University of Asia Pacific
Department of Civil Engineering
Final Semester Examination, Spring 2025
Program: B.Sc. in Civil Engineering
4th Year 1st Semester

Course Title: Professional Practices and Communication | Course Code: CE 403
Time: 2 hours | Credit Hour: 2.00 | Full Marks: 100

Answer all the questions

QUESTION 1 [20 MARKS]

A municipal bridge authority is evaluating two design proposals for a replacement suspension bridge.

1) **Design A** uses established, traditional steel cable technology with a history of failure rates well-documented over 70 years, considered the industry **"acceptable risk."**
2) **Design B** proposes a new, high-strength carbon fiber material. The Design B engineer claims the material is **"relatively safe"** because initial lab testing shows its short-term (5-year) performance exceeds that of traditional steel. However, the long-term (50-year) fatigue performance under varying climatic conditions is unknown.

a. Explain the **Concept of Relative Safety** in this context. How does the engineer's use of the term "relatively safe" align with or contradict the true meaning of **acceptable risk** for this public infrastructure project? **[10]**
b. Based on the engineer's **Responsibility for Safety**, outline the ethical and procedural steps in the **"Designing for Safety"** process that the bridge authority must insist upon before approving Design B. **[10]**

QUESTION 2 [20 MARKS]

Engineer R, a lead design manager, discovers that Engineer S, his subordinate and long-time colleague, has been certifying sub-par steel material from a friend's company, to save the friend money. Engineer S's actions jeopardize the **integrity** of the final structure. Engineer R is torn between protecting public safety and adhering to **collegiality**.

a. Identify and briefly define the three **Criteria of a Profession** that Engineer S's actions are violating. **[10]**
b. Define **Collegiality**. Explain why the engineer's primary professional obligation must supersede the collegiality owed to a colleague in this case. **[10]**

QUESTION 3 [20 MARKS]

An MNC establishes a large IT consultancy branch in Bangladesh. The MNC hires local engineers, providing them with job opportunities, technology transfer, and a salary package that is 10 times the local market rate for a similar job but only half the salary paid to expatriate [a person who lives outside their native country] engineers doing the exact same work.

a. Identify one **Social Benefit** and one potential **Social/Cultural Disturbance** that the MNC's presence typically brings to the host country. **[10]**
b. Discuss the ethical issue of **Fair Remuneration**. Explain the ethical **tension** that arises from setting the local wage extremely high compared to the local market but significantly lower than the international company standard. **[10]**

QUESTION 4 [10 MARKS]

Apply the provided Bill of Quantities (BOQ) (Table 1) for a commercial building's interior finishing work to calculate the **total estimated cost** of these works. Show all intermediate calculations clearly.

Item Description	Unit	Quantity	Unit Rate (BDT)
Plastering (Wall & Ceiling)	Sq.m	1,500	250
Ceramic Floor Tiling	Sq.m	800	950
Internal Wall Painting (Three coats)	Sq.m	1,200	180
Door and Window Installation (Wood/Aluminum)	Set	30	18,000
Electrical Wiring & Fixtures	Point	350	1,500

Table 1

QUESTION 5 [30 MARKS]

a. Summarize the salient features of Bangladesh Labour Law (BLL) regarding Women Workers. **[10]**
b. Which measures should be taken by the management to ensure Occupational Safety and Health? Discuss briefly. **[10]**
c. Suppose that you are the Managing Director of "ABC Construction Company Ltd.". Recently your Human Resources Manager has made a complaint against Assistant Engineer Mr. "X". The written complaint states that Mr. "X" is always late to work. Moreover, he had been absent from office for 12 working days without any notice/application. Which legal actions will you apply against Mr. "X"? Your action should conform to the Bangladesh Labour Law (BLL). **[10]**

University of Asia Pacific
Department of Civil Engineering
Final Examination Spring 2025
Program: B. Sc. Engineering (Civil)

Course Title: Geotechnical Engineering II | Course Code: CE 441
Time: 3 Hours | Credit Hours: 3.0 | Full Marks: 120

Answer all the questions

1. (a) Write down the names of any five (5) in-situ testing performed in the field under the field investigation phase of a sub-surface exploration program. Also mention the one, most frequently used in Bangladesh. Mention its reason. 3

   (b) Discuss, in short, regarding the extent of subsurface exploration performed by three other professionals than geotechnical engineers. 4.5

   (c) Write short note on preliminary information to be collected for a conventional bridge project 2.5

2. (a) Consider the following scenario for an existing two-storied building already constructed 15-years ago at a site at Dhanmondi area of Dhaka City: 7

