L-4/T-1/CE **Date : 14/10/2023**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-4/T-1 B. Sc. Engineering Examinations 2021-2022

Sub : **CE 401** (Project Planning and Construction Management)

Full Marks : 280 Time : 3 Hours

The figures in the margin indicate full marks.

USE SEPARATE SCRIPTS FOR EACH SECTION

SECTION – A

There are **FOUR** questions in this section. Answer any **THREE**.

1. (a) The network of a Civil Engineering project is shown in figure-1 along with the duration of each activity. Compute activity time and total float of each activity and also locate the critical path on the network. **(26⅔)**

   (b) Manifest the safety measures that should be taken during Excavation Works, Illustrate causes of fatal accidents in construction industries. **(5+5)**

   (c) Compile the steps in Project Planning. State the advantages and shortcomings of Bar charts. **(5+5)**

2. (a) Explain 'dummy activity' and 'pessimistic time'. Compile the standard forms of linear programming. **(5+5)**

   (b) Suppose we have to maximize $Z = 2x + 5y$. The constraints are **(14⅔)**

   $$x + 4y \leq 24,$$
   $$3x + y \leq 21 \text{ and}$$
   $$x + y \leq 9$$

   Where, $x \geq 0$ and $y \geq 0$. Solve the above Linear Programming problem using graphical method.

   (c) A construction company has an opportunity to submit a bid for the construction of a new Academic building. From the specifications provided by the client, the PERT network along with three time estimate (in week) for each activity are shown in figure-2. Compute Critical path and its Standard Deviation and probability of completion the project within 50 weeks. Supporting data is provided in Table-2. **(22)**

3. (a) What does project planning mean? Why is construction economics extremely important for engineers and construction managers? **(5+6)**

   (b) Choose a particular brand of excavator from two brands. Both the brands are available for a Down payment of Tk. 500,000 and have a service life of 4 years. Brand A is estimated to give A return of Tk. 100,000 for the first year, Tk. 150,000 for the second year, Tk. 200,000 for the Third year and Tk. 250,000 for the fourth year. Brand B is expected to give a return of Tk. 175,000 per year for all the four years. Use payback period method. **(10⅔)**

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Contd ... Q. No. 3

(c) A company is considering the purchase of a new truck that has an expected useful life of 6 years. This truck costs Tk. 1 crore and should generate a net annual income of 30 lakh. Its likely salvage value is 12 lakh. Another option is to purchase a used truck having an estimated life of 3 years for 35 lakh. The used truck would have no salvage value at the end of its useful life. The estimated net annual income for the used truck is Tk. 15 lakh. If the company's MARR is 11%, which truck, if either, should be chosen? **(25)**

4. (a) What is SWOT analysis? How will you conduct it? State briefly. **(10)**

(b) Explain the differences between economic analysis and financial evaluation of a project. **(16⅔)**

(c) A government is planning for a hydroelectric project that will also provide flood control, irrigation and recreation benefits. The established cost of the three alternatives are given in Table 1. The interest rate to be used for the analysis is 6%, and the life of each of the alternative X, Y and Z is to be assumed as 60 years. Choose the best alternative. **(20)**

Table: 1: Data for Benefit-Cost (B/C) ratio computation (all values in crore Tk.)

Alternatives	X	Y	Z
Initial cost	200	300	400
Annual power sales	12	16	20
Annual flood control benefit	3	4	6
Annual irrigation benefit	4	6	8
Annual recreation benefit	1	2	3
Annual operation & maintenance cost	2	3	4

SECTION – B

There are **FOUR** questions in this section. Answer any **THREE**.

5. Suppose the Bangladesh University of Engineering and Technology (BUET) authority plans to construct a 10-story academic building at the location of the existing Old Academic Building (OAB) within the BUET premises. The funding for this project is expected to come from the Bangladesh Government's development budget, as well as from BUET's own funds. The construction of this new academic building involves temporary relocation of existing facilities within the OAB premises, demolition of the existing structure, and the construction of new facilities. The new building will be equipped with modern facilities and will house several existing departments while also serving as a home for other institutions, laboratories, and offices. **Figure 3** illustrates the current location of the OAB building and its surrounding features.

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Contd ... Q. No. 5

(a) Identify and list the various important parties that will be involved in different stages of this project. Propose a project management team for this construction project. **(10)**

(b) List and briefly explain different potential project delivery methods for this project. Propose a suitable project delivery method for this project and justify your selection. **(15)**

(c) Prepare a list of the essential contract documents required for this construction project. **(15)**

(d) Suppose BUET authority plans to implement this project by hiring a contractor through a competitive bidding process. List the different stages in the tendering process relevant to this selection. **(6⅔)**

6. (a) For the purpose of project planning and scheduling, suppose you are to create a Work Breakdown Structure (WBS) for the project mentioned in question 5. Sketch a WBS diagram outlining at least three levels of detail for this construction project. **(15)**

(b) Sketch a site layout plan for the project mentioned in question 5, taking into account the surrounding features near the existing OAB building location, as depicted in Figure 3. **(15)**

(c) Throughout the construction, various heavy machinery will be required for the project mentioned in question 5. Compile a list of machinery that might be necessary in various construction phases. **(10)**

(d) Suppose you are asked to create a quality control plan for the project mentioned in question 5. List the key steps involved in the Construction Quality Control Process. **(6⅔)**

7. (a) Write short descriptions on the following inventory types stating their purpose. Give an example for each type of inventory. **(15)**

   (i) Pipeline inventory
   (ii) Seasonal inventory
   (iii) Cycle inventory
   (iv) Buffer inventory
   (v) Safety inventory

(b) Describe how human resource management contributes to the resolution of ethical and legal conflicts within a project. **(6⅔)**

(c) A computer assembly line requires the following tasks to be performed in the given sequence (Figure 4). Task durations are given in seconds. The factory has an annual demand of 3750 computers per week. The factory operates one shift (7 hours) per day, five days a week. Find the minimum number of workstations necessary to run this assembly line and assign tasks to these workstations. Multiple tasks can be assigned to a workstation as long as there is no bottleneck. You cannot violate the precedence of tasks for any workstation (i.e., task "C" cannot be assigned without assigning task "B" to a workstation first). Calculate the average efficiency of the assembly line. **(15)**

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Contd ... Q. No. 7

(d) A cement manufacturing plant produces cement bags at a rate of 500 bags per hour. The average time it takes for a cement bag to go through the entire production process, from raw material input to packaging, is 4 hours and 15 minutes. Calculate the average number of cement bags in the production system at any given moment. Also, determine the inventory turn for this manufacturing process. **(10)**

8. (a) What do you understand by capital appreciation? Briefly explain five causes for inflation. **(8)**

(b) Government of Bangladesh has approved the Dhaka Subway project which will be financed by public-private partnership. The project requires $500 million in financing which will be covered by a mix of equity ($350 million) and debt ($150 million). The risk-free rate and corporate tax rate issued by the Bangladesh Bank is 3% and 25% respectively. Expected return on the overall construction market is 16.5%. The agreed upon cost of debt is 2%. However, the cost of equity has to be adjusted to account for 7.5% inflation. Historical returns of the Subway construction market and historical returns of the general construction market are given in the following table. Find out the weighted average cost of capital for this mega project. **(15)**

Year	2018	2019	2020	2021	2022
Subway construction market	2%	3%	5%	4%	1%
General construction market	1%	2%	4%	3%	3%

(c) Consider the after-tax cash flows for three mutually exclusive projects: **(15)**

Year	A	B	C
0	-25000	-48000	-34000
1	15000	25000	15000
2	20000	17000	25000
3	-7000	-10000	-5000
4		21000	5000
5		5000	-5000
6			5000

All expenses are denominated in Bangladeshi Taka (BDT). Consider a 10% semiannual compounded discount rate and a 7.5% inflation rate for the present year. If these projects are perpetually repeated, which one should be chosen? The construction company has an annual hurdle rate of 8%. Determine whether the selected project meets this hurdle rate.

