4. Estimate the design force of member 1. Design a suitable section with the **lowest possible weight** for member 1 using one angle. (5 P)
5. Choose a suitable section for member 2, if the design force was – 10 tons (case II) and + 15.0 tons (case I1). (using two angles back to back) (5 P)
6. Find the maximum **tention and compresion** capacity (Case I and Case II) of member 3 if it was made of **2 UPN # 100** back to back. (5 P)
7. Give full design for member 4, if the design force of memebr 4 in the transversal wind bracing shown in the figure is ±2 tons. (5 P)
8. Find a suitable **UPN** section for a typical purlin in the middle span. (assume C_b=1.0). (10 P)
9. Check safety of the bending stresses of the crane track girder (CTG) which was designed as **HEB # 300**. (10 P)

Question No. 2 (10 points)

Design a column to carry a total load of **120 tons**. Using an open section composed of two UPN face to face as shown in **Figure 2**. The column is **hinged** at both ends and has the shown transversal wind bracing system. The column has a single setting of lacing bars with an inclination angle of 45°. Assume bolts diameter of 16 mm

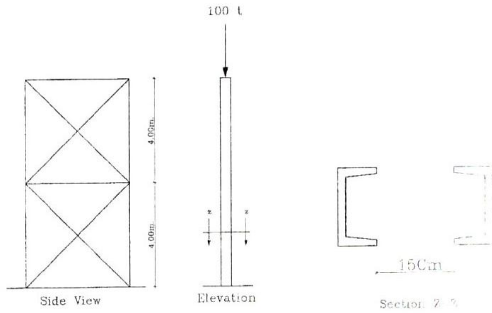


Figure (2)

Question No. 3 (10 points)

Figure 3 illustrates a Plan View of an industrial building to be constructed using a series of steel trusses. From Axes (1) to (6) the spacing between the trusses is 7.0m. However, From Axes (6) to (12) the spacing is 5.0m. The required minimum clear height under the lower chord is 7.0m. Draw to scale 1:400 a complete general layout of the building showing the main supporting elements and the bracing systems. (structural roof plan, elevation at axes (A), (C), and longitudinal bracing. Cross sections at Axes (1) and (6).

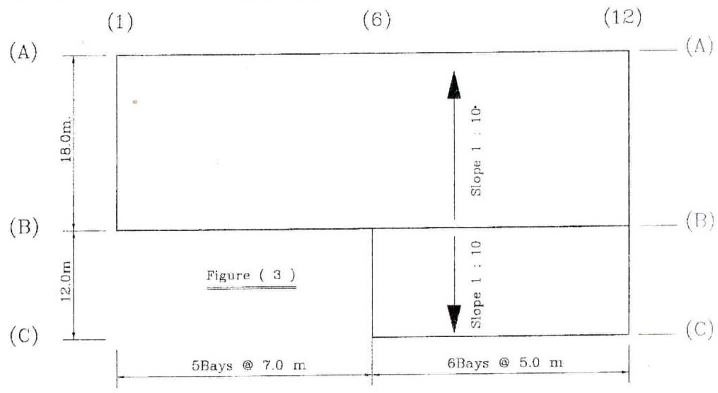


Figure (3)

Fayoum University
Faculty of Engineering
Department of Civil Engineering

1st Semester – 2015/2016
Total Grade: 70Points

Final Exam (3rd Year Civil)

