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Analysis and Design of a Steel Communication Tower

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Abstract— *The purpose of this paper is to analyze and design a steel communications tower using the Etabs program , and calculate the lateral loads for this tower according to the British code BS3699 part2 and enter these values after calculating them in the Etabs program to obtain the maximum value of the lateral loads that the tower can bear without being deformed ,as well as obtaining the maximum value of the shear force that can be borne by the sections of the tower ,and also obtaining the maximum value of the overturning moments that the tower can bear without collapsing ,and also obtaining the maximum values of displacement and deviation allowed according to British specifications. Based on these obtained values, the safe sections of the tower were designed after making sure that they are within the permissible limits in the British specifications.*

Keywords— *Lateral loads, deformations, shear force, overturning moment, displacement, deviation, steel communication tower.*

I. Introduction

Communication towers are along structure made mostly of iron used in high-voltage transmission lines. these towers have square bases.
Communication towers can be classified according to the following types: -
1-the monocoque: is separated columns made of galvanized steel with a length of up to 60 meters.
2- roof tops and buildings towers: is the tower that is erected on the roofs of buildings and its height is usually from 6 to 9 meters.
3-the ground towers: are the towers that are erected on natural ground, with a height ranging from 15 to 18 meters.
4- the green towers: it is one of the tallest towers, reaching 120 meters.
5- the wheel site or caw towers: these towers are known as mobile towers that can be moved from one place to another according to the area to be used by the company.
The towers are exposed to lateral loads (live and dead) as in normal buildings, in addition to the lateral loads resulting from the movement of the wind and the force resulting from the lateral loads to an increase in lateral displacement (side sway deflection) due to the increase in thinness in the tall towers.

II. Methodology

In this research, the Etabs program was used to analyze and design the tower and compare the design results obtained from the program with the design results using British specification BS5950.

Wind loads were calculated manually according to the British code (BS3699) following the steps:

The first step: determine the dynamic augmentation (Cr)

According to the height of the building (H) and the coefficient of the type of building (Kb) we define the building type parameter.

Table 1 – Building-type factor K_b

Type of building	K_b
Welded steel unclad flames	8
Bolted steel and reinforced concrete unclad frames	4
Portal sheds and similar light structures with few internal walls	2
Framed buildings with structural walls around lifts and stairs only (e.g. office buildings of open plan or with partitioning)	1
Framed buildings with structural walls around lifts and stairs with additional masonry subdivision walls (e.g. apartment buildings), buildings of masonry construction and timber-framed housing	0.5

Dynamic increase factor (Cr)

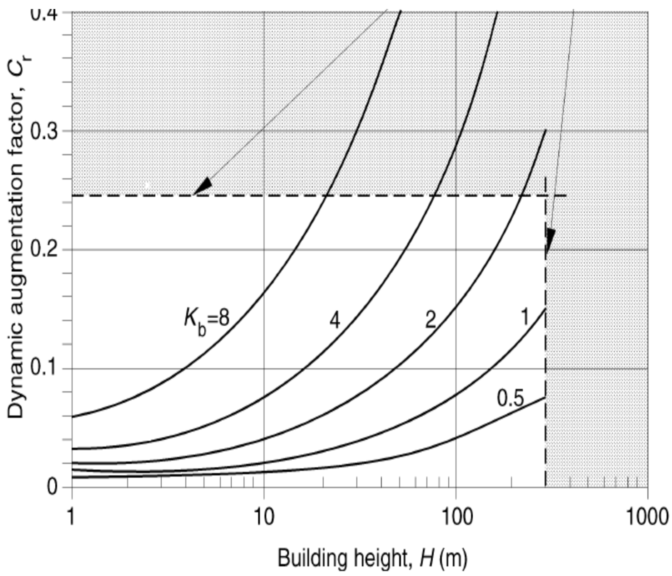

Figure 1. Dynamic augmentation factor Cr

The second step: - check limits of applicability

We must ensure the validity of using static methods based on the tables in the British code (BS6399 -2), or we use mechanical methods.
Cr < ,025 & H < 300 m (ok)
The third step: - determine the basic hourly mean wind speed (Vb).
The fourth step: - determine a site wind speed (Vs)
Vs = Vb *Sa * Sd* Ss* Sp – (1)
Sa = altitude factor

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Sa 1 + ,001 ΔS
ΔS = building level relative to sea level
Sd = direction coefficient = 1

Table 2. value of diraction factor

Direction φ	Direction factor S_d
0° North	0.78
30°	0.73
60°	0.73
90° East	0.74
120°	0.73
150°	0.80
180° South	0.85
210°	0.93
240°	1.00
270° West	0.99
300°	0.91
330°	0.82
360° North	0.78
NOTE Interpolation may be used within this table.	