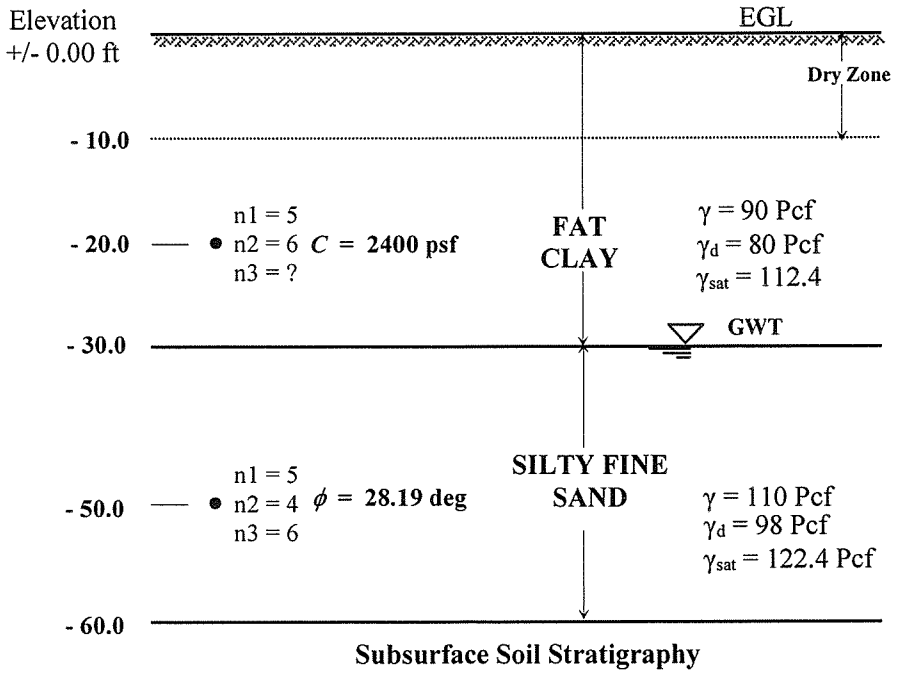
   - *A footing of the building was constructed without performing any geotechnical analysis having a dimension of 8 ft x 10 ft*
   - *Estimated applied column load on this footing for existing condition, Papp = 160 kips*
   - *Estimated ultimate bearing capacity as determined from geotechnical analysis performed for long-term condition for this site, (qu) = 10,000 psf.*

   Assess the actual factor of safety of the foundation for existing condition and comment on your result. Also estimate the amount of extra load that can be applied on this footing while maintaining a required factor of safety of 2.5.

   (b) With an analysis show that 2.5B criterion satisfies the 10% stress criterion for required depth of exploration for a square footing. 7

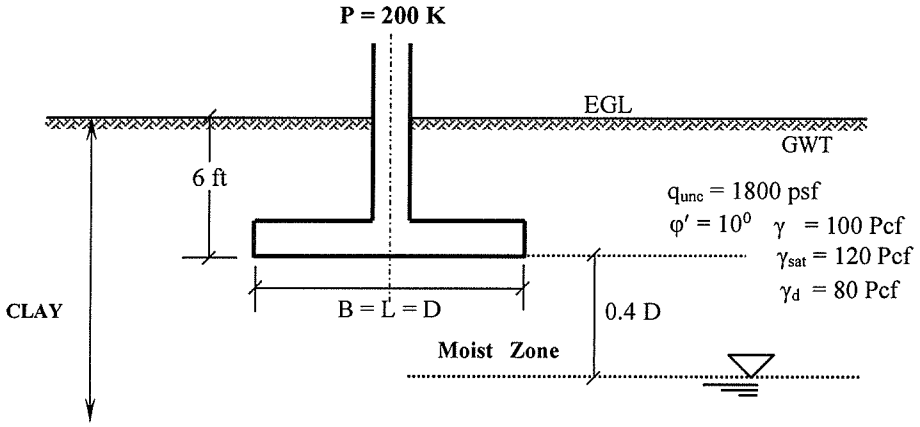
   (c) A geotechnical site investigation was conducted at a site in Bangladesh. Calculate n3 at 20 feet depth. Use Appendix in conjunction with the following information: 9

   - *Borehole dia = 4 inches*
   - *No liner was used during drilling*
   - *Note that Hammer Efficiency is not mentioned herein*