Steel Structures

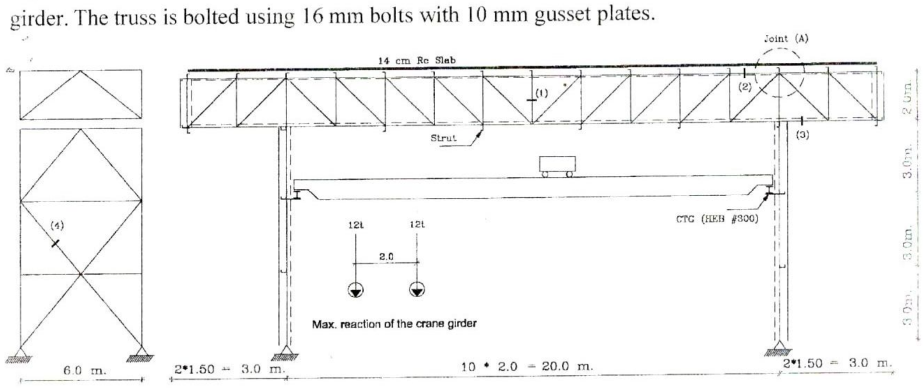
Date: Saturday 9 Jan. 2016 — Time: 09:30am – 12:30pm

Total Grade: 70 Points (70P) — Instructor: Dr.Tarek ELHadka, Lecturer

Notes: 1. Answer all questions and make reasonable assumptions ONLY IF needed.
2. No aids other than calculators
3. Answer should be neat, specific, and in order. Highlight the main steps and results.
4. Clear sketches and proper calculations are strictly required
5. Use steel 37 for design and use H.S.B. 10.9 for connections.

Question No. 1 (60 points)

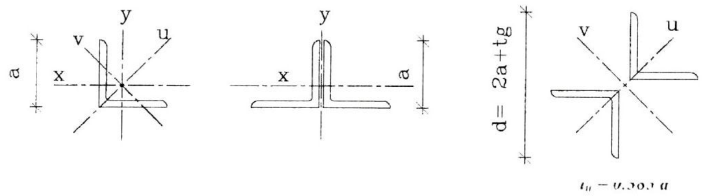
Steel 37 was used to construct the industrial building shown in figure 1. The building is located in cairo (wind presure = 60 Kg/m^2). The building roof covers an area of 26x60 m^2. The trusses are spaced every 6.0 m. The steel own weight is equal to 50 Kg/m^2. Rigid inaccessible roof cover of 14 cm RC slab is provided. The design live load is 80 Kg/m^2. The top flanges of the purlins are imbedded in the RC slab. Sides and both rear and front ends are covered with corrugated sheets. A crane of 16 ton capacity and a crane girder of 20 m span transfer maximum reactions of 12t@2m to the crane track girder. The truss is bolted using 16 mm bolts with 10 mm gusset plates.



TWB — *Main System*

Figure 1

1. Draw Neat sketches of the building layout (Elev., Plan and Side View) with scale 1:200. Illustrate the utilized wind bracing system in the layout. (10 P)
2. State how in-plan and out-of-plan wind load are transferred to ground. Explain your answer with neat sketches for the cantilever truss shown in figure 1. (5 P)
3. Calculate the load at joint (A) due to Dead Load, Live Load and Wind Load; hence find the maximum joint load at (A). (5 P)



*** Stiffness condition:** (λ = L/i)

$\lambda \leq 300$ for tension member

$\lambda \leq 180$ for compression member

$\lambda \leq 200$ for bracing member

*** Construction condition**

$a - t \geq 3\,\phi$

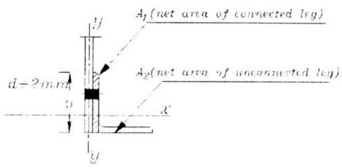
Allowable Tensile Stresses for Different Steel Grades

Grade of Steel	*F_t (t/cm²)*
St 37	1.40
St 44	1.60

The above values for the allowable stress, F_t, may be increased by 20% if secondary stresses are considered *(case of loading II)*.

Allowable Compressive Stresses for Different Steel Grades

Grade of Steel	*F_{pc} (t/cm²)*	
	$\lambda \leq 100$	$\lambda \geq 100$
St 37	**$1.4 - 0.000065\,\lambda^2$**	**$7500 / \lambda^2$**
St 44	**$1.6 - 0.000085\,\lambda^2$**	



$$A_{net} = A_1 + A_2\left(\frac{3A_1}{3A_1 + A_2}\right)$$

Where A_1 is the net area of the connected leg and A_2 is the area of the unconnected leg.

