Analysis of Transmission Tower for Wind Forces using IS 875:2015

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Abstract— Transmission line is an integrated system consisting of conductor subsystem, ground wire subsystem and one subsystem for each category of support structure. Mechanical supports of transmission line represent a significant portion of the cost of the line and they play an important role in the reliable power transmission. They are designed and constructed in wide variety of shapes, types, sizes, configurations and materials. In general, most towers may be idealized as statically determinate and analyzed for wind forces as per IS 875 part 3:1987. Revised code IS 875 is introduced in 2015. In revised code IS 875: Part 3-2015, loading and design parameters are changed. After implementation this code for suspension and angle transmission tower the analysis and design results are varies with respect to code IS 875:Part 2-1987 and EN 1991-1-4:2005.They are carried out.

Key words: Transmission line, Mechanical supports, Design Parameters, Loading

I. Introduction

India has a large population residing all over the country and the electricity supply need of this population creates requirement of a large transmission and distribution system. Transmission line is an integrated system consisting of conductor subsystem, ground wire subsystem and one subsystem for each category of support structure. They are designed and constructed in wide variety of shapes, types, sizes, configurations and materials. The supporting structure types used in transmission lines generally fall into one of the three categories: lattice, pole and guyed. In general, most towers may be idealized as statically determinate and analyzed for wind forces as per IS 875 part 3:1987. Revised code IS 875 is introduced in 2015. In revised code IS 875: Part 3-2015,some loading and design parameters are changed. In this study the analysis and design for various heights of suspension and angle transmission tower by using code IS 875: Part 2-1987 and EN 1991-1-4:2005 will be carried out.

A. Transmission Tower Taken For Wind Analysis

1) Suspension Tower

It is used on the line for straight run or for small angle of deviation upto 2^0 - 5^0 or upto 15^0 (with inclined V string) support of conductor and suspension tower (I-string, V-string, Y-string).It is also known as "Tangent tower". Suspension Tower (with I or V suspension insulator string)

1) Tangent tower (0^0) with suspension string - To be used on straight runs only
2) Intermediate tower (0^0 – 2^0) with suspension string - Straight run and upto 20 deviation
3) Light angle tower(0^0-5^0) - Straight run and up to 5^0 deviation

2) Angle Tower

It is also known as "Tension Tower". It is used where the angle of deviation exceeds. It is classified based on different deviation angle. Tension insulator string is used on tension/section/angle/dead end towers. It is provided on both side of tower in the direction of conductor.

1) Small angle tower with tension string(0^0 -15^0) – line deviation (0^0 - 15^0)tension string
2) Medium angle tower (0^0 – 30^0) or (15^0 – 30^0) line deviation 0^0 - 30^0
3) Large angle tower (30^0–60^0)-line deviation 30^0 - 60^0
4) Dead end tower with tension stringline deviation 0^0- 15^0 deviation

B. Codes use for Wind Forces

1) IS 875(Part 3):1987 Code of Practice for Design Loads (Other Than Earthquake) For Buildings and Structures, Part 3: wind Loads
2) IS 875(Part 3):2015 Code of Practice for Design Loads (Other Than Earthquake) For Buildings And Structures, Part 3: wind Loads
3) EN 1991-1-4-2005 Eurocode 1: Actions on structures - Part 1-4: General actions –

C. Codes Used for loading

1) IS 802 (Part 1/Sec 1):1995
2) IS 5613(Part 2/sec 1):1985

II. Properties of Transmission Tower

A. Sag tension calculation for conductor

SAG TENSION CALCULATION MANUAL CALCULATION
Name of the Conductor : ACSR "PANTHER" Stranding : 30/3.00+7/3.00 Area (A) : $261.5mm^2 = 261.5x10^{-6}m^2$ Diameter (ϕ) : 21mm = 0.021m Unit Weight (wt) : 974Kg/Km =0.974 Kg/m Ultimate Tensile Strength (T_{ult}): 89.672KN = 9144Kg Modulus of Elasticity (E): $8158Kg/mm^2$ $= 8158x10^{-6}Kg/m^2$ Coefficient of Linear Expansion (a) :$1.78Ex10^{-6}/^oC$ Basic Span (L) :305m
Everyday Temperature (q) : 32^0C
Maximum Temperature (θmax): 85^0C
No Wind (wNil) : 0 Kg/m^2
Full Wind (wFull) :152.1 Kg/m^2
75% Wind (w75%) :114.1 Kg/m^2
36% Wind (w36%) :54.8 Kg/m^2
Co Constant [R] R^2N No Wind [$=WT^2+(ϕxwNil)^2$] = [$0.974^2 + (0.021 x 0)^2$] = 0.9487 R^2F Full Wind [$=WT^2+(ϕxwFull)^2$] = [$0.974^2 + (0.021 x 152.1)^2$] =11.1510 R^2 75 75% Wind [$=WT^2+(ϕxw36\%)^2$] = [$0.974^2+(0.021 x 114.1)^2$] = 6.6900

