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Analysis And Design Of 220kv Transmission Line Tower In Different Zones I & V With Different Base Widths – A Comparative Study

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Abstract: -. In this study, an attempt is made that 220kV Transmission line tower is modeled using STADD Pro 2006. The towers are designed in two wind zones I & V with three different base widths 1/4, 1/5 &1/6 of total height of tower. Towers are modeled using parameters such as constant height, bracing system, angle sections and variable parameters of different Base widths and Wind zones. The loads are calculated from IS: 802(1995). After completing the analysis, the comparative study is done with respect to deflections, stresses, axial forces and weight of tower for all 6 different towers.

1. Introduction:

1.1Transmission line tower:

The advancement in electrical engineering shows need for supporting heavy conductors which led to existence of towers. Towers are tall structures, their height being much more than their lateral dimensions. These are space frames built with steel sections having generally an independent foundation under each leg. The height of tower is fixed by the user and the structural designer has the task of designing the general configuration, member and the joint details **(John D Holmes)**. A high voltage transmission line structure is a complex structure in that its design is characterized by the special requirements to be met from both electrical and structural points of view, the former decides the general shape of the tower in respect of its height and the length of its cross arms that carry electrical conductors**(Visweswara Rao, G 1995).** Hence it has given rise to the relative tall structures such as towers. The purpose of transmission line towers is to support conductors carrying electrical power and one or two ground wires at suitable distance. In this study, a 220kV Transmission line tower is modeled using STADD Pro 2006. The towers are designed in two wind zones I & V with three different base widths.

1.2 Conductor:

A substance or a material which allows the electric current to pass through its body when it is subjected to a difference of electric potential is known as Conductor. The materials which are used as conductors for over head transmission lines should have the following electrical and physical properties.

- It should have a high conductivity
- It should have tensile strength.
- It should have a high melting point and thermal stability.
- It should be flexible to permit us to handle easily and to transport to the site easily.
- It should be corrosion resistance.

ACSR Conductors:

Aluminium has an Ultimate Tensile Strength (U.T.S) of 16 – 20 kg / mm^2 where as the steel has a U.T.S of about 136 kg / mm^2. By a suitable combination of steel and aluminium the tensile strength of the conductor is increased greatly. Thus came into use the Aluminium Conductor Steel Reinforced (ACSR).

Table 1: Conductor mechanical and electrical properties:

Voltage Level	220kV
Code Name of Conductor	ACSR “ZEBRA”
No. of conductor/ Phase	ONE
Stranding/ Wire diameter	54/3.18mm AL + 7/3.18mm steel
Total sectional area	484.5 mm^2
Overall diameter	28.62 mm
Approx. Weight	1621 Kg/ Km
Calculated D.C resistance at 20 ^{0}C	0.06915 ohm/Km
Min.UTS	130.32 kN
Modulus of elasticity	7034 Kg/mm^2
Co – efficient of linear expansion	19.30 x 10^{-6}/ ^{0}C
Max. Allowable temperature	75^{0}C

1.3 Earthwire:

The earthwire is used for protection against direct lightning strokes and the high voltage surges resulting there from. There will be one or two earthwire depending upon the shielding angle or protection angle. The earthwire to be used for transmission line

Table 2: Earthwire mechanical and electrical properties

Voltage Level	220kV
Material of Earthwire	Galvanized steel
No. of earthwire	ONE
Stranding/ Wire diameter	7/3.15mm
Total sectional area	54.55 mm^2
Overall diameter	9.45 mm
Approx. Weight	428 Kg/ Km
Calculated D.C resistance at 20^0C	3.375 ohm/Km
Min.UTS	5710 Kg
Modulus of elasticity	19361 Kg/mm^2
Co – efficient of linear expansion	11.50 x 10^{-6}/ ^{0}C
Max. Allowable Temp.	53^0C

1.4 Insulator Strings:
Insulators are devices used in the electrical system to support the conductors or to support the conductors carrying at given voltages.

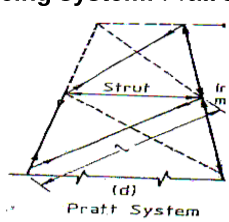
Functions of Insulators: The insulators separate the current carrying conductors of a transmission line from their support structures to prevent the flow of current through the structure to ground and to provide necessary mechanical support to the conductors at a safer height above the ground level. Their main functions may be summarized as follows.

