ID232

STRUCTURAL RESPOND ANALYSIS OF SELF SUPPORTING TOWER 60 M SUBJECT TO 12M STEEL TRUSS EXTENSION AT RAMBA, SOUTH SUMATRA, INDONESIA

Y.Idris[1] and A.Saggaff[2]

[1, 2]Civil Engineering Department, Sriwijaya University, Palembang, Indonesia

E-mail:[1] yakni_idris@yahoo.com

Telecommunication tower is a steel structure used to support communication systems used nowadays. Tower structure is influenced by the elevation factor. For a tower at high elevation, the influence of wind will be very significant to the structure. Therefore, wind site survey should be considered prior to tower design. The type of tower considered is self-supporting tower of 60 m high subjected to 12m steel truss extension, constructed at Ramba, South Sumatra, Indonesia. The minimum wind velocity used in the analysis was 50 mph or 80.46 km/hour or equivalent to 22.4 m/sec as required by EIA/TIA. The upper structure analysis is carried out with the help of SAP2000 computer software using LRFD concept.The analysis of the 60 meter high subjected to 12 meter steel truss extension self-supporting tower in this paper satisfies the specified limitations of twist, sway and displacement. The critical loading combination which includes wind loads has bigger effect on the tower than other load combinations.

Keywords: *Telecommunication Tower; Loading Combination*.

Introduction

Telecommunication tower is a tower structure using steel sections for its structural components. Telecommunication tower is an important part of communication systems used nowadays. Tower structure is influenced by the elevation factor and the type of load it will carry. Self-Supporting Tower (SST) is the type of space truss tower structure which behaves as cantilever beam with fixed support at its base. SST is suitable for telecommunication tower, since it can reach high elevation and also can carry strong horizontal wind loads. Design of tower structure should consider lateral wind loads besides its self-weights or gravitational loads. Wind loads on the steel sections of tower structural components should be evaluated for its magnitude and its directions. The wind load is more significant for high tower structure, since wind speed is bigger at higher elevation. Since tower structure is commonly slender, it is susceptible to structural failure caused by wind loads. Result of research study conducted by Sumargo (2007) showed that design tower communication of SST type in Indonesia was not governed by earthquake loads.

Structural stability

Structural stability requirements for overall stability design of tower structure are twist, sway and displacement. Twist is the angular rotation in the horizontal plane between any two elevations. Sway is the angular rotation in the vertical plane between any two elevations. Displacement is the horizontal translations of a joint relative to its undeformed position. According to TIA/EIA-222-F Standard, twist or sway between any two elevation (3m) shall not exceed 0.5 degree and the total twist or sway shall not exceed 5 degree, and displacement shall not exceed 1% of the total tower height. Strength requirements shall be satisfied by checking strength ratio using LRFD concept

Tower structural data

The telecommunication tower is self-supporting tower of square type and locatedin Ramba, South Sumatra Indonesia. The total height of the tower is 72m (60m+12m addition truss), using steel angle sections for its structural components, as shown in Figure 1 and 2. The properties of steel is described in Table 1.Tower geometrical dimensions are shown in Table 2, and steel angle sections used and its properties are described in Table 3 and Table 4.

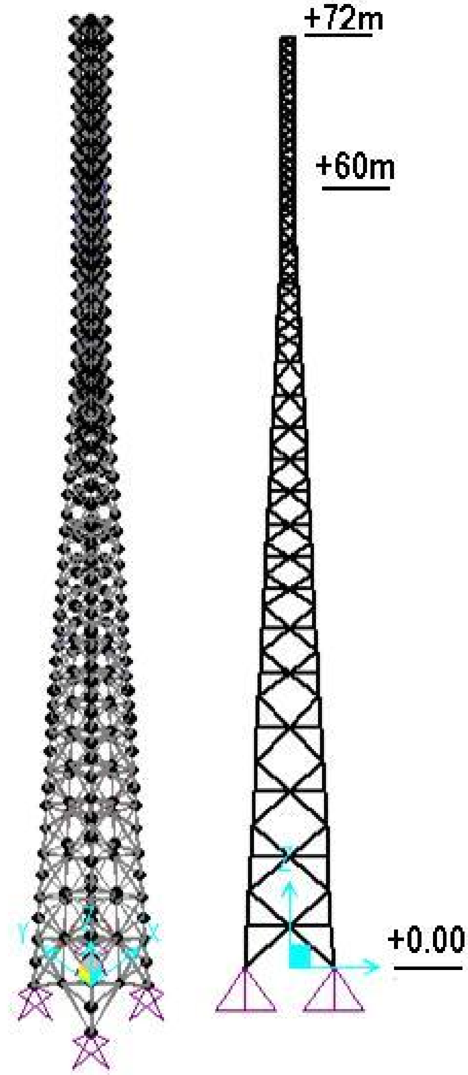


Figure 2. Computer Model

Figure 1. Existing Tower

Table 1. Steel sections properties

STEEL GRADE	THICKNESS (mm)	Fy (kg/cm^2)	Fu (kg/cm^2)
SS41	t<=16mm	2500	4100
A325 (Bolts)	12<t<25	6350	8250