Fifth step: - calculation of effective speed (Ve)

Ve = Vs * Sb – (2)

Table 3. factor Sb for standard method

Site in country or up to 2 km into town					Site in town, extending ≥ 2 km upwind from the site			
Effective height H_e m	Closest distance to sea upwind km				Effective height H_e m	Closest distance to sea upwind km		
	≤ 0.1	2	10	≥ 100		2	10	≥ 100
≤2	1.48	1.40	1.35	1.26	≤2	1.18	1.15	1.07
5	1.65	1.62	1.57	1.45	5	1.50	1.45	1.36
10	1.78	1.78	1.73	1.62	10	1.73	1.69	1.58
15	1.85	1.85	1.82	1.71	15	1.85	1.82	1.71
20	1.90	1.90	1.89	1.77	20	1.90	1.89	1.77
30	1.96	1.96	1.96	1.85	30	1.96	1.96	1.85
50	2.04	2.04	2.04	1.95	50	2.04	2.04	1.95
100	2.12	2.12	2.12	2.07	100	2.12	2.12	2.07

NOTE 1 Interpolation may be used within each table.
NOTE 2 The figures in this table have been derived from reference [5].
NOTE 3 Values assume a diagonal dimension a = 5 m.
NOTE 4 If H_e > 100 m use the directional method of Section 3.

Step seven: - dynamic pressure (Qs)
Qs = ,613 (Ve^2) {section (2.1.2) Bs6399-2} – (3)
Eighth step: - pressure coefficients (Cp)
Cp = 1.8
Step nine: - size effect factor (Ca)

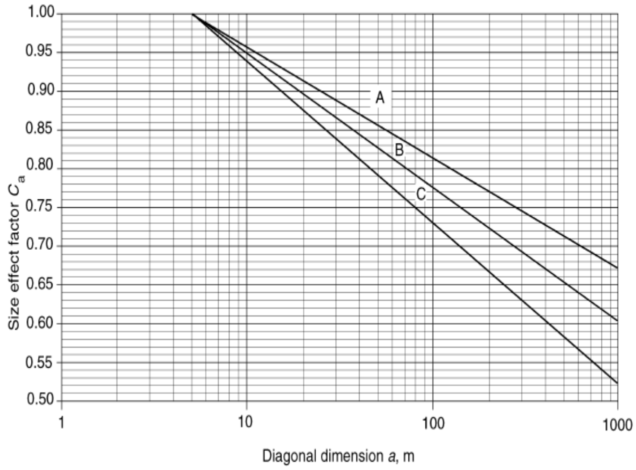

Figure 2. Size effect factor Ca

Effective height H_e m	Site in country: closest distance to sea (km)				Site in town: closest distance to sea (km)		
	0 to < 2	2 to < 10	10 to < 100	≥ 100	2 to < 10	10 to < 100	≥100
≤ 2	A	B	B	B	C	C	C
> 2 to 5	A	B	B	B	C	C	C
> 5 to 10	A	A	B	B	A	C	C
> 10 to 15	A	A	B	B	A	B	B
> 15 to 20	A	A	B	B	A	B	B
> 20 to 30	A	A	A	B	A	A	B
> 30 to 50	A	A	A	B	A	A	B
> 50	A	A	A	B	A	A	B

Tenth step: - external surface pressure (P)

$$P = q_{e*}Cp – (4)$$

Eleventh step: - net pressure across the surface (P)

P = p * A -(5)

After obtaining these values, the tower is modeled on the Etabs program and the values of lateral loads and wind loads that were calculated according to British specification are entered, then the tower is analyzed using the program to obtain the required design values according to British specification.