Mechanical: They should be strong to withstand maximum expected loading for different operating conditions such self – weight, wind and ice loads, weight of the conductors and weight of the technicians with tools.

Electrical: They should keep separate the conductors or other current carrying devices with support structures which are at ground potential, under all operating conditions.

2. Details of tower configuration:
a) Tower type: Suspension and self supporting tower.

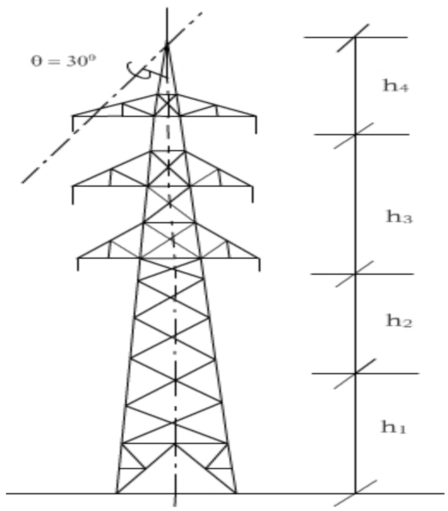
b) Bracing system: Pratt system



c) No. of Circuits: Double circuit

d) Wind: As per IS:875 part III, Two wind zones I & V with wind speeds 33 m/s & 50 m/s respectively are taken into consideration.

e) Tower Height:



H = h1 + h2 + h3 +h4

Minimum Permissible Ground Clearance (h1):

For 220kV - h1 = 7.01m

Maximum Sag (h2): The sag tension calculation for the conductor and earthwire shall be made in accordance with the relevant provisions of IS: 5613 (part – 2 / sec – 1):1985 for the following combinations.

i. 100% design wind pressure after accounting for drag co – efficient and gust response factor at every day temperature, and
ii. 36% design wind pressure after accounting for drag co–efficient and gust response factor at minimum temperature.

For the conductors with higher aluminium content normally used for 220kV lines increased sag of 2 to 4% of the maximum sag value is allowed.

$$T_2^2 [T_2 \frac{AL^2 p_\square^2 E}{24 T_\square^2} + A \alpha E (t_2 - t_1) - T_{1]} = \frac{AL^2 p_\square^2 E}{24}$$

From the above equation, we get sag tension of the conductor (T_2).

$$Sag = \frac{p_\square L^2}{8T_\square}$$

The following combinations will be considered:

No Wind, $t_2 = 0^0$ C

No Wind, $t_2 = 75^0$ C

No Wind, $t_2 = 32^0$ C

Full Wind, $t_2 = 32^0$ C

75% Full Wind, $t_2 = 32^0$ C

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Sag value for different temperatures and for different wind conditions are calculated and the maximum value of the above combinations + 4% extra will gives the **h2** of the conductor.

Spacing of Conductors (h3):

Type of tower	Vertical spacing between conductors (mm)	Horizontal spacing between conductors(mm)
220kV Double Circuit		
(0 - 2^0)	5,200	9,900

Vertical Clearance between Ground Wire and Top Conductor (h4): The same procedure is repeated as done in finding sag of the conductor (**h2)** but only difference is instead of conductor properties substitute earthwire properties.

H = h1 + h2 + h3 +h4 = **33.52 m.**

f) Tower Width: The width of the tower is specified at base, waist and cross – arm / boom level. **Base Width:** The spacing between the tower footings i.e., base width at concrete level is the distance from the centre of gravity of the corner leg angle to that of the adjacent corner leg angle.

3. Loadings on Tower:

Loads are calculated as per IS 802:1995 & CBIP manual.

4. Modelling Approach:

Transmission Line Tower is modeled using STAAD PRO – 06. Tower with different base widths are modeled and loading conditions are considered for two different wind zones I & V. Tower is modeled with 12 panels and is built up with steel angle section, and 3 cross arms with double circuit lines and ground wire at the peak. All the towers are having 12 panels, same angle sections and constant height. The variable parameters are base widths, different wind zones.