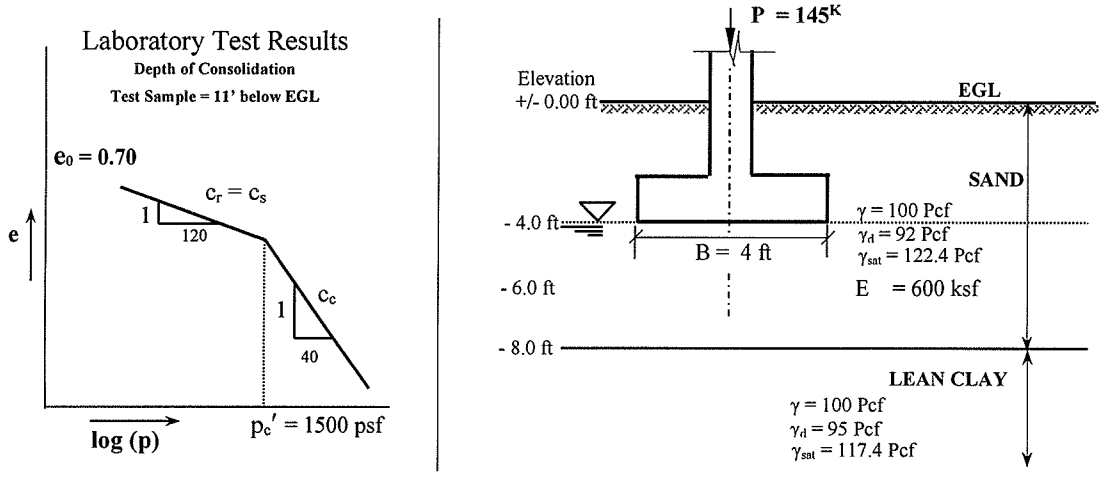


Subsurface Soil Stratigraphy

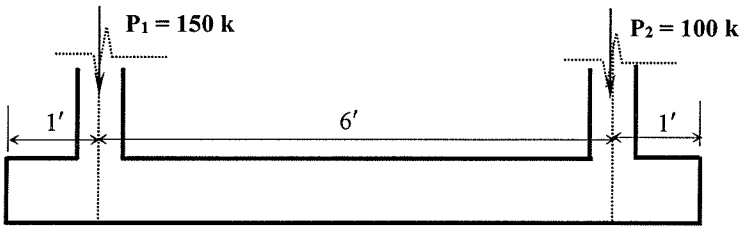
3. Using General Bearing Capacity Equation (GBCE), design the size of the circular footing for the conditions (long term) as shown in the figure below. Use $D_f/B <$ or $= 1$. 12



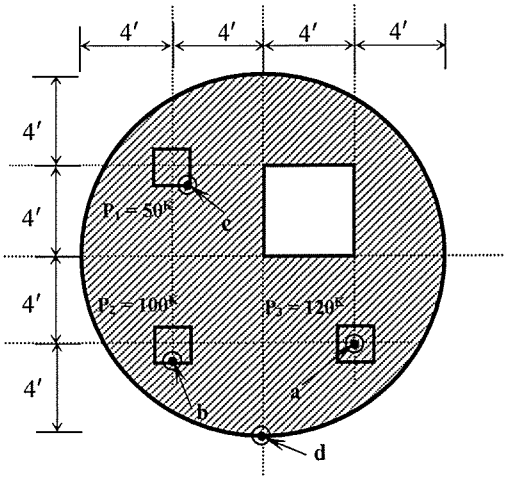
4. (a) A rectangular footing (4 ft x 6 ft) designed as per allowable bearing capacity based on shearing failure is shown in the following figure. Estimate total settlement for the layers. 11



(b) Find the dimensions of the trapezoidal foundation for the conditions shown below (q_a = 2.5 tsf) 7



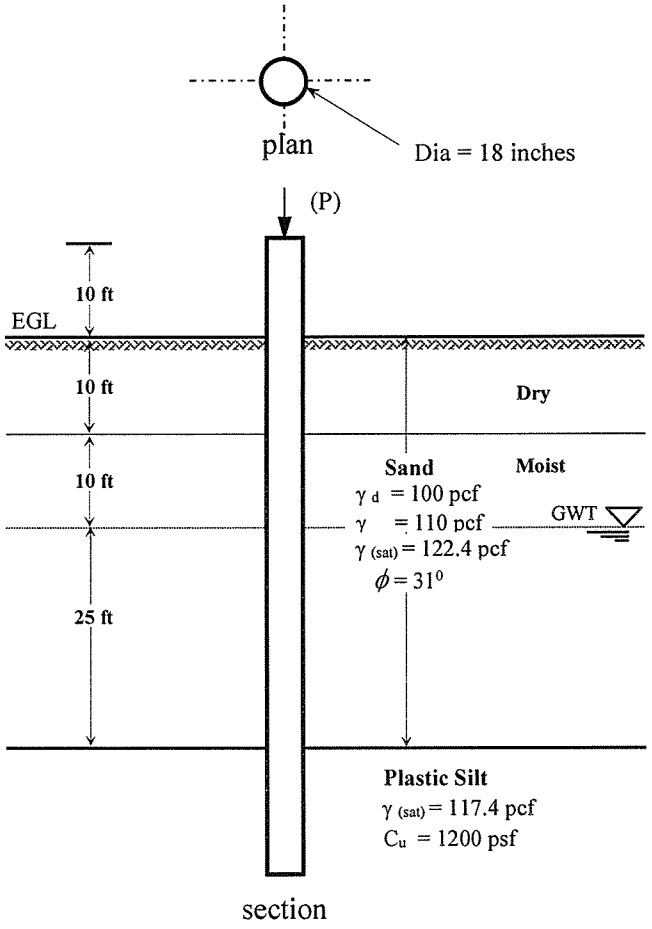
(c) The plan of a mat foundation with column loads and dimensions is shown in the following figure. Calculate the soil pressures at points a, b, c d and at the geometric centroid of the foundation (All the columns are 12 by 12 inches in size). 12



5. (a) Classify pile foundations. 4.5

(b) Draw arrangement of group piles for 11 piles. 2.5

(c) For the following condition, calculate the allowable capacity of a single pile. Assume reasonable factor of safeties for end bearing and skin resistance. Also calculate the capacity considering group (or block) effect of pile group consisting of nine piles. Use spacing of piles = 2.5 times the minimum dimension of the piles. Finally estimate the design capacity. 18

