ROYAL CIVIL SERVICE COMMISSION
BHUTAN CIVIL SERVICE EXAMINATION (BCSE) 2020
EXAMINATION CATEGORY: TECHNICAL

PAPER III: SUBJECT SPECIALISATION PAPER FOR CIVIL ENGINEERING

Date	: February 27, 2021
Total Marks	: 100
Writing Time	: 150 minutes (2.5 hours)
Reading Time	: 15 minutes (prior to writing time)

GENERAL INSTRUCTIONS:

1. Write your Registration Number clearly and correctly on the Answer Booklet.
2. The first 15 minutes is provided to check the number of pages of the Question Paper, printing errors, clarify doubts and to read the instructions. You are NOT permitted to write during this time.
3. This paper consists of **TWO SECTIONS**, namely SECTION A & SECTION B:
   - **SECTION A** has two parts: Part I - 30 Multiple Choice Questions
     Part II - 4 Short Answer Questions

     All questions under SECTION A are COMPULSORY.
   - **SECTION B** consists of two Case Studies. Choose only **ONE** case study and answer the questions of your choice.
4. All answers should be written on the Answer Booklet provided to you. Candidates are not allowed to write anything on the question paper. If required, ask for additional Answer Booklet.
5. All answers should be written with correct numbering of Section, Part and Question Number in the Answer Booklet provided to you. Note that any answer written without indicating the Section, Part and Question Number will NOT be evaluated and no marks will be awarded.
6. Begin each Section and Part on a fresh page of the Answer Booklet.
7. You are not permitted to tear off any sheet(s) of the Answer Booklet as well as the Question Paper.
8. Use of any other paper including paper for rough work is not permitted.
9. **You must hand over the Answer Booklet to the Invigilator before leaving the examination hall.**
10. This paper has **24 printed pages**, including this instruction page.

GOOD LUCK!

SECTION A

PART I: Multiple Choice Questions [30 marks]

Choose the correct answer and write down the letter of your chosen answer in the Answer Booklet against the question number e.g. 31 (d). Each question carries ONE mark. Any double writing, smudgy answers or writing more than one choice shall not be evaluated.

1. Factor of safety against sliding of a slope is the ratio of
   a) actual cohesion to that required to maintain stability of slope.
   b) shear strength to shear stress along the surface.
   c) both (a) and (b)
   d) None of the above.

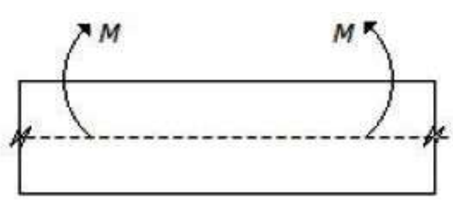
2. For a particular grade of concrete and with lowering the grade of steel, the $\rho_{t,lim}$
   a) increases.
   b) decreases.
   c) sometime increases and sometime decreases.
   d) remains constant.

3. The cross-section of a thermo-mechanically treated (TMT) reinforcing bars has
   a) soft ferrite-pearlite throughout.
   b) hard martensite throughout.
   c) a soft ferrite-pearlite core with hard martensite rim.
   d) a hard martensite core with a soft pearlite-bainitic rim.

4. Closed contours of decreasing values towards their centre represent
   a) a hill.
   b) a river bed.
   c) a saddle or pass.
   d) a depression.

5. The plinth area of a building does not include
   a) area of cantilevered porch.
   b) area of the walls at the floor level.
   c) area of stair cover.
   d) internal shaft for sanitary installations up to 2 sq m. in area.

6. The layer at the center of gravity of the beam as shown in the figure below will be
   a) in tension.
   b) in compression.
   c) neither in tension nor in compression.
   d) None of the above.

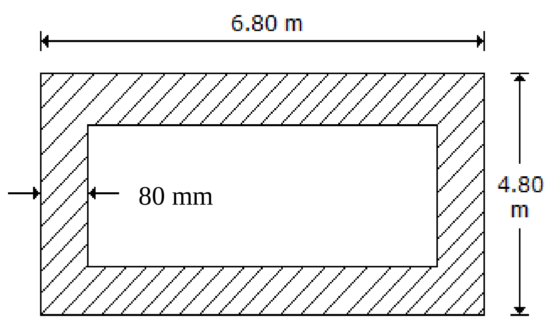


7. If you are given a sample of soil containing coarse grains to determine its water content, you will use
   a) Pycnometer.
   b) oven-drying method.
   c) calcium carbide method.
   d) alcohol method.

8. In a simply supported beam carrying a uniformly distributed load *w* per unit length, the point of contraflexure
   a) lies in the centre of the beam.
   b) does not exist.
   c) lies at the ends of the beam.
   d) depends upon the length of beam.

9. The total length of a valley formed by two gradients - 3% and + 2% curve between the two tangent points to provide a rate of change of centrifugal acceleration 0.6 m/sec2, for a design speed 100 kmph, is
   a) 16.0 m
   b) 42.3 m
   c) 84.6 m
   d) None of the above.

10. Referring to the given figure below, which one of the following statements is correct?



   a) The total length of centre line of four walls is 20 m
   b) Length of long wall out-to-out is 6.80 m
   c) Length of short walls in-to-in is 3.20 m
   d) All of the above

11. The rise of water table below the foundation influences the bearing capacity of soil mainly by reducing
   a) cohesion and effective angle of shearing resistance.
   b) cohesion and effective unit weight of soil.
   c) effective unit weight of soil and effective angle of shearing resistance.
   d) effective angle of shearing resistance.

12. Critical depth (h) of a channel is

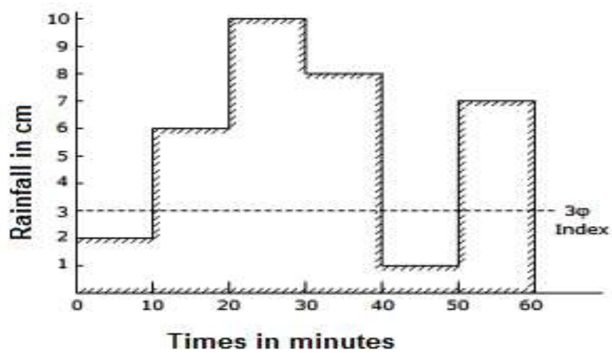
a) $h = \frac{v^2}{g}$

b) $h = \frac{v^2}{2g}$

c) $h = \frac{v}{2g}$

d) $h = \frac{v}{g}$

13. The rate of rainfall for successive 10 minute periods of a 60 minute duration storm, are shown in the figure below. If the value of φ_{index} is 3 cm/hour, the runoff will be



a) 2 cm
b) 3 cm
c) 4 cm
d) 5 cm

14. If there are **m** unknown member forces, **r** unknown reaction components and **j** number of joints, then the degree of static indeterminacy of a pin-jointed plane frame is given by

a) $m + r + 2j$
b) $m - r + 2j$
c) $m + r - 2j$
d) $m + r - 3j$

15. The main reason for providing number of reinforcing bars at a support in a simply supported beam is to resist

a) Compressive stress
b) Shear stress
c) Bond stress
d) Tensile stress

16. The stress-strain curve of the concrete as per IS: 456 is

a) a perfect straight line up to failure.
b) straight line up to 0.002 strain value and then parabolic up to failure.
c) linear up to 0.002 strain value and uniform up to failure.
d) parabolic up to 0.002 strain value and then uniform up to failure.

17. In a water treatment plant, dissolved iron manganese can be removed by
   a) aeration.
   b) aeration and coagulation.
   c) aeration and flocculation.
   d) aeration and sedimentation.