$R^2$36 36% Wind [=$WT^2+(\phi x w36\%)^2$] =[0.974^2 + $(0.021)^2$]= 2.2730

B. *Sag Tension Calculation for Earthwire*

SAG TENSION CALCULATIONMANUAL CALCULATION
Name of the Conductor : GSW E/W Stranding : 7/3.15
Area (A):54.55 mm^2 = $54.55x10^{-6}m^2$
Diameter (ϕ) : 9.45mm = 0.00945m
Unit Weight (WT) : 428Kg/Km =0.428 Kg/m
Ultimate Tensile Strength (Tult):55.996KN =5710Kg
Modulus of Elasticity(E): 19330Kg/mm^2 =$19330x10^6 Kg/m^2$
Coefficient of Linear Expansion (a):$1.15E^{-5}$ /^{0}C =$11.5x10^{-6}$/^{0}C
Basic Span (L) : 305m
Minimum Temperature (θmin) :0^0C
Everyday Temperature (θ) :32^0C
Maximum Temperature (θmax) :53^0C
No Wind (wNil) : 0 Kg/m^2 Full Wind (wFull) :188.5 Kg/m^2 75% Wind (w75%): 141.4 Kg/m^2 36% Wind (w36%): 67.9 Kg/m^2
FOS for Max^m Tension at Everyday Temperature with Full Wind (FFW) =70% of UTS FOS for Maxm Tension at Minimum Temperature with 36% Wind (F36%W) =70% of UTS FOS for Maxm Tension at Everyday Temperature with No Wind (FNW) =25% of UTS
EARTH-WIRE SAG < 90% OF CONDUCTOR SAG

III. COMPONENTS OF TRANSMISSION TOWER

A. *Properties of Suspension Transmission Tower*

1) Height of tower: GC + Max Sag + SE + DSI + Attachment + Dist. between insulator+peak distance =6.100+6.861+0.150+1.839+0.410+4.100+4.050+3.925 = 27.435 m
2) Type of tower: Suspension Tower (0-20)
3) Transmission line voltage: 132kV
4) Terrain type: Plain
5) Cross arm: Pointed

B. *Properties of Angle Transmission Tower*

1) Height of tower: GC + Max Sag + SE + DSI + Attachment + Dist. between insulator +peak distance =6.100+6.861+0.150+0.039+3.9+3.9+5.945 = 26.9 m
2) Type of tower: Suspension Tower (2º-15º)
3) Transmission line voltage: 132kV
4) Terrain type: Plain
5) Cross arm: Pointed