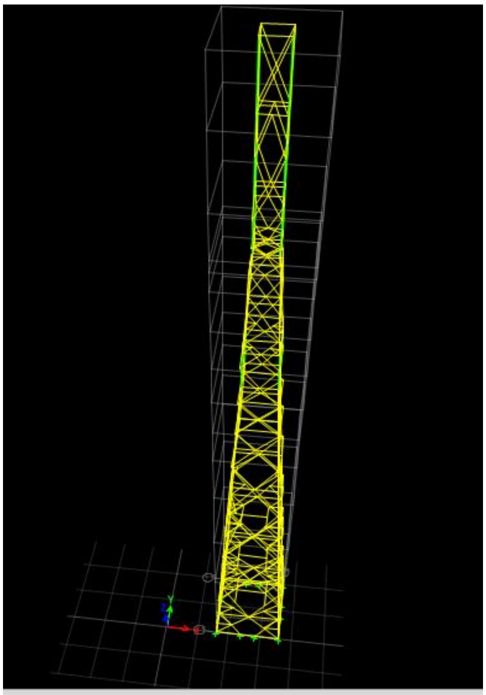

Figure 3. Final model for tower

III. Results and Discussion

Through this research, the values of shear and bending forces in the elements axial forces, moments and displacements resulting from the effect of lateral loads were obtained.

The design sectors of the tower elements were obtained, and the value of the reactions pf the base shown as a result of the effect to the maximum and utilization boundary condition and the effect of lateral loads in both directions x, y were obtained. As shown in the following table

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Table 4. Showing base reactions

Story	`	Load Case/Combo	FX KN	FYKN	FZ KN
Base	1	Dead	-2.9618	-2.3166	32.3017
Base	1	Live	0	0	0
Base	1	windx 1	-22.9017	-10.8522	156.341
Base	1	windx 2	-11.4228	-16.8013	150.1195
Base	1	windy 1	-22.9017	-10.8522	156.341
Base	1	windy 2	-11.4228	-16.8013	150.1195
Base	1	Usl	-3.5542	-2.7799	38.7621
Base	1	Sls	-2.9618	-2.3166	32.3017
Base	1	UDStlS7 Min	-36.209	-26.765	255.3897
Base	1	UDStlD1	-2.9618	-2.3166	32.3017
Base	1	UDStlD2	-2.9618	-2.3166	32.3017
Base	3	Dead	-2.6949	2.2929	33.6605
Base	3	Live	0	0	0
Base	3	windx 1	-21.5572	10.4546	159.1065
Base	3	windx 2	9.7512	-26.4515	-150.0066
Base	3	windy 1	-21.5572	10.4546	159.1065
Base	3	windy 2	9.7512	-26.4515	-150.0066
Base	3	Usl	-3.2339	2.7515	40.3926
Base	3	Sls	-2.6949	2.2929	33.6605
Base	3	UDStlS7 Min	-33.953	-33.8219	-162.8845
Base	3	UDStlD1	-2.6949	2.2929	33.6605
Base	3	UDStlD2	-2.6949	2.2929	33.6605
Base	5	Dead	2.9382	-2.8653	33.8729
Base	5	Live	0	0	0
Base	5	windx 1	-21.0956	10.8881	-156.2255
Base	5	windx 2	12.3649	-21.6231	166.121
Base	5	windy 1	-21.0956	10.8881	-156.2255
Base	5	windy 2	12.3649	-21.6231	166.121
Base	5	Usl	3.5258	-3.4384	40.6475
Base	5	Sls	2.9382	-2.8653	33.8729
Base	5	UDStlS8 Max	33.6472	26.2609	266.1377
Base	5	UDStlD1	2.9382	-2.8653	33.8729
Base	5	UDStlD2	2.9382	-2.8653	33.8729
Base	7	Dead	2.7186	2.889	31.5895
Base	7	Live	0	0	0
Base	7	windx 1	-21.645	-10.4906	-159.0884
Base	7	windx 2	-10.6934	-23.0431	-166.0982
Base	7	windy 1	-21.645	-10.4906	-159.0884
Base	7	windy 2	-10.6934	-23.0431	-166.0982
Base	7	Usl	3.2623	3.4668	37.9074
Base	7	Sls	2.7186	2.889	31.5895
Base	7	UDStlS8 Max	34.109	36.3049	276.7629
Base	7	UDStlD1	2.7186	2.889	31.5895
Base	7	UDStlD2	2.7186	2.889	31.5895

also, the floors shear values were obtained and the maximum value ,193389 and the lowest value -,002353 were obtained. as shown in the following table and figure