18. The exact equation for super-elevation is
   a) $\frac{V^2}{gR} = \frac{1+f.\tan(\theta)}{f-\tan(\theta)}$
   b) $\frac{V^2}{gR} = \frac{1-f.\tan(\theta)}{f+\tan(\theta)}$
   c) $\frac{V^2}{gR} = \frac{f+\tan(\theta)}{1-f.\tan(\theta)}$
   d) $\frac{V^2}{gR} = \frac{f-\tan(\theta)}{1+f.\tan(\theta)}$

19. The following measurements were made during testing a levelling instrument.

Instrument at A	Staff reading at	
	P_1	Q_1
P	2.800m	1.700m
Q	2.700m	1.800m

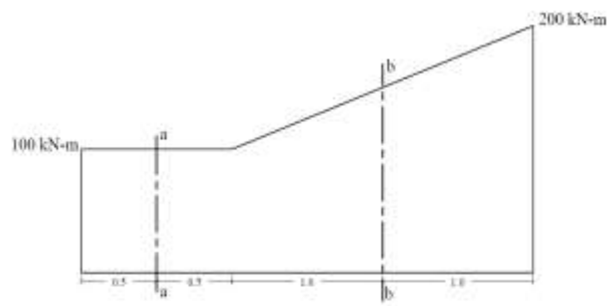
   P_1 is closed to P and Q_1 is closed to Q. If the reduced level of station P is 100.0000m, the reduced level of station Q is
   a) 101.000m
   b) 99.000m
   c) 100.000m
   d) 102.000m

20. In selecting a rolled I-section for a simply supported beam, along with minimum sectional modulus, a minimum value of span/depth ratio is also ensured. This is stipulated to ensure that
   a) the buckling of beam does not take place.
   b) the shear stress in beam remains within permissible limits.
   c) the deflection of beam remains within permissible limits.
   d) the bending stress in compression is within permissible limits.

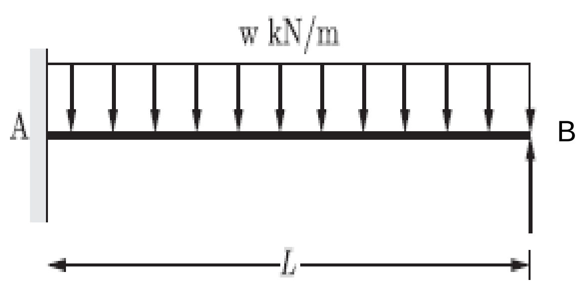
21. Two beams, one having square cross-section and other circular cross-section are subjected to the same amount of bending moment. If the cross-sectional area as well as the material of both the beams are same, then
    a) maximum bending stress developed in both the beams is the same.
    b) the square beam experiences more bending stress than the circular one.
    c) both the beams will experience the same deformation as the material is the same.
    d) the circular beam will experience more bending stress than the square one.

22. A pipe is replaced by two parallel pipes, each with the half the cross-sectional area of the original pipe. The discharge will
    a) remain the same.
    b) decrease by more than 10%.
    c) increase by more than 10%.
    d) change by less than 5%.

23. The bending moment diagram for a beam is given below. The shear force at sections aa and bb respectively are of the magnitude
    a) 100 kN, 150 kN
    b) zero, 100 kN
    c) zero, 50 kN
    d) 100 kN, 100 kN

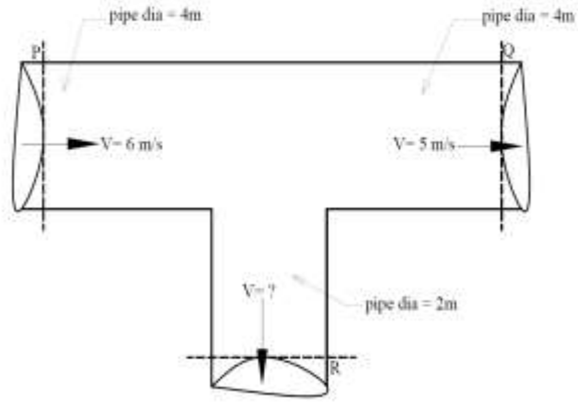


24. In the propped cantilever beam carrying a uniformly distributed load of w N/m, shown in the following figure, the reaction at the support B is
    a) $\frac{5}{8}\ wL$
    b) $\frac{3}{8}\ wL$
    c) $\frac{1}{2}\ wL$
    d) $\frac{3}{4}\ wL$



25. The circular water pipes shown in sketch are flowing full. The velocity of flow (in m/s) in the branch pipe "R" is

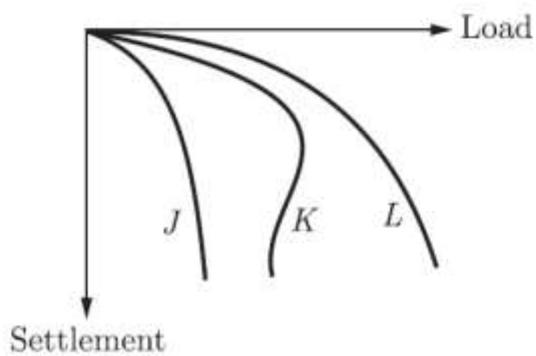
a) 4
b) 3
c) 5
d) 6



26. Group I contains representative load-settlement curves for different modes of bearing capacity failures of sandy soil. Group II enlists the various failure characteristics. Match the load-settlement curves with the corresponding failure characteristics

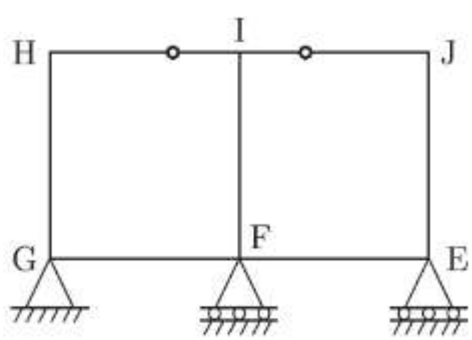
	Group I		Group II
P	Curve J	1	No apparent heaving of soil around the footing
Q	Curve K	2	Rankine's passive zone develops imperfectly
R	Curve L	3	Well defined slip surface extends to ground surface

a) P-1, Q-2, R-3
b) P-3, Q-2, R-1
c) P-3, Q-1, R-2
d) P-1, Q-3, R-2



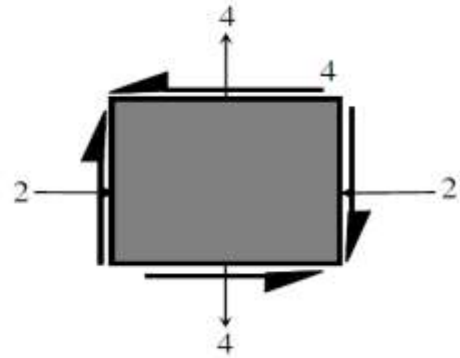
27. The degree of static indeterminacy of the rigid frame having two internal hinges as shown in the figure is

a) 8
b) 7
c) 5
d) 6

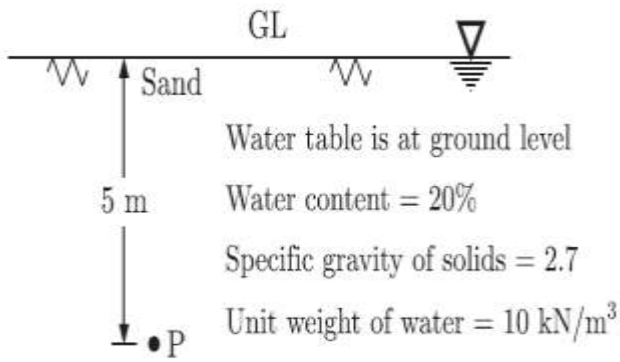


28. In the design of a reinforced concrete beam the requirement for the bond is not satisfied. The economical option to satisfy the requirement for the bond is
    a) bonding of bars.
    b) providing smaller diameter bars more in number.
    c) providing large diameter bars more in number.
    d) providing same diameter bars more in number.

29. For the state of stress (in Mpa) shown in the figure above, the maximum shear stress (in Mpa)
    a) 5
    b) 2
    c) 4
    d) 0



30. The ground conditions at a site are shown as given in figure below. The saturated unit weight of the sand (KN/m^3) is
    a) 15
    b) 18
    c) 21
    d) 24



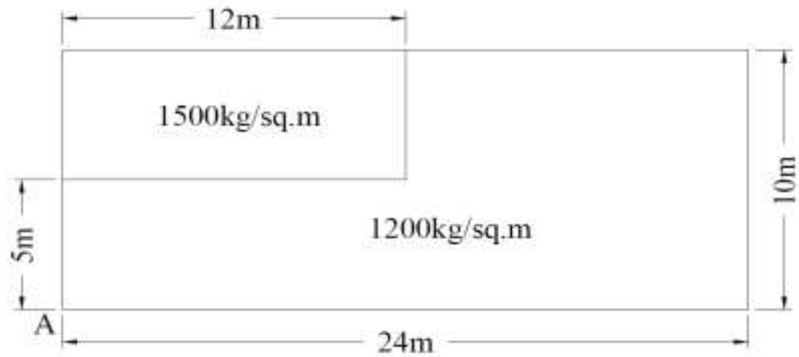
PART II – Short Answer Questions [20 marks]

This part has 4 Short Answer Questions. Answer ALL the questions. Each question carries 5 marks. Mark for each sub-question is indicated in the brackets.