Table 2.Tower geometrical dimensions

Elevation (m)	Length in x direction (m)	Length in y direction (m)
±0.00 (base)	6.6	6.6
+11.00	5.5	5.5
+21.00	4.5	4.5
+33.00	3.3	3.3
+56.00	1.0	1.0
+60.00	1.0	1.0
+72.00 (top)	1.0	1.0

Table 3.Steel angle sections used

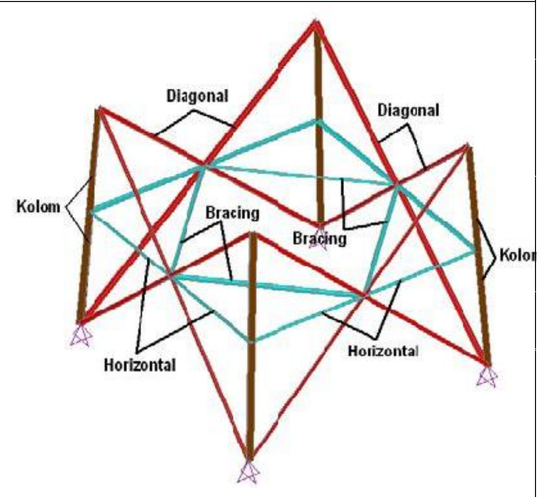
Elevation (m)	Column member	Diagonal member	Horizontal member	Bracing	Notes
0.00 – 6.00	L150.150.15	L100.100.10	L80.80.6	L80.80.6	
6.00-16.00	L130.130.12	L90.90.9	L80.80.6	L80.80.6	
16.00-24.50	L120.120.11	L70.70.7	L70.70.7	L70.70.7	
24.50-35.50	L100.100.10	L70.70.7	L70.70.7	L70.70.7	
35.50-43.00	L90.90.9	L60.60.6	L60.60.6	L60.60.6	
43.00-53.00	L70.70.7	L60.60.6	L60.60.6	L60.60.6	
53.00-60.00	L60.60.6	L60.60.6	L60.60.6	No bracing	
60.00-72.00	L60.60.6	L60.60.6	L60.60.6	No bracing	

Table 4.Steel angle sections properties

SectionName	t3	t2	tf	tw	Area	TotalWt
Text	m	m	m	m	m2	Kgf
L100.100.10	0.1	0.1	0.01	0.01	0.0019	1696.39
L120.120.11	0.12	0.12	0.011	0.011	0.002519	673.92
L130.130.12	0.13	0.13	0.012	0.012	0.002976	936.68
L150.150.15	0.15	0.15	0.015	0.015	0.004275	807.32
L60.60.6	0.06	0.06	0.006	0.006	0.000684	3600.14
L70.70.7	0.07	0.07	0.007	0.007	0.000931	3044.17
L80.80.6	0.08	0.08	0.006	0.006	0.000924	1168.37
L90.90.9	0.09	0.09	0.007	0.007	0.001211	865.61
					TOTAL =	12792.6

Tower structural computer model

Tower structureis modelled as three dimensional truss (space truss), using SAP2000 computer software. Number of joints is 388, and number of truss members is 1068. Tower legs are assumed as frame members, and other members (diagonal, horizontal and bracing) are assumed as truss members. For wind load calculation, the tower is divided into 23 sections (panels). Computer models are shown in Figures 3, 4, 5, 6 and 7.

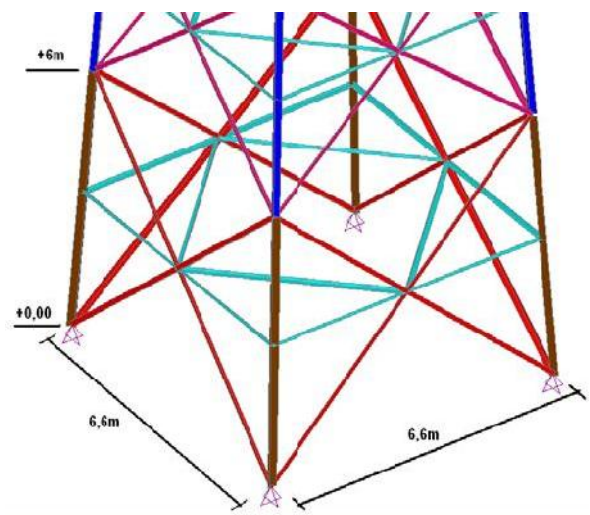


Figure 3. Elevation (XY-PLANE)