(d) Explain Maslow's hierarchy of needs with an engineering example. **(8⅔)**

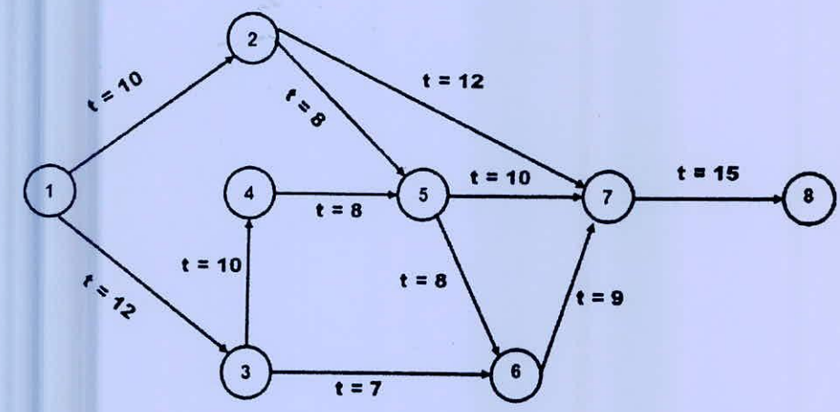

Figure - 1 Q. 1a

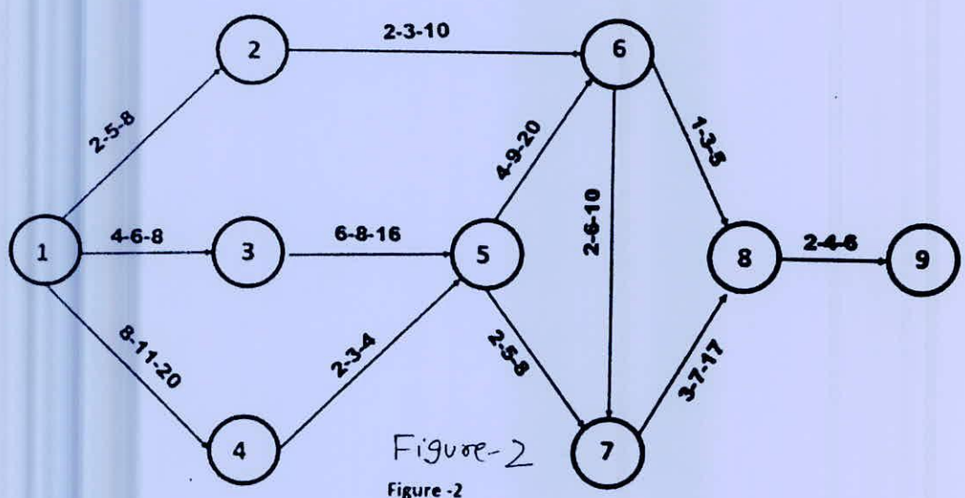

Figure-2

Figure -2

Q. 2c

Table 2: Standard Normal Distribution Function

Z (+)	Probability (P_r)(%)	Z (−)	Probability (P_r) (%)
0	50·0	0	50·0
+0·1	53·98	−0·1	46·02
+0·2	57·93	−0·2	42·07
+0·3	61·79	−0·3	38·21
+0·4	65·54	−0·4	34·46
+0·5	69·15	−0·5	30·85
+0·6	72·57	−0·6	27·43
+0·7	75·80	−0·7	24·20
+0·8	78·81	−0·8	21·19
+0·9	81·59	−0·9	18·41
+1·0	84·13	−1·0	15·87
+1·1	86·43	−1·1	13·57
+1·2	88·49	−1·2	11·51
+1·3	90·32	−1·3	9·68
+1·4	91·92	−1·4	8·08
+1·5	93·32	−1·5	6·68
+1·6	94·52	−1·6	5·48
+1·7	95·54	−1·7	4·46
+1·8	96·41	−1·8	3·59
+1·9	97·13	−1·9	2·87
+2·0	97·72	−2·0	2·28
+2·1	98·21	−2·1	1·79
+2·2	98·61	−2·2	1·39
+2·3	98·93	−2·3	1·07
+2·4	99·18	−2·4	0·82
+2·5	99·38	−2·5	0·62
+2·6	99·53	−2·6	0·47
+2·7	99·65	−2·7	0·35
+2·8	99·74	−2·8	0·26
+2·9	99·81	−2·9	0·19
+3·0	99·87	−3·0	0·13

For Q. 2(c)

Figure 1 (For question 5 and 6): Existing location of the OAB building and its surrounding features.

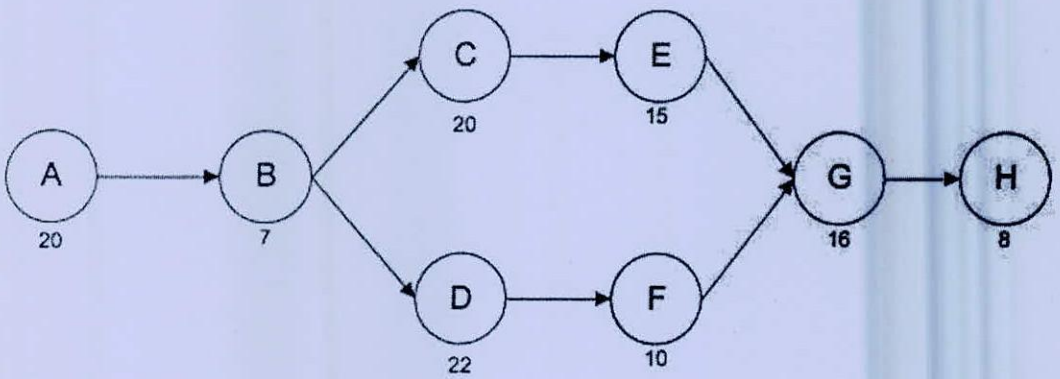

Figure 2 (For question 7 c)

L-4/T-1/CE **Date : 03/10/2023**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-4/T-1 B. Sc. Engineering Examinations 2021-2022

Sub : **CE 411** (Structural Analysis and Design II)

Full Marks : 210 Time : 3 Hours

The figures in the margin indicate full marks.

USE SEPARATE SCRIPTS FOR EACH SECTION

SECTION – A

There are **FOUR** questions in this section. Answer **All** questions.

Symbols and notations have their usual meanings.

Neglect axial deformation of beams and moment frame members unless otherwise noted.

1. For the continuous beam shown in Fig. 1, the definition of degrees of freedoms (DOF) at joints (known and unknowns), assembled global stiffness matrix and the member load vector is given as shown. Perform appropriate row and column interchange to separate the known and unknown DOFs by matrix partitioning and solve for the unknown DOFs. Then, following matrix calculations, determine the unknown support reactions (forces and moments). **(26 ¼)**

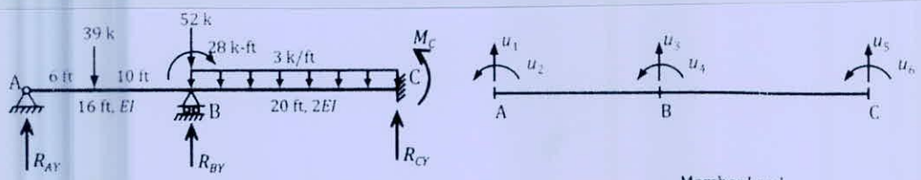

Fig. 1

Assembled Global Stiffness Matrix, [K]

$$EI\begin{bmatrix}
\frac{12}{16^3} & \frac{6}{16^2} & -\frac{12}{16^3} & \frac{6}{16^2} & 0 & 0 \\
\frac{6}{16^2} & \frac{4}{16} & -\frac{6}{16^2} & \frac{2}{16} & 0 & 0 \\
-\frac{12}{16^3} & -\frac{6}{16^2} & \frac{12}{16^3}+\frac{24}{20^3} & -\frac{6}{16^2}+\frac{12}{20^2} & -\frac{24}{20^3} & +\frac{12}{20^2} \\
\frac{6}{16^2} & \frac{2}{16} & -\frac{6}{16^2}+\frac{12}{20^2} & \frac{4}{16}+\frac{8}{20} & -\frac{12}{20^2} & \frac{4}{20} \\
0 & 0 & -\frac{24}{20^3} & -\frac{12}{20^2} & \frac{24}{20^3} & -\frac{12}{20^2} \\
0 & 0 & \frac{12}{20^2} & \frac{4}{20} & \frac{12}{20^2} & \frac{8}{20}
\end{bmatrix}$$

Member Load Vector, $[P_m]$

$$\begin{bmatrix} 91.41 \\ 45.16 \\ 26.66 \\ 42.3 \\ 30 \\ -100 \end{bmatrix}$$

2. Compute and write down the element stiffness matrices for members 1 and 4 of the pin-connected plane truss in Fig. 2. Assemble the element stiffness matrices in the global stiffness matrix for these two elements. After performing matrix calculations, following displacement vector is obtained, $[u]^T = [0, 0, 0, 0, 0, 0.5, 2, 2]$. Based on the element stiffness characteristics, determine the member forces in these two members. For all members, $E = 1000$ k/ft^2, $A = 0.1$ ft^2. **(26 ¼)**

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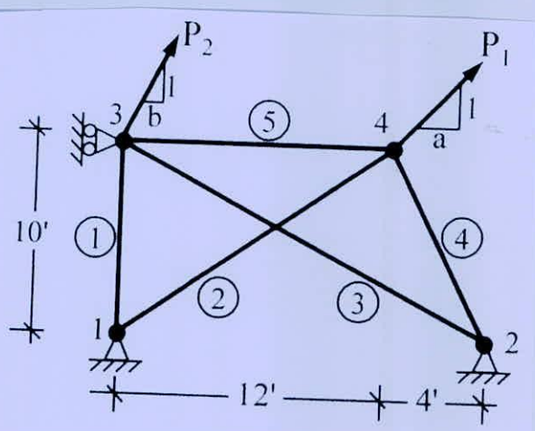
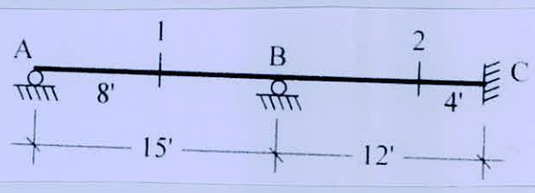
Fig. 2



3. Answer either (a) or (b).

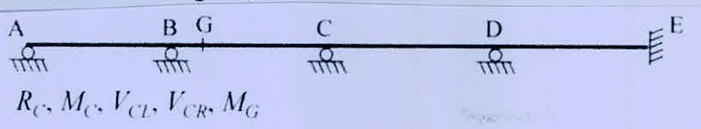
(a) For the statically indeterminate beam shown in Fig. 3, numerically determine the co-ordinates of influence line at location 1 and 2 for the support reaction at C. For this beam, *EI* is constant throughout. **(26 ¼)**

Fig.3



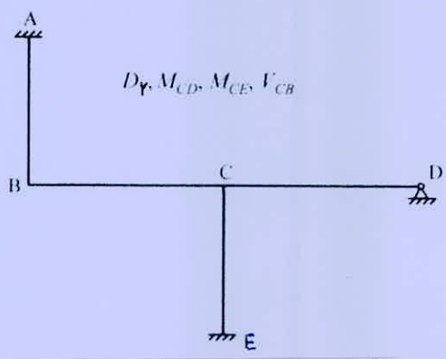
(b) Draw qualitative influence lines for indeterminate beams and frames for the respective parameters indicated on the Figs. 4, 5 and 6.