1. A horizontal cantilever 2.5 meter long is of rectangular cross-section 50mm wide throughout its length, and depth varying uniformly from 50mm at the free end to 150mm at the fixed end. A load of 3kN acts at the free end.

   Find the position of the highest stressed section and the value of the maximum bending stress induced? Neglect the self weight of the cantilever beam. (5 marks)

2. A building having non-uniform distribution of mass is shown in the figure below. Locate the centre of mass with respect to the lower left corner of the building indicated by A? (5 marks)



3. The following data are available in connection of an embankment:

   Soil from borrow pit: Natural density = 17.5 Mg/m^3, Natural water content = 12%

   Soil after compaction: density = 2 Mg/m^3, water content = 18%

   For every 100m^3 of compacted soil of the embankment, estimate:

   i. The quantity of soil to be excavated from the borrow pit. (2.5 marks)

   ii. The amount of water to be added. (2.5 marks)

   Note: 1 g/cm^3 = 1000kg/m^3 = 10^3x10^3 g/m^3 where Mg stands for Megagram = 10^6g

4. It is proposed to widen a stretch of a single lane road of length 30km to two lanes at a total cost of Nu 5 million per km and the rate of interest is 8% per year. The annual cost of maintenance of the existing single lane road is Nu 500,000 per km and that of the improved road would be Nu 700,000 per km. The average vehicle operation cost on the existing road is Nu 3.0 per vehicle per km and that on the improved is estimated to be Nu 1.75 per vehicle per km. If present traffic is 2500 motor vehicles per day and by the end of 15 years design period the traffic is estimated to be doubled, determine whether the investment on the improvement of the road is economically viable, during the 15 years period. (5 marks)

   Capital Recovery Factor, $\mathbf{CRF} = \frac{i(1+i)^n}{(1+i)^n - 1}$

SECTION B: CASE STUDY [50 marks]

Choose either CASE I or CASE II from this section. Each case study carries 50 marks. Mark for each sub-question is indicated in the brackets.

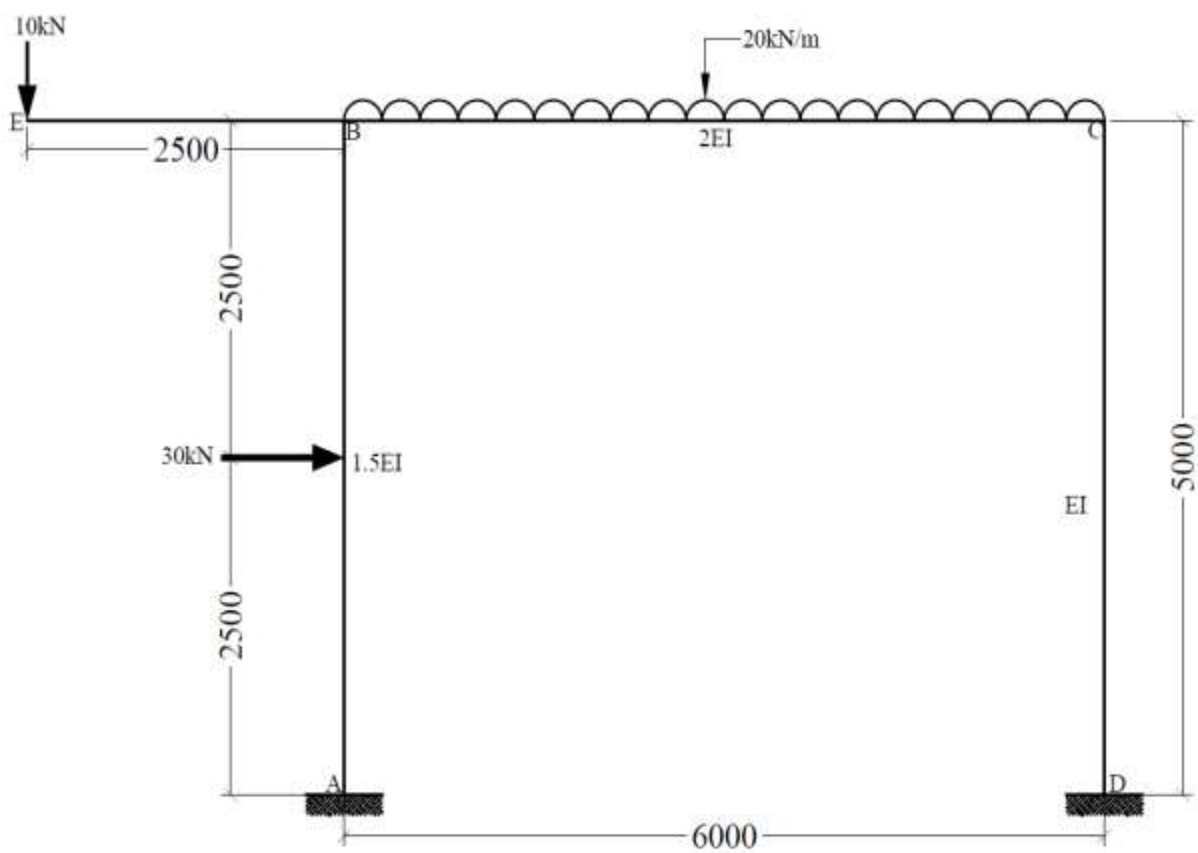
CASE I

Analyze the following 2D portal frame with the loading and support conditions as indicated in given figure by moment distribution method considering lateral sway of frame as well.

1. Find the responses to each member due to the combination of all loading conditions resulting from the loads that the frame has to undergo. Draw the bending moment diagram. The measurements indicated are in millimeters. (30 marks)

2. Design the member BC as reinforced concrete beam using following concrete grade of M25, reinforcement grade Fe500 and cover to reinforcement of 25mm. (10 marks)

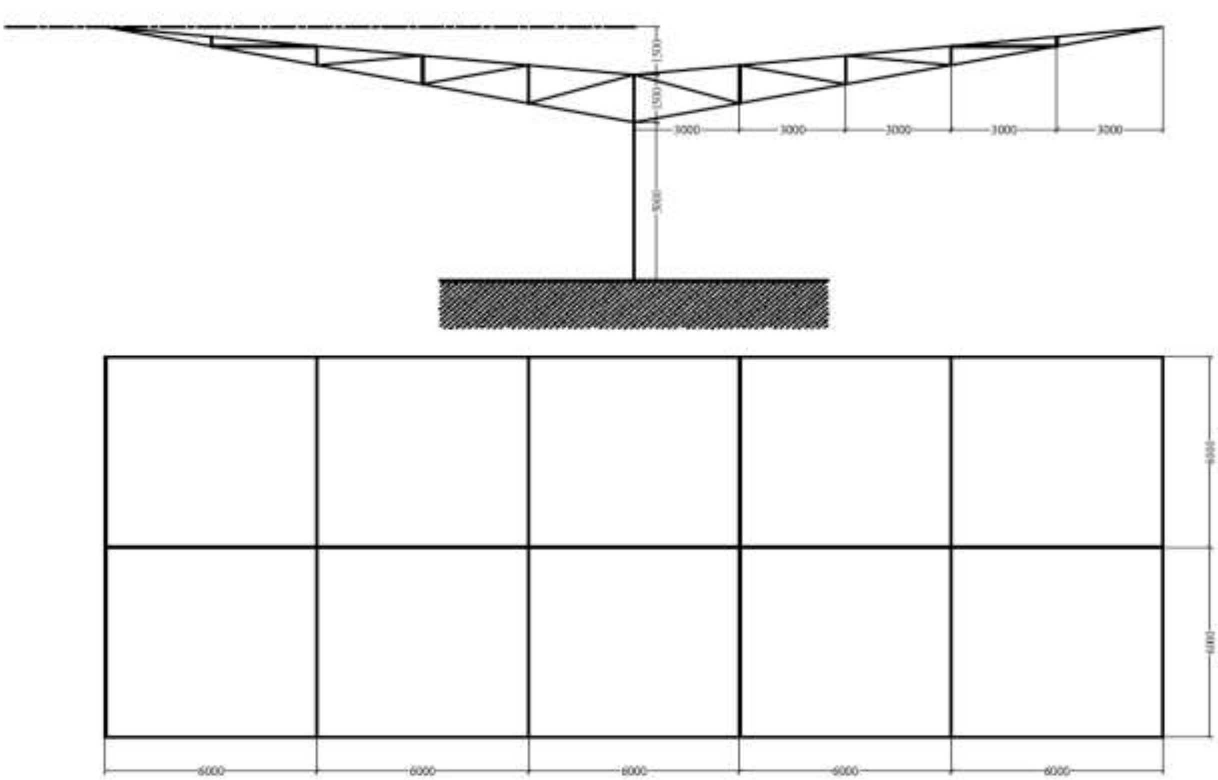
3. Design the member CD as reinforced concrete column using following concrete grade of M25, reinforcement grade Fe500 and cover to reinforcement of 40mm. (10 marks)



CASE II

The Royal Government of Bhutan (RGoB) intends to build bus stands along Thimphu Babesa Express way so that the commuters using the public transport services can be provided better waiting areas while they wait for the buses along the route. The architectural design consultant have proposed free standing sloped roof having dimensions indicated as shown below. The roof angle α is 10°.