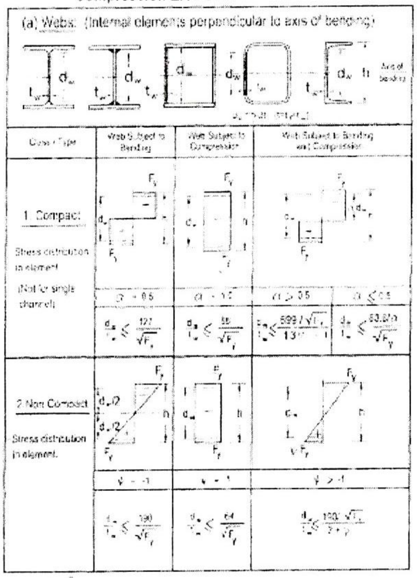
2.6.3 Allowable Stress in Shear q_{all}

2.6.3.1 On the gross effective area in resisting shear as defined below:

$$q_{all} = 0.35\,F_y \qquad \text{2.2}$$

Grade of Steel	q_{all} (t/cm²)	
	$t \leq 40$ mm	40 mm < t ≤ 100 mm
St 37	0.84	0.75
St 44	0.98	0.89
St 52	1.26	1.17

Table (2.1a) Maximum Width to Thickness Ratios for Stiffened Compression Elements



F_y in t/cm^2

2.6.5 Allowable Stress in Bending F_b

2.6.5.1 Tension and compression due to bending on extreme fibers of "compact" sections symmetric about the plane of their minor axis and bent about their major axis:

$$F_b = 0.64\, F_y \qquad 2.16$$

Grade of Steel	F_b (t/cm^2)	
	$t \le 40$ mm	40 mm $< t \le 100$ mm
St 37	1.54	1.38
St 44	1.76	1.63
St 52	2.30	2.14

In order to qualify under this section:

1- The member must meet the compact section requirements of Table 2.1

2- The laterally unsupported length (L_u) of the compression flange is limited by the smaller of:

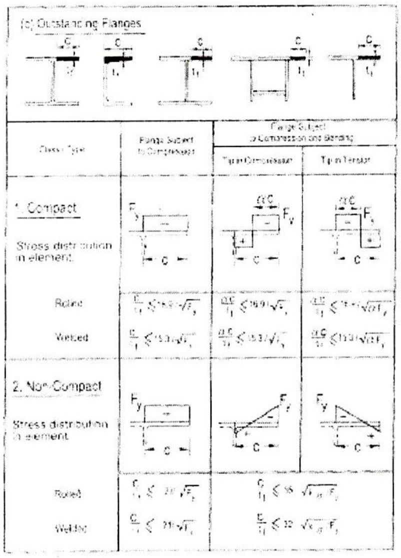
i- For box sections:

$$L_u < \frac{84}{F_y} b_f \quad \text{Or} \quad L_u \le \left(137 + 84\frac{M_1}{M_2}\right) b_f / F_y \qquad 2.17$$

ii- For other sections

$$L_u \le \frac{20 b_f}{\sqrt{F_y}} \quad \text{Or} \quad L_u \le \frac{1380 A_f}{d F_y} C_b \qquad 2.18$$

Table (2.1c) Maximum Width to Thickness Ratios for Unstiffened Compression Elements



Where b_f is the compression flange width. M_1/M_2 is the algebraic ratio of the smaller to the larger end moments taken as positive for reverse curvature bending. **d** is the beam depth and C_b is given in Equation 2.28.