Fig.4



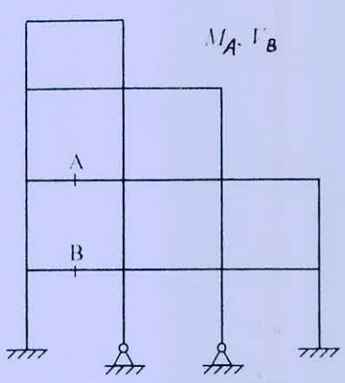
R_C, M_C, V_{CL}, V_{CR}, M_G **(10)**

Fig.5



D_Y, M_{CD}, M_{CE}, V_{CB} **(8)**

Fig.6



M_A, V_B **(8 ¼)**

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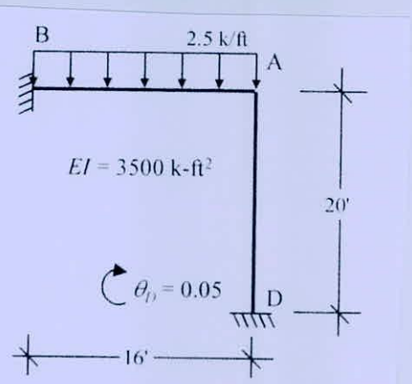
4. Answer either (a) or (b).

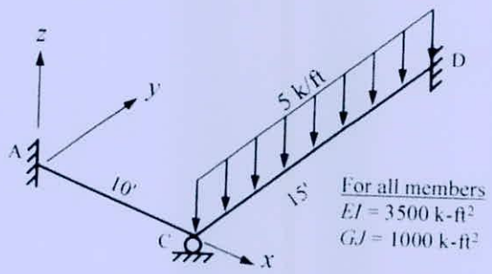
(a) For the plane frame shown in Fig. 7, support at D rotates 0.05 radian clock-wise. Analyze the frame using stiffness method and determine the moments and forces developed at all supports. Show your results on a neatly drawn free body of the structure. **(26 ¼)**

Fig.7



(b) Analyze the plane grid shown in Fig. 8 following stiffness method and determine the vertical reaction at support C. **(26 ¼)**

Fig.8



SECTION – B

There are **FOUR** questions in this section. Answer **All** the questions.
Symbols carry their usual meaning. Assume reasonable values for missing data, if any.

5. (a) Write down the general flexibility equation in conventional matrix form and identify the following matrices describing: (i) Displacements due to load; (ii) Effects of redundant; (iii) Type I support movement; (iv) Type II support movement. **(4 ¼)**

(b) What are the conditions that a released structure must satisfy? **(6)**

(c) Figure 9(a) shows an option to solve the indeterminate beam using external releases while Figure 9(b) shows another option to solve the same problem using internal releases. Which one will you prefer in solving the problem? Explain with necessary sketches. **(8)**

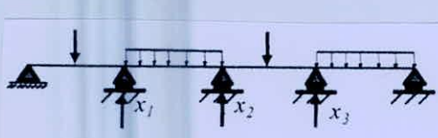


Figure ~~1(a)~~ 9(a)

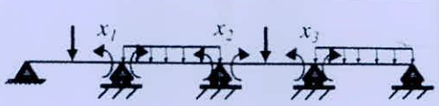


Figure ~~1(b)~~ 9(b)

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(d) Explain the principle of superposition as applied to solving a problem in flexibility method. Why the principle is not applicable for non-linear cases involving large displacements and large rotations? **(5+3)**

6. (a) The prismatic beam AB shown in Figure 10 is subjected to a unit rotation at end A. End B is fixed without any rotation. (i) Calculate the end moments, M_{AB} and M_{BA} from the basics. (ii) Obtain the stiffness, K_{AB}. (iii) Calculate the carry over factor, C_{AB}. **(8)**

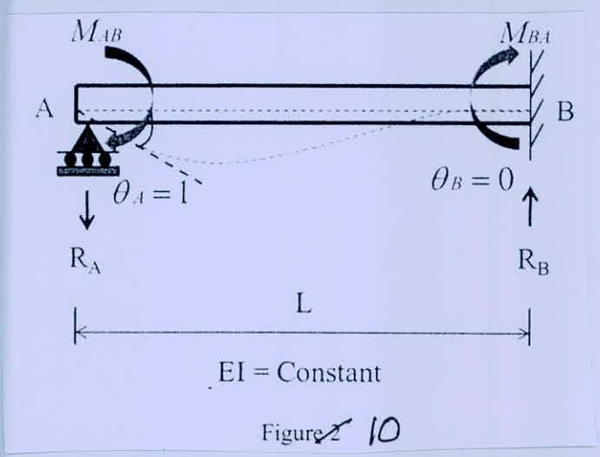

Figure 10

(b) The frame shown in Figure 11 is subjected to a clockwise moment M, around point B. This causes moments and/or rotations at A, B, C and D points. (i) Sketch the qualitative deflected shape due to this moment; (ii) Show the rotations and moments at A, B, C, D points marking the knowns and unknowns; (iii) Find out M_{BA}, M_{BC}, M_{BD} and quantify the rotation at B. **(6)**

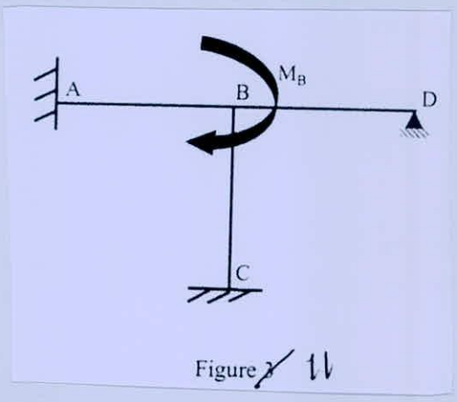

Figure 11

(c) Analyze the beam shown in Figure 12 using moment distribution method. Draw shear force and bending moment diagrams. **(12 ¼)**

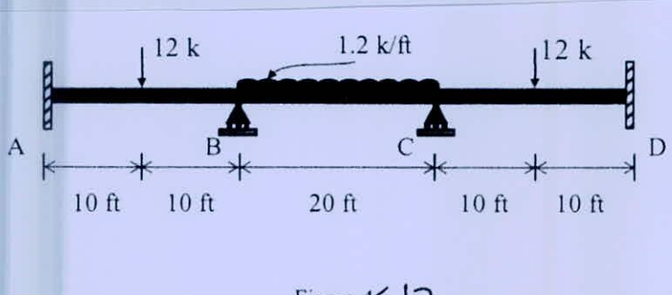

Figure 12

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7. (a) The loading and support settlement conditions for the non-prismatic beam is shown in Figure 13 along with its geometry. Analyze the beam using flexibility method. In this process (i) Mention the degree of statical indeterminancy; (ii) Select a released structure from three options and mention the reasoning of your selection; (iii) State the support reactions and moments; (iv) Draw the bending moment diagrams. **(4+6+12+4 ¼)**

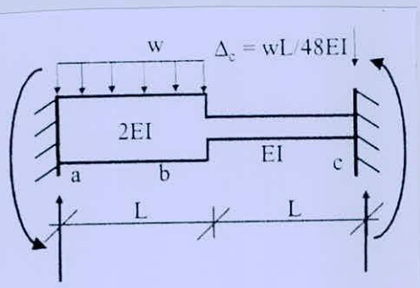

Figure 13

OR

(b) Figure 14 shows a plane frame subjected to a lateral load. (i) Choose a released structure through external release and draw sketches to show effects of each redundant in the released structure. (ii) Draw an alternate released structure with internal releases. (iii) Solve the problem using either of the released structures. **(8+4+14 ½)**

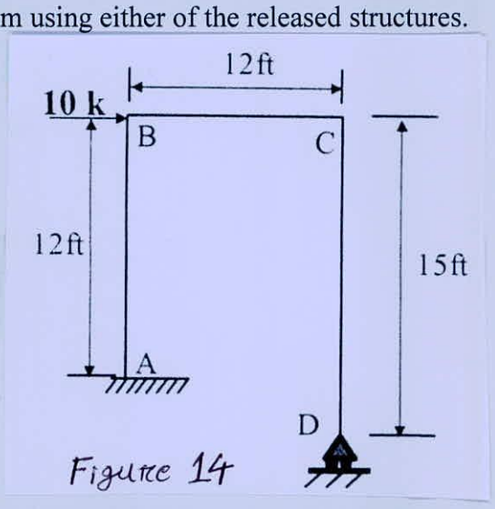

Figure 14

8. (a) Figure 15 shows a plane frame subjected to vertical load and lateral load. (i) Use moment distribution method and calculate the end moments. (ii) In solving the problem, mention the sub-problem(s) where you can employ symmetry conditions and where you cannot. Explain with reasons. **(16+10 ¼)**

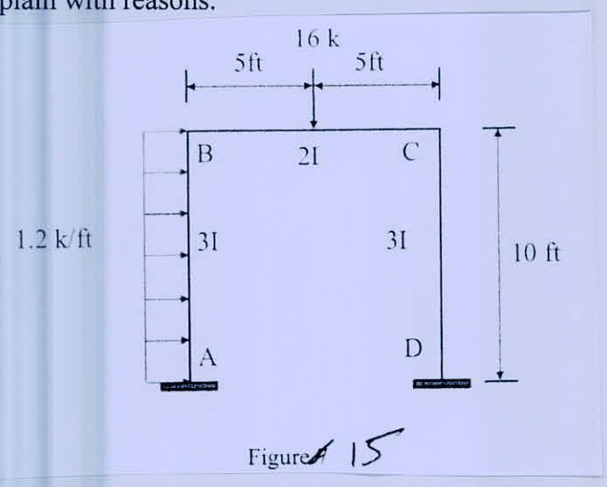

Figure 15

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Contd ... Q. No. 8

OR

(b) Figure 16(a) shows a one-story bent with an inclined leg, subjected to a lateral load. The relative stiffness, K values are shown in circles. (i) Draw neat sketches to quantify the amount of away for the member CD for an arbitrary unit sway at point B of the member AB (ii) State the method(s) with sketches to restrict this sway. (iii) Figure 16(b) shows the calculated value of horizontal force, end moment and end reactions worked out for an arbitrary unit sway at B. Calculate the end moments for the horizontal force shown in Figure 16(b). **(10+6+10 ¼)**

