EGT2
ENGINEERING TRIPOS PART IIA

---

Friday 24 April 2015 2.00 to 3.30

---

**Module 3D8**

**BUILDING PHYSICS AND ENVIRONMENTAL GEOTECHNICS**

*Answer not more than **three** questions.*

*All questions carry the same number of marks.*

*The **approximate** percentage of marks allocated to each part of a question is indicated in the right margin.*

*Write your candidate number **not** your name on the cover sheet.*

**STATIONERY REQUIREMENTS**
Single-sided script paper

**SPECIAL REQUIREMENTS TO BE SUPPLIED FOR THIS EXAM**
CUED approved calculator allowed
Attachment: 3D8 Building Physics and Env. Geotechnics Data Book (15 pages).
Supplementary page: one extra copy of Fig. 1 (Question 1)
Engineering Data Book

**10 minutes reading time is allowed for this paper.**

**You may not start to read the questions printed on the subsequent pages of this question paper until instructed to do so.**

1 (a) State Fourier's law in the context of heat flow through a saturated soil medium. Give two examples where heat flow through ground may be important. [15%]

(b) Explain the terms 'advection' and 'diffusion' with respect to contaminant transport in the ground. What parallels can you draw between these and the mechanisms of heat transfer in saturated ground? [15%]

(c) A rectangular concrete block ABCD shown in Fig. 1 retains 9 m of water on one side. The unit weight of the concrete is 24 kN $m^{-3}$. It is embedded in the soil to a depth of 1 m and has free board of 1 m above the water level. To increase the stability of this barrage structure a triangular block CDE has been added. There is an inspection gallery of dimensions 4 m × 9 m in block ABCD. The soil below the blocks is silty sand with a hydraulic conductivity of $1.75 \times 10^{-5}$ m $s^{-1}$.

(i) Draw a 'flow net' at steady state of the problem on the extra copy of Fig. 1 provided. Highlight any limitations of the flow net you have constructed. You must submit this copy with your script. [25%]

(ii) Determine the quantity of leakage due to seepage through the silty sand in the units of millions of litres per year per metre width. Sketch the pore water pressure distribution along the face BCE. Estimate the upward hydraulic gradient at the location marked 'X'. [20%]

(iii) Calculate the factor of safety against sliding of the whole block ABCED. The friction angle between concrete and sand is 28°. You may ignore any passive resistance offered by the soil on the sides of the embedded blocks. [15%]

(iv) Comment on what can happen if the construction joint between blocks ABCD and CDE fails due to differential settlement of the blocks. [10%]

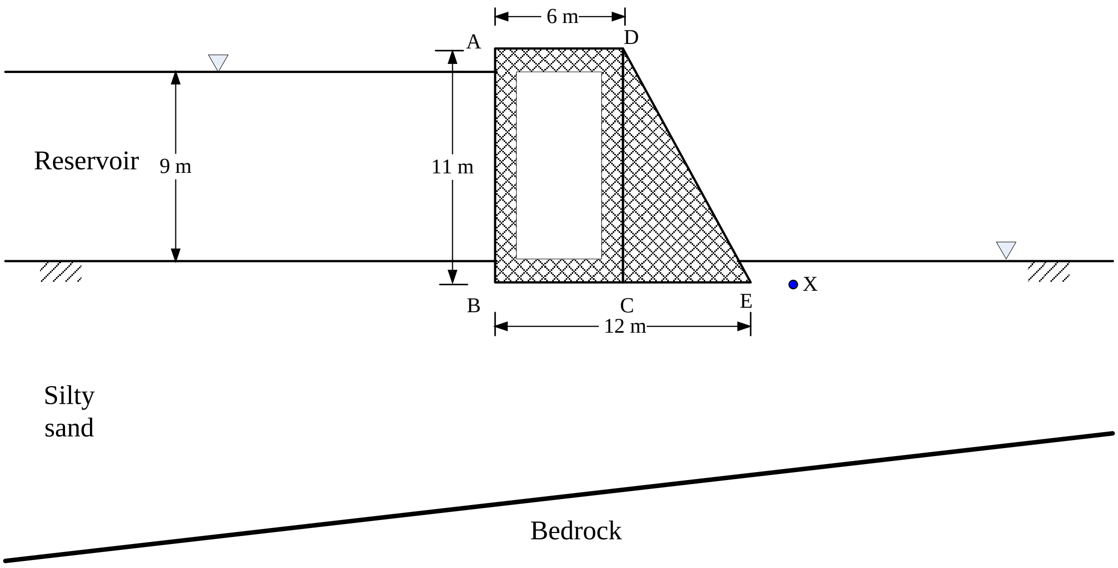



Fig. 1

2 (a) Explain briefly how soil particles are formed due to geological actions on rock. [10%]

