National Exams May 2019

18-Env-A3, Geotechnical and Hydrogeological Engineering

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. Most questions require an answer in essay format. Clarity and organization of the answer are important.

Question 1 (20 marks):

The unit weight of a soil sample in natural conditions is 19.1 kN/m^3 and its saturated unit weight is 20.1 kN/m^3. Assuming a specific gravity of solids of 2.5, calculate the following properties of the soil in its natural conditions:

a) (**4 marks**) void ratio,

b) (**4 marks**) porosity,

c) (**4 marks**) degree of saturation,

d) (**4 marks**) moisture content, and

e) (**4 marks**) buoyant unit weight.

Question 2 (20 marks):

A sample of soil for a constant-head permeability test has a diameter of 7.6 cm, length of 20.0 cm, void ratio of 0.55, saturated unit weight of 19.6 kN/m^3, head loss Δh of 15.0 cm, test duration of 6.0 min, and discharged volume of 1200 cm^3.

a) **(5 mark)** What is the saturated hydraulic conductivity of this soil?

b) **(5 mark)** What are three soil characteristics that most affect hydraulic conductivity?

c) **(5 marks)** What is the seepage flow velocity through the soil column?

d) **(5 marks)** How would the change in the water content affect hydraulic conductivity of an unsaturated soil?

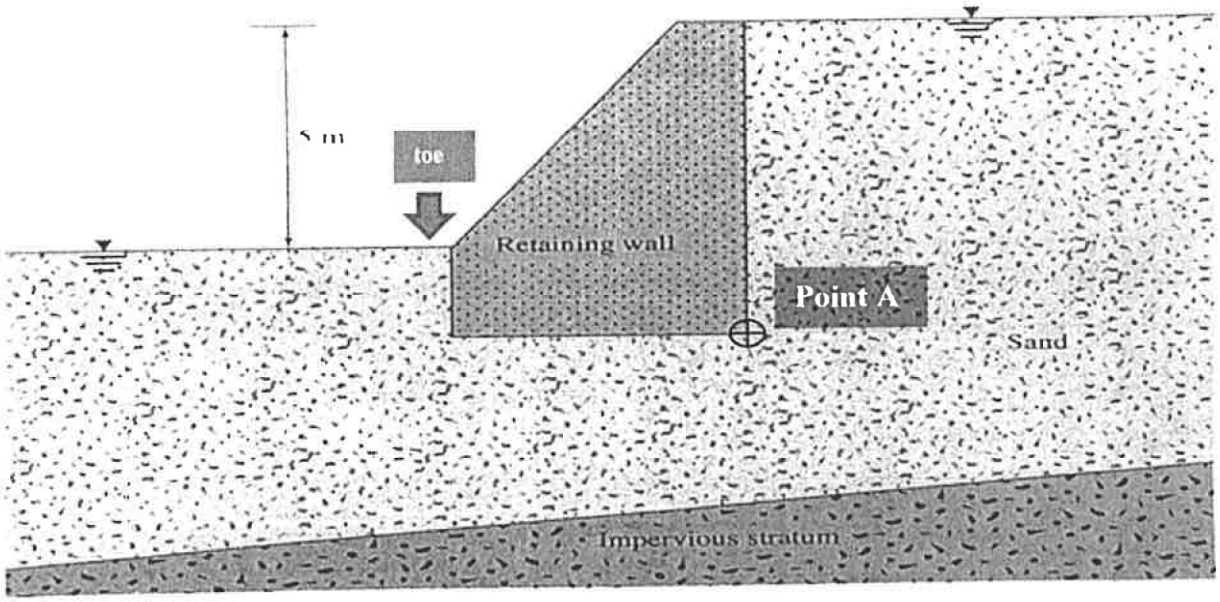
Question 3 (20 marks):

Figure below shows the cross-section of a concrete Retaining Wall and the sandy soil with specific gravity of 2.65 and porosity of 20% underlain by impervious stratum. The sandy soil is fully saturated with saturated hydraulic conductivity of 1.5×10^{-3} cm/s and the water level is at the ground surface on the both sides of the wall. The wall is 100 m long (perpendicular to the picture).

a) **(8 mark)** Calculate total seepage flow rate beneath the wall (m^3/hr)

b) **(8 mark)** Calculate groundwater piezometric head at Point A shown below (m)

c) **(4 mark)** Calculate the factor of safety against downstream heave at the toe of the wall.