IV. WIND LOAD ON TOWER

A. *Suspension Transmission Tower*

Fwt = Pd x Cdt x Ae x Gt

II Zone

For Peak – TXA

For Translational = 1289.2 x 2.17 x 0.973 x 2.341 = 6372.27 N

For Longitudinal = 1289.2 x 2.377 x 1.609 x 2.341 = 11542.68 N

For TXA – MXA

For Translational = 1289.2 x 2.7 x 1.342 x 2.302 = 10753.3 N

For Longitudinal = 1289.2 x 2.632 x 2.007 x 2.302 = 15676.85 N

For MXA – BXA

For Translational = 1289.2 x 2.716 x 1.590 x 2.261 = 12587.74 N

For Longitudinal = 1289.2 x 2.640 x 2.327 x 2.261 = 17906.93 N

For BXA – 6m

For Translational = 1289.2 x 3.115 x 3.304 x 2.201 = 29203.73 N

For Longitudinal = 1289.2 x 3.115 x 3.304 x 2.201 = 29203.73 N

For 6m – 0m

For Translational = 1289.2 x 3.922 x 3.320 x 1.994 = 33472.73 N

For Longitudinal = 1289.2 x 3.922 x 3.320 x 1.994 = 33472.73 N

III Zone

For Peak – TXA

For Translational = 2136.52 x 2.17 x 0.973 x 2.341 = 10560.41 N

For Longitudinal = 2136.52 x 2.377 x 1.609 x 2.341 = 19129.05 N

For TXA – MXA

For Translational = 2136.52 x 2.7 x 1.342 x 2.302 = 17820.85 N

For Longitudinal = 2136.52 x 2.632 x 2.007 x 2.302 = 25980.3 N

For MXA – BXA

For Translational = 2136.52 x 2.716 x 1.590 x 2.261 = 20860.9 N

For Longitudinal = 2136.52 x 2.640 x 2.327 x 2.261 = 29676.1 N

For BXA – 6m

For Translational = 2136.52 x 3.115 x 3.304 x 2.201 = 48397.74N

For Longitudinal = 2136.52 x 3.115 x 3.304 x 2.201 = 48397.74N

For 6m – 0m

For Translational = 2136.52 x 3.922 x 3.320 x 1.994 = 55472.5N

For Longitudinal = 2136.52 x 3.922 x 3.320 x 1.994 = 55472.5N

IV Zone

For Peak – TXA

For Translational = 1907.61 x 2.17 x 0.973 x 2.341 = 9428.95N

For Longitudinal = 1907.61 x 2.377 x 1.609 x 2.341 = 17079.5N

For TXA – MXA

For Translational = 1907.61 x 2.7 x 1.342 x 2.302 =15911.5N

For Longitudinal = 1907.61 x 2.632 x 2.007 x 2.302 = 23196.8N

For MXA – BXA

For Translational = 1907.61 x 2.716 x 1.590 x 2.261 = 18625.9 N
For Longitudinal = 1907.61 x 2.640 x 2.327 x 2.261 = 26496.62 N
For BXA – 6m
For Translational = 1907.61 x 3.115 x 3.304 x 2.201 = 43212.33 N
For Longitudinal = 1907.61 x 3.115 x 3.304 x 2.201 = 43212.33N
For 6m – 0m
For Translational = 1907.61 x 3.922 x 3.320 x 1.994 = 49529.1 N
For Longitudinal = 1907.61 x 3.922 x 3.320 x 1.994 = 49529.1 N

1) Angle Transmission Tower

Fwt = Pd x Cdt x Ae x Gt
II Zone
For Peak - TXA
For Translational = 1289.2 x 2.386 x 1.702 x 2.326 = 12177.5 N
For Longitudinal = 1289.2 x 2.284 x 2.334 x 2.326 = 15985.5 N
For TXA – MXA
For Translational = 1289.2 x 2.556 x 1.705 x 2.277 = 12792.8 N
For Longitudinal = 1289.2 x 2.404 x 2.313 x 2.277 = 16322.75 N
For MXA – BXA
For Translational = 1289.2 x 2.524 x 2.050 x 2.238 = 14928.75 N
For Longitudinal = 1289.2 x 2.407 x 2.659 x 2.238 = 18466.08 N
For BXA – 6m
For Translational = 1289.2 x 2.945 x 2.934 x 2.175 = 24228.4N
For Longitudinal = 1289.2 x 2.945 x 2.934 x 2.175 = 24228.4N
For 6m – 0m
For Translational = 1289.2 x 3.275 x 4.740 x 1.996 = 39945.74N
For Longitudinal = 1289.2 x 3.275 x 4.740 x 1.996 = 39945.75 N
III Zone
For Peak - TXA
For Translational = 2136.52 x 2.386 x 1.702 x 2.326 = 26491.9N
For Longitudinal = 2136.52 x 2.284 x 2.334 x 2.326 = 20181.18 N
For TXA – MXA
For Translational = 2136.52 x 2.556 x 1.705 x 2.277 = 21200.9 N
For Longitudinal = 2136.52 x 2.404 x 2.313 x 2.277 = 27050.8 N
For MXA – BXA
For Translational = 2136.52 x 2.524 x 2.050 x 2.238 = 24740.6 N
For Longitudinal = 2136.52 x 2.407 x 2.659 x 2.238 = 30602.8 N
For BXA – 6m
For Translational = 2136.52 x 2.945 x 2.934 x 2.175 = 40152.41 N
For Longitudinal = 2136.52 x 2.945 x 2.934 x 2.175 = 40152.41 N
For 6m – 0m
For Translational = 2136.52 x 3.275 x 4.740 x 1.996 = 66199.8 N
For Longitudinal = 2136.52 x 3.275 x 4.740 x 1.996 = 66199.8 N
IV Zone
For Peak - TXA
For Translational = 1907.61 x 2.386 x 1.702 x 2.326 = 18018.94 N
For Longitudinal = 1907.61 x 2.284 x 2.334 x 2.326 = 23653.42 N
For TXA – MXA
For Translational = 1907.61 x 2.556 x 1.705 x 2.277 = 18929.3 N
For Longitudinal = 1907.61 x 2.404 x 2.313 x 2.277 = 24152.4 N
For MXA – BXA
For Translational = 1907.61 x 2.524 x 2.050 x 2.238 = 22089.7 N
For Longitudinal = 1907.61 x 2.407 x 2.659 x 2.238 = 27323.8 N
For BXA – 6m
For Translational = 1907.61 x 2.945 x 2.934 x 2.175 = 35850.23 N
For Longitudinal = 1907.61 x 2.945 x 2.934 x 2.175 = 35850.23 N
For 6m – 0m
For Translational = 1907.61 x 3.275 x 4.740 x 1.996 = 59106.8 N
For Longitudinal = 1907.61 x 3.275 x 4.740 x 1.996 = 59106.8 N