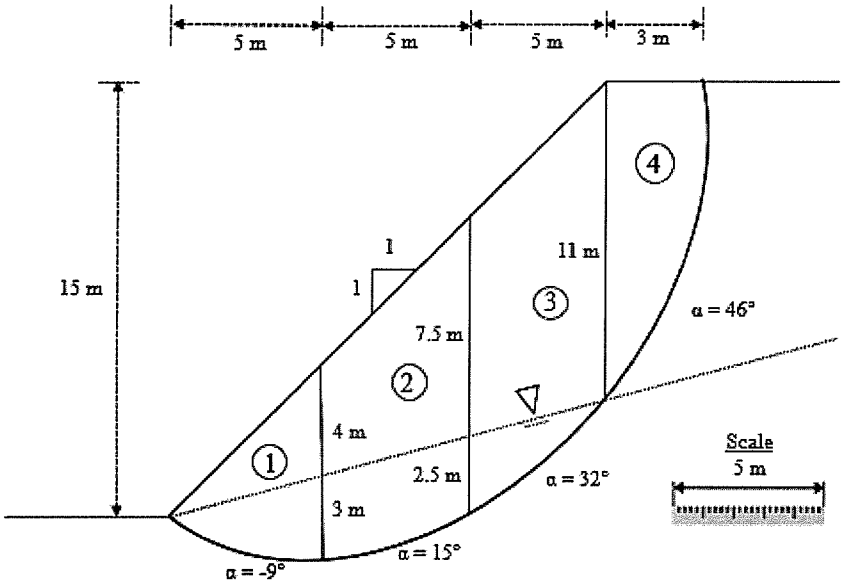


section

6. (a) A manmade 15 ft tall and 1:1 slope is to be built as shown in figure below. The soil is homogeneous with the shear strength parameter, c'= 45 kPa and ϕ'=20^0. The unit weight of soil both above and below the water table is 18 kN/m^3. Using the following equation of Ordinary Method of Slices, compute the factor of safety along the trial failure surface. 15

[Note: The angle alpha (α) is the inclination of the base of each individual slice relative to the horizontal. Scale all dimensions from the figure if needed.]

$$FS = \frac{\sum_{i=1}^{n} \left(c' l_i + (W_i \cos \alpha_i - u_i l_i) \tan \phi'\right)}{\sum_{i=1}^{n} W_i \sin \alpha_i}$$



(b) Using the following equation, determine the factor of safety for an infinite slope having H= 11 m and β= 18^0, where seepage is occurring through the soil and the groundwater table coincides with the ground surface. Given that the soil is cohesionless with the following properties, ϕ'=22^0 and Υ_{sat} = 19.2 kN/m^3. 5

$$FOS = \frac{c' + \gamma H \cos^2 \alpha \cdot \tan \phi'}{\gamma H \sin \alpha \cos \alpha}$$

University of Asia Pacific
Department of Civil Engineering
Final Examination, Spring 2025
Program: B.Sc. in Civil Engineering
4th Year 1st Semester

Course Title: Structural Engineering V | Course Code: CE 415
Time: 2 hours | Credit Hour: 2.00 | Full Marks: 50

Answer all the questions

QUESTION 1 [25 MARKS]

A post-tensioned prestressed concrete beam has the following data:
f_b = - 13.5 MPa,
f_t = -10 MPa,
f_0 = 1040 Mpa,
f_{se} = 900 Mpa,
M_G = 60 kN-m,
M_T = 450 kN-m,
h = 920 mm,

a. **Design** the post-tensioned prestressed concrete beam considering that there is no tensile stress in concrete.
b. The bottom tensile stress of concrete (f'_b) is 1.75 MPa, top tensile stress of concrete (f'_t) is 2.0 MPa. **Design** the post-tensioned prestressed concrete beam.

[12.5+12.5]

QUESTION 2 [5 MARKS]

A prestressed concrete rectangular beam has a simple span of 20 meter and a cross section of 350 mm x 800 mm, carries a uniformly distributed dead load of 5 kN/m including self-weight and live load of 15 kN/m. The prestressing is applied using 2530 mm^2 of straight high-tensile steel wires with an eccentricity of 190 mm (below center), initially stressed to 1000 MPa, and anchored against bulkheads. **Calculate** the extreme fiber stresses of concrete using the ***Internal Couple Resisting Method***.

[5]

QUESTION 3 [15 MARKS]

The symmetrical I beam shown in **Figure 1** carries an effective prestressing force of 1300 kN and supports a superimposed dead load of 20 kN/m and a service live load of 5 kN/m, in addition to its own weight of 2.5 kN/m, over a 30 meter simple span. At the section A-A shown in **Figure 2**, the main steel is placed 120 mm eccentrically (below center). The vertical component of the strands (Vp) contributing to the shear capacity of 14 kN. The compressive strength of concrete (f'c) is 35 MPa, yield strength of the stirrups (f_{yt}) is 420 MPa, and the ultimate strength of the prestressed strands (f_{pu}) is 1860 MPa.

a. **Analyze** the beam to calculate the shear force causing ***web shear-cracking*** and ***flexure shear cracking*** with the ACI recommended formulae.

b. If 6-legged, 10 mm diameter shear reinforcement is placed at a spacing of 100 mm center to center, **obtain** the shear strength contribution of the reinforcement.