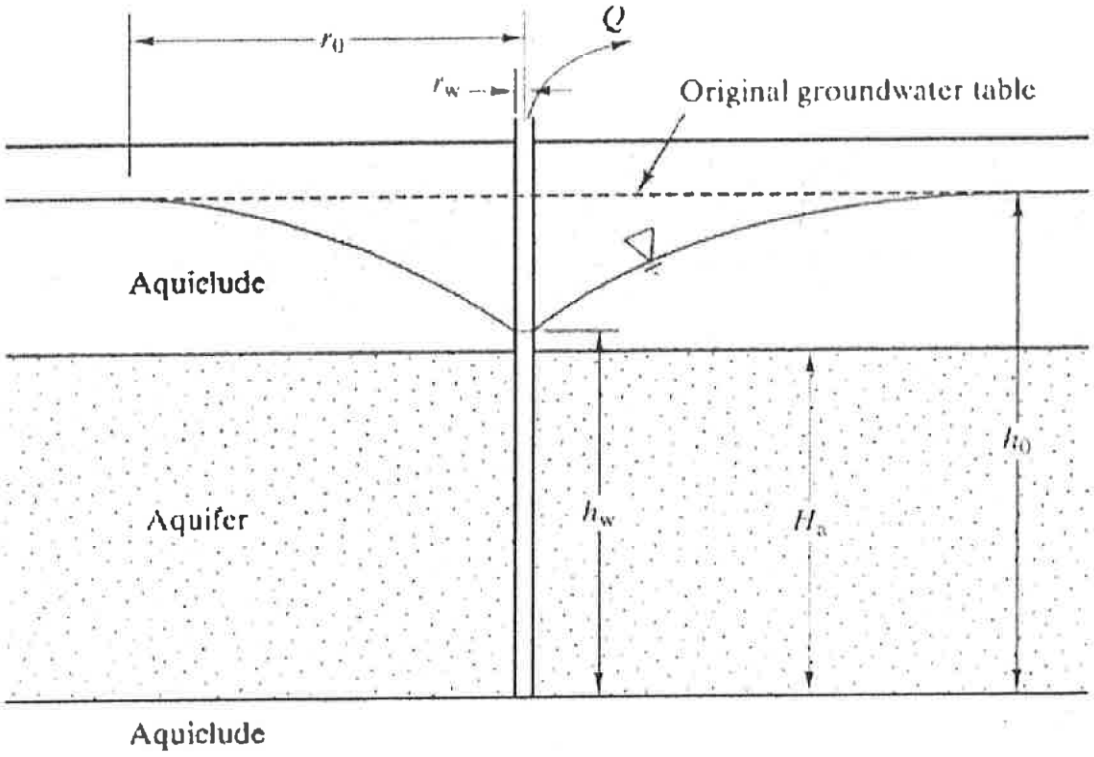
Question 4 (20 marks):

A municipal water supply well is built in a confined aquifer. Assuming $h_0 = 20$ m, $h_w = 12$ m, hydraulic conductivity of aquifer $k = 8$ m/d, $r_w = 0.25$ m, aquifer thickness $H_a = 10$ m. Consider the following questions:

a) **(8 marks)** Calculate the steady state discharge Q of the pump.

b) **(8 marks)** Calculate the rise in the well water level h_w if the steady state discharge Q in part a) is dropped by half.

c) **(4 mark)** Determine the radius of the circular Wellhead Protection Area (WHPA) for this municipal water supply well based on the 2 year time of travel capture zone.



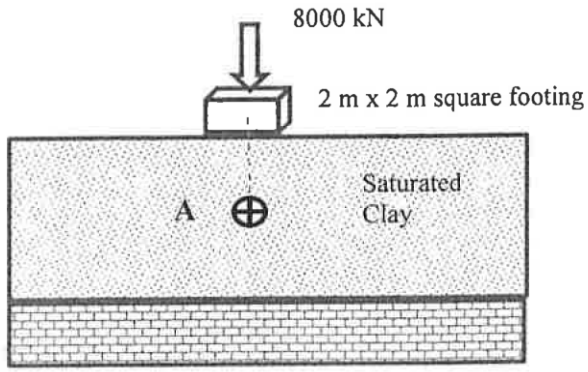
Question 5 (20 marks):

A 2-m thick normally-consolidated, saturated clay is resting on impermeable rock. A 2-m wide square footing is placed on the ground surface with 8000 kN load. For the clay soil, specific gravity of solids is 2.75, initial void ratio is 2.5, the compression index is $C_c = 0.40$ and recompression index is $C_r = 0.10$.

a) (8 marks) Compute initial and final effective vertical stresses at midpoint of the clay layer straight below the centre of the square footing (i.e., Point "A") before and after the placement of the load;

b) (8 marks) Compute the ultimate primary consolidation of the clay layer straight below the centre of the footing; and

c) (4 marks) Calculate the change in the void ratio of the clay below the centre of the square footing due to the primary consolidation.



Question 6 (20 marks):

For the slope shown, the unit weight of the non-cohesive dry Sandy soil is $\gamma = 16\ kN/m^3$, the angle of internal friction $\varphi' = 30°$. The porosity of the Sandy soil is 30%.

a) (**10 marks**) Find the Factor of Safety for slope shear failure using the Ordinary Method of Slices for the failure plane shown below and using the two labeled slices.

b) (**10 marks**) Find the Factor of Safety for slope shear failure after a major rainfall event assuming the Sandy soil will be fully saturated for the failure plane shown in the diagram below and using the two labeled slices.