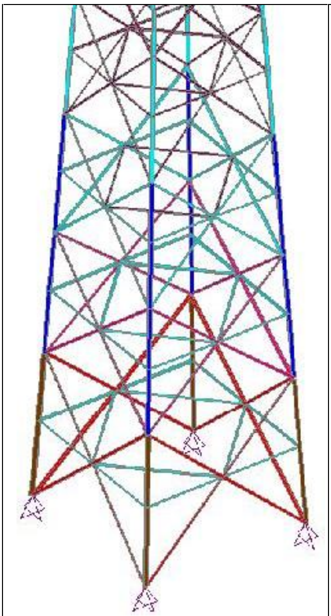


Figure 4. Bottom part

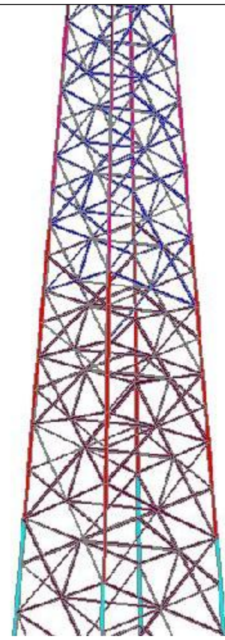


Figure 5. Middle part

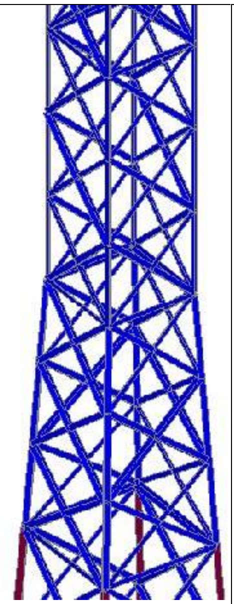


Figure 6. Upper part

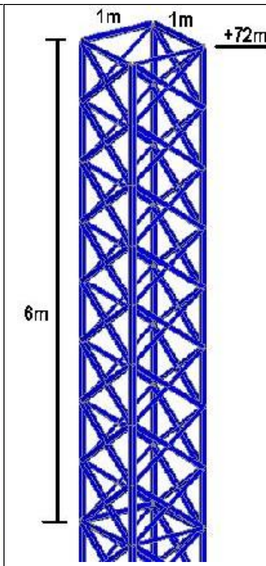


Figure 7. Top of the tower part

Loadings on the Tower structure

(i) Dead Loads (DL) including selfweight of steel sections, sector antenna, paraboloid transmitter, cables, ladder and its accessories.

- Weight of paraboloid transmitter =1200kg at elevation +46m
- Weight of paraboloid transmitter =600kg at elevation +53m
- Weght of sector antenna =100kg, two each at elevation +50m
- Weight of cables and cable tray = 25 kg/m along the height upto 60m
- Weight of steel platform = 120 kg/m^{2}at elevation +40,5m and +23m

(ii). Live Loads (LL)

- Worker and his equipment = 100 kg/worker, including 4 workers at top of the tower (iii). Wind Loads

Wind loads on the tower are exerted on the tower and over the paraboloid transmitter and antenna.

Wind pressures are assumed as joint loads at the joints and calculated at vevery segments (panels), according to:

a. Wind code of Indonesia, PPPURG 1987 [2]

$$W = \frac{v^2}{16} > 25kg/m2$$

b. EIA/TIA-222-F [3]

$$F = 0.5 \text{ x } \rho \text{ x } C_d \text{ x } L \text{ x } B \text{ x } V^2 \text{ x } \text{Sin}^2 \text{ (psi) x extern}$$

c. Indian Standard

Design wind speed (Vz) = Vb k1 k2 k3 (m/s)

The design wind pressures at different heights are computed as

$Pz = 0.6\ Vz^2$

$Pz = 0.6\ (39 \times 1.06 \times 1.2 \times k2)^2\ (N/m^2)$

d. Data fromMeteorology and Geophysics Station Klas II Kenten Palembang, for regions which covers Ramba, maximum wind speed was 19knot, which occured in January 2012.

So the basic wind speed = Vb =19knot =35.188 km/hour =9.774444m/second.

EIA/TIA, section 11.2 , states that minimum wind speed for tower stucture design shall be or exceed 50 Mph=80.46km/hour= 22.40 m/s.Since field wind speed is less than the minimum wind speed requirements, so basic wind speed for analysis is Vb = 22.40 m/s.

e. Wind pressure calculation

Basic wind speed (Vb)=	50	mph		
Basic wind speed (Vb)=	80.45	km/h		
	22.35	m/s		

According to Indian Standard[5]

Design wind speed (Vz) = k1*k2*k3*Vb

k1 =	1.05	(Table.1)		
k2=	1.166	(Table.2)	(Catagory 1-Class C)	
k3=	1	(Clause 5.3.3.1 page 12)		
Design wind speed (Vz) =	27.36	m/s		

Design wind pressure (Pz) = 0,6* Vz^2

Design wind pressure (Pz) =	449.13	N/m2=	0.45	kN/m2
			44.91	kgf/m2

According to PPPURG 1987 [2]

Design wind pressure (Pz) = (1,56/16)* Vb^2

Design wind pressure (Pz) =	48.69	kgf/m2

Conclusion:

Design wind pressure (Pz)
= 48.69 kgf/m2

So the design wind pressure (Pz) = 48.69 kgf/m2

f. Calculation of wind pressures for each elevation of the tower [5]:

k2=Terrain factor , varies with the height of the tower, p.12 Table 2 [5]

Ø =Solidity ratios of panel

$$\text{Ø} = \frac{\text{Projected area of all the individual elements}}{\text{Area enclosed by the boundary of the frame normal to the wind direction}}$$

cf = Overall force coeff Table30 P.47 [5]

Table 5. Wind pressure calculation

Panel	Elevation	k2	Pz=48,69*k2^2	ϕ	cf	[illegible]
23	69.0	1.163	55.84	0.3400	2.600	[illegible]
22	63.0	1.156	55.02	0.3400	2.600	[illegible]
21	58.0	1.149	54.28	0.3347	2.626	[illegible]
19	54.5	1.145	53.88	0.3038	2.781	[illegible]
18	52.4	1.143	53.60	0.2792	2.904	[illegible]
17	51.2	1.141	53.43	0.2199	3.201	[illegible]
16	49.9	1.140	53.25	0.2086	3.257	[illegible]
15	48.0	1.135	52.73	0.2046	3.277	[illegible]
14	45.5	1.129	52.04	0.1925	3.338	[illegible]
13	43.0	1.123	51.35	0.1884	3.358	[illegible]
12	40.5	1.116	50.67	0.1862	3.369	[illegible]
11	38.0	1.110	59.99	0.1767	3.417	[illegible]
10	35.5	1.104	59.32	0.1770	3.415	[illegible]
9	33.0	1.098	58.65	0.1820	3.390	[illegible]
8	30.5	1.091	57.98	0.1811	3.394	[illegible]
7	28.0	1.084	57.22	0.1595	3.502	[illegible]
6	24.5	1.074	56.11	0.1454	3.573	[illegible]
5	21.0	1.063	55.02	0.1321	3.639	[illegible]
4	15.0	1.036	52.25	0.1226	3.687	[illegible]
3	11.0	0.997	48.40	0.1254	3.673	[illegible]
2	6.0	0.958	44.69	0.1231	3.685	[illegible]
1	1.6	0.923	41.44	0.1165	3.717	[illegible]

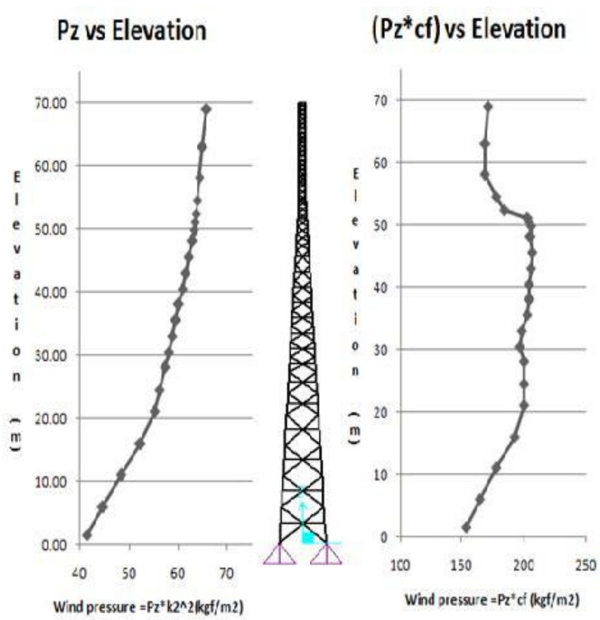


Figure 8. Wind pressure variation

So, the basic wind speed is Vb=22,34m/s; design wind pressure is, Pz=48,69kg/m2, and the variation of wind pressure is 41,44kg/m2 at the tower base and 65,84kg/m2 at the top of the tower. Wind pressure on the face of steel tower structure varies from 154.05kgf/m2 at the base section of the tower and 171.17kgf/m2 at the top section of the tower (see Table 5 and Figure 8).

(iv) Load combinations according to Indonesian code SNI 03-1729-2002 [1],

1. U = 1.2 DL + 1.6 LL

2. U = 1.2 DL ± 1.3 WL_1 + 0,5LL (wind direction perpendicular to the tower); or

U = 1.2 DL ± 1,3*$WL_{1\text{-NORTH-SOUTH}}$ ± 1,3*$WL_{1\text{-WEST-EAST}}$+ 0,5LL

3. U = 1.2 DL ± 1.3 WL_2 + 0,5LL (wind direction angle is $45^0$to the tower); or

U = 1.2 DL ± 0,707*$WL_{1\text{-NORTH-SOUTH}}$± 0,707*$WL_{1\text{-WEST-EAST}}$+ 0,5LL