B. Wind Load Calculation as Per IS 875:2015

1) Design Wind Speed, V_Z

The basic wind speed (V_Z) to get design wind velocity at any height

$V_Z = V_b * k1 * k2 * k3 * k4$

V_b for II Zone 39m/s
V_b for III Zone 44m/s
V_b for IV Zone 47m/s

ZONE	K_1	K_2	K_3	K_4
II	1.06	1.142	1	1.15
III	1.07	1.142	1	1.3
IV	1.07	1.142	1	1.15

V_Z for II Zone = 39 x 1.06 x 1.142 x 1 x 1.15 =54.29m/s
V_z for III Zone = 44 x 1.07 x 1.142 x 1 x 1.3 =69.89m/s
V_Z for IV Zone = 47 x 1.07 x 1.142 x 1 x 1.15 =66.04m/s

2. WIND PRESSURE AT HEIGHT Z

P_z for II Zone = $0.6V_z^2$=0.6x 54.29^2 =1768.44N/m^2
P_z for III Zone=$0.6V_z^2$ =0.6 x 69.89^2 =2930.76N/m^2
P_z for IV Zone=$0.6V_z^2$ = 0.6 x 66.04^2 =2616.76N/m^2

3.DESIGN WIND PRESSURE, P_d

P_d for II Zone = K_d x Ka x Kc x P_z = 0.9 x 0.9 x 0.9 x 1768.44 =1289.2N/m^2
P_d for III Zone = K_d x Ka x Kc x P_z = 0.9 x 0.9 x 0.9 x 2930.76 = 2136.52N/m^2
P_d for IV Zone = K_d x Ka x Kc x P_z = 0.9 x 0.9 x 0.9 x 2616.76 = 1907.61N/m^2

