The Open University of Sri Lanka
Faculty of Engineering Technology
Department of Civil Engineering

Study Programme	: Bachelor of Science Honors in Engineering
Name of the Examination	: Final Examination
Course Code and Title	**: CVX3441 Structural Analysis and Design 1**
Academic Year	: 2024/2025
Date	: 06th February 2026
Time	: 1400-1700 hrs
Duration	: **3 hours**

General Instructions

1. Read all the instructions carefully before answering the questions.
2. This question paper consists of **Eight (8)** questions in **Twelve (12)** pages.
3. Answer any **Five (5)** questions only. All questions carry equal marks.
4. Answer for each question should commence from a new page.
5. Relevant charts / codes are provided.
6. This is a Closed Book Test **(CBT).**
7. Answers should be in clear handwriting.
8. Do not use Red colour pen.
9. Marks are deducted if the instructions are not followed.

SECTION A

Q1a). State four assumptions used in analyzing pin-jointed trusses (4 Marks)

b). A pin-jointed truss shown in Figure Q1 is hinged to a support at L1, on a roller support at L3 and loaded as shown in the figure below. Determine the forces in all the members of the frame by the method of joints. (12 Marks)

c). Determine the forces in members U2U1, U2L2, L2L3 of the truss by the 'method of section. (4 Marks)

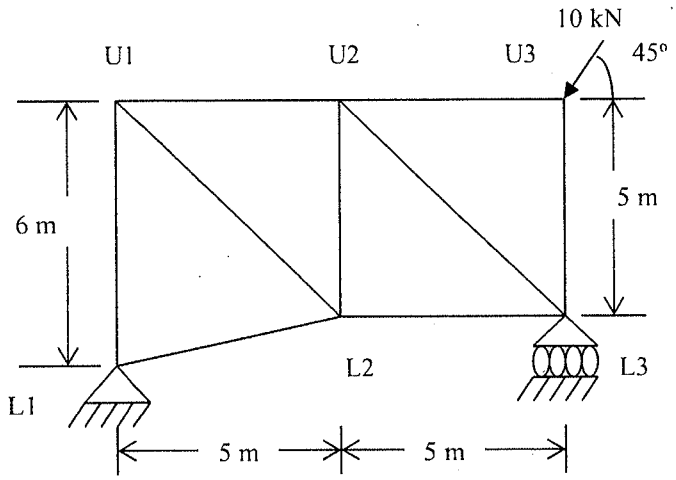


Figure Q1

Q2.) a). Discuss the advantages of virtual work method for calculation of displacement of trusses over strain energy method. (5 Marks)

b).

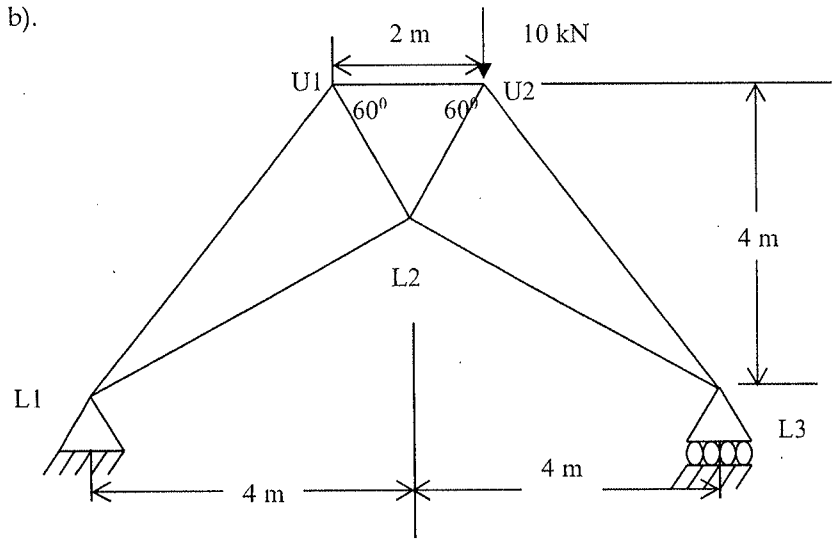


Figure Q2

Figure Q2 shows a pin-jointed frame, which is hinged to the support at L1 and on a roller support at L3. Take EA as constant for all members.