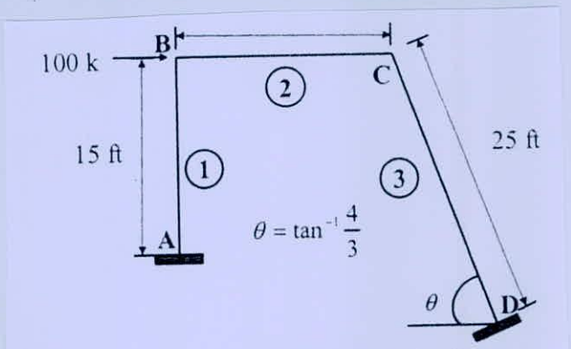


Figure ~~8(a)~~ 16(a)

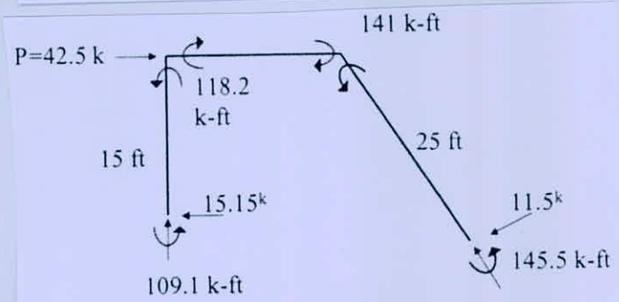
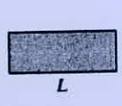
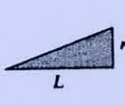
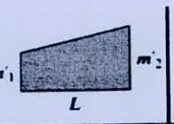
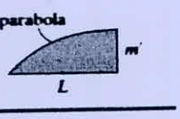
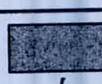
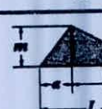


Figure ~~8(b)~~ 16(b)

APPENDIX

Table of Product Integral

$\int_0^L m\,m'\,dx$				
	$mm'L$	$\frac{1}{2}mm'L$	$\frac{1}{2}m(m'_1 + m'_2)L$	$\frac{2}{3}mm'L$
	$\frac{1}{2}mm'L$	$\frac{1}{3}mm'L$	$\frac{1}{6}m(m'_1 + 2m'_2)L$	$\frac{5}{12}mm'L$
	$\frac{1}{2}m'(m_1 + m_2)L$	$\frac{1}{6}m'(m_1 + 2m_2)L$	$\frac{1}{6}[m'_1(2m_1 + m_2) + m'_2(m_1 + 2m_2)]L$	$\frac{1}{12}[m'(3m_1 + 5m_2)]L$
	$\frac{1}{2}mm'L$	$\frac{1}{6}mm'(L + a)$	$\frac{1}{6}m[m'_1(L + b) + m'_2(L + a)]$	$\frac{1}{12}mm'\left(3 + \frac{3a}{L} - \frac{a^2}{L^2}\right)L$
	$\frac{1}{2}mm'L$	$\frac{1}{6}mm'L$	$\frac{1}{6}m(2m'_1 + m'_2)L$	$\frac{1}{4}mm'L$

L-4/T-1/CE **Date : 08/10/2023**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-4/T-1 B. Sc. Engineering Examinations 2021-2022

Sub : **CE 441** (Foundation Engineering)

Full Marks : 210 Time : 3 Hours

The figures in the margin indicate full marks.

USE SEPARATE SCRIPTS FOR EACH SECTION

SECTION – A

There are **FOUR** questions in this section. Answer any **THREE**.

1. (a) Why geotechnical investigations are necessary in the feasibility stage of a mega project? Briefly describe based on a case-study. **(10)**

   (b) Why SPT N-values are abnormally high in deposits containing boulders? How do you determine the electrical resistivity and thickness of various soil layers based on the empirical method of electrical resistivity survey? **(10)**

   (c) Derive the expression of factor if safety (Fs) for an infinite slope of a c-ϕ soil that makes an angle β with the horizontal (considering the case of seepage). Compare with the expression for the case of no seepage and explain the fundamental differences. **(15)**

2. (a) Show the correlation between $\sigma_{v'}$, q_c and φ for normally consolidated quartz sand (after Robertson and Campanella, 1983) in a neat sketch. Also, discuss why slope of the curves between $\sigma_{v'}$ and q_c varies with varying peak angle of internal friction, φ. **(10)**

   (b) State, with appropriate sketches, the operational process of a piston sampler. Explain-how a Piston Sampler provides good quality undisturbed sample compared to Shelby tube. **(10)**

   (c) Describe and critically analyze the variations in the methods of determining water table in high and low permeability soil. **(15)**

   In the course of subsurface investigation, an SPT N-value of 10 was recorded for a clay layer situated at a depth of 20 feet. Subsequently, an examination of the drilling equipment unveiled that the hammer employed by the drilling operator weighed 20 lb less than the standard weight. Is there any way to correct the measured SPT N-value? If so, give justification of the correction procedure and determine the corrected SPT N-value.

3. (a) What are the factors to be considered in deciding on a slope stability analysis procedure? Discuss the effect of pore water pressure on the stability of a slope. **(10)**

   (b) Show the variations of $\sigma_{v'}$, D_r, and q_c for normally consolidated quartz sand (based on Bali et al., 1982 and Robertson and Campanella, 1983) in a neat sketch. Also, discuss why the curves between $\sigma_{v'}$ and q_c varies with varying relative density, D_r. **(10)**

Contd P/2

CE 441

Contd ... Q. No. 3

(c) **Fig. 1** shows the cross-section of an earth slope in homogenous clay soil. The figure also shows an arbitrary failure surface, its center and five slices. Calculate the factor of safety, using Bishop's Simplified Method of Slices. Given, unit weight of soil = 17 kN/m^3 and q_u = 50 kPa. For homogeneous soil and Bishop's simplified method of slices, Factor of Safety (Fs) is given by: **(15)**

$$F_s = \frac{\sum_{n=1}^{n=p} \left(cb_n + W_n \tan\phi\right) \frac{1}{m_{\alpha(n)}}}{\sum_{n=1}^{n=p} W_n \sin\alpha_n}$$

where,

$$m_{\alpha(n)} = \cos\alpha_n + \frac{\tan\phi \,.\, \sin\alpha_n}{Fs}$$

4. (a) A pile group consisting of 15 piles **(3 by 5 matrix)** arranged into a pile-cap under a column supporting a total design vertical load of 1800 ton, with eccentricity e_x = 0.3 m (alone longer direction of pile-cap) and e_y = 0.4 m (along shorter direction). The piles are 0.45 m by 0.45 m in cross section, 18 m long, spaced 1.0 m center-to-center and driven using a Hydraulic Static Pile Driver. Determine the maximum compressional and uplift (if there be any) load on an individual pile. Based on subsoil conditions at site, the allowable load carrying capacity of a single pile (as above) is 150 ton in compression and 15 ton in tension (including self-weight of pile). Comment on the adequacy of the foundation system and suggest possible countermeasures, if necessary. **(20)**

(b) 6 m by 6 m footing in x-y plane is subjected to eccentric load with two way eccentricity (Given: e_x = 0.50 m and e_y = 0.8 m). The footing is founded at a depth 2.5 m below the ground surface. The soil properties are: c = 0, N_{cor} = 21 and γ = 19 kN/m^3. The subsoil is medium dense sand. The relevant N_q and N_γ (of Hansen) are: 33 and 34, respectively. By using Hansen's shape and depth factors, determine the ultimate load in kN that the footing can carry. **(15)**

Hansen's factors are:

$$s_c = 1 + \left(N_q / N_c\right)\left(B/L\right); \quad d_c = 1 + 0.4\frac{D_f}{B}$$

$$s_q = 1 + \left(B/L\right)\tan\phi; \quad d_q = 1 + 2\tan\phi\left(1 - \sin\phi\right)^2 \frac{D_f}{B}$$

$$s_\gamma = 1 - 0.4\left(B/L\right); \quad d_\gamma = 1 \text{ for all } \phi$$

Contd P/3

CE 441

SECTION – B

There are **FOUR** questions in this section. Answer any **THREE**.

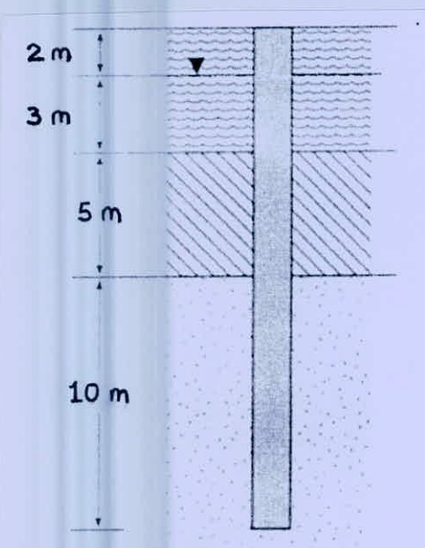
Assume any reasonable value of missing data.