1. Calculate the wind pressures and design forces on the roof so that the member components of the roof can be designed using following basic data: (30 marks)
   a) basic wind velocity, $v_z = 44m/s$
   b) terrain category 2
   c) topography factor, $k_3 = 1.0$
   d) weight of PPGI sheet = $0.465\ kg/m^2$
   e) weight of purlins = $200\ N/m^2$
   f) weight of bracing = $12\ N/m^2$



2. Calculate the resultant wind load on the rafter of the proposed truss and design it as tubular steel section? (10 marks)

3. Calculate the resultant forces on the vertical member supporting the truss and design it as a compression member. The compression member can also be designed as tubular steel section? (10 marks)

TABLE 1 RISK COEFFICIENTS FOR DIFFERENT CLASSES OF STRUCTURES IN DIFFERENT WIND SPEED ZONES

(*Clause* 5.3.1)

Class of Structure	Mean Probable Design Life of Structure in Years	k_1 Factor for Basic Wind Speed (m/s) of					
		33	39	44	47	50	55
All general buildings and structures	50	1·0	1·0	1·0	1·0	1·0	1·0
Temporary sheds, structures such as those used during construction operations (for example, formwork and falsework), structures during construction stages and boundary walls	5	0·82	0·76	0·73	0·71	0·70	0·67
Buildings and structures presenting a low degree of hazard to life and property in the event of failure, such as isolated towers in wooded areas, farm buildings other than residential buildings	25	0·94	0·92	0·91	0·90	0·90	0·89
Important buildings and structures such as hospitals communication buildings / towers, power plant structures	100	1·05	1·06	1·07	1·07	1·08	1·08

NOTE — The factor k_1 is based on statistical concepts which take account of the degree of reliability required and period of time in years during which these will be exposure to wind, that is, life of the structure. Whatever wind speed is adopted for design purposes, there is always a probability (however small) that it may be exceeded in a storm of exceptional violence; the greater the period of years over which these will be exposure to the wind, the greater is the probability. Higher return periods ranging from 100 to 1 000 years (implying lower risk level) in association with greater periods of exposure may have to be selected for exceptionally important structures, such as, nuclear power reactors and satellite communication towers. Equation given below may be used in such cases to estimate k_1 factors for different periods of exposure and chosen probability of exceedance (risk level). The probability level of 0·63 is normally considered sufficient for design of buildings and structures against wind effects and the values of k_1 corresponding to this risk level are given above.

$$k_1 = \frac{X_{N,P}}{X_{50,\,0\cdot63}} = \frac{A - B\left[ln \left\{ -\frac{1}{N} ln \left(1 - P_N\right)\right\}\right]}{A + 4B}$$

where

N = mean probable design life of structure in years;

P_N = risk level in N consecutive years (probability that the design wind speed is exceeded at least once in N successive years), nominal value = 0·63;

$X_{N,P}$ = extreme wind speed for given values of N and P_N; and

$X_{50,\,0\cdot63}$ = extreme wind speed for N = 50 years and P_N = 0·63.

A and B are coefficients having the following values for different basic wind speed zones:

Zone	A	B
33 m/s	83·2	9·2
39 m/s	84·0	14·0
44 m/s	88·0	18·0
47 m/s	88·0	20·5
50 m/s	88·8	22·8
55 m/s	90·8	27·3

TABLE 2 k_2 FACTORS TO OBTAIN DESIGN WIND SPEED VARIATION WITH HEIGHT IN DIFFERENT TERRAINS FOR DIFFERENT CLASSES OF BUILDINGS/STRUCTURES

(*Clause* 5.3.2.2)

HEIGHT	TERRAIN CATEGORY 1 CLASS			TERRAIN CATEGORY 2 CLASS			TERRAIN CATEGORY 3 CLASS			TERRAIN CATEGORY 4 CLASS		
m	*A*	*B*	*C*	*A*	*B*	*C*	*A*	*B*	*C*	*A*	*B*	*C*
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
10	1·05	1·03	0·99	1·00	0·98	0·93	0·91	0·88	0·82	0·80	0·76	0·67
15	1·09	1·07	1·03	1·05	1·02	0·97	0·97	0·94	0·87	0·80	0·76	0·67
20	1·12	1·10	1·06	1·07	1·05	1·00	1·01	0·98	0·91	0·80	0·76	0·67
30	1·15	1·13	1·09	1·12	1·10	1·04	1·06	1·03	0·96	0·97	0·93	0·83
50	1·20	1·18	1·14	1·17	1·15	1·10	1·12	1·09	1·02	1·10	1·05	0·95
100	1·26	1·24	1·20	1·24	1·22	1·17	1·20	1·17	1·10	1·20	1·15	1·05
150	1·30	1·28	1·24	1·28	1·25	1·21	1·24	1·21	1·15	1·24	1·20	1·10
200	1·32	1·30	1·26	1·30	1·28	1·24	1·27	1·24	1·18	1·27	1·22	1·13
250	1·34	1·32	1·28	1·32	1·31	1·26	1·29	1·26	1·20	1·28	1·24	1·16
300	1·35	1·34	1·30	1·34	1 32	1·28	1·31	1·28	1·22	1·30	1·26	1·17
350	1·37	1·35	1·31	1·36	1·34	1·29	1·32	1·30	1·24	1·31	1·27	1·19
400	1·38	1·36	1·32	1·37	1·35	1·30	1·34	1·31	1·25	1·32	1·28	1·20
450	1·39	1·37	1·33	1·38	1·36	1·31	1·35	1·32	1·26	1·33	1·29	1·21
500	1·40	1·38	1·34	1·39	1·37	1·32	1·36	1·33	1·28	1·34	1·30	1·22

NOTE 1 — *See* **5.3.2.2** for definitions of Class A, Class B and Class C structures.

NOTE 2 — Intermediate values may be obtained by linear interpolation, if desired. It is permissible to assume constant wind speed between 2 heights for simplicity.

TABLE 3 FETCH AND DEVELOPED HEIGHT RELATIONSHIP

(*Clause* 5.3.2.4)

FETCH (x) km	DEVELOPED HEIGHT, h_x IN METRES			
	Terrain Category 1	Terrain Category 2	Terrain Category 3	Terrain Category 4
(1)	(2)	(3)	(4)	(5)
0·2	12	20	35	60
0·5	20	30	35	95
1	25	45	80	130
2	35	65	110	190
5	60	100	170	300
10	80	140	250	450
20	120	200	350	500
50	180	300	400	500

5.3 Design Wind Speed (V_z) — The basic wind speed (V_b) for any site shall be obtained from Fig. 1 and shall be modified to include the following effects to get design wind velocity at any height (V_z) for the chosen structure:

a) Risk level;

b) Terrain roughness, height and size of structure; and

c) Local topography.

It can be mathematically expressed as follows:

$$V_z = V_b\, k_1\, k_2\, k_3$$

where

V_z = design wind speed at any height z in m/s;

k_1 = probability factor (risk coefficient) (*see* **5.3.1**);

k_2 = terrain, height and structure size factor (*see* **5.3.2**); and

k_3 = topography factor (*see* **5.3.3**).

NOTE — Design wind speep up to 10 m height from mean ground level shall be considered constant.

