Department: Civil Engineering
Level: Third (Classes) & Fourth (Credit)
Semester: Second, 2022-2023
Subject: Steel Design 2
Code: CIE 324 & CIE 407

Ministry of Higher Education
High Institute of Engineering & Technology
New Damietta

Final-Term Exam
Time Allowed: 3:00 hr
Full marks: 100%
Page Numbers: 2
Date: 11/6/2023

Attempt all questions. *Use neat sketches when it is necessary.*
Assume any missing data reasonably.

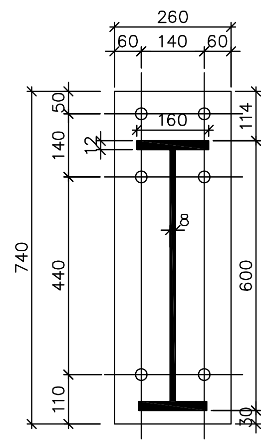
An industrial steel building shown below. The building is composed of steel frames spaced at 6.0 m, it is required to:	Topic	Competencies	LO's
1- (25%) Design the welded built-up cross-section of the crane track girder (A).	1	C1	a3, b3, c3
2- (25%) Design combined column (h-i) M=36 t.m, N=55 t, Q=8 t. (Use I-sections IPN).	6 7	C1 C11	a3, b3, c3 a1, c1
3- (25%) Design the column (a-b-c) hinged base at (a) N = 70 t, Q = 14 t.	5	C11 C12	c1 b1
4- (25%) Choose suitable high strength friction type bolts size for the connection at (c). Then, perform complete design (head plate, fillet weld). (M=18 t.m, Q=8 t).	2 3 4	C1 C11 C12	c3 c1 b1

Data:

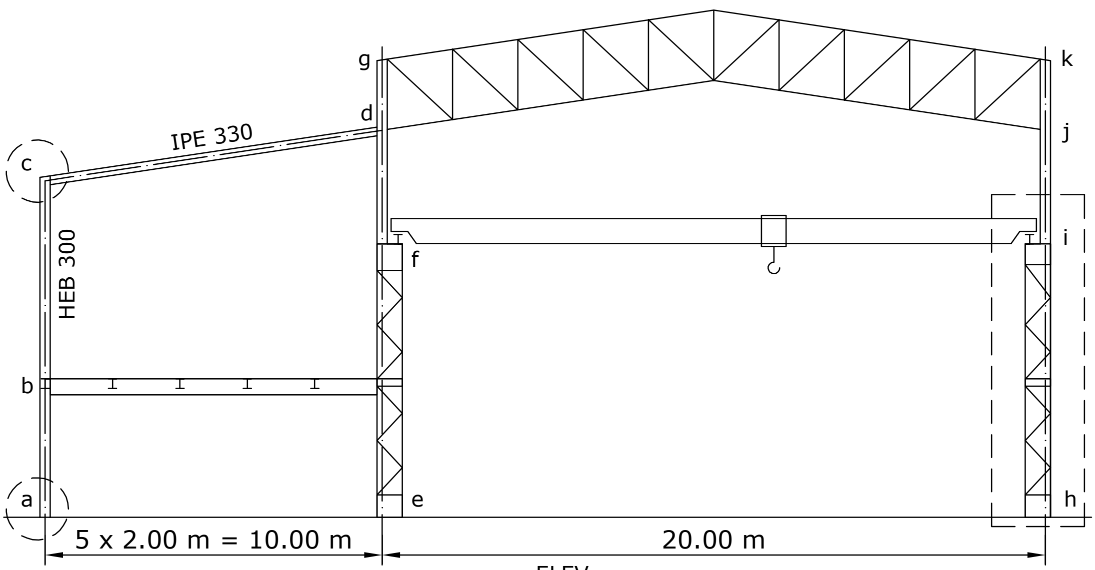
Steel Grade St37

All loads are from Case I

High Strength Bolt Grade 10.9



Connection at (c)



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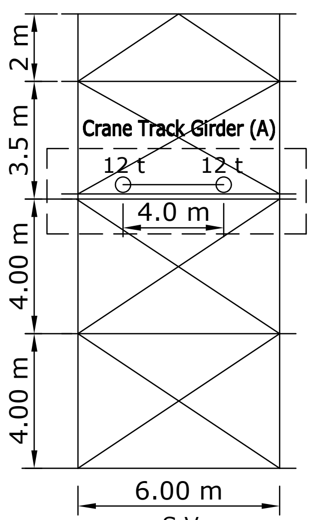