5. Discussions and Results:

The parameters of this study are maximum compressive and tensile stresses in the tower members, axial forces in the members and maximum deflections of the nodes in x, y & z directions and the above parameters are compared in wind zones I & V with wind speed 33 & 50 m/s respectively. Table 3 represents the maximum axial deflections of nodes in x, y, & z directions in wind zones I & V with the base widths 5.5866 m, 6.704 m & 8.38m. Tables 4 & 5 represent the maximum axial force in tower members in zone I & V with 3 base widths. Table 6, 7, 8 & 9 represents the maximum compressive, tensile stresses in members in wind zones I & V with the base widths 5.5866 m, 6.704 m & 8.38m. The maximum deflections in X, Y & Z direction are presented in figure 1, 2, 3. The tower weight with different base widths is presented in figure 4. The maximum compressive stresses with different base widths are presented in figure 5,7,10. The maximum tensile stresses with different base widths are presented in figure 6, 8, 9. The maximum axial forces in members are presented in figure 11,12.

Table 3: Maximum Axial Deflections

Base Width (m)	Maximum Axial Deflections (mm)					
	X – direction		Y –direction		Z - direction	
Zone	I	V	I	V	I	V
5.586	-72.4	-72.4	-20.3	-20.3	98.7	216.4
6.704	-83.9	-83.9	-23.5	-23.5	109	239.2
8.38	-60.7	-60.7	-18.7	-18.7	76.7	168.1

Table 4: Maximum Axial Forces in Zone – I

Panel	member	Base Widths (m)		
		5.5866	6.704	8.38
1	104	432068.8	398540.5	339702.6
2	204	358970.7	361839.2	306625.4
3	304	304624.3	333643.7	289215.6
4	404	275876.9	327103.8	287655.4
5	504	223834.7	277166.2	252119.1
6	604	223663.1	269772.8	243563.3
7	704	180881.9	201285.9	183547.1
8	804	143089.4	139285.5	129246.1
9	904	137079.9	135127.3	123970.3
10	1004	81932.05	82279.29	75883.05
11	1104	55589.12	55571.58	51608.34
12	1204	47892.86	47861.2	43629.27

Table 5: Maximum Axial Forces in Zone – V

Panel	member	Base Widths (m)		
		5.5866	6.704	8.38
1	104	725345.3	663334	559603
2	204	587120.4	591254	495289
3	304	480807	530769	455485
4	404	421085.8	506641	442819
5	504	332449.9	416218	378150
6	604	336236.3	407419	368760
7	704	260576.6	291877	265645
8	804	191371.2	186225	173461
9	904	185998.3	183757	169289
10	1004	104437.4	105047	96728
11	1104	90378.4	90260	81828
12	1204	52874.76	52804	48198

Table 6: Maximum Compressive Stresses (N / mm^2) in Zone – I with different base widths

Panel	Member	Zone -1		
		5.5866	6.704	8.38
1	104	137.413	129.834	122.226
2	204	116.845	117.459	110.347
3	304	137.145	141.568	129.946
4	404	141.567	175.039	156.617
5	504	117.5	148.735	133.601
6	607	123.126	143.931	133.807
7	708	124.795	141.269	123.405
8	810	88.312	92.787	84.827
9	907	91.613	84.166	79.775
10	1010	87.517	87.518	78.107
11	1124	85.648	85.706	79.872
12	1204	47.996	47.969	45.465

Table 7: Maximum Compressive Stresses (N / mm^2) in Zone – V with different base widths

Panel	Member	Zone -V		
		5.5866	6.704	8.38
1	104	225.538	122.226	187.747
2	204	182.967	110.347	164.757
3	304	210.269	129.946	196.89
4	404	209.557	156.617	224.752
5	504	178.382	133.601	201.928
6	607	215.604	133.807	229.601
7	708	207.838	123.405	202.085
8	810	144.545	84.827	141.018
9	907	175.613	79.775	140.283
10	1010	189.757	78.107	160.968
11	1124	135.031	79.872	122.219
12	1204	52.686	45.465	49.203