TABLE 4 EXTERNAL PRESSURE COEFFICIENTS (C_{pe}) FOR WALLS OF RECTANGULAR CLAD BUILDINGS

(*Clause* 6.2.2.1)

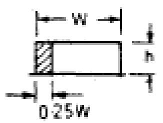
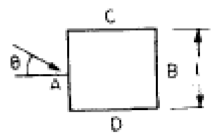
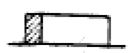
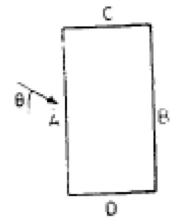
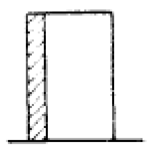
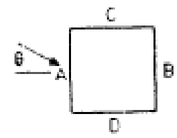
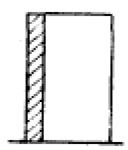
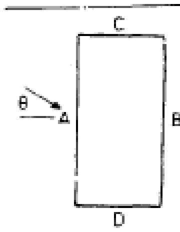
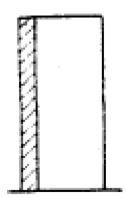
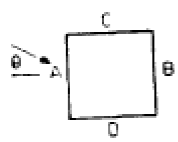
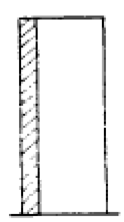
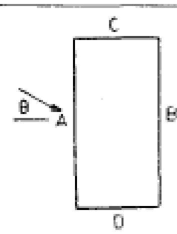
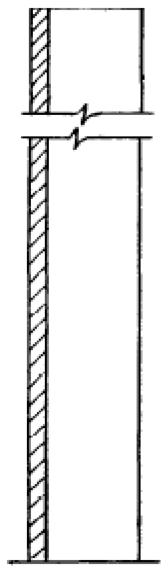
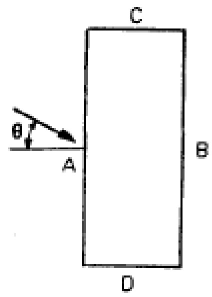
Building Height Ratio	Building Plan Ratio	Elevation	Plan	Wind Angle θ	C_{pe} for Surface A	B	C	D	Local C_{pe}
				degrees					
$\frac{h}{w} < \frac{1}{2}$	$1 < \frac{l}{w} < \frac{3}{2}$			0 90	+0·7 −0·5	−0·2 −0·5	−0·5 +0·7	−0·5 −0·2	−0·8
	$\frac{3}{2} < \frac{l}{w} < 4$			0 90	+0·7 −0·5	−0·25 −0·5	−0·6 +0·7	−0·6 −0·1	−1·0
$\frac{1}{2} < \frac{h}{w} < \frac{3}{2}$	$1 < \frac{l}{w} < \frac{3}{2}$			0 90	+0·7 −0·6	−0·25 −0·6	−0·6 +0·7	−0·6 −0·25	−1·1
	$\frac{3}{2} < \frac{l}{w} < 4$			0 90	+0·7 −0·5	−0·3 −0·5	−0·7 +0·7	−0·7 −0·1	−1·1
$\frac{3}{2} < \frac{h}{w} < 6$	$1 < \frac{l}{w} < \frac{3}{2}$			0 90	+0·8 −0·8	−0·25 −0·8	−0·8 +0·8	−0·8 −0·25	−1·2
	$\frac{3}{2} < \frac{l}{w} < 4$			0 90	+0·7 −0·5	−0·4 −0·5	−0·7 +0·8	−0·7 −0·1	−1·2

TABLE 4 EXTERNAL PRESSURE COEFFICIENTS (C_{pe}) FOR WALLS OF RECTANGULAR CLAD BUILDINGS — *Contd*

Building Height Ratio	Building Plan Ratio	Elevation	Plan	Wind Angle θ	C_{pe} for Surface A	B	C	D	Local C_{pe}
$\frac{h}{w} > \infty$	$\frac{l}{w} = \frac{3}{2}$			0 90	+0·95 −0·8	−1·85 −0·8	−0·9 +0·9	−0·9 −0·85	−1·25
	$\frac{l}{w} = 1·0$			0 90	+0·95 −0·7	−1·25 −0·7	−0·7 +0·95	−0·7 −1·25	−1·25
	$\frac{l}{w} = 2$			0 90	+0·85 −0·75	−0·75 −0,75	−0·75 +0·85	−0·75 −0·75	−1·25

NOTE — *h* is the height to eaves or parapet, *l* is the greater horizontal dimension of a building and *w* is the lesser horizontal dimension of a building.

Table 2 Tensile Properties of Steel Tubes for Structural Purposes

(*Clauses* 3.1 *and* 11.2)

Grade	Tensile Strength (*Min*) MPa	Yield Stress (*Min*) MPa	Elongation on Gauge Length $5.65\sqrt{S_o}$, *Min* Percent
YSt 210	330	210	20
YSt 240	410	240	17
YSt 310	450	310	14

NOTES

1 1 MPa = 1N/mm² = 0.102 kgf/mm².

2 Elongation percent for tubes up to and including 25 mm nominal bore for all grades shall be 12 minimum.

Table 3 Steel and Supply Conditions

(*Clause* 5.1)

Sl No.	Manufacturing Process	Steel	Supply Conditions
i)	HFW	IS 10748	Only YSt 210 or YSt 240
ii)	HFS	Bars/ingots with suitable chemical composition as per IS 10748 to achieve mechanical properties for respective grades	YSt 210, YSt 240 or YSt 310
iii)	ERW/HRIW	IS 10748	YSt 210, YSt 240 or YSt 310 as welded, heat treated or cold drawn and normalized

NOTE If required the copper bearing steel may be used to impart weather resistant properties in the steel. Copper content shall be between 0.20 to 0.35 percent subject to mutual agreement between the supplier and the purchaser.

TABLE 5 EXTERNAL PRESSURE COEFFICIENTS (C_{pe}) FOR PITCHED ROOFS OF RECTANGULAR CLAD BUILDINGS

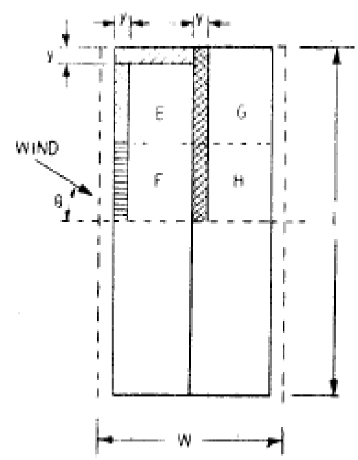
(*Clause* 6.2.2.2)

Building Height Ratio	Roof Angle α (degrees)	Wind Angle θ 0°: EF	Wind Angle θ 0°: GH	Wind Angle θ 90°: EG	Wind Angle θ 90°: FH	Local Coefficients			
$\frac{h}{w} \leqslant \frac{1}{2}$	0	−0·8	−0·4	−0·8	−0·4	−2·0	2·0	−2·0	—
	5	−0·9	−0·4	−0·8	−0·4	−1·4	−1·2	−1·2	−1·0
	10	−1·2	−0·4	−0·8	−0·6	−1·4	−1·4		−1·2
	20	−0·4	−0·4	−0·7	−0·6	−1·0			−1·2
	30	0	−0·4	−0·7	−0·6	−0·8			−1·1
	45	+0·3	−0·5	−0·7	−0·6				−1·1
	60	+0·7	−0·6	−0·7	−0·6				−1·1
$\frac{1}{2} < \frac{h}{w} \leqslant \frac{3}{2}$	0	−0·8	−0·6	−1·0	−0·6	−2·0	−2·0	−2·0	—
	5	−0·9	−0·6	−0·9	−0·6	−2·0	−2·0	−1·5	−1·0
	10	−1·1	−0·6	−0·8	−0·6	−2·0	−2·0	−1·5	−1·2
	20	−0·7	−0·5	−0·8	−0·6	−1·5	−1·5	−1·5	−1·0
	30	−0·2	−0·5	−0·8	−0·8	−1·0			−1·0
	45	+0·2	−0·5	−0·8	−0·8				
	60	+0·6	−0·5	−0·8	−0·8				
$\frac{3}{2} < \frac{h}{w} < 6$	0	−0·7	−0·6	−0·9	−0·7	−2·0	−2·0	−2·0	—
	5	−0·7	−0·6	−0·8	−0·8	−2·0	−2·0	−1·5	−1·0
	10	−0·7	−0·6	−0·8	−0·8	−2·0	−2·0	−1·5	−1·2
	20	−0·8	−0·6	−0·8	−0·8	−1·5	−1·5	−1·5	−1·2
	30	−1·0	−0·5	−0·8	−0·7	−1·5			
	40	−0·2	−0·5	−0·8	−0·7	−1·0			
	50	+0·2	−0·5	−0·8	−0·7				
	60	+0·5	−0·5	−0·8	−0·7				

NOTE 1 — h is the height to eaves or parapet and w is the lesser horizontal dimension of a building.