Calculate movements of the following joints in the specified directions due to the given load:

i). the vertical deflection of point U2 (9 Marks)

ii). the vertical deflection of point L2 (6 Marks)

3.a) Draw the influence lines of following actions of the beam given below.

i). Reaction at A

ii). Moment at A

iii). Bending moment at mid span of AB (3x4 Marks)

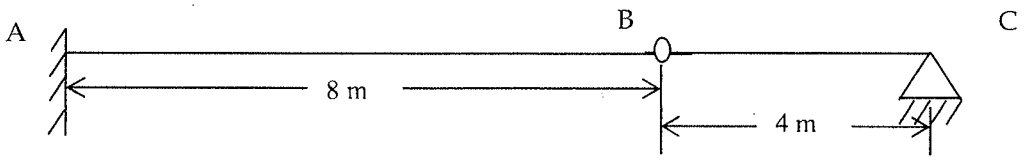


Figure Q3

b). Find the maximum Bending Moment at mid span of AB for following moving loads

i). 5 kN point load
ii). Two-point loads of 5 kN each with 4 m apart.
iii). 5 kN/m uniformly distributed load (udl) with 15 m length.
iv). 2 kN/m uniformly distributed load (udl) with 5 m length. (8 Marks)

Q4.

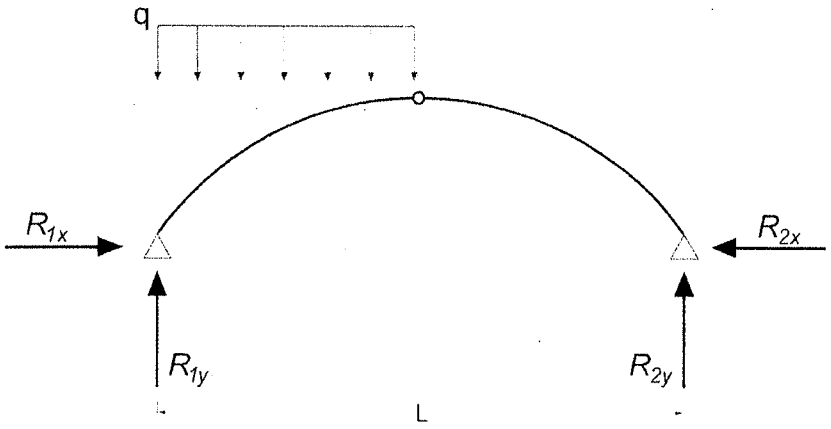


Figure Q4

i). State the difference between 2 pin Arch and 3 pin Arch with neat sketches. (3 Marks)

ii). 3 Pin Arch given in Figure Q4 is loaded with uniformly distributed load of intensity q and length 0.5L. The general equation of the arches can be given as $y = ax^2 + bx + c$

a). Find the constants a,b and c with the terms of L (Length of the arch) and h (height of the arch (5 Marks)

b). If the uniformly distributed load q = 4 kN/m, Length L = 6 m and h = 3 m find

i). Support Reactio (5 Marks)

ii). Bending Moment, Shear Force and Axial Load at the distance 4m from the left support. (7 Marks)

SECTION B

5. a). How does BS code allows for the effect of eccentricity of connections? (5 Marks)

b). i). Find the tensile capacity of the 80x80x10 single angle member used as a web member of a roof truss. The single angle member is connected to a 12 mm thickness gusset plate with 18 mm diameter bolts.
Permissible Tensile Stress - 170 N/mm^2 (7 Marks)

ii). If 50 kN Tensile Force is applied to back-to-back double angle member design with 80 x 80 x 8 EA sections, check the member is safe? (3 Marks)

c). If load applied on the tensile member is 50 kN, determine the number of bolts required to connect the member to gusset plate in both single angle member and double angle member given in Q5. b). (5 Marks)