5. (a) State and merits and demerits of various methods (MLT, QML and CRP tests) to conduct full-scale static load test on a pile according to ASTM D1143. Quote the major limitation of the 'Static Load test' and explain the necessity of using O-cell in such a test. **(15)**

(b) Static pile load test was carried out on a 400mm-by-400mm solid concrete pile (with γ_{con} = 4 ksi) installed 20 m into a loose-to-medium sandy soil. The pile was driven into the soil. Selected load displacement data are shown in the table below. (a) determine the allowable load if the serviceability limit is 12 mm. (b) Is the maximum load the ultimate load? Justify your answer. (c) estimate the structural capacity of the tested pile. **(20)**

Load (ton)	0	24	50	75	100	125	150	175	191	195	175
Displacement (mm)	0	0.3	0.85	1.21	1.85	2.72	3.93	5.67	13.54	24.7	24.1

6. (a) A square concrete pile 0.40 m diameter is driven to a depth of 20 m into a dense sand layer (extending from –10 m to –20 m depth and is continued to deep depth) with average SPT N-value (corrected for pressure) of 21 and γ_{sat} = 20 kN/m^3. The pile is driven through a granular fill soil for 10 m with possessing corrected SPT N-value of 12 after compaction (using vibratory roller) and γ_{sat} = 19 kN/m^3. The equivalent ϕ'_{cs} is 2 degrees less than ϕ, which is estimated from Berenzashav's empirical equation (as a function of N_{cor}). Note that in the estimation the minimum possible design value of field ϕ'_{cs} (the angle of internal friction at critical state) would not be less than 28°. Find Q_a in kN with F_s = 2. Use TSA and/or ESA method of estimation whenever it applies. **(15)**



Layer 1: compacted fill sand;
N_{cor} = 12, γ = 19.0 kN/m^3;

Layer 2: medium sand;
N_{cor} = 12, γ = 19.0 kN/m^3;

Layer 3: Dense Sand;
N_{cor} = 21, γ = 20.0 kN/m^3;

Fig. for Ques. No. 6(a)

Contd P/4

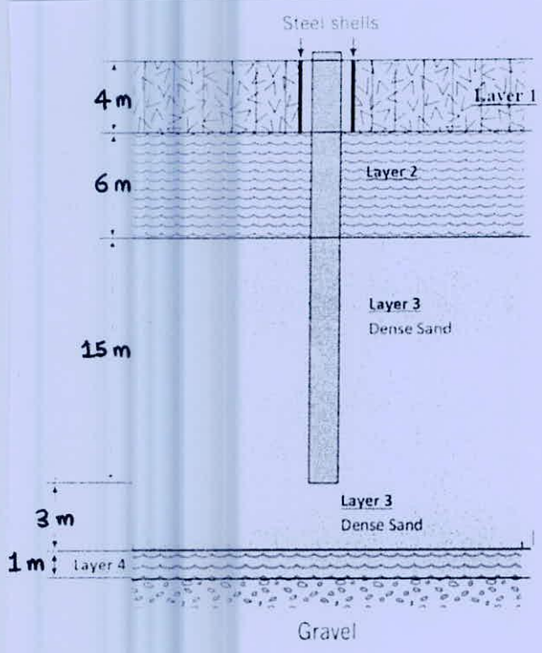
CE 441

Contd ... Q. No. 6

(b) Using the outcome above for a driven pile, estimate an equivalent Q_a for a similar sized bored pile under otherwise similar conditions. **(3+12+5)**

Further, use the data of **Q. 6(a)** to estimate Q_a of a 'drilled shaft' with the same pile length and diameter. Consider both 'find grained soil' and 'clean sand' options separately to estimate the relevant Q_f. Assume that the corrected SPT N (N_{cor}) is equivalent to N_{60}. Comment on the relevance of using various outcome for a bored pile/drilled shaft.

7. (a) A 3 × 4 concrete pile group with a pile spacing of 1.10 m center-to-center, pile diameter of 0.5 m and 25 m long supports a load of 15.0 MN. Consider the soil profile stated below with a single pile installed as having a 'steel shell' in the upper layer. Note that the use of 'steel shell' is to make the upper loose soil separated from the pile itself. (a) Determine the factor of safety for the pile group (Use: $N_q = 0.6e^{0.126\phi'_{cs}}$). The piles were driven. **(25)**



Layer 1: Recent fill;
ϕ'_{cs} = 30°, γ = 18.0 kN/m³, E'_{so} = 22 MPa;

Layer 2: **Medium, NC clay**;
s_u = 50 kPa, ϕ'_{cs} = 25°, γ_{sat} = 20.0 kN/m³;
E'_{so} = 25 MPa;

Layer 3: Dense Sand;
ϕ'_p = 38°, ϕ'_{cs} = 31°, γ_{sat} = 18.0 kN/m³;
E'_{so} = 30 MPa, and E_p = 30,000 MPa

Layer 4: Soft Cay;
m_v = 3.5 x 10⁻⁴ m²/kPa, γ_{sat} = 19.0 kN/m³;

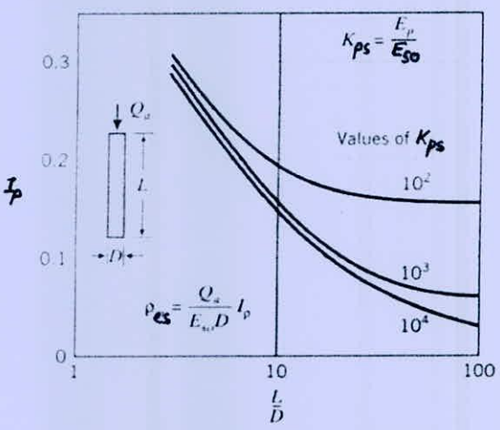


Figure for Ques. No. 7(a)

CE 441

Contd ... Q. No. 7

(b) Estimate the elastic settlement/shortening of the group pile system mentioned in **Q. 7(a)** based on either the respective (i) allowable load **or** (ii) design load. Given E_p = 30,000 MPa. Assume that elastic modulus (E_{SO}) of various soil layers is constant with the depth and neglect the elastic settlement of a pile due to end bearing. Given:

$$\rho_{es} = \frac{Q_{af}}{E_{SO} x L} I \; ; \; I = 0.5 + \log\left(L/D\right); \; \rho_{es} = \frac{Q_{af}}{E_{SO} x D} I_p \; ; \; \rho_p = C \frac{Q_{af}}{E_p x A_p} L \, . \qquad \textbf{(10)}$$

8. (a) What is down-drag? Why does if occur? **(5+15+5)**

Estimate down-drag of an individual pile in the group in **Q. 7(a)**, under otherwise similar conditions, except (i) no 'Steel shell' is driven in Layer 1, and hence, the surrounding soil in Layer 1 is in direct contact with the piles, and (ii) Layer 2 is replaced with a deposit of very soft, normally consolidated clay having s_u = 20 kPa, ϕ'_{cs} = 26°, γ_{sat} = 19.0 kN/m^3. What is the allowable capacity of a single pile? Given: the factor of safety is 1.5 (against friction) and 2.5 (against end bearing), and γ_{con} = 25 kN/m^3.

(b) Estimate the uplift capacity of a single pile based on the soil profile and outcome of **Q. 8(a)**. **(10)**

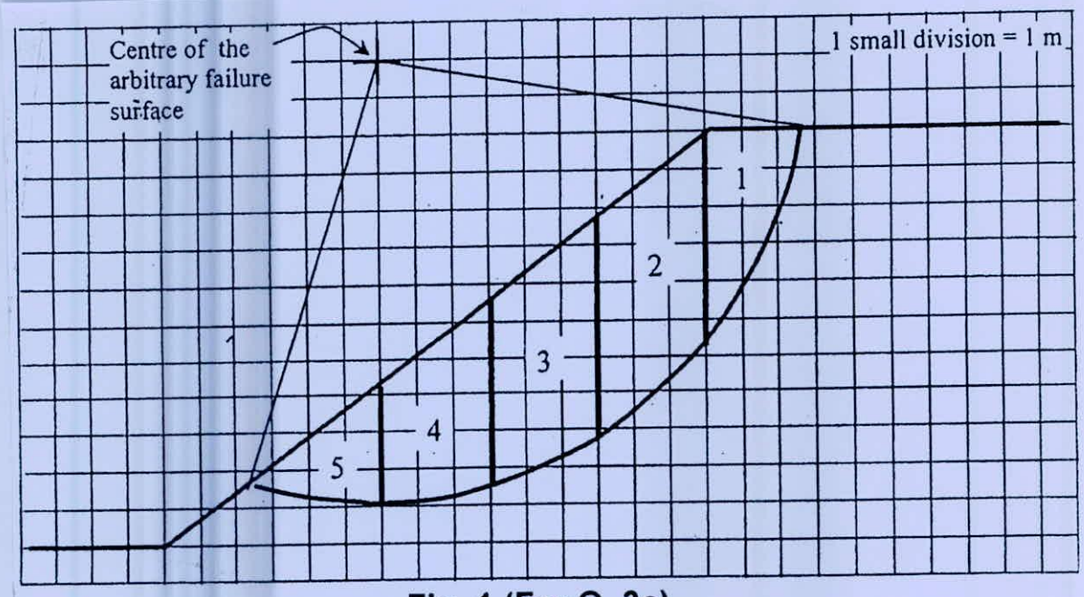

Centre of the arbitrary failure surface
1 small division = 1 m
1
2
3
4
5

Fig. 1 (For Q. 3c)

L-4/T-1/CE **Date: 30/10/2023**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-4/T-1 B. Sc. Engineering Examinations 2021-2022

Sub: **CE 451** (Transportation Engineering II: Pavement Design and Railway Engineering)

Full Marks: 280 Time: 3 Hours

The figures in the margin indicate full marks

USE SEPARATE SCRIPTS FOR EACH SECTION

SECTION – A

There are **FOUR** questions in this section. Answer any **THREE**.