NOTE 2 — Where no local coefficients are given, the overall coefficients apply.

NOTE 3 — For hipped roofs the local coefficient for the hip ridge may be conservatively taken as the appropriate ridge value.

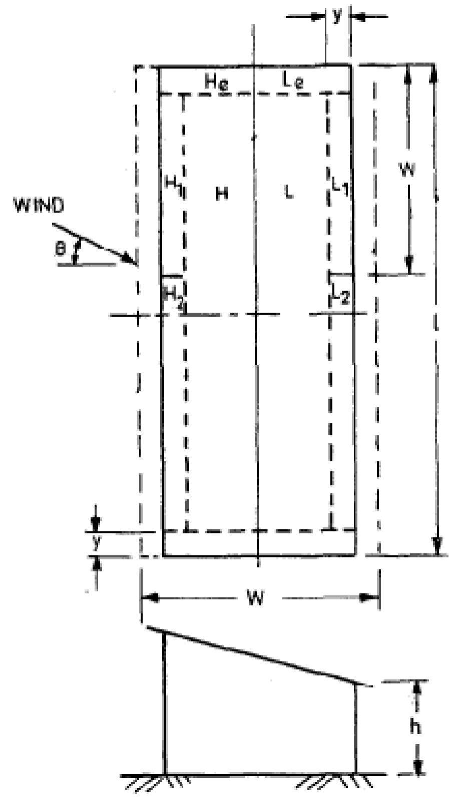


KEY PLAN

$y = h$ or $0{\cdot}15\,w$,
whichever is the lesser.

TABLE 6 EXTERNAL PRESSURE COEFFICIENTS (C_{pe}) FOR MONOSLOPE ROOFS FOR RECTANGULAR CLAD BUILDINGS WITH $\frac{h}{w} < 2$

(*Clause* 6.2.2.3)



$y = h$ or $0{\cdot}15\ w$, whichever is the lesser.

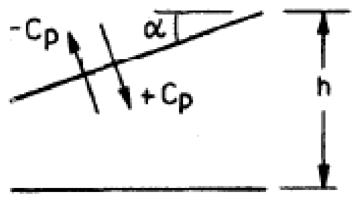
NOTE — Area *H* and area *L* refer to the whole quadrant.

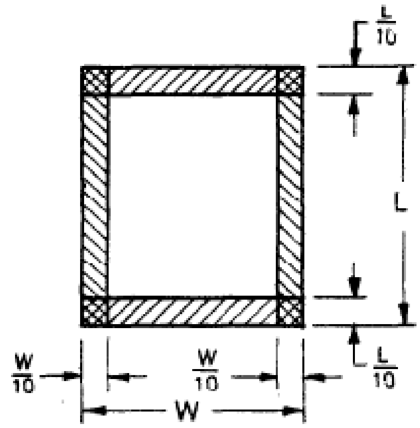
ROOF ANGLE α	WIND ANGLE θ										LOCAL C_{pe}					
	0°		45°		90°		135°		180°							
Degree	*H*	*L*	*H*	*L*	*H* & *L* Applies to length *w*/2 from windward end	*H* & *L* Applies to remainder	*H*	*L*	*H*	*L*	H_1	H_2	L_1	L_2	H_e	L_e
5	−1·0	−0·5	−1·0	−0·9	−1·0	−0·5	−0·9	−1·0	−0·5	−1·0	−2·0	−1·5	−2·0	−1·5	−2·0	−2·0
10	−1·0	−0·5	−1·0	−0·8	−1·0	−0·5	−0·8	−1·0	−0·4	−1·0	−2·0	−1·5	−2·0	−1·5	−2·0	−2·0
15	−0·9	−0·5	−1·0	−0·7	−1·0	−0·5	−0·6	−1·0	−0·3	−1·0	−1·8	−0·9	−1·8	−1·4	−2·0	−2·0
20	−0·8	−0·5	−1·0	−0·6	−0·9	−0·5	−0·5	−1·0	−0·2	−1·0	−1·8	−0·8	−1·8	−1·4	−2·0	−2·0
25	−0·7	−0·5	−1·0	−0·6	−0·8	−0·5	−0·3	−0·9	−0·1	−0·9	−1·8	−0·7	−0·9	−0·9	−2·0	−2·0
30	−0·5	−0·5	−1·0	−0·6	−0·8	−0·5	−0·1	−0·6	0	−0·6	−1·8	−0·5	−0·5	−0·5	−2·0	−2·0

NOTE — *h* is the height to eaves at lower side, *l* is the greater horizontal dimension of a building and *w* is the lesser horizontal dimension of a building.

TABLE 7 PRESSURE COEFFICIENTS FOR MONOSLOPE FREE ROOFS

(*Clause* 6.2.2.4)



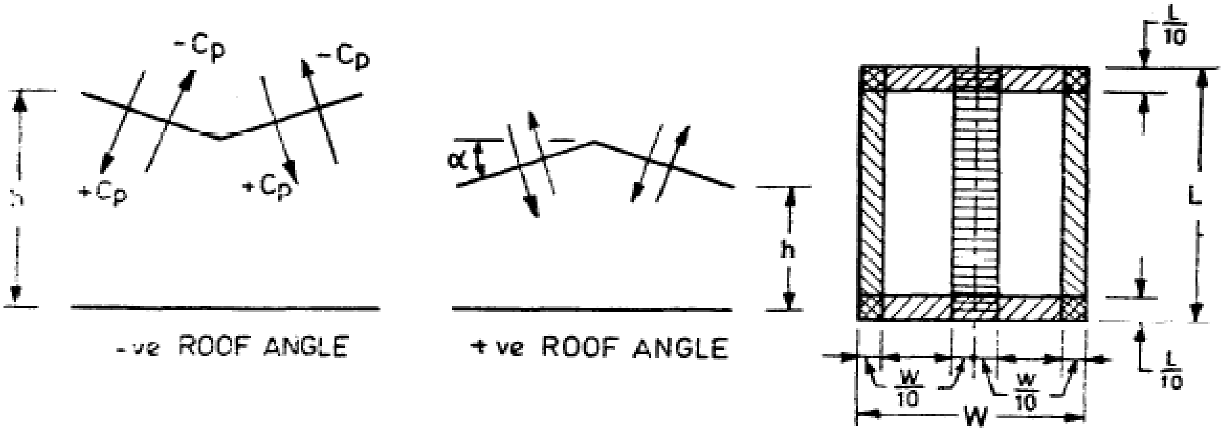


Roof Angle (Degrees)	Solidity Ratio	Maximum (Largest + ve) and Minimum (Largest − ve) Pressure Coefficients			
		Overall Coefficients	Local Coefficients		
					
0	All values of ϕ	+0·2	+0·5	+1·8	+1·1
5		+0·4	+0·8	+2·1	+1·3
10		+0·5	+1·2	+2·4	+1·6
15		+0·7	+1·4	+2·7	+1·8
20		+0·8	+1·7	+2·9	+2·1
25		+1·0	+2·0	+3·1	+2·3
30		+1·2	+2·2	+3·2	+2·4
0	$\phi=0$	−0·5	−0·6	−1·3	−1·4
	$\phi=1$	−1·0	−1·2	−1·8	−1·9
5	$\phi=0$	−0·7	−1·1	−1·7	−1·8
	$\phi=1$	−1·1	−1·6	−2·2	−2·3
10	$\phi=0$	−0·9	−1·5	−2·0	−2·1
	$\phi=1$	−1·3	−2·1	−2·6	−2·7
15	$\phi=0$	−1·1	−1·8	−2·4	−2·5
	$\phi=1$	−1·4	−2·3	−2·9	−3·0
20	$\phi=0$	−1·3	−2·2	−2·8	−2·9
	$\phi=1$	−1·5	−2·6	−3·1	−3·2
25	$\phi=0$	−1·6	−2·6	−3·2	−3·2
	$\phi=1$	−1·7	−2·8	−3·5	−3·5
30	$\phi=0$	−1·8	−3·0	−3·8	−3·6
	$\phi=1$	−1·8	−3·0	−3·8	−3·6

NOTE — For monopitch canopies the centre of pressure should be taken to act at 0·3 *w* from the windward edge.