Table 5. Showing story strong shear forces

Story	Elevation m	Location	X-Dir KN	Y-Dir KN
Story15	45	Top	0.0003	0.02
		Bottom	0.0003	0.02
Story14	41.88	Top	0.0008	0.0558
		Bottom	0.0008	0.0558
Story13	38.13	Top	0.0012	0.0844
		Bottom	0.0012	0.0844
Story12	35.63	Top	0.0022	0.1529
		Bottom	0.0022	0.1549
Story11	35	Top	0.0017	0.1218
		Bottom	0.0017	0.1081
Story10	33.85	Top	0.0025	0.1722
		Bottom	0.002	0.151
Story9	31.34	Top	0.002	0.169
		Bottom	0.0035	0.1827
Story8	28.83	Top	0.0031	0.1908
		Bottom	0.0027	0.1784
Story7	26.32	Top	0.0028	0.1897
		Bottom	0.0032	0.1796
Story6	23.82	Top	0.0034	0.1895
		Bottom	0.0025	0.1818
Story5	21.31	Top	0.0026	0.1908
		Bottom	0.0036	0.1831
Story4	17.7	Top	0.0038	0.1923
		Bottom	0.002	0.187
Story3	12.68	Top	0.0022	0.1934
		Bottom	0.003	0.1761
Story2	7.6	Top	0.0031	0.1785
		Bottom	0.0009	0.171
Story1	2.64	Top	0.0009	0.1711
		Bottom	-0.0024	0.1711
Base	0	Top	0	0
		Bottom	0	0

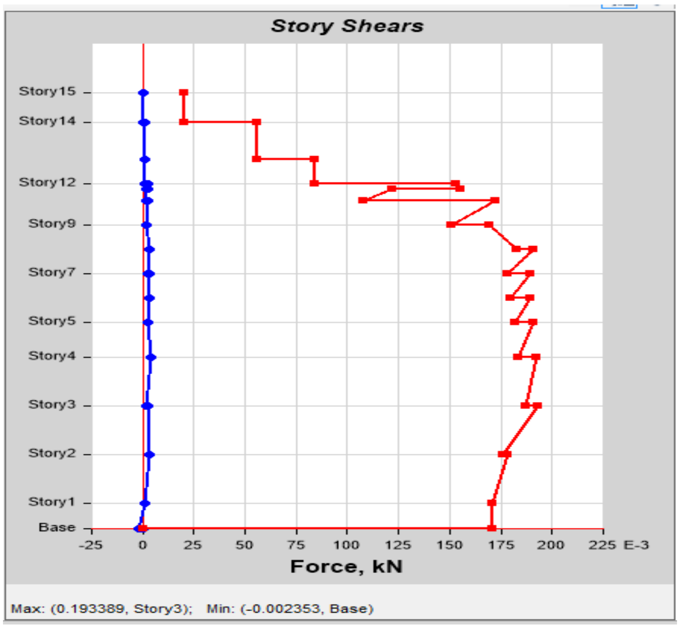

Figure 4. Shown story shear force

the floor displacements were also obtained and the maximum displacement ,659579 mm and the lowest value 0 were obtained.
As shown in the following table and figure

Table 6. Shown story displacement

Story	Elevation	Location	X-Dir	Y-Dir
	m		Mm	mm
Story15	45	Top	0.055	0.112
Story14	41.88	Top	0.088	0.133
Story13	38.13	Top	0.078	0.115
Story12	35.63	Top	0.057	0.092
Story11	35	Top	0.056	0.092
Story10	33.85	Top	0.079	0.111
Story9	31.34	Top	0.065	0.103
Story8	28.83	Top	0.079	0.104
Story7	26.32	Top	0.079	0.122
Story6	23.82	Top	0.083	0.098
Story5	21.31	Top	0.097	0.168
Story4	17.7	Top	0.168	0.174
Story3	12.68	Top	0.495	0.281
Story2	7.6	Top	0.206	0.206
Story1	2.64	Top	0.12	0.086
Base	0	Top	0	0