1. (a) Show with a neat sketch different components of Permanent Way and how the gauge is measured. **(12)**

(b) State the functions of rails. Also, discus the advantages of flat-footed rails. **(16)**

(c) Compute the steepest gradient that a train of 20 wagons with a locomotive can travel with the following data: **(18⅔)**

(i)	Weight of each wagon	...	20 tonnes
(ii)	Weight of Locomotive	...	150 tonnes
(iii)	Tractive effort of Locomotive	...	15 tonnes
(iv)	Rolling resistance of Locomotive	...	3 kg/tonne
(v)	Rolling resistance of wagon	...	2.5 kg/tonne
(vi)	Speed of the train	...	60 kmph.

2. (a) Classify the properties of Asphalt materials. Discuss the properties of HFMS-2h and CSS-1h type Asphalt binder. Also, differentiate medium and rapid-curing Cutback Asphalts. **(16⅔)**

(b) Mention the RHD specifications for coarse and mineral filler for bituminous mix suitable for roads in Bangladesh. **(10)**

(c) Discuss the importance of particle shape and surface texture of coarse aggregates used in flexible and rigid pavement construction. "It is important to recognize that some aggregates appear to have a greater affinity for water than for asphalt cement"— explain. Combine the following aggregate samples to meet the specification. **(20)**

Passing Sieve	Retained Sieve	% by Weight			Specific Limit
3/4"	1/2"	5	—	—	0-5
1/2"	3/8"	35	—	—	8-40
3/8"	# 4	40	—	—	10-50
# 4	# 10	15	8	—	6-25
# 10	# 40	5	30	—	5-20
# 40	# 80	—	35	5	10-30
# 80	# 200	—	26	35	5-8
# 200		—	1	60	2-6

Contd P/2

CE 451/CE

3. (a) Write the objectives of asphaltic concrete mix design. Briefly state the main differences between Marshal and HVEEM method of mix design with regard to (i) compaction of specimens, (ii) design criteria, and (iii) tests of specimens. **(16⅔)**

(b) Show the qualitative shape of Marshal Property curves. "It is important that the compaction effort used to simulate the design traffic expected in the pavement be selected accordingly in the laboratory"— Explain. **(15)**

(c) How to find CKE and surface capacity in the Hveem method of mix design? An asphaltic concrete sample cut from a completed pavement weighs 3540 gm in air and 1962 gm in water. The laboratory compacted specimen of the same mix has a bulk specific gravity G_{mb} of 2.384 and voids of 5.5 percent. Find the % air voids in the field sample. Is the mix satisfactory? **(15)**

4. (a) Write down the panel size considerations to reduce the risk of cracking in odd-shaped panels of curved areas. Draw stress distribution patterns over time. Differentiate flexible and rigid pavements w.r.t Load Distribution Mechanism and Aggregate Type. Briefly state the significance of PMB use in Bangladesh. **(16)**

(b) Why are joints used in rigid pavement? State the different types of joints. Provide short explanations for repair techniques: Fog-seal, Slurry seal, and Micro-seal. **(12)**

(c) Why structural design of pavement is a complex one? **(18⅔)**

Design a flexible pavement by AASHTO method for the data given below. Give one trial and put your comments for next trial thickness (if any). Solution could be given in the worksheet provided at the end of question paper.

Given:

Assumed Structural Number, SN = 6.0

Estimated Design ESAL, W_{18} = 35 million ESAL

Consider:

Design period = 20 years

Initial Serviceability, P_O = 4.5

Terminal Serviceability, Pt = 2.5

Reliability, R = 0.950

Overall std. dev., S_O = 0.350

Z_R = –1.645

Pavement Layer	Material Used	Resilient Modulus M_R (psi)		Layer Coefficients	Drainage Coefficients	
Surface Course (AC)	Asphalt Concrete	E_{AC} =	400,000	$a_1 = 0.169*[LN(E_{AC}) - 1.764$	m_1 =	1.0
Base Course (BS)	Granular	E_{BS} =	30,000	$a_2 = 0.249*LOG_{10}(E_{BS}) - 0.977$	m_2 =	1.3
Subbase Course (SB)	Granular	E_{SB} =	11,000	$a_3 = 0.227*LOG_{10}(E_{SB}) - 0.839$	m_3 =	1.3
Roadbed Course (RB)	Compacted soil	E_{RB} =	5,700			

Contd P/3

CE 451/CE

SECTION – B

There are **FOUR** questions in this section. Answer any **THREE** questions.

5. (a) 'Low cost pavement surface construction can be a strategy for phased pavement construction'— Explain. What should be the changed strategies for low volume earth and paved road construction for optimized cost and performance. Compare the bonding mechanisms and construction sequences for Penetration Macadam and Dense Bituminous Surface Treatment (DBST). Explain general crack scheme for flexible pavement. **(8+6+9=23)**

(b) Make a comparison among Geo-cell paving, non-reinforced concrete paving and jointed reinforced concrete paving features and relevant construction processes. Also, compare between Herring Bone Bond Brick (HBB) type and Cement Treated Layer type paving as low cost road surface option in Bangladesh condition. Discuss the features, reason and remedies for Alligator and shrinkage cracking type distresses in asphalt pavement. **(12+6+5⅔=23⅔)**

6. (a) Make a list of at least 10 (Ten) equipment required to be mobilized for a road and bridge construction process noting down the use of each equipment. What is rehabilitation of a flexible pavement? Discuss the steps involved in the rehabilitation process of a flexible pavement. **(5+5+3+10=23)**

(b) What are the uniformity tests for cement concrete paving and why uniformity testing is done? Discuss various methods of texturing the cement concrete pavement surface. Also, write down the important considerations for dowel bar installation in jointed cement concrete pavement. **(8+8+7⅔=23⅔)**

7. (a) Write short notes on: **(23⅔)**

   (i) Asphalt pavement recycling
   (ii) Wheel track Paving
   (iii) Utility lines cracks and asphalt pavement
   (iv) Prime coat and Tack coat
   (v) Perpetual Pavement and
   (vi) AASHO Road Test.

(b) Draw typical sections for flexible and rigid pavements and also show their load distribution mechanisms. **(8)**

(c) Briefly differentiate between: **(15)**

   (i) Flexible and Rigid pavements
   (ii) Jointed Plain Concrete Pavement (JPCP) & Continuously reinforced concrete pavement (CRCP)
   (iii) Tie bar and Dowel bar
   (iv) Contraction and Construction Joints

Contd P/4

(v) Shoving and Ravelling type distress in flexible pavement

8. (a) Explain deficiency in super-elevation of railways. **(10)**

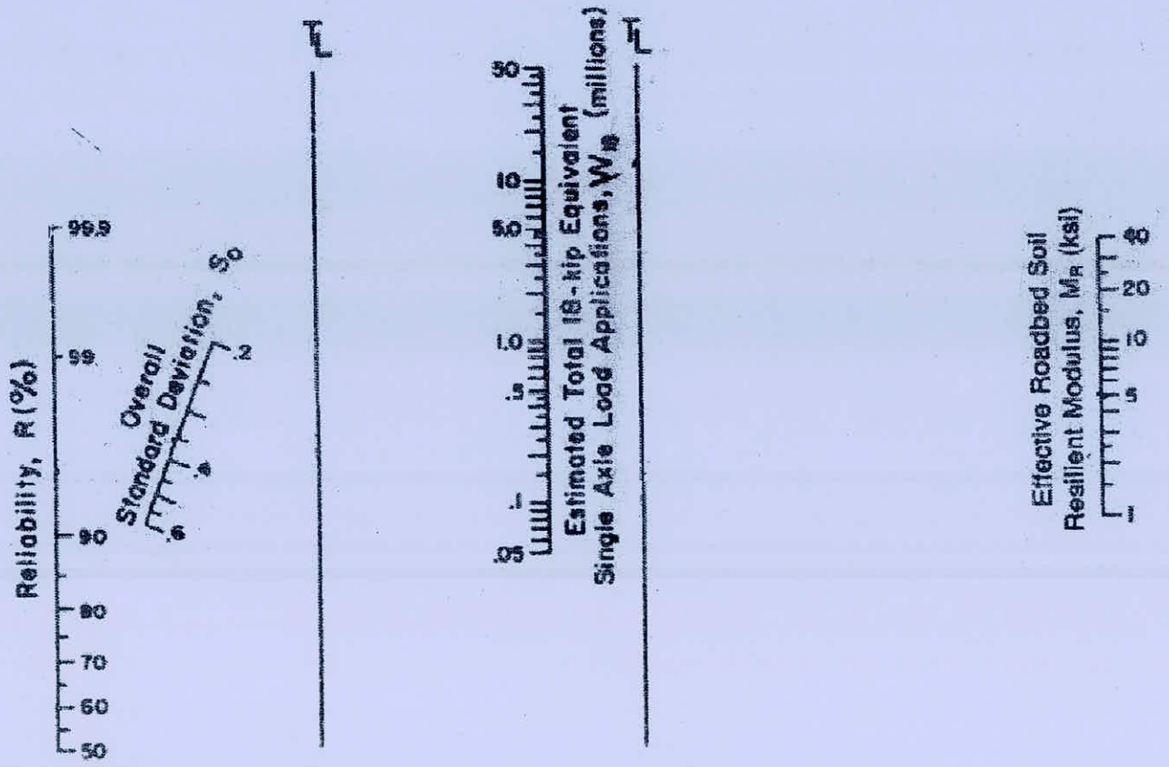
(b) Explain with neat sketches the layout of signals according to location at diverging and converging rail junctions. **(16⅔)**