2.6.5.2 Tension and compression due to bending on extreme fibers of doubly symmetrical I-shape members meeting the compact section requirements of Tables 2.1a & 2.1c, and bent about their minor axis, solid round and square bars, solid rectangular sections bent about their minor axis:

$$F_b = 0.72\, F_y \qquad 2.19$$

2.6.5.3 Tension and compression on extreme fibers of rectangular tubular sections meeting the compact section requirements of Tables 2.1a & 2.1b, and bent about their minor axis

$$F_b = 0.64\, F_y \qquad 2.20$$

2.6.5.4 Tension and compression on extreme fibers of box type flexural members meeting the "non-compact" section requirements of Table 2.1b, and bent about either axis

$$F_b = 0.58\, F_y \qquad 2.21$$

2.6.5.5 On extreme fibers of flexural members not covered by Clauses 2.6.5.1 – 2.6.5.4.

1- **Tension F_{bt}**

$$F_{bt} = 0.58\, F_y \qquad 2.22$$

Hence, F_{bt} is taken as follows:

Grade of Steel	F_{bt} (t/cm^2)	
	$t \le 40$ mm	40 mm $< t \le 100$ mm
St 37	1.4	1.3
St 44	1.6	1.5
St 52	2.1	2.0

2- Compression F_{bc}

I. When the compression flange is braced laterally at intervals exceeding L_u as defined by Equations 2.17 or 2.18, the allowable bending stress in compression F_{bc} will be taken as the larger value from Equations 2.23 and 2.24, 2.25, or 2.26 with a maximum value of 0.58 F_y.

i- For shallow thick flanged sections, where approximately ($\frac{t_f L_u}{b_f d} > 4$), for any value of L_u/r_T, the lateral torsional buckling stress is governed by the torsional strength given by:

$$F_{ltb_1} = \frac{800}{L_u \cdot d / A_f} C_b \le 0.58\ F_y \quad \ldots\ldots\ldots \quad 2.23$$

ii- For deep thin flanged sections, where approximately ($\frac{t_f L_u}{b_f d} < 0.40$), the lateral torsional buckling stress is governed by the buckling strength given by:

a- When $L_u / r_T < 84\sqrt{\frac{C_b}{F_y}}$, then.

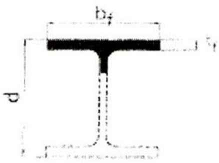
$$F_{ltb_2} = 0.58\ F_y \quad \ldots\ldots\ldots \quad 2.24$$

b- When $84\sqrt{\frac{C_b}{F_y}} \le L_u / r_T \le 188\sqrt{\frac{C_b}{F_y}}$, then:

$$F_{ltb_2} = (0.64 - \frac{(L_u / r_T)^2 F_y}{1.176 \times 10^5 C_b}) F_y \le 0.58\ F_y \quad \ldots\ldots\ldots \quad 2.25$$

c- When $L_u / r_T > 188\sqrt{\frac{C_b}{F_y}}$, then:

$$F_{ltb_2} = \frac{12000}{(L_u / r_T)^2} C_b \le 0.58\ F_y \quad \ldots\ldots\ldots \quad 2.26$$



Alternatively, the lateral torsional buckling stress can be computed more accurately as the resultant of the above mentioned two components as:

$$F_{ltb} = \sqrt{F_{ltb_1}^2 + F_{ltb_2}^2} \le 0.58 F_y \quad \ldots\ldots\ldots \quad 2.27$$

Table (9.1) Maximum Deflection in Buildings and Bridges

Member	Max. Deflection
Beams and trusses in buildings carrying plaster or other brittle finish	L/300
All other beams	L/200
Cantilevers	L/180
Horizontal deflection at tops of columns in single-storey buildings other than portal frames	Height / 300
Horizontal deflection in each storey of a building with more than one storey	Height of storey under consideration / 300
Horizontal deflection at the top of a building with more than one storey	Total height of building / 500
Horizontal deflection at tops of columns in portal frames without cranes	Height / 150
Horizontal deflection at tops of columns in portal frames with cranes	To be decided according to the recommendations of the gantry crane manufacturer, but should not exceed the height / 150
Crane track girders	L/800
Railway bridges	L/800
Roadway bridges	L/600
Overhanging portions of bridges	L/300

9.1.5.3 Equivalent Slenderness Ratio of Battened or Latti Compression Members

For battened or latticed compression members, the slenderne ratio ($k\ell$) shall be modified as given below:

a- For buckling in plane (y-y) Figure 9.2, the permissible stress members shall be obtained by using the slenderness ratios and th formulae for solid members given in Chapter 2.