6 a). State how the buckling failure in compression members of roof truss can be checked. (4 Marks)

b). A single angle member 80x80x10 used in roof truss is 3.0 m long and which is connected by two 18 mm bolts at each end. Determine its compressive strength. (8 Marks)

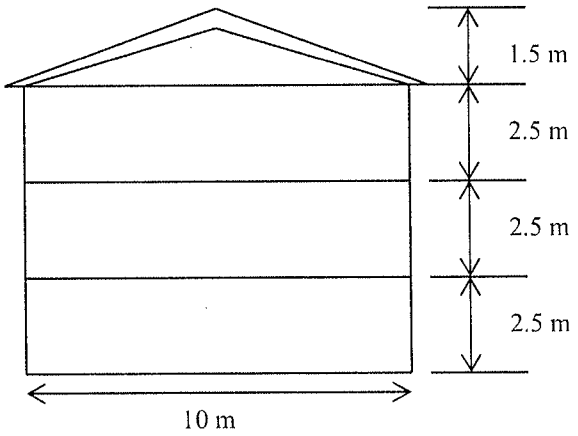
c). If the member is subjected to 30 kN axial compression load and 5 kNm maximum bending moment, check the suitability of 80x80x10 single angle. (8 Marks)

7 a). Explain the difference between the "Normal" and "Post Disaster" buildings or structures. (2 Marks)

b). Discuss three factors used in determination of design wind speed according to BSCP 3 Chapter v part 2. (6 Marks)

c). Explain the terms "Wind ward slope" and "Lee ward slope" used in wind load calculation with diagrams. (2 Marks)

d).



Above figure shows a sketch of a typical frame of a school building situated in Matara area (Zone 3). Calculate the total wind load on the frame per 1 m width of the roof.

Wind loading conditions:

- The site is in ground roughness category type 3, i.e. a small town;
- The greatest horizontal dimension of the building is 20 m;
- Center to center distance of two frames is 5 m.
- Assume that only wind blowing parallel to the truss span is effective; i.e. $\alpha = 0°$
- Assume that the internal pressure coefficient Cpi = +0.1

(10 Marks)

Zone	Basic wind speed V in m/s	
	Post-disaster structures	Normal structures
1	53.5	49.0
2	47.0	42.5
3	38.0	33.5

Q8). a). Derive Euler Buckling load of a column with top end is pin connected and bottom end fix connected. (7 Marks)

b). If steel RHS of size 100 mm x 150 mm with thickness 10 mm is proposed for the column discussed in Q8. a) find the suitability of the section if only axial load of 1000 kN is applied. (5 Marks)

The height of the column = 3 m
Elastic Modulus of steel = 200 GPa

c). A simply supported beam with span 5m designed to support a concrete slab of a hotel building.

Loads applied on the Beam

Dead Load

- Load due to the partition and finishing = 1.0 kN/m

Imposed Load

- Load due to the people = 1.0 kN/m

i). Find Critical Shear Force and bending Moment (2 Marks)

ii). If a Universal beam (UB) 356x171x45 mm is selected for a given beam check the suitability of the selected section. (6 Marks)

Properties of 356 x 171 x 45 UB

Depth - 351.4 mm, width - 171.6 mm, web thickness - 7 mm, Flange thickness - 9.7 mm, Inner depth between flanges - 332 mm, Root Tillet radius - 10.2 mm, Depth of straight portion of web - 311.6 mm

Sectional Area - 57.33 cm^2, Second Moment of Areas on Major Axis - 12066 cm^4, Minor Axis - 811.1 cm^4