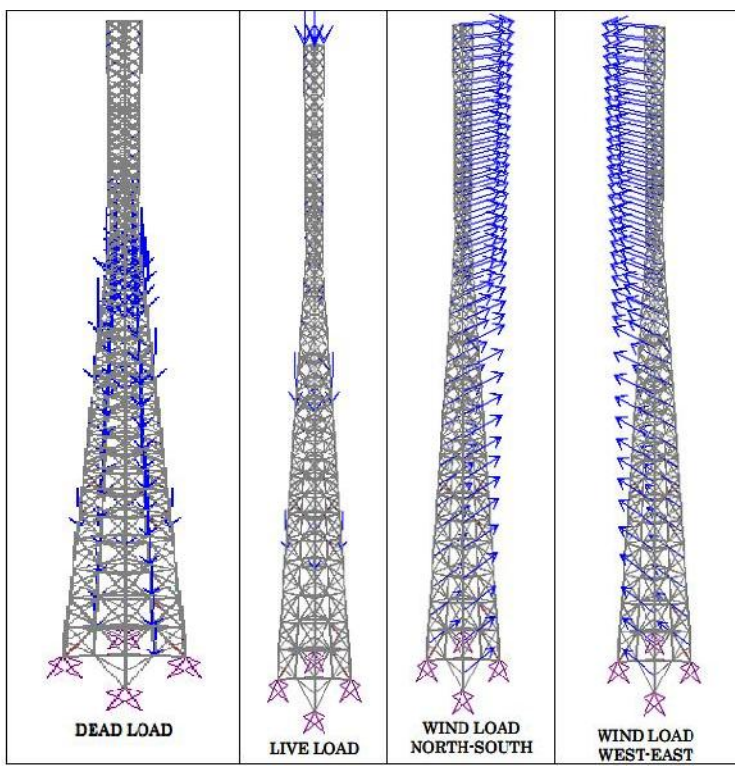
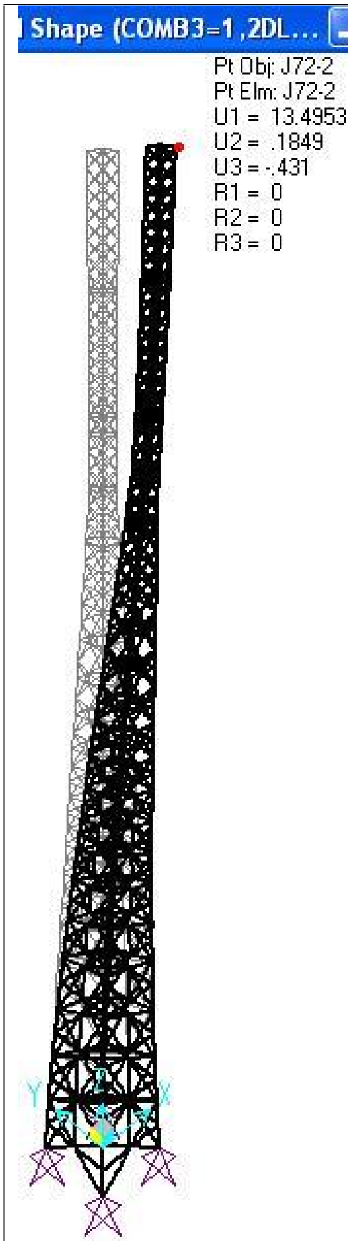


Figure 9. Loading on the tower structure

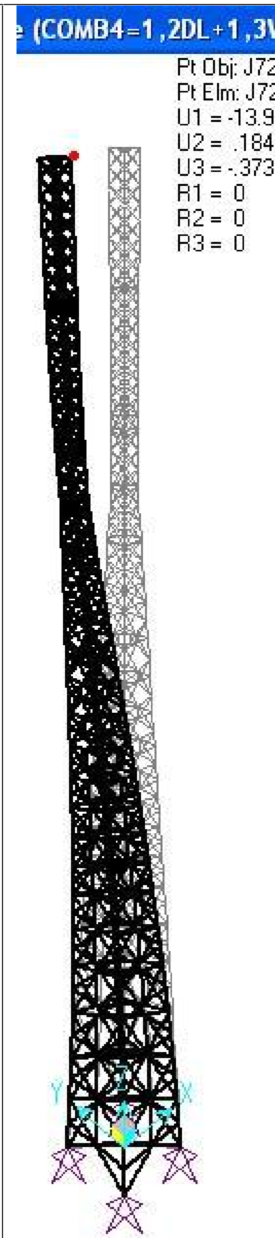
Analysis results

Displacement (unit = cm)