S.V

1) Axial Compression & Bi-axial Bending:

$$\frac{f_{ca}}{F_c}+\frac{f_{bcx}}{F_{bcx}}A_1+\frac{f_{bcy}}{F_{bcy}}A_2 \le 1.0$$

Actual compressive stress: $f_c = \dfrac{N}{A}\ (t/cm^2)$

Allowable compressive stress:

$$F_c = 1.4 - 0.000065\ \lambda^2 \quad \cdots\ \lambda \le 100$$

$$F_c = \frac{7500}{\lambda^2} \quad \cdots\ \lambda \ge 100$$

Where: $\lambda = max\{\lambda_x, \lambda_y\}$, $\quad F_c\ in\ (t/cm^2)$

$$if\ \frac{f_{ca}}{F_c} < 0.15:\ A_1 = A_2 = 1.0$$

$$if\ \frac{f_{ca}}{F_c} \ge 0.15:\ A_1 = \frac{C_{mx}}{1-\dfrac{f_{ca}}{F_{Ex}}} \ge 1.0, \qquad A_2 = \frac{C_{my}}{1-\dfrac{f_{ca}}{F_{Ey}}} \ge 1.0$$

F_{Ex}, F_{Ey} = Euler stress divided by a factor of safety for buckling in (t/cm^2)

$$F_{Ex} = \frac{7500}{\lambda_x^2}, \qquad F_{Ey} = \frac{7500}{\lambda_y^2}$$

1) Axial Compression & Bi-axial Bending:

$$\frac{f_{ca}}{F_c}+\frac{f_{bcx}}{F_{bcx}}A_1+\frac{f_{bcy}}{F_{bcy}}A_2 \le 1.0$$

$L_u > L_{u,max}$: $\quad F_{bcy} = 0.58\ F_y$

$$F_{bcx} = F_{ltb} = \sqrt{F_{ltb1}^2 + F_{ltb2}^2} \le 0.58\ F_y$$

$$F_{ltb1} = \frac{800\ A_f}{L_u\ d}\ C_b \le 0.58\ F_y$$

F_{ltb2}:

$$if\ \frac{L_u}{r_T} < 84\sqrt{\frac{C_b}{F_y}} \qquad F_{ltb2} = 0.58\ F_y$$

$$if\ \ 84\sqrt{\frac{C_b}{F_y}} \le \frac{L_u}{r_T} \le 188\sqrt{\frac{C_b}{F_y}}$$

$$F_{ltb2} = \left(0.64 - \frac{(L_u/r_T)^2\ F_y}{1.176\times 10^5 C_b}\right) F_y \le 0.58\ F_y$$

$$if\ \frac{L_u}{r_T} > 188\sqrt{\frac{C_b}{F_y}} \qquad F_{ltb2} = \frac{12000}{(L_u/r_T)^2}\ C_b \le 0.58\ F_y$$

Compute r_T
For compression flange $+\frac{1}{6}$ web

$z = \dfrac{d - 2\,t_f}{6}$

$A_T = b_f\,t_f + z\,t_w$

$I_{yT} = \dfrac{1}{12}(t_f\,b_f^3 + z\,t_w^3)$

$r_T = \sqrt{I_{yT}/A_T}$

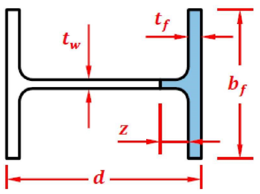

Table (6.3) Properties and Strength of High Strength Bolts (Grade 10.9)