C. Wind Load Calculation as Per IS 875:1987

1) Design Wind Speed, V_Z

The basic wind speed (V_Z) to get design wind velocity at any height

$V_Z = V_b * k1 * k2 * k3$

V_b for II Zone 39m/s

V_b for III Zone 44m/s

V_b for IV Zone 47m/s

ZONE	K1	K2	K3
II	1.06	1.07	1
III	1.07	1.07	1
IV	1.07	1.07	1

V_Z for II Zone = 39 x 1.06 x 1.07 x 1 = 44.23m/s

Vz for III Zone = 44 x 1.07 x 1.07 x 1 = 50.37m/s

Vz for IV Zone = 47 x 1.07 x 1.07 x 1 = 53.81m/s

2. DESIGN WIND PRESSURE, Pz

P_z for II Zone = $0.6V_z^2$ =0.6 x 44.23^2 =1173.77N/m^2

P_z for III Zone =$0.6V_z^2$ =0.6 x 50.37^2 =1522.28N/m^2

P_z for IV Zone = $0.6V_z^2$ =0.6 x 53.81^2 =1737.3N/m^2

D. Wind Load Calculation as Per EN 1991-1-4:2005

1) Basic Wind Velocity, Vb

Vb = C_{dir} x C_{season} x V_{Bq}

Vb for II Zone = 1x1x22 =22m/s

Vb for III Zone = 1x1x24 =24m/s

Vb for IV Zone = 1x1x26 =26m/s

2) Mean Wind Velocity, Vm(z)

Vm(z) = Cr(z) x C_0(z) x Vb

Cr(z) = Kr x ln (z/z_0)

Kr = $0.19(z_0/z_{0II})^{0.07}$

= $0.19\ (0.01/0.05)^{0.07}$

= 0.169

Cr(z) = 0.169 x ln(1/0.01)

= 0.663

Vm(z) for II Zone = 0.663 x 1 x 22 =14.59m/s

Vm(z) for III Zone = 0.663 x 1 x 24 = 15.91m/s

Vm(z) for IV Zone = 0.663 x 1 x 26 = 17.23m/s

3) Peak Velocity Pressure, $q_p(z)$

$Q_p(z)$ = Ce(z) x q_b

Qb for II Zone = $\left| q_b = \frac{1}{2}\cdot\rho\cdot v_b^2 \right.$ $\left| q_b = \frac{1}{2}\cdot\rho\cdot v_b^2 \right.$ = ½ x 1.25 x 22^2 = 302.5N/m^2

Qb for III Zone =1/2x 1.25 x 24^2
= 360 N/m^2

Qb for IV Zone = ½ x 1.25 x 26^2
= 422.5N/m^2

$Q_p(z)$ for II Zone = (1+7/ln(1/0.05)) x ½ x 1.25 x 14.59^2
=443.91N/m^2

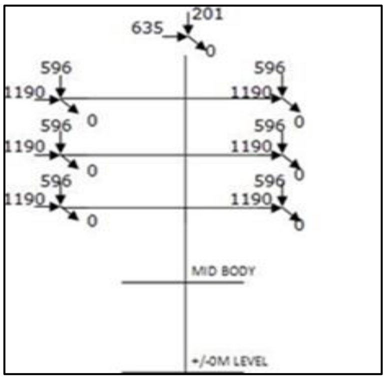
Qp(z) for III Zone = (1+7/ln(1/0.05)) x ½ x 1.25 x 15.91^2
=527.87N/m^2

Qp(z) for IV Zone = (1+7/ln(1/0.05)) x ½ x 1.25 x 17.23^2
= 619.1 N/m^2

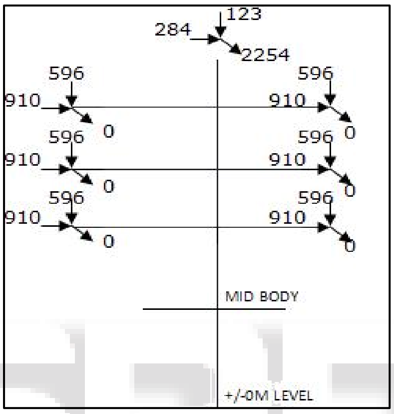
V. LOAD CONSIDERED IN STAAD ANALYSIS

1) Dead Load (DL)
2) WLX (Wind Load in positive X direction)
3) WLX- (Wind Load in negative X direction)
4) WLZ (Wind Load in positive Z direction)
5) WLZ- (Wind Load in negative Z direction)

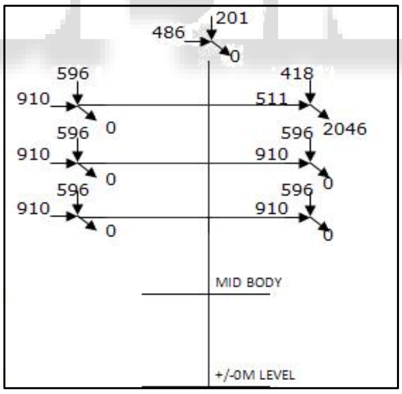
A. Cable Case 1 (Normal Condition Full Wind 90º Perpendicular)