[5+5+5]

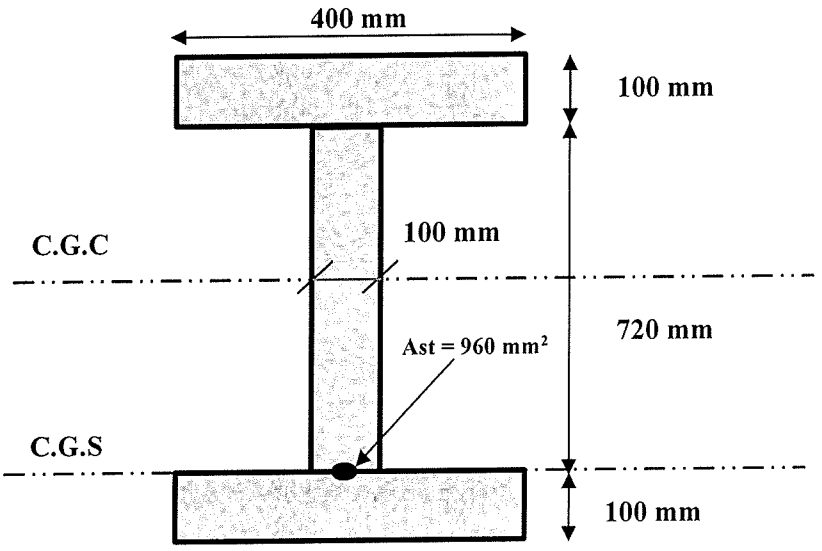


Figure 1: Cross section of an I-beam

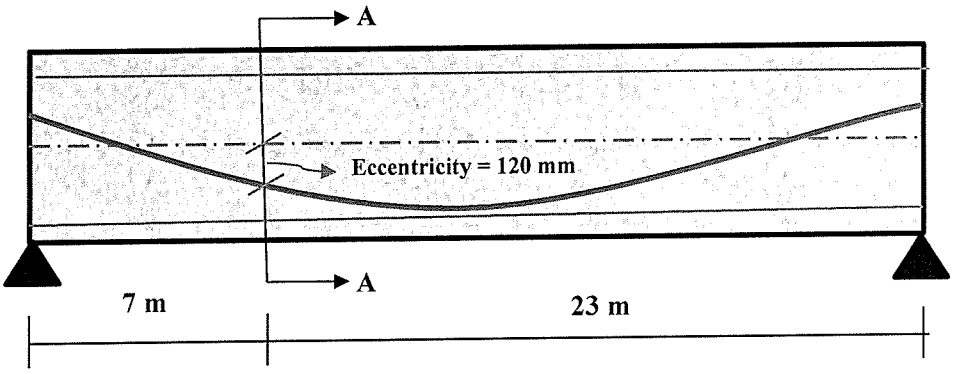


Figure 2: Long Section (A-A) of an I beam

Set of Formulae

flexure shear cracking $V_{ci} = 0.05\sqrt{f'c}\,b_w d + V_d + \frac{V_i M_{cr}}{M_{max}} \geq 0.14\sqrt{f'c}\,b_w d$

$$M_{cr} = \frac{I}{y_t}(0.5\sqrt{f'c} + f_{pe} - f_d)$$

web shear cracking $V_{cw} = (0.29\sqrt{f'c} + 0.3\,f_{pc})b_w d + V_P$

$$\text{Spacing, } S = \frac{\emptyset A_v f_{yt} d}{\emptyset V_s}$$

Design Related:

$A_c = \frac{A_{ps} f_{se}}{0.5 f_c}$, $f_c = (\text{smallest between } f_t \,\&\, f_b)$, $F = \frac{M_T}{0.65h}, F = \frac{M_L}{0.50h}$,

$e - k_b = \frac{M_G}{F_o}, F = \frac{M_T}{e + K_t}$, $A_c = \frac{F_o h}{f_b c_t}$, $A_c = \frac{Fh}{f_t c_b}$

$A_c = \frac{Fh}{f_t c_b - f'_b c_t}$, $A_c = \frac{F_o h}{f_b c_t - f'_t c_b}$, $F = \frac{M_T - f'_b A k_t}{a}$, $e_1 + e_2 = \frac{M_G + f'_t A k_b}{F_o}$

University of Asia Pacific
Department of Civil Engineering
Final Examination Spring 2025
Program: B.Sc. in Engineering (Civil)
4th Year 1st Semester

Course Title: Structural Engineering X | Course Code: CE 425
Time: 2 hours | Credit Hour: 2.00 | Full Marks: 50

QUESTION 1 [10 MARKS]

(a) Discuss briefly on 1) Scanning Electron Microscopy (SEM) and 2) X-Ray Diffraction Analysis (XRD) [4]

(b) In a laboratory experiment, concrete cylinders of 150 mm diameter and 300 mm height were tested for split tensile strength according to ASTM C496. The following load values at failure were recorded for three samples: [6]

Specimen	Failure Load (kN)
A	260
B	275
C	268

i. Calculate the average split tensile strength of the concrete
ii. Compare the obtained tensile strength (%) with the estimated value from the compressive strength using the empirical relation $f_t = 0.56\sqrt{f_c'}$ where $f_c' = 35$ MPa
iii. Discuss briefly the reasons why the experimental tensile strength may differ from the theoretical value