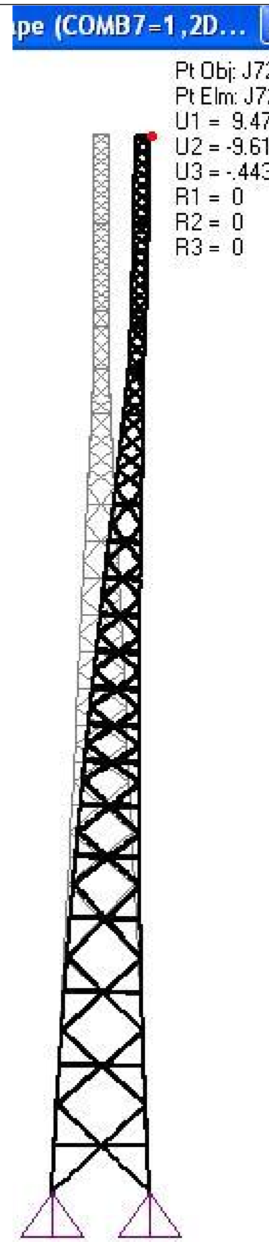


L

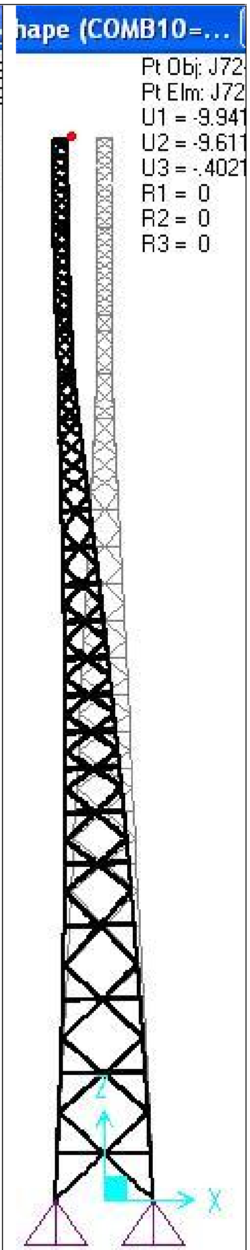
OAD COMBI-3



LOAD COMBI-4



LOAD COMBI-7



LOAD COMBI-
10

(I). Check structural stabiliy (twist), sway, deflection, and stress ratio)

A. TWIST < 0,5^0

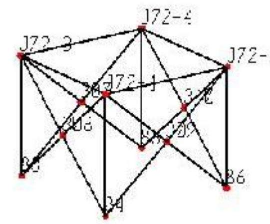
$$\theta_z = arctan\left\{\frac{U_{x(n-1)} - U_{x(n)}}{Z_{(n-1)} - Z_n}\right\} < 0,5^0$$

TABLE: Joint Displacements

Joint	OutputCase	U1	U2	U3
Text	Text	cm	cm	cm
J72-2	COMB4=1,2DL+1,3WSN+0,5LL	-13.963574	0.184722	-0.373
86	COMB4=1,2DL+1,3WSN+0,5LL	-13.92062	0.18391	-0.3724

0.042954

Twist = 0.02405424 derajat



Result: θ_z=0,02405^0<0,5^0==>OK

B. Sway < 0,5^0

$$\theta_x = arctan\left\{\frac{U_{y(n)} - U_{y(n-4)}}{Z_{(n)} - Z_{(n-4)}}\right\} < 0,5^0$$

TABLE: Joint Displacements

Joint	OutputCase	U1	U2	U3
Text	Text	cm	cm	cm
J72-2	COMB4=1,2DL+1,3WSN+0,5LL	-13.963574	0.184722	-0.37314

Sway-x= 0.10860544 derajat

Result: θ_x =0,108605^0<0,5^0==>OK

$$\theta_y = arctan\left\{\frac{U_{x(n)} - U_{x(n-4)}}{Z_{(n)} - Z_{(n-4)}}\right\} < 0,5^0$$

TABLE: Joint Displacements

Joint	OutputCase	U1	U2	U3
Text	Text	cm	cm	cm
J72-1	COMB5=1.2DL+1,3(WEW)+0,5LL	-0.233899	14.041404	-0.373608