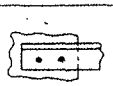
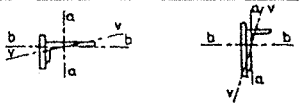
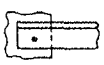
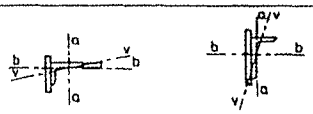
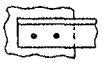
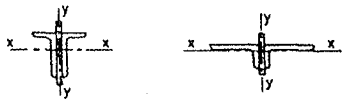
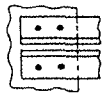
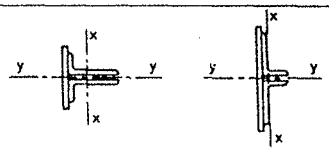
Radius of Gyration, Major Axis - 145.1 mm, Minor Axis - 37.1 mm

Elastic Section Modulus, Major Axis - 686.7 cm^3, Minor Axis - 94.8 cm^3

Data Sheets

A	T	M	r1	r2	A	C of G	Moment Of Inertia			Radius Of Gyration			Z
						Cx, Cy	X-X, Y-Y	U-U	V-V	X-X, Y-Y	U-U	V-V	
Mm	Mm	kg	Mm	mm	cm^2	Cm	cm^4	cm^4	cm^4	cm	Cm	Cm	cm^3
50 x 50	5	3.77	7,0	2,4	4.80	1.40	11.0	17.4	4.54	1.51	1.90	0.97	3.05
	6	4.47	7,0	2,4	5.69	1.45	12.8	20.4	5.33	1.50	1.89	0.97	3.61
	7	5.82	7,0	2,4	7.41	1.52	16.3	25.7	6.87	1.48	1.86	0.96	4.68
60 x 60	5	4.57	8,0	2,4	5.82	1.64	19.4	30.7	8.02	1.82	2.30	1.17	4.45
	6	5.42	8,0	2,4	6.91	1.69	22.8	36.2	9.43	1.82	2.29	1.17	5.29
	8	7.09	8,0	2,4	9.03	1.77	29.2	46.2	12.1	1.80	2.26	1.16	6..89
	10	8.69	8,0	2,4	11.1	1.85	34.9	55.1	14.8	1.78	2.23	1.16	8.41
70 x 70	6	6.38	9,0	2,4	8.13	1.93	36.9	58.5	15.2	2.13	2.68	1.37	7.27
	8	8.36	9,0	2,4	10.6	2.01	47.5	75.3	19.7	2.11	2.66	1.36	9.52
	10	10.3	9,0	2,4	13.1	2.09	57.2	90.5	23.9	2.09	2.63	1.35	11.7
80 x 80	6	7.34	10,0	4,8	9.35	2.17	55.8	88.5	23.1	2.44	3.08	1.57	9.57
	8	9.63	10,0	4,8	12.3	2.26	72.2	115	29.8	2.43	3.06	1.56	12.6
	10	11.9	10,0	4,8	15.1	2.34	87.5	139	36.3	2.41	3.03	1.55	15.4
90 x 90	6	8.3	11,0	4,8	10.6	2.41	80.3	127	33.3	2.76	3.47	1.78	12.2
	8	10.9	11,0	4,8	13.9	2.50	104	166	43.1	2.74	3.45	1.76	16.1
	10	13.4	11,0	4,8	17.1	2.58	127	201	52.6	2.72	3.42	1.76	19.8
	12	15.9	11,0	4,8	20.3	2.66	148	234	61.7	2.70	3.40	1.75	23.3
100x100	8	12.2	12,0	4,8	15.5	2.74	145	230	59.8	3.06	3.85	1.96	19.9
	12	17.8	12,0	4,8	22.7	2.90	207	328	85.7	3.02	3.80	1.94	29.1
	15	21.9	12,0	4,8	27.9	3.02	249	393	104	2.98	3.75	1.93	35.6