QUESTION 2 [10 MARKS]

(a) Discuss the sources of chlorides that may induce to concrete. [6]

(b) Explain the mechanism of carbonation into concrete. [4]

QUESTION 3 [10 MARKS]

(a) Compare between Non-Destructive Testing and Destructive Testing. [4]

(b) Explain how Ultrasonic Pulse Velocity Test is used to assess the integrity of concrete. [6]

QUESTION 4 [10 MARKS]

(a) Discuss the environmental benefits of No-Fines Concrete. [4]

(b) Compare High Performance and Ultra High-Performance concrete. [6]

QUESTION 5 [10 MARKS]

A reinforced concrete wall needs to be constructed at a construction site. The following necessary data are provided for the wall and its formwork.

Cross sectional size of the wall: Thickness = 400 mm, Length = 10 m. Height = 3 m

Concrete type: Blended cement containing 20% of fly ash with a retarder admixture.

Form height = 4 m.

Density of concrete = 2400 kg/m^3.

Concrete temperature at placement = 35°C.

Uniform volume supply rate = One 6 m^3 truck every 45 mins.

Calculate the concrete lateral pressure and draw the pressure envelope as a function of height for form work design. **[10]**

Table 1: Values of coefficients C1 and C2

Walls: C l = 1 .0	
Columns: C l = 1 .5	
Concrete:	**Value of C2**
Ordinary Portland Cement (OPC) without admixture	0.3
OPC with any admixture, except a retarder	0.3
OPC with a retarder	0.45
Blended cement containing less than 70% slag or 40% fly ash without admixture	0.45
Blended cement containing less than 70% slag or 40% fly ash with any admixture, except a retarder	0.45
Blended cement containing less than 70% slag or 40% fly ash with a retarder	0.6
Blended cement containing more than 70% slag or 40% fly ash	0.6

Formula:

$$P_{max} = D\left[C_1\sqrt{R} + C_2 K\sqrt{H - C_1\sqrt{R}}\right] \quad \text{and} \quad D \times h$$

University of Asia Pacific
Department of Civil Engineering
Final Examination, ~~Fall 2024~~ Spring 2025
Program: B.Sc. in Civil Engineering
4th Year 1st Semester

Course Title: Irrigation and Flood Control | Course Code: CE 461
Time: 3 hours | Credit Hour: 3.00 | Full Marks: 120

Answer all the questions

QUESTION 1 [12 MARKS]

a. Explain a few characteristics of a flood event and how it can be controlled or prevented using the following methods. [7]
   i) Dikes
   ii) Mangrove and Coral reef
   iii) Floodplain zoning

b. Summarize the definition and principles of Integrated Water Resources Management. [5]

QUESTION 2 [24 MARKS]

a. Express three requirements of a good canal module. [3]

b. Characterize cross regulation through its definition and two functions. [3]

c. i) Describe the working mechanism of a centrifugal pump. [5+4]
   ii) Examine the maximum depth from which the pump with following characteristics can lift water when the required discharge is 40 liters per second. Neglect head loss.
   Pump efficiency= 75%
   Delivery efficiency= 97%
   Motor efficiency= 85%
   Energy input= 15 KW

d. i) Derive the equation of flexibility criteria of an outlet in term of water depth in distributary channel and head over outlet. [5+4]
   ii) For a wide rectangular channel, the discharge is given as $Q= ky^{5/3}$.
   Irrigation water discharge flowing over a v-notch is represented as $q=CH^{5/2}$.
   The depth in the distributary channel is 1.0 m. The head over the weir is 0.3 m.
   For the information given above, calculate the followings.
   - Proportionality of the outlet
   - Sensitivity

QUESTION 3 [24 MARKS]

a. Illustrate the following irrigation methods with relevant figures. [3x3=9]
   i) Border Flooding
   ii) Basin Flooding and
   iii) Furrow Irrigation

b. A stream of 0.65 cumec is applied to a border strip 15 m wide, such that the average depth of water flow is estimated to be 25 cm while the soil has an average infiltration rate of 35 cm/hr. Determine the maximum distance up to which water will advance. [3]

c. Demonstrate surface and sub-surface drainage methods through short description and figures. [8]

d. Calculate the irrigation requirement of a rice crop when the leaching requirement of the rice soil is 32% and the soil water has been depleted 60%. The available water holding capacity of the root zone is 50 cm. [4]

QUESTION 4 [30 MARKS]

a. Outline a distribution system for canal irrigation with proper notation. [6]

b. The cultivable command area is of a watercourse is 2500 hectares as shown in the Figure 1 below. Find the discharge capacity required at the head of the watercourse year-round. [10]
Also determine the design discharge at the outlet if capacity factor is equal to 0.85. Can the design discharge be modified during pre-monsoon season?