(b) Derive a relationship between the capillary rise $h_c$ , the surface tension of water $T$, the contact angle of the meniscus with respect to the vertical $\theta_c$ , the diameter of a capillary tube $d$ and the unit weight of water $\gamma_w$. [20%]

(c) A horizontal, fine silty sand deposit of 12 m thickness overlies an aquifer formed by a gravel layer. The silty sand particles have $D_{10}$ and $D_{20}$ sizes of 0.01 mm and 0.05 mm respectively and a specific gravity of 2.65. The surface tension of pore water is $7 \times 10^{-5}$ kN m$^{-1}$ and the contact angle $\theta_c$ between the water meniscus and the soil particles is $30^o$. The void ratio of the deposit is 0.65. The natural water table at this site is 6 m below the ground level. Sketch the pore pressure distribution with depth and hence the effective stress profile in the silty sand layer marking the salient values. [25%]

(d) A bore well tube with an internal diameter of 100 mm is sunk into the silty sand deposit to a depth of 9 m with a porous strainer of 2 m height, such that water can be extracted between elevations of 7 m and 9 m only. The intrinsic permeability $k$ of the silty sand is $2 \times 10^{-6}$ mm$^2$. The dynamic viscosity of the pore water is $1.307 \times 10^{-3}$ N s m$^{-2}$. When pumping water from this bore well at the rate of 50 gallons per hour, the draw down was observed to be 1 m. Calculate the radius of influence of this bore well. [30%]

(e) Explain the term ‘sorption’ in the context of chemical contaminants in a porous medium. If the silty sand layer had contaminants that sorbed onto the soil particles, can they be removed by pumping of groundwater? [15%]

3 (a) List one advantage and one disadvantage of a window that has a low solar heat gain coefficient. [10%]

(b) A room of volume 30 $m^3$ is ventilated at the rate of 2 air changes per hour. The outside air temperature is –5 $^oC$ with 90% relative humidity. Internal temperature is maintained at 20 $^oC$ by a heating system. The room has one external wall and one window, which have the net area of 25 $m^2$ and 5 $m^2$ respectively. The total U-value of the wall is 0.2 W $m^{-2}$ $K^{-1}$. The window is double glazed with internal blind inside the air-gap between the two glass panes.

(i) Draw a network diagram showing all sources of heat transfer to the internal air temperature node for this room. [10%]

(ii) Calculate the U-value of the double glazed window, with the assumption that the temperatures at the enclosing surfaces of the air-gap are 0 $^oC$ and 15 $^oC$. The thickness of each glass pane is 5 mm. The width of the air gap between the two glass panes is 4 cm. The internal blind is opaque, and it is located in the middle of the 4 cm air gap. The emissivity of all surfaces is 0.9. The thermal conductivity of the glass panes is 1.0 W $m^{-1}$ $K^{-1}$. Neglect the thermal resistance of the internal blind. [25%]

(iii) Calculate the amount of heat that must be released by a heating system in order to maintain the internal air temperature of the room. [15%]

(iv) In this room, 0.75 kg of water vapour is produced per hour whilst cooking. The moisture supply at the start of the cooking was 3.5 g $m^{-3}$. Calculate the relative humidity of the air inside the room after 10 minutes of cooking. How long would it take before there will be condensation on the double glazed window? [40%]



(TURN OVER

4 (a) Give three conditions when dynamic analysis of heat transfer is necessary in buildings. [15%]

(b) For a very thick concrete wall of an old church, the temperature at location $x$ and time $t$ due to a step change can be calculated by:

$$T(x,t) = T_0 + (T_1 - T_0) \cdot \left( \frac{2}{\sqrt{\pi}} \int_{s=\frac{x}{\sqrt{4at}}}^{\infty} e^{-s^2} ds \right)$$

at $t = 0$, $0 \leq x \leq \infty$: $T = T_0$ is the initial temperature, and at $t \geq 0$, $x = 0$: $T = T_1 - T_0$ is the boundary condition, and $a$ is the thermal diffusivity of the material.