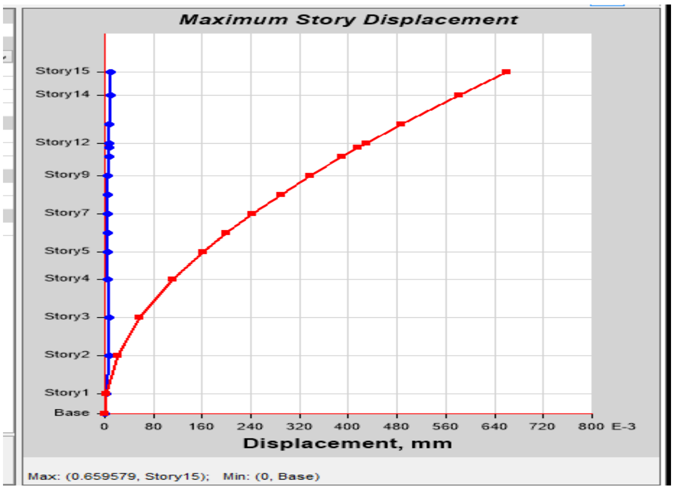

Figure 5. Shown story displacement

Also the overturning moment of the floors was obtained, and the maximum value 9,72412 KN.M was the lowest value -4,672011 KN.M
As shown in the following table and figure

Table 7. Shown floor overturning moment

Story	Elevation m	Location	X-DirKN.m	Y-DirKN.m
Story15	45	Top	0	0
Story14	41.88	Top	0.0481	-0.023
Story13	38.13	Top	0.2323	-0.1108
Story12	35.63	Top	0.4402	-0.2098
Story11	35	Top	0.505	-0.2406
Story10	33.85	Top	0.6421	-0.3058
Story9	31.34	Top	0.9985	-0.4752
Story8	28.83	Top	1.4224	-0.6765
Story7	26.32	Top	1.9158	-0.9109
Story6	23.82	Top	2.4607	-1.1702
Story5	21.31	Top	3.0649	-1.4584
Story4	17.7	Top	4.0352	-1.9232
Story3	12.68	Top	5.5286	-2.6421
Story2	7.6	Top	7.1728	-3.4365
Story1	2.64	Top	8.836	-4.242
Base	0	Top	9.7241	-4.672

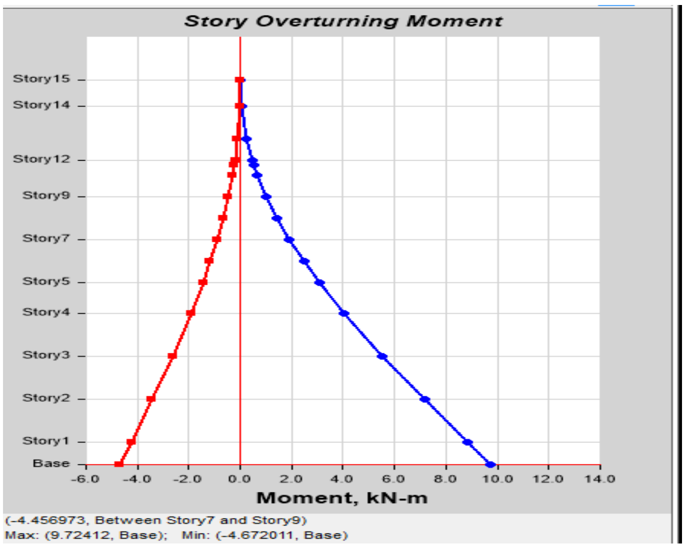

Figure 6. Shown story overturning moment

The deviations of the floors were also obtained, and they were the maximum value ,000019mm
As shown in the following table and figure

Table 8. Shown story deviation

Story	Elevation m	Location	X-Dir	Y-Dir
Story15	45	Top	0.000004	0.000009
Story14	41.88	Top	0.000004	0.000009
Story13	38.13	Top	0.000004	0.000009
Story12	35.63	Top	0.000005	0.000009
Story11	35	Top	0.000005	0.000011
Story10	33.85	Top	0.000006	0.000013
Story9	31.34	Top	0.000006	0.000013
Story8	28.83	Top	0.000008	0.000019
Story7	26.32	Top	0.000009	0.000019
Story6	23.82	Top	0.000008	0.000017
Story5	21.31	Top	0.000006	0.000013
Story4	17.7	Top	0.000005	0.000009
Story3	12.68	Top	0.000004	0.000007
Story2	7.6	Top	0.000003	0.000005
Story1	2.64	Top	4.601E-08	6.262E-08
Base	0	Top	0	0