Sway-y= 0.10921078 derajat

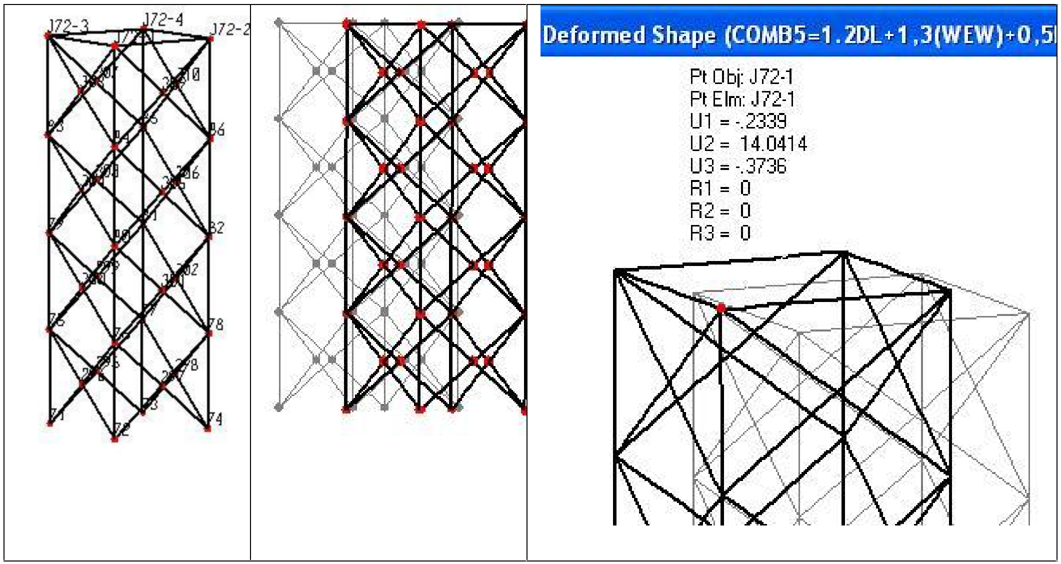
Result: θ_y =0,10921^0<0,5^0==>OK

C. Maximum deflection < H/200=7200/200cm=36cm (Check top of the tower)

TABLE: Joint Displacements

Joint	OutputCase	U1	U2	U3
Text	Text	cm	cm	cm
J72-1	COMB5=1.2DL+1,3(WEW)+0,5LL	-0.233899	14.041404	-0.373608