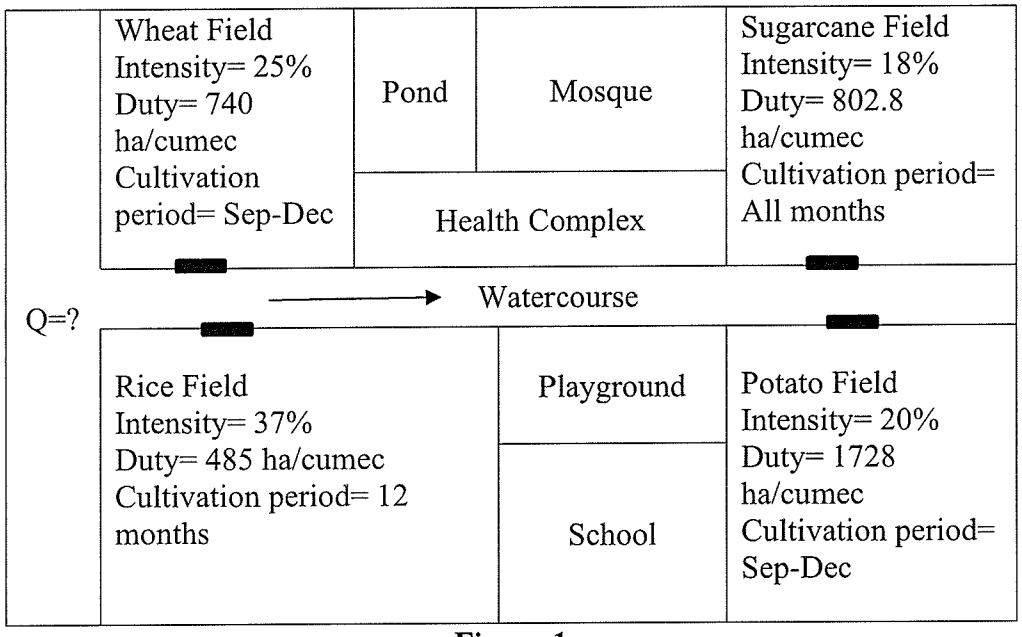


Figure 1

c. i) Design a regime channel with 0.5H:1V for the design discharge calculated in the previous question if the average particle size for the field is 0.52 mm. Show your design in a diagram with proper freeboard extent from Table 1. Also find the bed slope. [Hint: Use Lacey's theory for the design] [10+4]
ii) Specify two key differences between Kennedy's and Lacey's method of design.

$f=1.76\sqrt{d_{mm}}$ $\quad R=\frac{5}{2}\left(\frac{V^2}{f}\right)$

$P=4.75\sqrt{Q}$ $\quad S_0=\left[\frac{f^{\frac{5}{3}}}{3340Q^{\frac{1}{6}}}\right]$

$V=\left(\frac{Q*f^2}{140}\right)^{\frac{1}{6}}$

QUESTION 5 [30 MARKS]

a. Explain the concept of a regime channel. [3]

b. A trapezoidal irrigation canal needs to be designed for a project area located in Rajshahi Division, Bangladesh, a region characterized by mixed soil conditions, where the upper catchment has non-alluvial soils and the lower plains have alluvial soils. The area supports dry-season Boro rice and Wheat as major crops, with a required discharge of 27 cumec. [8+13+6]

The side slope bed slope may be taken as 1:1 and 1 in 5000 respectively.

i) Design a canal along non-alluvial soil area, with a Chezy's constant of 44 and a permissible mean velocity of 0.86 m/s. Assume other reasonable value.

ii) Design a canal along alluvial soil area with a coefficient of rugosity= 0.023. Use Kennedy's method to design. Assume other reasonable value.

iii) Show your designs for both non-alluvial and alluvial soil in separate diagrams with proper freeboard extent from Table 1. Lastly, express which design would be more economical based on excavation work.

$[V_0=0.546D^{0.64},\ C=\frac{\frac{1}{n}+(23+\frac{0.00155}{S_0})}{1+(23+\frac{0.00155}{S_0})\frac{n}{\sqrt{R}}}]$

Table 1: Freeboard extent based on discharge

Discharge (m^3/s)	Extent of freeboard (m)
1 to 5	0.50
5 to 10	0.60
10 to 30	0.75
30 to 150	0.90

University of Asia Pacific
Department of Civil Engineering
Final Examination, Spring 2025
Program: B.Sc. in Civil Engineering
4th Year 1st Semester

Course Title: Transportation Engineering II | Course Code: CE 451
Time: 3 hours | Credit Hour: 3.00 | Full Marks: 120

Answer all the questions. Submit annexures with relevant parts of answer scripts.

PART A

QUESTION 1 [24 MARKS]

Design a rigid pavement for Dhaka Bypass Expressway using the AASHTO 1993 rigid pavement design method. The pavement will be constructed over a 12-inch granular subbase. The depth to rock is 5 ft below the subgrade surface, the projected slab thickness is 10 inches, and the potential loss of subbase support is 1. Seasonal variations in subgrade and subbase support are significant, which are given in Table 1.

i) Estimate the effective modulus of the subgrade reaction.
ii) Determine whether the projected slab thickness will be adequate for 30-year design period using the given data. Assume any reasonable value if needed. [24]

Table 1: Monthly Resilient Modulus Values for Pavement Layers.