b- For buckling in the plane (x-x), the slenderness ratio (ℓ_y/r_y) these formulae shall be replaced by the values given hereunder

i. For members with lacing bars and batten plates at their ends:

$$\sqrt{\left(\frac{\ell_y}{r_y}\right)^2 + \left(\frac{\ell_z}{r_z}\right)^2} \quad \ldots\ldots\ldots \quad 9.$$

ii. For members with batten plates only:

$$\sqrt{\left(\frac{\ell_y}{r_y}\right)^2 + \left(1.25\frac{\ell_z}{r_z}\right)^2} \quad \ldots\ldots\ldots \quad 9.$$

Where :

ℓ_z = Unsupported length of each separate part as defined before.

r_z = Radius of gyration for one part for the axis (z-z).

c- Members connected in both directions by lacing bars or batten plates shall be designed similarly by calculating the value indicated in Equations 9.1 and 9.2 for the axis (x-x) or (y-y) giving the smallest moment of inertia for the total section and (r_z) for the axis (z-z) giving the least moment of inertia for one separate part.

9.1.5.1 Lacing of Compression Members

9

As far as practicable, the lacing system shall not be varied throughout the length of the compression member.

Lacing bars shall be inclined at an angle of 50° to 70° to the axis of the member where a single intersection system is used and at an angle of 40° to 50° where a double intersection system is used.

Lacing bars shall be connected such that there will be no appreciable interruption of the triangulation of the system.

The maximum unsupported length of the compression member between lacing bars *(lz)* whether connected by welding, bolting or riveting, shall be such that the slenderness ratio of each component part between consecutive connections (l_z/rz) shall not be more than 50 in bridges and 60 in buildings or *2/ 3* times the slenderness ratio of the member as a whole about the x-x axis, whichever is the lesser.

The required section of lacing bars shall be determined by using the permissible stresses for compression and tension members given in Chapter 2 .

The ratio (kl/r) of the lacing bars shall not exceed 140. For this purpose the effective length (kl) shall be taken as follows:

i- In bolted or riveted connections: the length between the inner end bolts or rivets of the lacing bar in single intersection lacing and 0.7 of this length for double intersection lacing effectively connected at the intersection.

ii-In welded connections: the distance between the inner ends of effective lengths of welds connecting the bars to the components in single intersection lacings, and 0.7 of the length for double intersection lacing effectively connected at the intersection.

Laced compression members shall be provided with batten plates at the ends of the lacing system, at points where the lacing system is interrupted, and where the member is connected to another member.

The length of end batten plates measured between end fastenings along the longitudinal axis of the member shall be not less than the perpendicular distance between the centroids of the main components, and the length of intermediate batten plates shall not be less than *3/4* of this distance, see Figure 9.1.
The thickness of the plates shall not be less than *1/50* of the distance between the innermost lines of welds, bolts or rivets

Lacing bars and their fastenings shall be capable of carrying the forces for which the lacing system is designed, (considered as 2% of the force in the member under design).