(i) Using this formulation, derive the expression for heat flow $Q$ $(x,t)$ through the thick wall in Watts due to step change in temperature. [30%]

(ii) Explain the significance of thermal diffusivity $a$ and thermal effusivity $b$ in energy efficient buildings. [15%]

(iii) Two materials, one at temperature $T_1$ and the other at temperature $T_2$ come in contact with each other. Derive the expression for calculating the resulting contact temperature at the interface. Use the expression for heat flow $Q$ $(x,t)$ derived in 4 (b) (i) as the starting point. [20%]

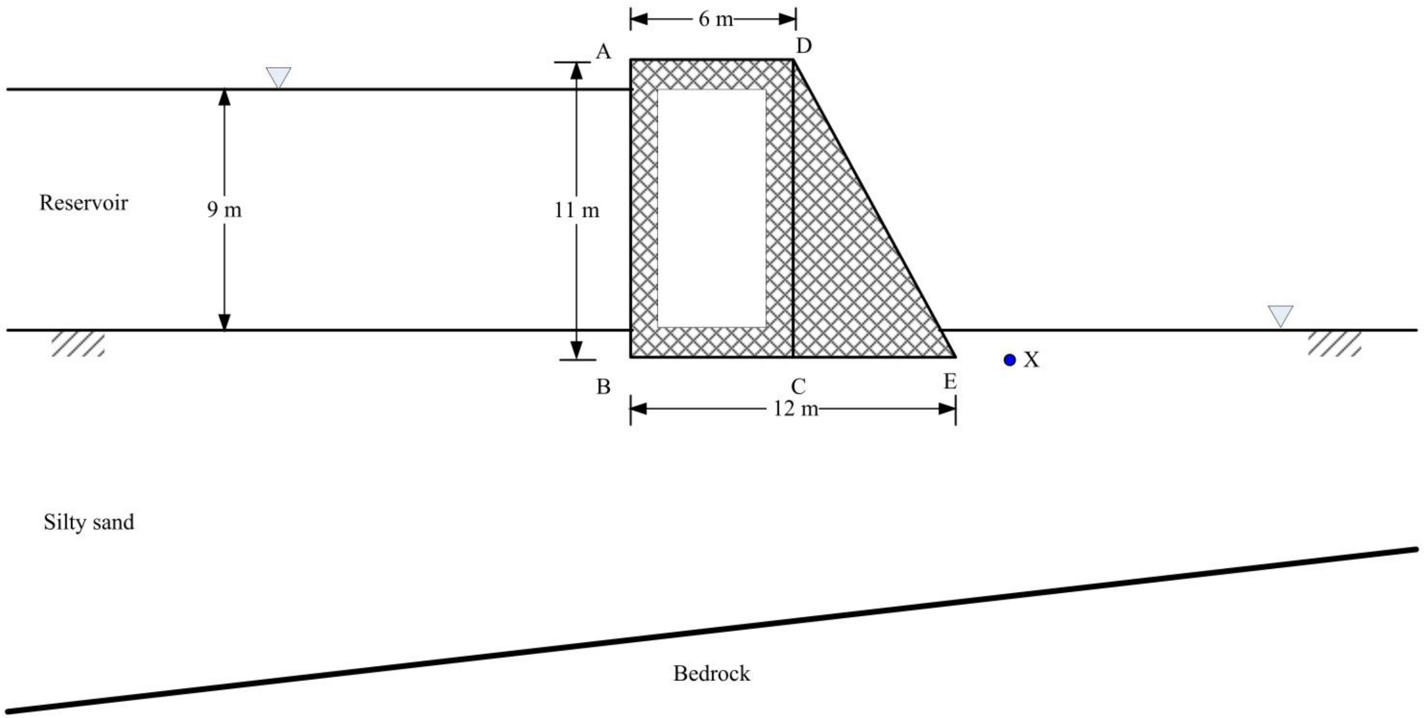
(iv) It is required that during concrete casting, the temperature of the concrete should not drop below 0 $^{o}$C. Calculate the temperature of the concrete during the casting period so that its temperature at the contact surface with granite does not drop below 0 $^{o}$C. The temperature of the granite is at –10 $^{o}$C. [20%]

**END OF PAPER**

Candidate No:

ENGINEERING TRIPOS PART IIA FRIDAY 24 APRIL 2015 1400 TO 1530

DRAWN TO SCALE




Extra copy of Fig. 1

THIS PAGE IS BLANK