Result: δ_{max}=14,04cm< 36cm==>OK



D. **Stress ratio < 1 (Check at tower bottom legs)**

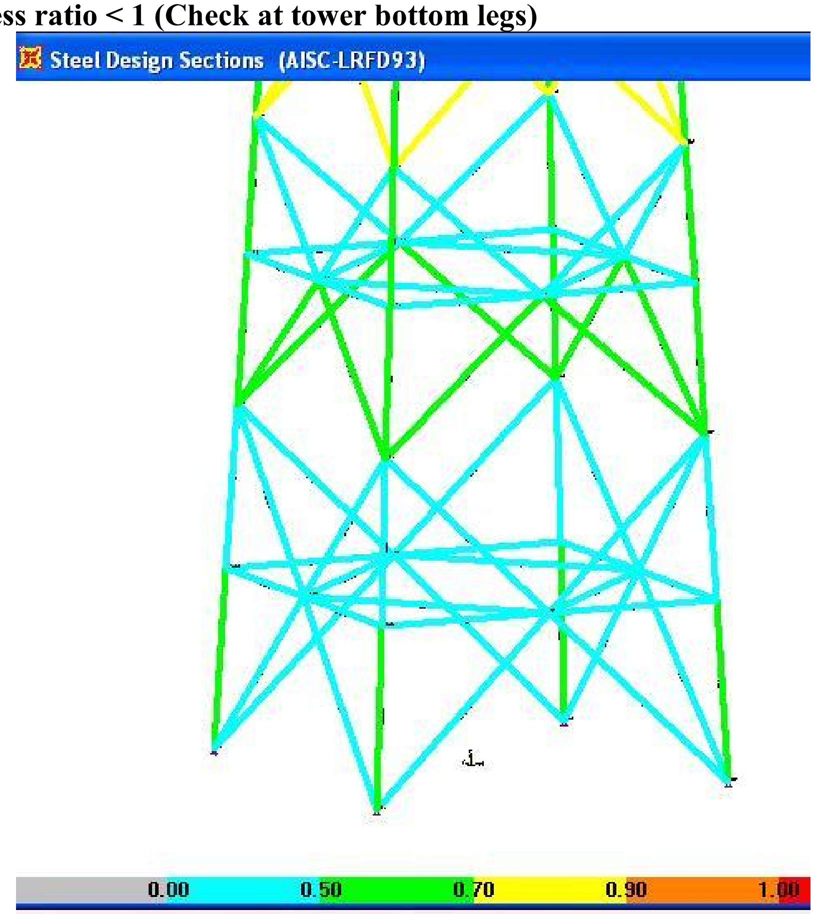


TABLE: Steel Design 1 - Summary Data - AISC-LRFD93

Frame	DesignSect	DesignType	Ratio	RatioType	Combo
Text	Text	Text	Unitless	Text	Text
K14	L150.150.15	Column	0.53	PMM	COMB8=1,2DL+1,3WD2+0,5LL
K18	L150.150.15	Column	0.46	PMM	COMB8=1,2DL+1,3WD2+0,5LL
H11	L80.80.6	Beam	0.08	PMM	COMB3=1,2DL+1,3WNS+0,5LL
H12	L80.80.6	Beam	0.08	PMM	COMB4=1,2DL+1,3WSN+0,5LL
H14	L80.80.6	Beam	0.08	PMM	COMB5=1.2DL+1,3(WEW)+0,5LL
H16	L80.80.6	Beam	0.08	PMM	COMB6=1,2DL+1,3(WWE)+0,5LL
H18	L80.80.6	Beam	0.08	PMM	COMB4=1,2DL+1,3WSN+0,5LL
H17	L80.80.6	Beam	0.08	PMM	COMB3=1,2DL+1,3WNS+0,5LL
H15	L80.80.6	Beam	0.08	PMM	COMB6=1,2DL+1,3(WWE)+0,5LL
H13	L80.80.6	Beam	0.08	PMM	COMB5=1.2DL+1,3(WEW)+0,5LL
K13	L150.150.15	Column	0.53	PMM	COMB9=1,2DL+1,3WD3+0,5LL
K17	L150.150.15	Column	0.47	PMM	COMB9=1,2DL+1,3WD3+0,5LL
K15	L150.150.15	Column	0.46	PMM	COMB10=1,2DL+1,3WD4+0,5LL
K11	L150.150.15	Column	0.53	PMM	COMB10=1,2DL+1,3WD4+0,5LL
K16	L150.150.15	Column	0.46	PMM	COMB7=1,2DL+1,3*WD1+0,5LL
K12	L150.150.15	Column	0.53	PMM	COMB7=1,2DL+1,3*WD1+0,5LL
D14	L100.100.10	Brace	0.49	PMM	COMB6=1,2DL+1,3(WWE)+0,5LL
D114	L100.100.10	Brace	0.34	PMM	COMB6=1,2DL+1,3(WWE)+0,5LL
D116	L100.100.10	Brace	0.33	PMM	COMB4=1,2DL+1,3WSN+0,5LL
D17	L100.100.10	Brace	0.49	PMM	COMB4=1,2DL+1,3WSN+0,5LL
D15	L100.100.10	Brace	0.49	PMM	COMB5=1.2DL+1,3(WEW)+0,5LL

D111	L100.100.10	Brace	0.33	PMM	COMB5=1.2DL+1,3(WEW)+0,5LL
D19	L100.100.10	Brace	0.33	PMM	COMB3=1,2DL+1,3WNS+0,5LL
D12	L100.100.10	Brace	0.49	PMM	COMB3=1,2DL+1,3WNS+0,5LL
D11	L100.100.10	Brace	0.49	PMM	COMB4=1,2DL+1,3WSN+0,5LL
D110	L100.100.10	Brace	0.33	PMM	COMB4=1,2DL+1,3WSN+0,5LL
D112	L100.100.10	Brace	0.33	PMM	COMB5=1.2DL+1,3(WEW)+0,5LL
D16	L100.100.10	Brace	0.49	PMM	COMB5=1.2DL+1,3(WEW)+0,5LL
D18	L100.100.10	Brace	0.49	PMM	COMB3=1,2DL+1,3WNS+0,5LL
D115	L100.100.10	Brace	0.33	PMM	COMB3=1,2DL+1,3WNS+0,5LL
D113	L100.100.10	Brace	0.33	PMM	COMB6=1,2DL+1,3(WWE)+0,5LL
D13	L100.100.10	Brace	0.49	PMM	COMB6=1,2DL+1,3(WWE)+0,5LL
B13	L80.80.6	Beam	0.13	PMM	COMB1=1,4DL
B14	L80.80.6	Beam	0.13	PMM	COMB1=1,4DL
B12	L80.80.6	Beam	0.13	PMM	COMB1=1,4DL
B11	L80.80.6	Beam	0.13	PMM	COMB1=1,4DL

Result: Stress ratio < 1 ----> OK.

Conclusion

1. Basic wind speed used in the analysis is Vb = 22.40 m/s, and design wind pressure is Pz=48,69kg/m^2
2. The variation of wind pressure is 41,44kg/m2 at the tower base and 65,84kg/m^2 at the top of the tower. Wind pressure on the face of steel tower structure varies from 154.05kgf/m2 at the base section of the tower and 171.17kgf/m^2 at the top section of the tower
3. Result of structural stability calculation, yields :
   A. Twist= $0,02405^0$, satisfies the maximum requirement of $0,5^0$.
   B. Sway = $0,1092^0$, satisfies the maximum requirement of $0,5^0$..
   C. Horizontal displacement = $\delta_{horizontal}$ =14,04cm satifies the maximum requirement of 36cm
   D. Stress ratio<=1, satifies the capacity requirement.

Reference

AISC, 2005a. ANSI/AISC 360-05: An American National Standard – Specification for Structural Steel Building, American Institute of Steel Construction. One East Wacker Drive, Suite 700, Chicago, Illinois, 60601. March 9.

American Society of Civil Engineers (ASCE). Guidelines for electrical transmission line structural loading. ASCE Manuals and Reports on Engineering Practice, No.74, New York, 1991,

EIA/TIA-222-F, 1991, "Structural Standards for Steel Antenna Tower and Antenna SupportingStructures", Washington D.C.

Pedoman Perencanaan Pembebanan Untuk Rumah dan Gedung, SKBI-1.3.53.1987 (Indonesian Building Loads Standards)

Indian Standard: 875(Part-3):1987 "Code of practice for design loads (other than earthquake) for buildings and structures".-Wind Load

"Tata Cara Perencanaan Struktur Baja Untuk Bangunan Gedung," Standar Nasional Indonesia SNI 03-1729-2002. (Indonesian Steel Design Code)