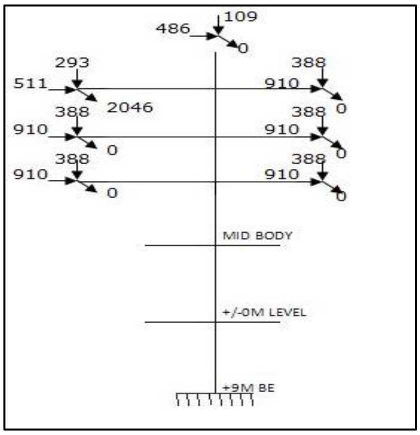
B. Cable Case 2 (Normal Condition Full Wind 45º Diagonal)



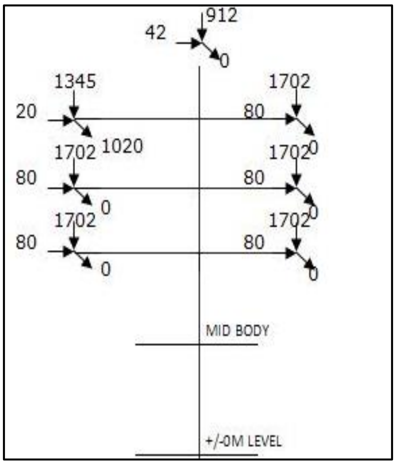
C. Cable Case 3 (Earthwire & Any One Conductor Broken)



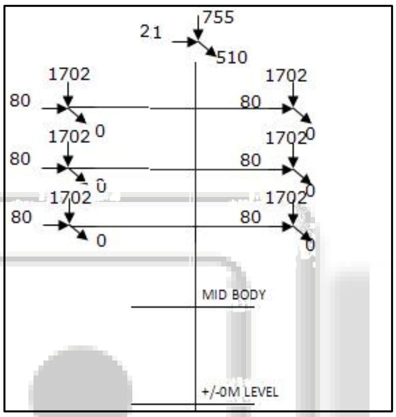
D. Cable Case 4 (Any Two Conductors Broken)



E. Cable Case 5(Anticascade Condition)



F. Cable Case 6 (Normal Condition with No Wind Pressure on Tower Body)



1) Load Combinations for Tower Analysis

a) CAB_CASE 1:
1) DL+CAB_CASE 1
2) DL+CAB_CASE 1+WLX
3) DL+CAB_CASE 1+WLX-
4) DL+CAB_CASE 1+WLZ
5) DL+CAB_CASE 1+WLZ-

b) CAB_CASE 2:
1) DL+CAB_CASE 2
2) DL+CAB_CASE 2+WLX
3) DL+CAB_CASE 2+WLX-
4) DL+CAB_CASE 2+WLZ
5) DL+CAB_CASE 2+WLZ-

c) CAB_CASE 3:
1) DL+CAB_CASE 3
2) DL+CAB_CASE 3+WLX
3) DL+CAB_CASE 3+WLX-
4) DL+CAB_CASE 3+WLZ
5) DL+CAB_CASE 3+WLZ-

d) CAB_CASE 4:
1) DL+CAB_CASE 4
2) DL+CAB_CASE 4+WLX
3) DL+CAB_CASE 4+WLX-
4) DL+CAB_CASE 4+WLZ
5) DL+CAB_CASE 4+WLZ-

e) CAB_CASE 5:
1) DL+CAB_CASE 5
2) DL+CAB_CASE 5+WLX
3) DL+CAB_CASE 5+WLX-
4) DL+CAB_CASE 5+WLZ
5) DL+CAB_CASE 5+WLZ-

f) CAB_CASE 6:
1) DL+CAB_CASE 6
2) DL+CAB_CASE 6+WLX
3) DL+CAB_CASE 6+WLX-
4) DL+CAB_CASE 6+WLZ
5) DL+CAB_CASE 6+WLZ-

VI. Results and Comparison

The 18 models of Transmission Tower are analysed to obtain the results for member foeces and support reactions. The comparative study is done with respect to axial force (Fx) in members and reaction (Fy), moments (Mx & Mz) in supports for all different towers. The analysis results are studied and compared for the following columns and beams.