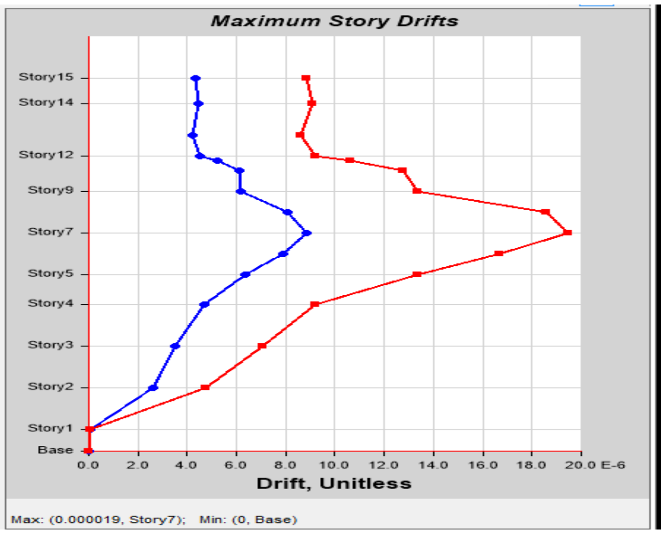

Figure 7. Shown story deviation

After obtaining the results of the analysis from the Etabs program, the steel sections of the tower were designed under the influence of wind loads according to the British specifications using the Etabs program.
As shown in the following table 9.
Then the base plate (t_p) was designed as follows
Area required (A_{req})
A_{req} = F /,6 FCU =2360.05 mm^2 – (6)
Effective area (A_e)
A_e=(A+2c) (t+2c) * 2 – (7)
c=51.244 mm
t_p=c (3 *.6fcu/$p_{yp})^{.5}$-(8)
from table 9 p_{yp}=274 N/mm^2
t_p= 20.73 mm > t= 8mm ok
take t_p = 25 mm

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Table 9. Shown tower section design

Story	Design Section	Check deflection?	deflection Type	DL Ratio	SDL+LL Ratio	LL Ratio	Total Ratio	Camber Ratio
Story14	UKA150X150X15	Yes	Ratio	120	120	360	240	240
Story13	UKA150X150X15	Yes	Ratio	120	120	360	240	240
Story12	UKA150X150X15	Yes	Ratio	120	120	360	240	240
Story8	UKA150X150X15	Yes	Ratio	120	120	360	240	240
Story15	UKA100X100X12	Yes	Ratio	120	120	360	240	240
Story4	UKA150X150X15	Yes	Ratio	120	120	360	240	240
Story3	UKA200X200X20	Yes	Ratio	120	120	360	240	240
Story11	UKA150X150X15	Yes	Ratio	120	120	360	240	240
Story10	UKA150X150X15	Yes	Ratio	120	120	360	240	240
Story9	UKA150X150X15	Yes	Ratio	120	120	360	240	240
Story7	UKA150X150X15	Yes	Ratio	120	120	360	240	240
Story6	UKA150X150X15	Yes	Ratio	120	120	360	240	240
Story5	UKA150X150X15	Yes	Ratio	120	120	360	240	240
Story2	UKA200X200X20	Yes	Ratio	120	120	360	240	240
Story1	UKA150X150X18	Yes	Ratio	120	120	360	240	240

link design: -
bolt connections
strength grade 8.8
D= 16mm, aperture = 18 mm, number of bolt = 4, the distance between the two bolt = 100mm, terminal distance between the center of the bolt and the edge of the plate =50mm.
Then the base plate was verified according to the British specifications as follows
Shear energy: -
P_s = As * PS – (9)
From table 30 PS = 375 N/mm^2
As=At=157 mm^2
P_s=58875 N
Bolt bearing capacity
F_s = 4 * P_s -(10) =235.5 KN
Run over energy
P_{bb} = d * t * Pbb – (11)
T=25mm, d= 16mm
From table 31, Pbb= 320N/mm^2
P_{bb} =400 KN
Bearing capacity of the set bolts
Fbb = 4* P_{bb} -(12) = 1600 KN
P_{bs} = Kbs * d * t_p * Pbs – (13)
From table 32, Pbs = 460 N/mm^2
P_{bs} =184 KN < .5 Kbs * e * t_p * P_{bs}
184 < 287 KN OK

IV. Conclusion

1- Using the Etabs program, the sections were modeled to obtain the final shape of the tower as shown in figure (3), and then these sections were analyzed according to British specification to obtain the strong, safe design of the sections as shown in table (9).
2- After calculating the shear energy and bearing capacity of the bolt according to the British specification the base plate was designed as shown in Equation (6) (7) (8) (9) (10) (11) (12) (13).

Reference

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