TABLE 18. ANGLE STRUTS

Connection	Sections and axes	Slenderness ratios (see notes 1 and 2)
		*vv axis:* $0.85L_{vv}/r_{vv}$ but $\geq 0.7L_{vv}/r_{vv} + 15$ *aa axis:* $1.0L_{aa}/r_{aa}$ but $\geq 0.7L_{aa}/r_{aa} + 30$ *bb axis:* $0.85L_{bb}/r_{bb}$ but $\geq 0.7L_{bb}/r_{bb} + 30$
 (See note 3)		*vv axis:* $1.0L_{vv}/r_{vv}$ but $\geq 0.7L_{vv}/r_{vv} + 15$ *aa axis:* $1.0L_{aa}/r_{aa}$ but $\geq 0.7L_{aa}/r_{aa} + 30$ *bb axis:* $1.0L_{bb}/r_{bb}$ but $\geq 0.7L_{bb}/r_{bb} + 30$ (See note 3)
 (See note 4)		*xx axis:* $0.85L_{xx}/r_{xx}$ but $\geq 0.7L_{xx}/r_{xx} + 30$ *yy axis:* $1.0L_{yy}/r_{yy} + 10$
 (See note 4)		*xx axis:* $1.0L_{xx}/r_{xx}$ but $\geq 0.7L_{xx}/r_{xx} + 30$ *yy axis:* $0.85L_{yy}/r_{yy}$ but $\geq 0.7L_{yy}/r_{yy} + 10$

NOTE 1. The length L is taken between the intersections of the centroidal axes or the intersections of the setting out lines of the bolts, irrespective of whether the strut is connected to a gusset or directly to another member.

NOTE 2. Intermediate lateral restraints reduce the value of L for buckling about the relevant axes. For single angle members, L_w is taken between lateral restraints perpendicular to either aa or bb.

NOTE 3. For single angles connected by one bolt, the allowable stress is also reduced to 80 per cent of that for an axially loaded member.

NOTE 4. Double angles are interconnected back-to-back to satisfy Clause 37.

TABLE 2. ALLOWABLE STRESS p_{bc} OR p_{bt} IN BENDING
(See also Clauses 19 and 20 and Tables 3 and 4)

Form	Grade	Thickness of material	p_{bc} or p_{bt}
Sections, bars, plates, wide flats and hot rolled hollow sections. Compound beams composed of rolled sections plated, with thickness of plate. Double channel sections forming a symmetrical I-section which acts as an integral unit.	43	≤ 40 >40 but ≤ 100	180 165
	50	≤ 63 >63 but ≤ 100	230 215
	55	≤ 25	280
Plate girders with single or multiple webs	43	≤ 40 >40 but ≤ 100	170 155
	50	≤ 63 >63 but ≤ 100	215 200
	55	≤ 25	265
Slab bases	All steels		185

TABLE 17*a*. ALLOWABLE STRESS p_c ON GROSS SECTION FOR AXIAL COMPRESSION

As altered Dec. 1989

l/r	p_c (N/mm²) for grade 43 steel									
	0	1	2	3	4	5	6	7	8	9
0	170	169	169	168	168	167	167	166	166	165
10	165	164	164	163	163	162	162	161	160	160
20	159	159	158	158	157	157	156	156	155	155
30	154	154	153	153	153	152	152	151	151	150
40	150	149	149	148	148	147	146	146	145	144
50	144	143	142	141	140	139	139	138	137	136
60	135	134	133	131	130	129	128	127	126	124
70	123	122	120	119	118	116	115	114	112	111
80	109	108	107	105	104	102	101	100	98	97
90	95	94	93	91	90	89	87	86	85	84
100	82	81	80	79	78	77	75	74	73	72
110	71	70	69	68	67	66	65	64	63	62
120	62	61	60	59	58	57	57	56	55	54
130	54	53	52	51	51	50	49	49	48	47
140	47	46	46	45	45	44	43	43	42	42
150	41	41	40	40	39	39	38	38	38	37
160	37	36	36	35	35	35	34	34	33	33
170	33	32	32	32	31	31	31	30	30	30
180	29	29	29	28	28	28	28	27	27	27
190	26	26	26	26	25	25	25	25	24	24
200	24	24	24	23	23	23	23	22	22	22
210	22	22	21	21	21	21	21	20	20	20
220	20	20	20	19	19	19	19	19	19	18
230	18	18	18	18	18	18	17	17	17	17
240	17	17	17	16	16	16	16	16	16	16
250	16	15	15	15	15	15	15	15	15	15
300	11	11	11	11	11	11	10	10	10	10
350	8	8	8	8	8	8	8	8	8	8