Bolt Diameter d (mm)	Bolt Area A (cm 2)	Stress Area A (cm 2)	Pretension Force T (ton)	Permissible Friction Load of One Bolt Per One Friction Surface, Ps (ton): Ordinary Steel Work, St. 37 & 42~44, μ = 0.4, Case of Loading I	II	Ordinary Steel Work, St. 50~55, μ = 0.5, Case of Loading I	II	Bridges and Cranes, St. 37 & 42~44, μ = 0.4, Case of Loading I	II	Bridges and Cranes, St. 50~55, μ = 0.5, Case of Loading I	II
M12	1.13	0.84	5.29	1.69	2.01	2.11	2.52	1.32	1.56	1.65	1.95
M16	2.01	1.57	9.89	3.16	3.37	3.95	4.71	2.47	2.92	3.09	3.66
M20	3.14	2.45	15.43	4.93	5.90	6.17	7.36	3.85	4.56	4.82	5.71
M22	3.80	3.03	19.08	6.10	7.27	7.63	9.10	4.77	5.65	5.96	7.06
M24	4.52	3.53	22.23	7.11	8.45	8.89	10.60	5.55	6.58	6.94	8.22
M27	5.73	4.59	28.91	9.25	11.03	11.56	13.78	7.22	8.55	9.03	10.70
M30	7.06	5.61	35.34	11.30	13.48	14.13	16.86	8.83	10.46	11.04	13.07
M36	10.18	8.17	51.47	16.47	19.64	20.58	24.55	12.86	15.24	16.08	19.05

* For HSB Grade 8.8, the above values shall be multiplied x 0.7

$$P = \left[\frac{\dfrac{1}{2} - \dfrac{w\ t_p^4}{30\ a\ b^2 A_s}}{\left(\dfrac{3a}{4b}\right)\left(\dfrac{a}{4b}+1\right) + \dfrac{w\ t_p^4}{30\ a\ b^2 A_s}}\right].T_{ext,b,M,1}$$

$$t_p \approx 0.613\ \sqrt{T_{ext,b,M,1}\ \frac{2b + 2s + t_b}{w\ F_b}}$$

$$P \approx \left(\frac{3b}{8a} - \frac{t_p^3}{327}\right) T_{ext,b,M,1}$$

Designation		Dimensions							Section properties: Area	Strong axis x-x					Weak axis y-y				Torsion	
	Wt kg/m	h mm	b mm	t_w mm	t_f mm	r_1 mm	r_2 mm	d mm	A cm^2	I_x cm^4	S_x cm^3 Elastic	Z_x cm^3 Plastic	r_x cm	A_{vx} cm^2	I_y cm^4	S_y cm^3 Elastic	Z_y cm^3 Plastic	r_y cm	J cm^4	I_w cm^6 $x10^3$
IPN 260	41.9	260	113	9.4	14.1	9.4	5.6	208.9	53.3	5740	442	514	10.4	26.08	288	51	85.9	2.32	33.5	44.1
IPN 280	47.9	280	119	10.1	15.2	10.1	6.1	225.1	61	7590	542	632	11.1	30.18	364	61.2	103	2.45	44.2	64.6
IPN 300	54.2	300	125	10.8	16.2	10.8	6.5	241.6	69	9800	653	762	11.9	34.58	451	72.2	121	2.56	56.8	91.8
IPN 320	61	320	131	11.5	17.3	11.5	6.9	257.9	77.7	12510	782	914	12.7	39.26	555	84.7	143	2.67	72.5	129
IPN 340	68	340	137	12.2	18.3	12.2	7.3	274.3	86.7	15700	923	1080	13.5	44.27	674	98.4	166	2.8	90.4	176
IPN 360	76.1	360	143	13	19.5	13	7.8	290.2	97	19610	1090	1276	14.2	49.95	818	114	194	2.9	115	240
IPN 380	84	380	149	13.7	20.5	13.7	8.2	306.7	107	24010	1260	1482	15	55.55	975	131	221	3.02	141	319
IPN 400	92.4	400	155	14.4	21.6	14.4	8.6	322.9	118	29210	1460	1714	15.7	61.69	1160	149	253	3.13	170	420
IPN 450	115	450	170	16.2	24.3	16.2	9.7	363.6	147	45850	2040	2400	17.7	77.79	1730	203	345	3.43	267	791
IPN 500	141	500	185	18	27	18	10.8	404.3	179	68740	2750	3240	19.6	95.6	2480	268	456	3.72	402	1400
IPN 550	166	550	200	19	30	19	11.9	445.6	212	99180	3610	4240	21.6	111.3	3490	349	592	4.02	544	2390
IPN 600	199	600	215	21.6	32.4	21.6	13	485.8	254	138800	4627	5452	23.39	138	4674	435	752	4.29	787	3814
IPE 330	49.1	330	160	7.5	11.5	18	307	271	63	11770	713.1	804.3	13.71	30.81	788.1	98.52	153.7	3.55	28.15	199.1
HEB 300	117	300	300	11	19	27	262	208	149.1	25170	1678	1869	12.99	47.43	8563	570.9	870.1	7.58	185	1688