TABLE 8 PRESSURE COEFFICIENTS FOR FREE STANDING DOUBLE SLOPED ROOFS

(*Clause* 6.2.2.4)

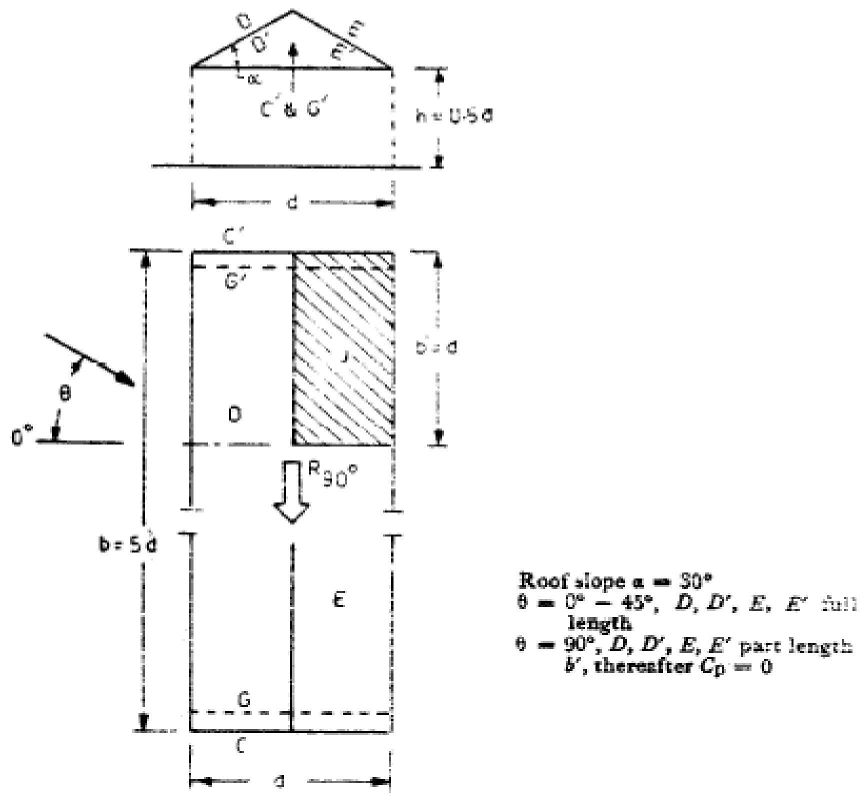


Roof Angle (Degrees)	Solidity Ratio	Maximum (Largest +ve) and Minimum (Largest − ve) Pressure Coefficients				
		Overall Coefficients	Local Coefficients			
						
−20	All values of φ	+0·7	+0·8	+1·6	+0·6	+1·7
−15		+0·5	+0·6	+1·5	+0·7	+1·4
−10		+0·4	+0·6	+1·4	+0·8	+1·1
−5		+0·3	+0·5	+1·5	+0·8	+0·8
+5		+0·3	+0·6	+1·8	+1·3	+0·4
+10		+0·4	+0·7	+1·8	+1·4	+0·4
+15		+0·4	+0·9	+1·9	+1·4	+0·4
+20		+0·6	+1·1	+1·9	+1·5	+0·4
+25		+0·7	+1·2	+1·9	+1·6	+0·5
+30		+0·9	+1·3	+1·9	+1·6	+0·7
−20	φ=0	−0·7	−0·9	−1·3	−1·6	−0·6
	φ=1	−0·9	−1·2	−1·7	−1·9	−1·2
−15	φ=0	−0·6	−0·8	−1·3	−1·6	−0·6
	φ=1	−0·8	−1·1	−1·7	−1·9	−1·2
−10	φ=0	−0·6	−0·8	−1·3	−1·5	−0·6
	φ=1	−0·8	−1·1	−1·7	−1·9	−1·3
−5	φ=0	−0·5	−0·7	−1·3	−1·6	−0·6
	φ=1	−0·8	−1·5	−1·7	−1·9	−1·4
+5	φ=0	−0·6	−0·6	−1·4	−1·4	−1·1
	φ=1	−0·9	−1·3	−1·8	−1·8	−2·1
+10	φ=0	−0·7	−0·7	−1·5	−1·4	−1·4
	φ=1	−1·1	−1·4	−2·0	−1·8	−2·4
+15	φ=0	−0·8	−0·9	−1·7	−1·4	−1·8
	φ=1	−1·2	−1·5	−2·2	−1·9	−2·8
+20	φ=0	−0·9	−1·2	−1·8	−1·4	−2·0
	φ=1	−1·3	−1·7	−2·3	−1·9	−3·0
+25	φ=0	−1·0	−1·4	−1·9	−1·4	−2·0
	φ=1	−1·4	−1·9	−2·4	−2·1	−3·0
+30	φ=0	−1·0	−1·4	−1·9	−1·4	−2·0
	φ=1	−1·4	−2·1	−2·6	−2·2	−3·0

Each slope of a duopitch canopy should be able to withstand forces using both the maximum and the minimum coefficients, and the whole canopy should be able to support forces using one slope at the maximum coefficient with the other slope at the minimum coefficient. For duopitch canopies the centre of pressure should be taken to act at the centre of each slope.

TABLE 9 PRESSURE COEFFICIENTS (TOP AND BOTTOM) FOR PITCHED ROOFS, $\alpha = 30°$

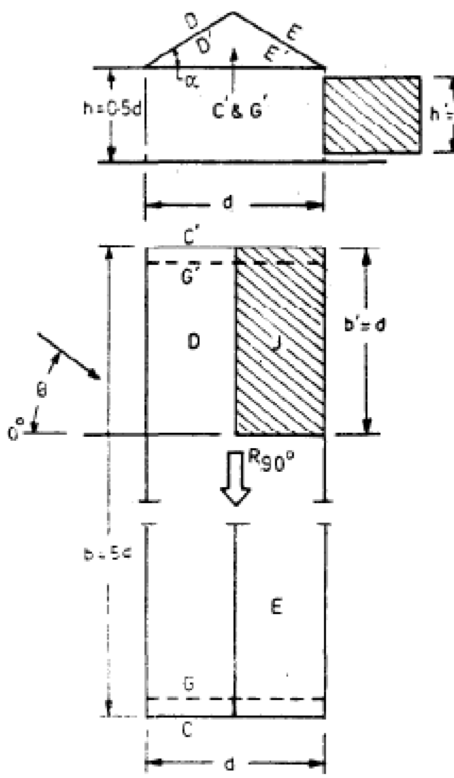
(*Clause* 6.2.2.4)



θ	Pressure Coefficients, C_p							
	D	D′	E	E′	End Surfaces			
					C	C′	G	G′
0	0·6	−1·0	−0·5	−0·9				
45°	0·1	−0·3	−0·6	−0·3				
90°	−0·3	−0·4	−0·3	−0·4	−0·3	0·8	0·3	0·4
45°	For j : C_p top = −1·0; C_p bottom = −0·2							
90°	Tangentially acting friction: $R_{90°} = 0·05\ p_d bd$							

TABLE 10 PRESSURE COEFFICIENTS (TOP AND BOTTOM) FOR PITCHED FREE ROOFS, $\alpha = 30°$ WITH EFFECTS OF TRAIN OR STORED MATERIALS

(*Clause* 6.2.2.4)

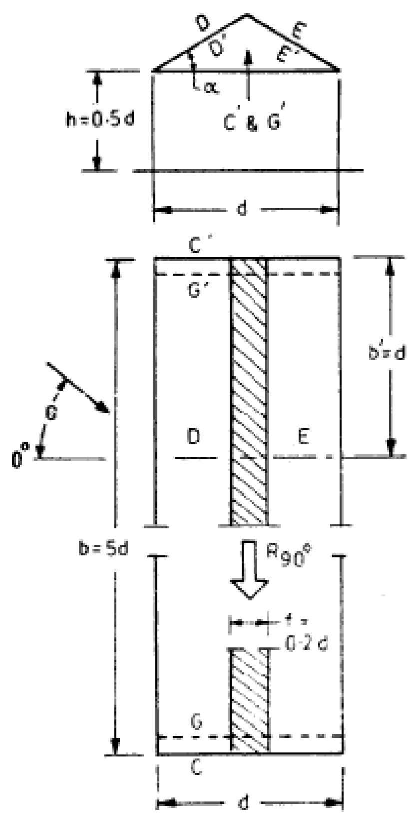


Roof slope $\alpha = 30°$
Effects of trains or stored materials:
$\theta = 0° - 45°$, or $135° - 180°$, D, D', E, E' full length
$\theta = 90°$, D, D', E, E' part length b', thereafter $C_p = 0$