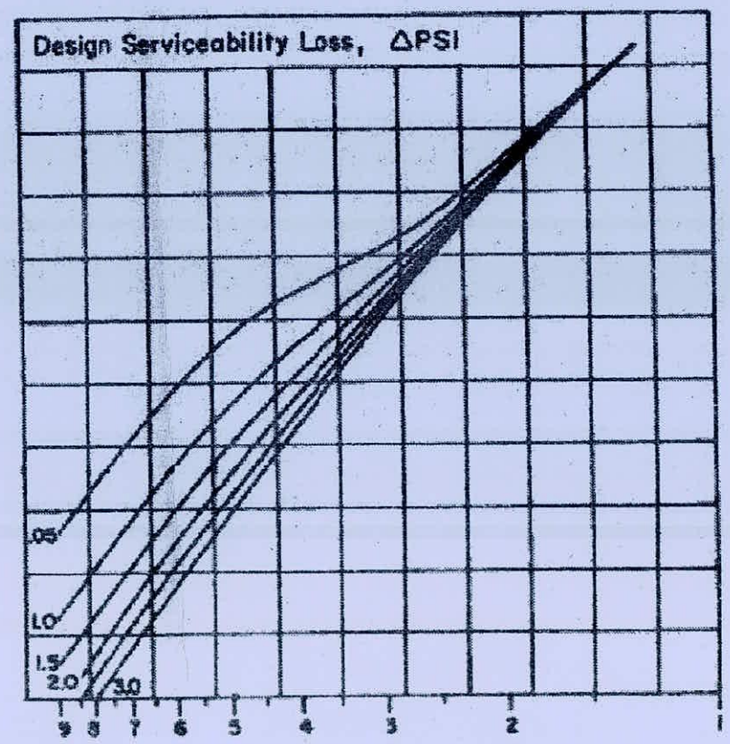
(c) Determine the maximum permissible train load that can be pulled by a locomotive having four pairs of driving wheels having an axle load of 28.42 tonnes each on a BG track with a ruling gradient of 1 in 200 and maximum curvature of 3 degrees at a speed of 48.3 Kmph. Take coefficient of friction as 0.2. **(20)**

AASHTO Design Nomograph for Flexible Pavement

NOMOGRAPH SOLVES:

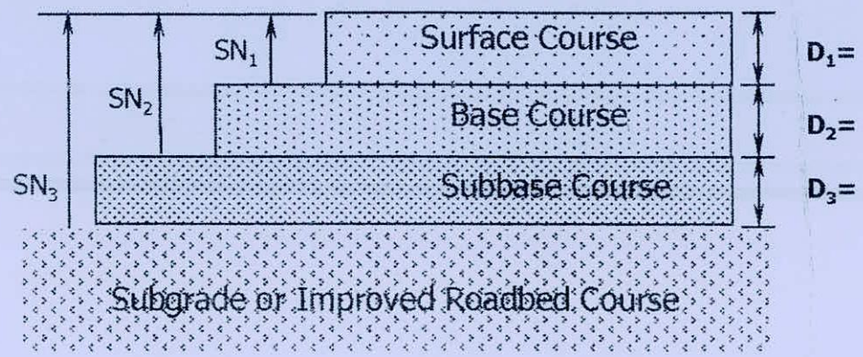
$$\log_{10} W_{18} = Z_R * S_o + 9.36 * \log_{10}(SN+1) - 0.20 + \frac{\log_{10}\left[\frac{\Delta PSI}{4.2 - 1.5}\right]}{0.40 + \frac{1094}{(SN+1)^{5.19}}} + 2.32 * \log_{10} M_R - 8.07$$





AASHTO Worksheet For Flexible Pavement Design

Pavement Layer	Material Used	Resilient Modulus M_R (psi)		Layer Coefficients		Drainage Coefficient		Required SN above the layer	Calculations For Layer Thicknessed	Thickness D (inch)
Surface Course	Asphalt Concrete	E_{AC} =	400,000	$a_1 = 0.169*LN(E_{AC}) - 1.764$ =		m_1 =	1.0			
Base Course	Granular	E_{BS} =	30,000	$a_2 = 0.249*LOG_{10}(E_{BS}) - 0.977$ =		m_2 =	1.3			
Subbase Course	Granular	E_{SB} =	11,000	$a_3 = 0.227*LOG_{10}(E_{SB}) - 0.839$ =		m_3 =	1.3			
Roadbed Course	Compacted soil	E_{RB} =	5,700							
Check for SN3 = a1m1D1 + a2m2D2 + a3m3D3 =										



For Q 4(c)

L-4/T-1/CE Date : 19/10/2023

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-4/T-1 B. Sc. Engineering Examinations 2021-2022

Sub : **WRE 451** (Hydrology, Irrigation and Flood Management)

Full Marks : 210 Time : 3 Hours

The figures in the margin indicate full marks.

USE SEPARATE SCRIPTS FOR EACH SECTION

SECTION – A

There are **FOUR** questions in this section. Answer any **THREE**.

Assume any reasonable value if missing.

1. (a) Bangladesh Agricultural Development Corporation (BADC) is supposed to implement an irrigation project in any area of Bangladesh. The size of the irrigation project is about 700 ha, in which several components are required to be designed. During the project planning, detailed EIA was performed, which identified that the irrigation water could pose an adverse effect (salt accumulation) in the ground. It is required to be addressed those issues during the operational stage of the project. As such the leaching fraction has been found as 6.5% for the field. Now, you have been assigned to design a non-silting and non-scouring regime main channel for the project area. Given that the main channel supplies water to four irrigation fields connected through distributaries with the main channel, which conveys 8.2, 9.0, 10.1, and 9.8 m^3/s of water, respectively. The length of these distributaries are 200 m, 300 m, 250 m, and 400 m, respectively. Based on soil data, it has been identified that the seepage/percolation loss of the distributaries are 0.0065 m^2/s per unit length of the distributary channels. The conveyance efficiency of the main channel is 80%. Calculate the non-silting and non-scouring design parameters of the main channel following appropriate method and report the results to nearest three digits. The soil type of the main channel is silt-clay loam (median grain size is 0.45 mm). Assume any other reasonable value if missing. **(28)**

   (b) In irrigation canals, seepage losses are dependent on several factors. From your irrigation engineering knowledge, describe which type of seepage loss is more in irrigation canal, and why? **(7)**

2. (a) Why the Water Policy 1999 is significantly different from the Bangladesh Water Rules 2018? Do you see any significant paradigm shift in those two policy and rules? Justify. **(8)**

   (b) Pouring water on fields is still a common irrigation method today. What could be the possible reasons in the context of Bangladesh? **(6)**

   (c) Proper irrigation scheduling also affects the irrigation requirements of different crops. Justify this statement. **(6)**

Contd P/2

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Contd ... Q. No. 2

(d) From a stream, 150 *l*/s was diverted to an irrigation canal and 120 *l*/s was delivered to an irrigation field (2.2 ha), which is 200 m long and being irrigated for 7.5 hours. The effective root zone depth was 1.8 m. The runoff loss in the field was 490 m^3. The depth of water penetration varied linearly (slope of which is 0.3%) from 1.8 m at the head to the tail end of the field. Available moisture holding capacity of the soil is 22 cm/m depth of soil. Calculate: (i) conveyance efficiency, (ii) application efficiency, (iii) storage efficiency, and (iv) distribution efficiency. Assume, irrigation was started at a moisture content when the moisture level goes to 55% of the available moisture. **(15)**

3. (a) Irrigation water is being delivered to a field (which area is 2 ha) through a distributary channel. Compute the consumptive use and other irrigation requirements if application and conveyance efficiencies are 85% and 80%, respectively for the given crop data. Also given that the maximum water that can be supplied at the head of the distributary channel is 7.0 *l*/s. What will be the volume of water required for the irrigation field? Do you think the channel has adequate flow for the whole period? **(15)**

Dates and growth Period	Pan evaporation, Ep in cm	Consumptive use coefficient (K)	Effective precipitation (cm)
Oct 16-31	8.49	0.44	3.42
Nov 1-30	15.57	0.54	2.19
Dec 1-31	16.59	0.94	0.54
Jan 1-31	19.10	0.99	0.15
Feb 1-2	1.54	0.73	0.02

(b) Suppose you are producing rice and wheat in an area of Bangladesh during the Rabi season. Can you develop an efficient furrow irrigation system for those crops? Why or why not? **(7)**

(c) In an agricultural field, how soil texture, root zone depths and atmospheric pressure impact saturation, field capacity and permanent wilting point. Discuss. **(8)**

(d) In Dhaka City, after a heavy rainfall event, several roads and residential areas go under water. Given the nature of inundation type, will you classify this as urban flooding? Why or why not? **(5)**

4. (a) What are some widely used non-structural measures for flood management? Which non-structural measures for flood management could be useful for Bangladesh, why? **(8)**

(b) How salinity and toxicity in irrigation water impact the irrigation scheduling? What are the common salinity measuring parameters the agricultural engineer generally consider for selecting a source for irrigation water? **(7)**

Contd P/3

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Contd ... Q. No. 4

(c) Calculate the required diameter and drainage coefficient of a subsurface drain for an agricultural field (hydraulic conductivity of soil is 2.65 cm/hr) if water table is 0.5 m below the ground surface and the position of retarding layer below the ground is at 5.5 m. Also, given that the slope of drain is 0.25 m/100 m, drain spacing is 50 m, roughness coefficient is 0.015 and length of the irrigation field is 250 m. Assume that the drain pipe will be buried at 2.25 m below the ground surface. **(10)**

(d) How different impurities in irrigation water can impact the consumer health? **(5)**

(e) What is hydroponic irrigation system? How the system is developed? **(5)**

SECTION – B

There are **FOUR** questions in this section. Answer any **THREE**.