NOTE 1. Intermediate values may be obtained by linear interpolation.
NOTE 2. For material over 40 mm thick refer to subclause 30*a*.

CE/0569

Appendix - BS 449: Part2: 1969 Tables & Clause

from **BS 449 Table 10: Allowable maximum shear stress p_q**

Allowable maximum shear stress p_q for sections, bars, plates, wide flats and hot rolled sections of grade 43 steel:

For thickness ≤ 40 mm: 125 N/mm^2
For 40 < thickness ≤ 100 mm: 115 N/mm^2

BS 449 Table 20: Allowable stresses in Rivets and Bolts (N/mm^2)

Description of fasteners	Axial tension	Shear	Bearing
Power-driven rivets	100	100	300
Hand-driven rivets	80	80	250
Close tolerance and turned bolts	120	100	300
Bolts in clearance holes	120	80	250

BS 449 Table 20A : Allowable Bearing stresses on connected parts (N/mm^2)

Description of fasteners	Material of connected part		
	Grade 43	Grade 50	Grade 55
Power-driven rivets Close tolerance and turned bolts	300	420	480
Hand-driven rivets Bolts in clearance holes	250	350	400

BS 449 Table 21: Edge distance of Holes

Diameter of hole	Distance to sheared or hand flame cut edge	Distance to rolled, machine flame cut, sawn or planed edge
Mm	Mm	mm
39	68	62
36	62	56
33	56	50
30	50	44
26	42	36
24	38	32
22	34	30
20	30	28

TABLE 3 *a*. ALLOWABLE STRESS p_{bc} IN BENDING (N/mm^2) FOR CASE A OF CLAUSE 19*a*(2) FOR GRADE 43 STEEL

l/r_y	*D*/*T*									
	5	10	15	20	25	30	35	40	45	50
40	180	180	180	180	180	180	180	180	180	180
45	180	180	180	180	180	180	180	180	180	180
50	180	180	180	180	180	180	180	180	180	180
55	180	180	180	178	176	175	174	174	173	173
60	180	180	176	172	170	169	168	167	167	166
65	180	180	172	167	164	163	162	161	160	160
70	180	177	167	162	159	157	156	155	154	154
75	180	174	163	157	154	151	150	149	148	147
80	180	171	159	153	148	146	144	143	142	141
85	180	168	156	148	143	140	138	137	136	135
90	180	165	152	144	139	135	133	131	130	129
95	180	162	148	140	134	130	127	125	124	123
100	180	160	145	136	129	125	122	119	118	117
105	180	157	142	132	125	120	116	114	112	111
110	180	155	139	128	120	115	111	108	106	105
115	178	152	136	124	116	110	106	103	101	99
120	177	150	133	120	112	106	101	98	96	95
130	174	146	127	113	104	97	94	91	89	88
140	171	142	121	107	97	92	88	85	83	81
150	168	138	116	100	92	87	82	79	77	75
160	166	134	111	96	88	82	77	74	72	70
170	163	130	106	92	84	77	73	69	67	65
180	161	126	102	89	80	73	69	65	63	60
190	158	123	97	85	76	70	65	61	59	56
200	156	119	95	82	73	66	62	58	55	53
210	154	116	92	79	70	63	58	55	52	50
220	151	113	90	77	67	61	56	52	49	47
230	149	110	87	74	65	58	53	49	47	44
240	147	107	85	72	62	56	51	47	44	42
250	145	104	83	69	60	53	48	45	42	40
260	143	101	80	67	58	51	46	43	40	38
270	141	98	78	65	56	49	45	41	38	36
280	139	96	76	63	54	48	43	39	37	35
290	137	94	75	61	52	46	41	38	35	33
300	135	93	73	60	51	44	40	36	34	32