θ	Pressure Coefficients, C_p							
	D	*D'*	*E*	*E'*	End Surfaces			
					C	*C'*	*G*	*G'*
0°	0·1	0·8	−0·7	0·9	−0·3	0·8	0·3	−0·4
45°	−0·1	0·5	−0·8	0·5				
90°	−0·4	−0·5	−0·4	−0·5				
180°	−0·3	−0·6	0·4	−0·6				
45°	For j : C_p top = −1·5; C_p bottom = 0·5							
90°	Tangentially acting friction: $R_{90°} = 0·05\ p_d bd$							

TABLE 11 PRESSURE COEFFICIENTS (TOP AND BOTTOM) FOR PITCHED FREE ROOFS, α = 10°

(*Clause* 6.2.2.4)



Roof slope α = 10°
θ = 0° – 45°, D, D', E, E' full length
θ = 90°, D, D', E, E' part length b', thereafter C_p = 0

θ	Pressure Coefficients, C_p							
					End Surfaces			
	D	*D'*	*E*	*E'*	*C*	*C'*	*G*	*G'*
0°	−1·0	0·3	−0·5	0·2				
45°	−0·3	0·1	−0·3	0·1				
90°	−0·3	0	−0·3	0	−0·4	0·8	0·3	−0·6
0°	For *f*: C_p top = −1·0; C_p bottom = 0·4							
0° – 90°	Tangentially acting friction, $R_{90°}$ = 0·1 $p_d bd$							

Table 1 Sizes and Properties of Steel Tubes for Structural Purposes

(*Clauses* 3.1, 6.1, 6.1.1 *and* 6.1.2)

Nominal Bore	Outside Diameter	Class	Thickness	Weight	Area of Cross Section	Internal Volume	Surface External	Surface Internal	Moment of Inertia	Modulus of Section	Radius of Gyration	Square of Radius of Gyration
mm	mm		mm	kg/m	cm^2	cm^3/m	cm^3/m	cm^3/m	cm^4	cm^3	cm	cm^2
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
15	21.3	Light	2.0	0.947	1.21	235		543	0.57	0.54	0.69	0.47
		Medium	2.6	1.21	1.53	203	669	506	0.69	0.64	0.66	0.44
		Heavy	3.2	1.44	1.82	174		468	0.75	0.70	0.55	0.42
20	26.9	Light	2.3	1.38	1.78	390		700	1.36	1.01	0.87	0.76
		Medium	2.6	1.56	1.98	370	845	681	1.48	1.10	0.86	0.74
		Heavy	3.2	1.87	2.38	330		644	1.70	1.26	0.84	0.71
25	33.7	Light	2.6	1.98	2.54	638		895	3.09	1.83	1.10	1.21
		Medium	3.2	2.41	3.06	585	1 059	857	3.61	2.14	1.08	1.17
		Heavy	4.0	2.93	3.73	518		807	4.19	2.48	1.05	1.11
32	42.4	Light	2.6	2.54	3.25	1 086		1 168	6.47	3.05	1.41	1.98
		Medium	3.2	3.10	3.94	1 017	1 332	1 130	7.62	3.59	1.39	1.93
		Heavy	4.0	3.79	4.82	929		1 080	8.99	4.24	1.36	1.86
40	48.3	Light	2.9	3.23	4.13	1 418		1 335	10.70	4.43	1.61	2.59
		Medium	3.2	3.56	4.53	1 378	1 517	1 316	11.59	4.80	1.59	2.54
		Heavy	4.0	4.37	5.56	1 275		1 265	13.77	5.70	1.57	2.47
50	60.3	Light	2.9	4.08	5.23	2 332		1 711	21.59	7.16	2.03	4.13
		Medium	3.6	5.03	6.41	2 213		1 667	25.88	8.58	2.00	4.02
		Heavy	4.5	6.19	7.88	2 066		1 611	30.90	10.2	1.98	3.92
65	76.1	Light	3.2	5.71	7.32	3 814		2 189	48.79	12.82	2.58	6.66
		Medium	3.6	6.42	8.20	3 727	2 391	2 163	54.02	14.20	2.57	6.60
		Heavy	4.5	7.93	10.1	3 534		2 107	65.12	17.1	2.54	6.43
80	88.9	Light	3.2	6.72	8.61	5 343		2 591	79.23	17.82	3.03	9.19
		Medium	4.0	8.36	10.7	5 138	2 793	2 540	96.36	21.68	3.00	9.00
		Heavy	4.8	9.90	12.7	4 936		2 490	112.52	25.31	2.98	8.88
90	101.6	Light	3.6	8.70	11.1	6 995		2 964	133.27	26.23	3.47	12.03
		Medium	4.0	9.63	12.3	6 877	3 192	2 939	146.32	28.80	3.45	11.91
		Heavy	4.8	11.5	14.6	6 644		2 889	171.44	33.75	3.43	11.76

100	114.3	Light	3.6	9.75	12.5	9 004		3 363	192.03	33.60	3.92	15.36
		Medium	4.5	12.2	15.5	8 704	3 591	3 306	234.3	41.0	3.89	15.10
		Heavy	5.4	14.5	18.5	8 409		3 250	274.5	48.0	3.85	14.86
110	127.0	Light	4.5	13.6	17.3	10 930		3 705	325.3	51.2	4.33	18.78
		Medium	4.8	14.5	18.4	10 819	3 990	3 686	344.58	54.27	4.32	18.69
		Heavy	5.4	16.2	20.6	10 599		3 649	382.0	60.2	4.30	18.52
125	139.7	Light	4.5	15.0	19.1	13 410		4 104	437.2	62.6	4.78	22.87
		Medium	4.8	15.9	20.3	13 287	4 389	4 085	463.44	66.35	4.77	22.76
		Heavy	5.4	17.9	22.8	13 043		4 047	514.5	73.7	4.75	22.58
135	152.4	Light	4.5	16.4	20.9	16 142		4 503	572.2	75.1	5.23	27.37
		Medium	4.8	17.5	22.2	16 008	4 788	4 484	606.92	79.65	5.22	27.25
		Heavy	5.4	19.6	25.0	15 740		4 446	674.5	88.5	5.20	27.05
150	165.1	Light	4.5	17.8	22.7	19 128		4 902	732.6	88.7	5.68	32.27
		Medium	4.8	18.9	24.2	18 981	5 187	4 883	777.32	94.16	5.67	32.14
		Heavy	5.4	21.3	27.1	18 690		4 845	864.7	105.0	5.65	31.92
150	168.3	Light	4.5	18.2	23.1	19 921		5 002	777.2	92.4	5.79	33.56
		Medium	4.8	19.4	24.7	19 771	5 287	4 983	824.78	98.01	5.78	33.42
		Heavy 1	5.4	21.7	27.6	19 473		4 946	917.7	109.0	5.76	33.21
		Heavy 2	6.3	25.2	32.0	19 030		4 889	1 053	125.0	5.73	32.85
175	193.7	Light	4.8	22.4	28.5	26 606		5 781	1 271.71	131.31	6.68	44.63
		Medium	5.4	25.1	32.0	26 260	6 085	5 743	1 417	146	6.66	44.36
		Heavy	5.9	27.3	34.8	25 974		5 712	1 535.2	158.65	6.64	41.11
200	219.1	Light	4.8	25.4	32.3	34 454		6 578	1 856.51	169.47	7.58	57.45
		Medium	5.6	29.5	37.5	33 930	6 883	6 528	2 141	195	7.55	57.02
		Heavy	5.9	31.0	39.5	33 734		6 509	2 247	205	7.54	56.86
225	244.5	Heavy	5.9	34.7	44.2	42 507	7 681	7 307	3 149	258	8.44	71.21
250	273.0	Heavy	5.9	38.9	49.5	53 557	8 578	8 202	4 412	323	9.45	89.30
300	323.9	Heavy	6.3	49.3	62.8	76 073	10 177	9 775	7 992	493	11.2	125.44
350	355.6	Heavy	8.0	68.6	87.3	90 533	11 173	10 663	13 111	737	12.3	151.29

TASHI DELEK