5. (a) Describe in brief the effects of snowmelt in the hydrologic cycle of Bangladesh. **(5)**

(b) The ordinates of a 4-h unit hydrograph (UH) are given below. Compute the ordinates of a 6-h unit hydrograph. **(15)**

Time (h)	0	2	4	6	8	10	12	14	16	18	20
Ordinates of 4-h UH (m^3/s)	0	30	70	100	85	60	50	30	25	10	0

(c) The average rainfall values over a catchment in three successive 4-h, 6-h and 4-h intervals are known to be 3, 5.5 and 4 cm, respectively. The ϕ-index for the catchment is estimated to be 0.25 cm/h. At the beginning the base flow is 5 m^3/s and it increases by 2 m^3/s every 12-h. Estimate the ordinates of the resulting flood hydrograph. Use the 4-h and 6-h unit hydrograph ordinates from Q. No. 5(b). **(15)**

6. (a) Give a qualitative compression of infiltration capacity for forest soil and urban soil. **(5)**

(b) The parameters in Horton's Infiltration Capacity Equation are given as, f_{co} = 7.62 cm/h, f_{cf} = 1.34 cm/h and k_h = –4.182/h. Compute the infiltration capacity (f_{ct}) and cumulation infiltration at the end of 2h. Given, the cumulative infiltration at the end of $t(h) = \int_0^t f_{ct}\, dt$. The notations have their usual meaning. **(15)**

(c) The area of interest is a hexagon with six corners at (4, 0), (0, 3), (0, 7), (4, 11), (8, 7) and (8, 3). The coordinates of rain gage locations and recorded rainfall after a storm event are given below: **(15)**

Contd P/4

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Contd ... Q. No. 6(c)

Rain gage location	Rainfall (mm)
(4, 13)	8
(3, 8)	15
(6, 8)	17
(4, 5)	25
(4, 2)	35
(4, –2)	45

All coordinate are expressed in kilometers. Compute the average rainfall in the area by Isohyetal Method. Consider Isohyets of 10, 20 and 30 mm. Use plain graph paper.

7. (a) Differentiate between perennial and intermittent streams with appropriate figures. **(5)**

(b) The ordinates of a storm hydrograph of a river draining a catchment area of 790 km^2 due to a 6-h rainfall are given below. Derive the ordinates of a 6-h unit hydrograph. Further compute the 12-h unit hydrograph using the method of superposition. **(15)**

Time (h)	0	6	12	18	24	30	36	42	48
Discharge (m^3/s)	20	80	200	300	150	100	80	40	40

(c) At a climatic station, air pressure, air temperature and relative humidity are 100 kPa, 25°C and 70%, respectively. Calculate the corresponding vapor pressure, specific humidity, air density and dew-point temperature. **(15)**

8. (a) Explain in brief the use of Plotting Position formula in time series analysis. **(5)**

(b) The design precipitation intensity is 2.5 in/h for a storm with a T-year return period for a slope of 0.007 and maximum length of travel of water of 1500 m. Estimate the design return period (T). In addition, estimate the design precipitation volume (m^3) and design peak discharge (m^3/s) using rational method. The area of the catchment is 3 km^2 and runoff coefficient is 0.7. Use IDF curves (Fig. 1) and Kirpich formula for your estimation. **(15)**

(c) The annual maximum recorded floods in a river for the period 2005 to 2018 are given below. Check whether the Gumbel Distribution fit the data or not. Given, $\bar{y}_n = 0.51$ and $s_n = 1.0095$ for N = 14. The notations have their usual meaning. **(15)**

Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Maximum Flood (m^3/s)	3800	2900	4800	3900	3350	6650	5400	4250	3760	4160	8890	3980	4200	5700

Extra Equations if Required

(5)

1. $\Delta = \frac{8.64\,B}{D}$
2. $\eta_d = \left(1 - \frac{d}{D}\right)$
3. $CIR = C_u - R_e$
4. $C_u = \frac{k.p}{40}[1.8t + 32]$
5. $E_p = 0.459.\ R.C_t.C_w.C_h.C_s.C_e$
6. $E_t = \frac{A.H_n + E_a\gamma}{A+\gamma}$
7. $V = \left[\frac{Qf^2}{140}\right]^{1/6}$
8. $D_{iw} = D_c + D_d$
17. $S = \frac{f^{5/3}}{3340Q^{1/6}}$
18. $SAR = \frac{Na^+}{\sqrt{\frac{Ca^{2+}+Mg^{2+}}{2}}}$
19. $SP = \frac{Na^+}{Na^+ + Ca^{++} + Mg^{++} + K^+} \times 100$
20. $LR = {}^{D_d}/_{D_{iw}} = {}^{EC_{iw}}/_{EC_d}$
21. $D_{iw} = [EC_d/(EC_d - EC_{iw})] \times D_c$
22. $C_e = 0.97 + 0.00984\,E$
23. $q_d = \frac{2\pi K m_0 D}{L};\ D_c = \frac{q_d}{L}$
24. $ID = 51.7(D_c \times A \times n)^{0.375} S^{-0.1875}$

9. $C_t = 0.393 + 0.02796\,T_c + 0.0001189T_c^2$
10. $C_w = 0.708 + 0.0034W - 0.0000038W^2$
11. $C_h = 1.250 - 0.0087H + 0.75 \times 10^4 H^2 - 0.85 \times 10^{-8} H^4$
12. $C_s = 0.542 + 0.008S - 0.78 \times 10^{-4} S^2 + 0.62 \times 10^{-6} S^3$
13. $H_n = H_c(1-r)\left(a + b\frac{n}{N}\right) - \sigma T_a^4\left(0.56 - 0.092\sqrt{e_a}\right) \times \left(0.10 + 0.90\frac{n}{N}\right)$
14. $q_{min} = (5.95 \times 10^{-6}) \times \frac{L \times S_0^{0.5}}{n}$

$$q_d = \frac{2\pi K m_0 D}{86,400L}$$

15. $q_{apl} = CU_q \frac{L^{1.0562} \times n^{0.1094} \times k^{1.225} \times a^{3.832}}{S^{0.09} \times D_{req}^{0.823}}$
16. $T_{apl} = CU_T \frac{L^{1.1} \times n^{0.0093} \times S_0^{0.0203} \times k^{0.387} \times D_{req}^{0.952}}{q_{apl}^{1.0885} \times a^{0.75}}$

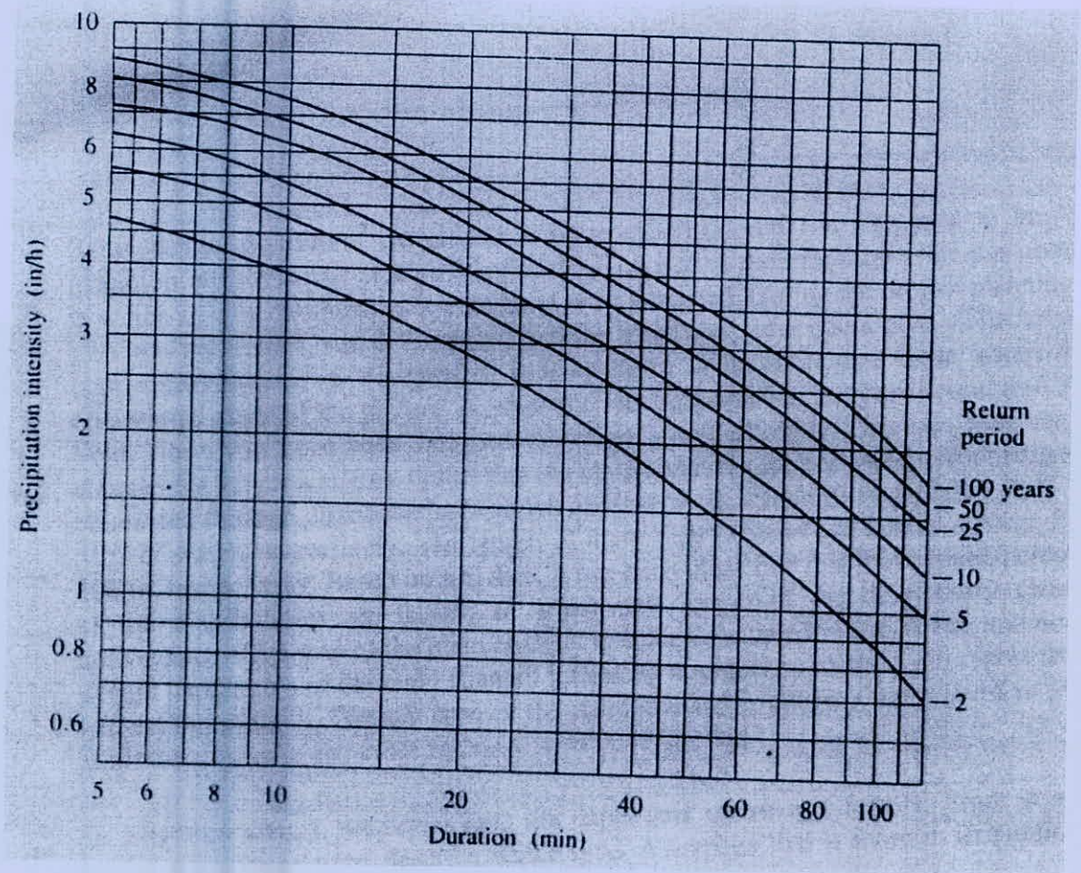

Fig. 1 : Intensity - Duration - Frequency (IDF) Curves for Q. No. 8(b)