Table 3. Ground roughness, building size and height above ground, factor S_2

H	(1) Open country with no obstructions			(2) Open country with scattered windbreaks			(3) Country with many windbreaks; small towns; outskirts of large cities			(4) Surface with large and frequent obstructions, e.g. city centres		
	Class			Class			Class			Class		
	A	B	C	A	B	C	A	B	C	A	B	C
m												
3 or less	0.83	0.78	0.73	0.72	0.67	0.63	0.64	0.60	0.55	0.56	0.52	0.47
5	0.88	0.83	0.78	0.79	0.74	0.70	0.70	0.65	0.60	0.60	0.55	0.50
10	1.00	0.95	0.90	0.93	0.88	0.83	0.78	0.74	0.69	0.67	0.62	0.58
15	1.03	0.99	0.94	1.00	0.95	0.91	0.88	0.83	0.78	0.74	0.69	0.64
20	1.06	1.01	0.96	1.03	0.98	0.94	0.95	0.90	0.85	0.79	0.75	0.70
30	1.09	1.05	1.00	1.07	1.03	0.98	1.01	0.97	0.92	0.90	0.85	0.79
40	1.12	1.08	1.03	1.10	1.06	1.01	1.05	1.01	0.96	0.97	0.93	0.89
50	1.14	1.10	1.06	1.12	1.08	1.04	1.08	1.04	1.00	1.02	0.98	0.94
60	1.15	1.12	1.08	1.14	1.10	1.06	1.10	1.06	1.02	1.05	1.02	0.98
80	1.18	1.15	1.11	1.17	1.13	1.09	1.13	1.10	1.06	1.10	1.07	1.03
100	1.20	1.17	1.13	1.19	1.16	1.12	1.16	1.12	1.09	1.13	1.10	1.07
120	1.22	1.19	1.15	1.21	1.18	1.14	1.18	1.15	1.11	1.15	1.13	1.10
140	1.24	1.20	1.17	1.22	1.19	1.16	1.20	1.17	1.13	1.17	1.15	1.12
160	1.25	1.22	1.19	1.24	1.21	1.18	1.21	1.18	1.15	1.19	1.17	1.14
180	1.26	1.23	1.20	1.25	1.22	1.19	1.23	1.20	1.17	1.20	1.19	1.16
200	1.27	1.24	1.21	1.26	1.24	1.21	1.24	1.21	1.18	1.22	1.21	1.18

CVX3441 – Final Examination 2024/2025

0054

Table 8. Pressure coefficients C_{pe} for pitch roofs of rectangular clad buildings

Building height ratio	Roof angle	Wind angle α 0°		Wind angle α 90°		Local coefficients			
		E F	G H	E G	F H				
	degrees								
$\frac{h}{w} \leq \frac{1}{2}$	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
$\frac{1}{2} < \frac{h}{w} \leq 1$	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				
$1 < \frac{h}{w} < 6$	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				

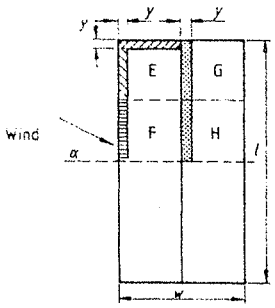
NOTE 1. h is the height to eaves or parapet and w is the lesser horizontal dimension of a building.

NOTE 2. The pressure coefficient on the underside of any roof overhang should be taken as that on the adjoining wall surface.

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 $0.15w$, whichever is the lesser.