 2H : 1V slope in a homogeneous isotropic clay is 10 m in height. Bedrock is located at a depth of 20 m below the crest (top) of the slope. UU-triaxial tests were conducted on representative samples (γ = 18.0 kN/m^3) of the clay. The principal stress ratio at failure, σ_{1f}/σ_{3f}, was 3.0, at a confining cell pressure of 50 kN/m^2. Determine the factor of safety, F, of the proposed slope in terms of total stress (ϕ' = 0), given $N_s = c_u/F\gamma H$.





Factor of Safety, F, of 2:1 Slope = __________

(6.ii) 15 Marks

A narrow trench is to be excavated to a depth of 8 m in a sand deposit. It will be supported up to the surface with bentonite mud. The properties of the sand are: γ_{sat} = 18.0 kN/m^3; ϕ' = 30°; c' = 0. The groundwater level is at the surface. What "mud weight" will ensure a minimum factor of safety of 1.5 of the proposed slurry trench excavation?

Required Mud Weight to ensure a Factor of Safety of 1.5 = __________ kN/m^3