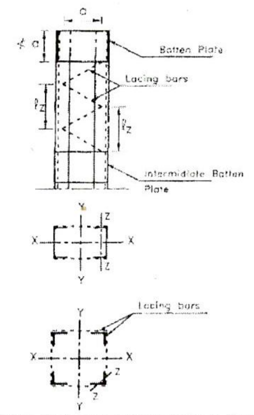


Figure (9.1) Laced Compression Members

UPN No	Area cm^2	h (mm)	b (mm)	$S=t_w$ (mm)	$t_f=r_1$ (mm)	I_x (cm^4)	Z_x (cm^3)	i_x (cm)	I_y (cm^4)	Z_y (cm^3)	i_y (cm)	e_y (cm)
50	7.12	50	38	5	7	26.4	10.6	1.92	9.12	3.75	1.13	1.37
60	6.46	60	30	6	6	31.6	10.5	2.21	4.51	2.16	0.84	0.91
65	9.03	65	42	5.5	7.5	57.5	17.7	2.25	14.1	5.07	1.25	1.42
70	8.57	70	40	6	6.5	61.1	17.5	2.67	11.4	4.1	1.15	1.42
80	11	80	45	6	8	106	26.5	3.1	19.4	6.36	1.33	1.45
100	13.5	100	50	6	8.5	206	41.2	3.19	29.3	8.49	1.47	1.55
120	17	120	55	7	9	364	60.7	4.62	43.2	11.1	1.59	1.6
140	20.4	140	60	7	10	605	86.4	5.45	62.7	14.8	1.75	1.75
160	24	160	65	7.5	10.5	925	116	6.21	85.3	18.3	1.89	1.84
180	28	180	70	8	11	1350	150	6.95	114	22.4	2.02	1.92
200	32.2	200	75	8.5	11.5	1910	191	7.7	148	27	2.14	2.01
220	37.4	220	80	9	12.5	2690	254	8.84	197	33.6	2.3	2.14
240	42.3	240	85	9.5	13	3600	300	9.22	248	39.6	2.42	2.23
260	48.3	260	90	10	14	4820	371	9.99	317	47.7	2.56	2.36
280	53.3	280	95	10	15	6280	448	10.9	399	57.2	2.74	2.53
300	58.8	300	100	10	16	8030	535	11.7	459	67.8	2.9	2.7
320	75.8	320	100	14	17.5	10870	679	21.1	597	80.6	2.81	2.6
350	77.3	350	100	14	16	12840	734	12.9	570	75	2.72	2.4
380	80.4	380	102	13.5	16	15760	829	14	615	78.7	2.77	2.38
400	91.5	400	110	14	18	20350	1020	14.9	846	102	3.04	2.65

HEB	Area	Dimensions (mm)				X-X			Y-Y		
NO	(cm^2)	h	b	t_w	t_f	I_x (cm^4)	Z_Y (cm^3)	i_x (cm)	I_y (cm^4)	Z_y (cm^3)	i_y (cm)
100	26	100	100	6	10	450	89.9	4.16	167	33.5	2.53
120	34	120	120	6.5	11	864	144	5.04	318	52.9	3.06
140	43	140	140	7	12	1510	216	5.93	550	78.5	3.58
160	54.3	160	160	8	13	2490	311	6.78	889	111	4.05
180	65.3	180	180	8.5	14	3830	426	7.66	1360	151	4.57
200	78.1	200	200	9	15	5700	570	8.54	2000	200	5.07
220	91	220	220	9.5	16	8090	736	9.43	2840	258	5.59
240	106	240	240	10	17	11260	938	10.3	3920	327	6.08
260	118	260	260	10	17.5	14920	1150	11.2	5130	395	6.58
280	131	280	280	10.5	18	19270	1380	12.1	6590	471	7.09
300	149	300	300	11	19	25170	1680	13	8560	571	7.58
320	161	320	300	11.5	20.5	30820	1930	13.8	9240	616	7.57
340	171	340	300	12	21.5	36660	2160	14.6	9690	646	7.53
360	181	360	300	12.5	22.5	43190	2400	15.6	1014	676	7.49
400	198	400	300	13.5	24	57680	2880	17.1	1082	721	7.4
450	218	450	300	14	26	79890	3550	19.1	1172	781	7.33
500	239	500	300	14.5	28	10720	4290	21.2	1262	482	7.27
550	254	550	300	15	29	13670	4970	23.2	1308	872	7.17
600	270	600	300	15.5	30	17100	5700	25.2	1353	902	7.08
650	286	650	300	16	31	21060	6480	27.1	1398	932	6.99
700	306	700	300	17	32	25690	7340	29	1444	963	6.87
800	334	800	300	17.5	33	35910	8980	32.8	1490	994	6.68
900	371	900	300	18.5	35	49410	10980	36.5	1582	1050	6.53
1000	400	1000	300	19	36	64470	12890	40.1	1628	1090	6.38