Month	Roadbed Modulus (lb/in^2)	Sub-base Modulus (lb/in^2)
August	5,000	15,000
September	7,000	20,000
October	10,000	30,000
November	16,000	50,000
December	18,000	60,000

Given Data:

- ESAL on design lane during first year of operation: 548/day
- Traffic growth rate: 6%
- Terminal serviceability index: 3
- Elastic modulus of the concrete = 3×10^6 lb/in^2
- Modulus of rupture of concrete = 800 lb/in^2
- Load transfer coefficient = 2.8
- Drainage coefficient = 0.7
- Reliability = 90%

QUESTION 2 [16 MARKS]

a. Determine the tensile stress that will be developed in the concrete pavement designed in Question 1 due to a circular wheel load of 3000 lb located at the edge of the pavement, using Ioannides equation. Consider, radius of loaded area = 5" [06]

b. Calculate the allowable steepest gradient from Dhaka to Mymensingh railway track using the data provided below. [10]

No of wagons = 18
Weight of one wagon = 15 tonnes
Weight of locomotive = 150 tonnes
Tractive effort of locomotive = 20 tonnes
Speed of train = 80 km/h
Maximum curvature of the Broad-Gauge track = 5°
Wind speed = 4 km/h
Exposed area of train = 4000 m^2

PART B

QUESTION 3 [35 MARKS]

a. Compare different types of sleepers. If length of rail is 20m and the track is meter gauge, estimate the minimum sleeper's density per rail? If the joint spacing is 0.20m, determine the minimum sleeper's density per km? Consider sleeper density is M+4. [4+3]

b. Explain the main reasons for the occurrence of rail wear. Describe its effects on the track and train operation, and discuss the measures that can be taken to reduce it. [6]

c. Discuss the difficulties that designers face in providing superelevation on a railway track when a branch line diverges from the main track. [7]

d. Compute the length of a transition curve required for an M.G. curve of 8 degrees. The maximum permissible speed on the curve is 210 km.p.h. This transition curve is to be used to join the ends of a 4° circular curve with the straight. Set out the transition curve from the straight by taking offsets at every 420m interval. [15]

QUESTION 4 [20 MARKS]

In Sylhet, a new six-lane rural divided highway was being planned to connect nearby upazilas with the city. Engineer Amina and her team were assigned to design the pavement for a 20-year service life. To begin, they needed to determine ESAL for the project. The given data included a structural number (SN or D) of 3, a terminal serviceability index (P_t) of 2.5, and an Average Daily Traffic (ADT) of 8,310 vehicles in both directions. Using information provided in Table 2, the team had to compute the total ESAL, which would guide the final pavement design for the Sylhet rural highway. [20]

Table 2: Traffic Information

Vehicle Types	Current AADT	Growth Rate	Percentage of Traffic
Passengers Cars (1000 lb/axle)	4425	3.0%	10%
Small Buses (2000 lb/axle)	525	2.5%	30%
3-axle Large Buses (6000 lb/axle)	347	3.1%	15%
Pickup Trucks (3000 lb/axle)	1455	2.4%	15%
2-axle trucks (1500 lb/axle)	425	4.5%	5%
3 or more axle trucks (7000 lb/axle)	63	4.0%	15%
5 or more axle trailer (10000 lb/axle)	1070	1.9%	10%

QUESTION 5 [25 MARKS]

Design a suitable pavement of an asphalt mixture surface within a limited budget with an elastic modulus of 150,000 lb/in^2, a base layer with a structural coefficient of 0.118 on a subgrade having a resilient modulus of elasticity of 5000 lb/in^2. It takes about 1 week for the base course and 1 month for the sub-base course to drain out the water with a saturation of 4%. Use a reliability level of 70%. Consider the value of design ESAL as calculated in question no 4 (ESAL from Q4/1000). The CBR value of the sub-base course is 50. The resilient modulus of the base course and sub-base course is 20000 lb/in^2 and 10000 lb/in^2 respectively. [25]

Formula:

$$\sigma_e = \frac{0.572P}{h^2}\left[4\log_{10}\left(\frac{\ell}{b}\right) + \log_{10} b\right]$$

$$\sigma_e = \frac{0.572P}{h^2}\left[4\log_{10}\left(\frac{\ell}{b}\right) + 0.359\right]$$

$$\sigma_i = \frac{0.316P}{h^2}\left[4\log 10\left(\frac{\ell}{b}\right) + 1.069\right]$$

$$\sigma_e = \frac{0.803P}{h^2}\left[4\log_{10}\left(\frac{\ell}{a}\right) + 0.666\frac{a}{\ell} - 0.034\right]$$

$$\sigma_e = \frac{0.803P}{h^2}\left[4\log_{10}\left(\frac{\ell}{a}\right) + 0.282\frac{a}{\ell} + 0.650\right]$$

For BG and MG $V = 4.4\sqrt{R-70}$

For NG $V = 3.6\sqrt{R-6}$

$S = L^2/24R$

$Y = X^3/6RL$

(1) $L = 7.20e$

(2) $L = 0.073D\,V_{max}$

(3) $L = 0.073e\,V_{max}$

For BG

S.E.$= 1.315\,V^2/R$

For MG

S.E.$= 0.80V^2/R$

For NG

S.E.$= 0.60V^2/R$