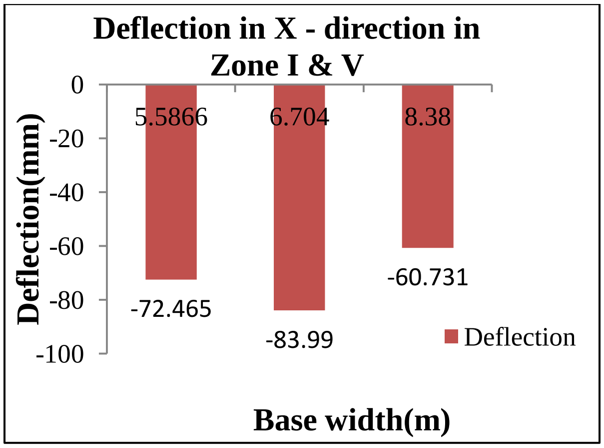

Figure. 1

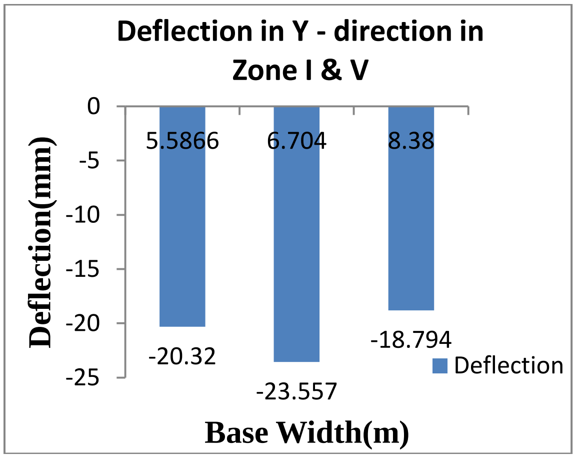

Figure.2

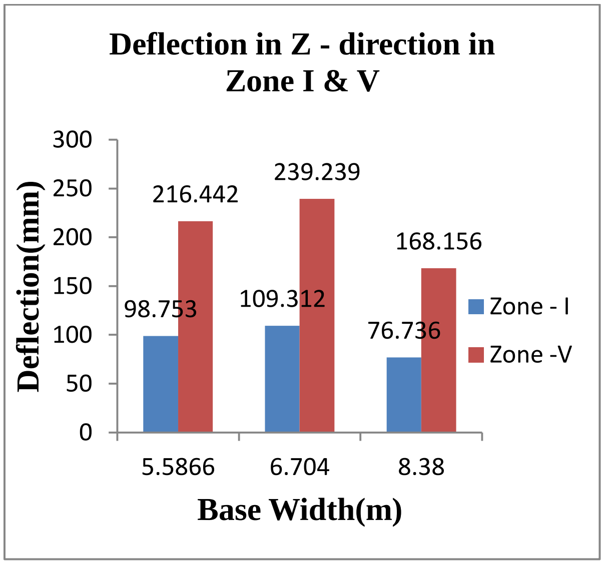

Figure.3

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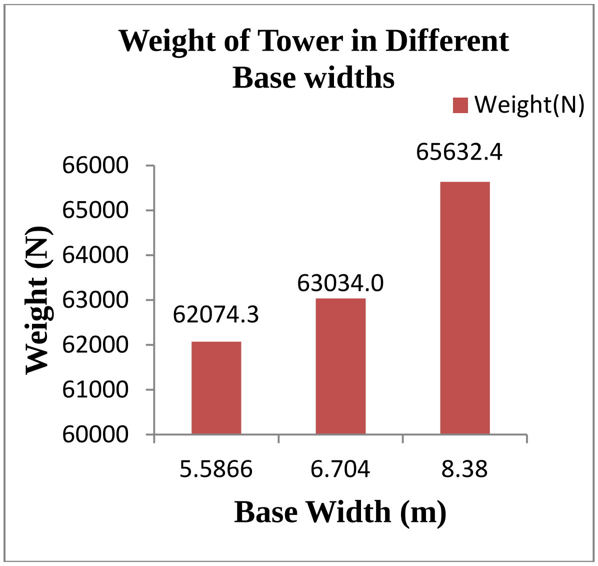

Figure.4

Table 8: Maximum Tensile Stresses (N / mm^2) in Zone – I with different base widths

Panel	Member	Zone -1		
		5.5866	**6.704**	**8.38**
1	109	-114.429	-109.987	-130.641
2	202	-101.513	-100.731	-104.876
3	302	-104.944	-120.074	-102.314
4	402	-115.159	-128.716	-111.643
5	502	-121.768	-117.818	-110.762
6	602	-98.21	-127.299	-111.919
7	709	-103.337	-117.813	-105.262
8	825	-101.485	-104.741	-97.61
9	906	-73.421	-68.02	-61.386
10	1009	-83.377	-82.939	-75.071
11	1127	-98.556	-98.523	-93.846
12	1202	-52.228	-52.159	-48.601

Table 9: Maximum Tensile Stresses (N/mm^2) in Zone – V with different base widths

Panel	Member	Zone -V		
		5.5866	**6.704**	**8.38**
1	109	-198.393	-130.641	-162.115
2	202	-166.25	-104.876	-146.002
3	302	-174.69	-102.314	-169.024
4	402	-188.607	-111.643	-186.205
5	502	-192.664	-110.762	-174.83
6	602	-163.805	-111.919	-184.652
7	709	-194.269	-105.262	-201.746
8	825	-149.759	-97.61	-141.14
9	906	-138.954	-61.386	-112.305
10	1009	-175.844	-75.071	-151.259
11	1127	-123.258	-93.846	-115.468
12	1202	-59.849	-48.601	-55.112

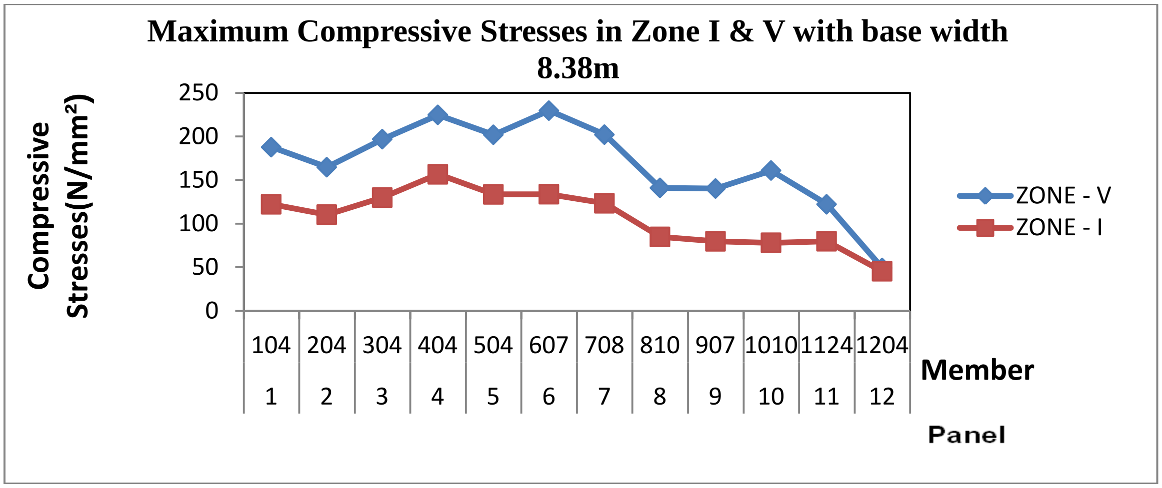

Figure.5

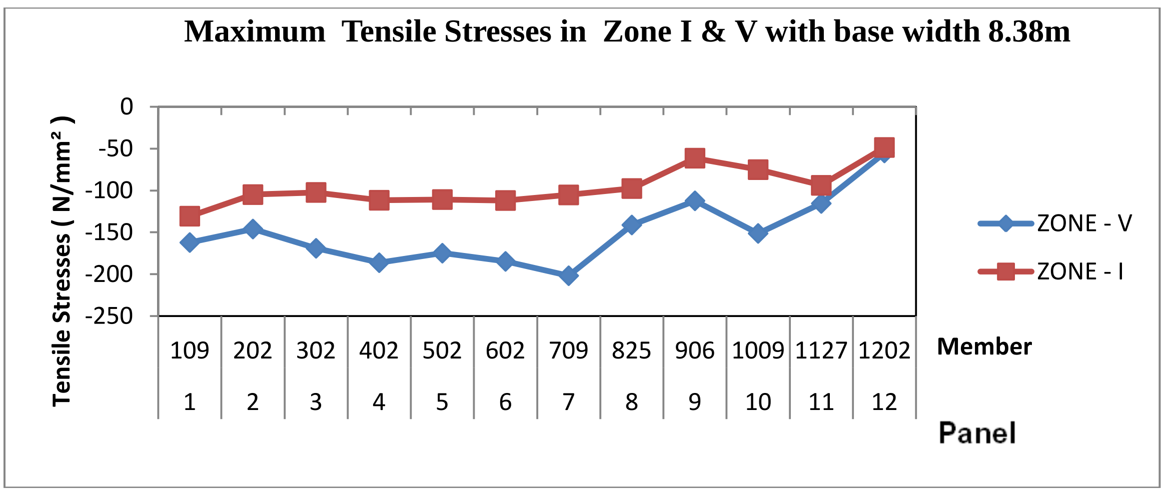

Figure.6

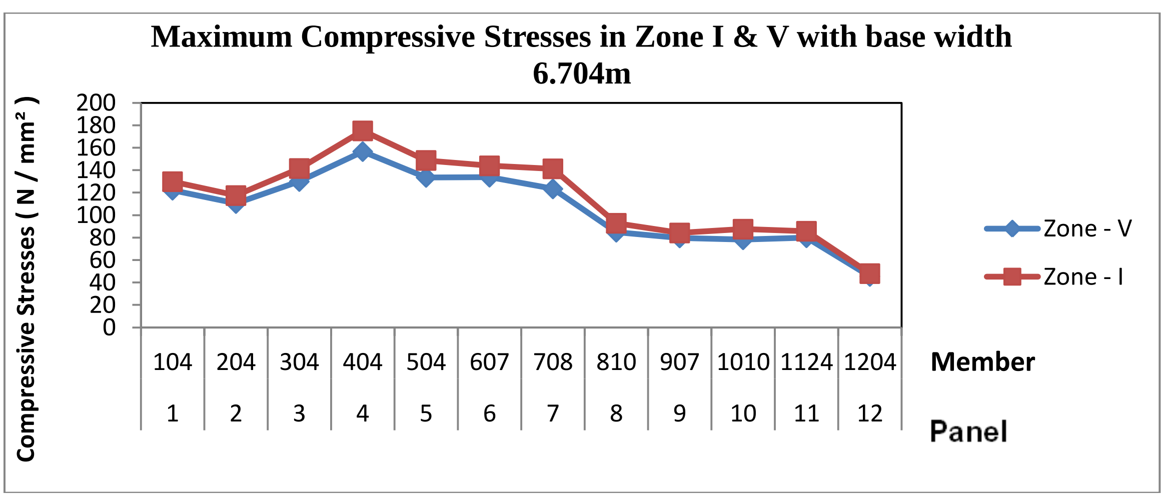

Figure.7

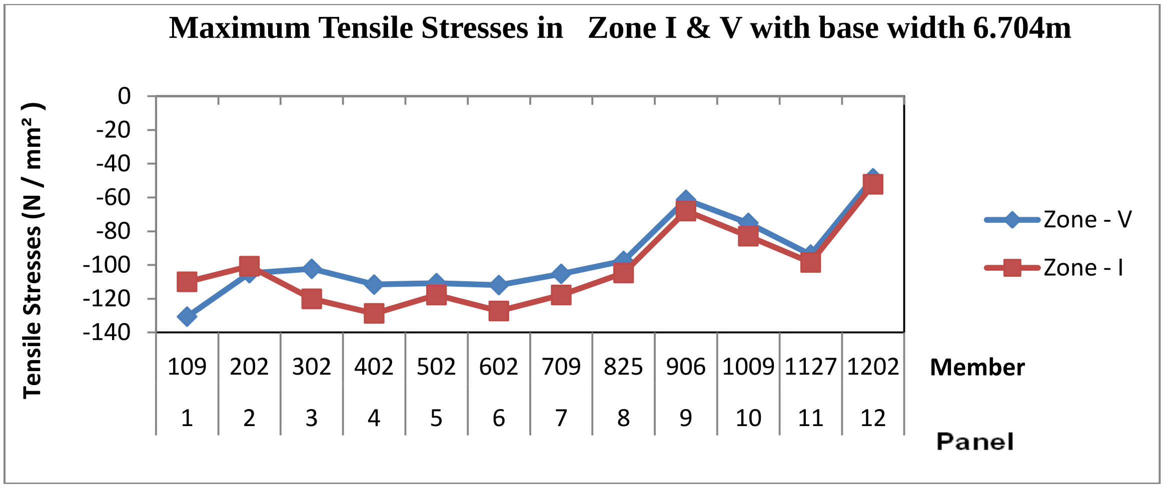

Figure.8

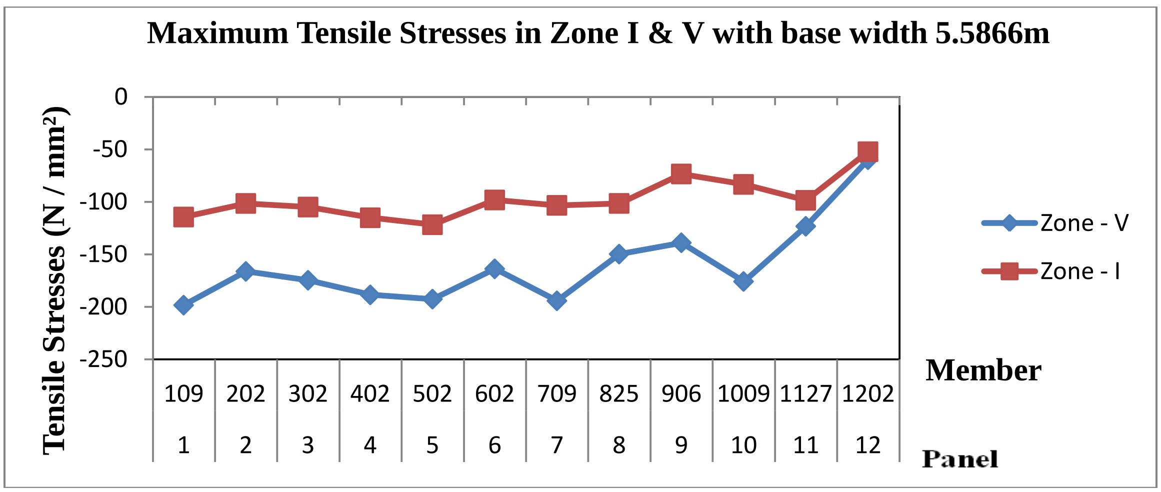

Figure 9

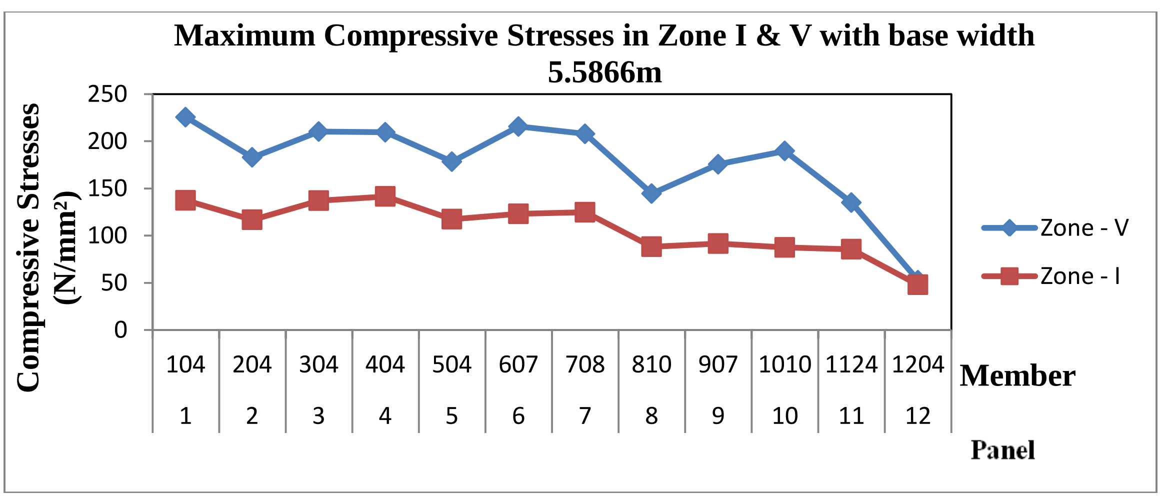

Figure 10

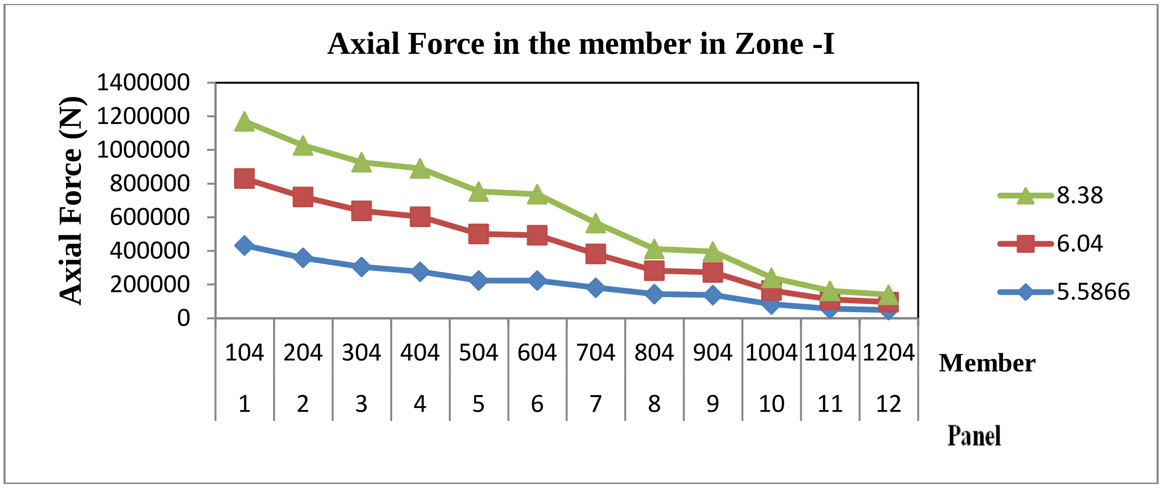

Figure 11

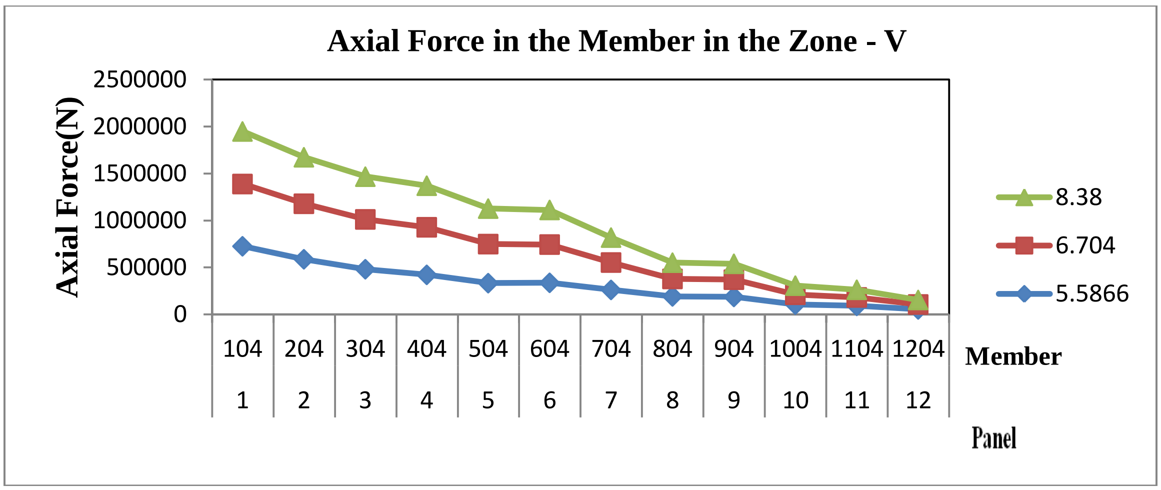

Figure 12

Conclusions:

1. At a base width of 6.704m, in all directions, deflections are found to be maximum than other two base widths 5.5866m, 8.380m
2. The maximum axial deflection At a base width of 6.704m is having 15% more than the values at base width of 5.5866m and 35% more than the values at base width of 8.380m in all X, Y & Z directions for both Zone - I & Zone - V.
3. When compared to X and Y directions, deflections in Z-directions shows maximum values in both Zone - I & Zone - V.
4. At base width 6.704 m, the tensile stresses are maximum at member 402 in Zone – I is 128.716 N/mm^2 & at member 109 in Zone –V is 130.641 N/mm^2.
5. The compressive stresses are maximum at member 404 in Zone – I is 175.039 N/mm^2 & in Zone –V is 156.617 N/mm^2 at base width 6.704 m**.**
6. All the deflections are in permissible limits is less than H/100.
7. The maximum axial forces are 398540.5 N in Zone – I and 663334 N in Zone – V at 6.704 m base width.

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