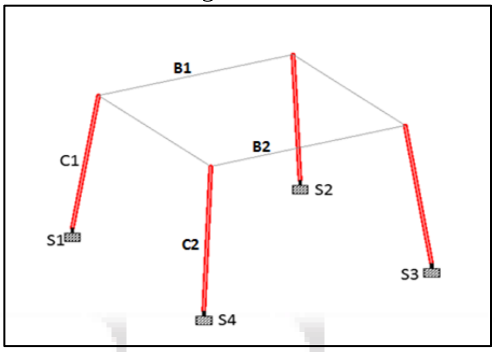


Fig. 5.1: Columns studied in Analysis

A. Member Forces & Support Reactions for Zone II in Wind Analysis of Suspension Tower for Cross, Diagonal & K Braced Tower as Per IS 875:1987

Member	L/C	Fx	Fy	Fz	Mx	My	Mz
C 1	DL+Cab_Case1+WLX	-2208.37	2.549	-8.651	0.011	30.657	7.929
C 2	DL+Cab_Case1+WLX	-2033.19	4.007	5.478	0.004	-22.04	11.35
B1	DL+Cab_Case1+WLX	-8.448	-36.75	12.592	-0.037	-12.391	-36.9
B 2	DL+Cab_Case1+WLX	0.788	-36.03	-8.5	-0.031	8.6	-37.98

Table 6.1.A.1: Member Forces

Member	L/C	Fx	Fy	Fz	Mx	My	Mz
S1	DL+Cab_Case1+WLX	-306.86	-3172.64	-147.6	1.003	-0.477	-1.246
S2	DL+Cab_Case1+WLX	-295.667	2995.68	141.45	-1.211	-0.45	-1.665

S3	DL+Cab_Case1+WLX	-174.41	2972.71	-253.7	-0.704	-0.325	-3.612
S4	DL+Cab_Case1+WLX	-175.56	-2998.7	259.8	1.254	-0.351	-3.264

Table 6.1.A.2: Support Reaction for Maximum Value Fy

Member	L/C	Fx	Fy	Fz	Mx	My	Mz
S1	DL+Cab_Case2+WLX	-370.04	-3633.56	-177.35	1.537	-1.114	-0.437
S2	DL+Cab_Case2+WLX	-352.553	3456.61	171.398	-1.184	-0.445	-1.791
S3	DL+Cab_Case2+WLX	-228.822	3429.11	-284.27	-0.75	-0.339	-3.766
S4	DL+Cab_Case2+WLX	-236.26	-3455.14	290.23	0.744	0.273	-2.494

Table 6.1.A.3: Support Reaction for Maximum Value Mx

Member	L/C	Fx	Fy	Fz	Mx	My	Mz
S1	DL+Cab_Case3+WLX	-227.88	-3432.12	288.936	1.302	-0.367	-3.404
S2	DL+Cab_Case3+WLX	-233.017	3406.08	-282.5	-0.196	0.298	-2.829
S3	DL+Cab_Case3+WLX	-356.73	3433.3	169.6	-1.743	-1.085	-0.842
S4	DL+Cab_Case3+WLX	-361.62	-3610.3	-176.02	0.974	-0.47	-1.359

Table 6.1.A.4: Support Reaction For Maximum Value Mz

B. Member Forces & Support Reactions for Zone III in Wind Analysis of Suspension Tower for Cross, Diagonal & K Braced Tower as Per IS 875:1987

Member	L/C	Fx	Fy	Fz	Mx	My	Mz
C 1	DL+Cab_Case1+WLX	-383.42	4.169	-10.689	-0.004	34.192	12.36
C 2	DL+Cab_Case1+WLX	-474.25	3.076	12.498	0.015	-39.92	9.234
B 1	DL+Cab_Case1+WLX	464.25	-45.69	34.524	-0.010	-34.45	-46.159
B 2	DL+Cab_Case1+WLX	97.63	-46.628	0.487	0.006	-0.102	-46.55

Table 6.2.A.1: Member Forces

Member	L/C	Fx	Fy	Fz	Mx	My	Mz
S1	DL+Cab_Case1+WLX	-215.04	-1526.78	-65.44	1.003	-0.564	0.801
S2	DL+Cab_Case1+WLX	-207.59	1408.82	61.34	-1.161	-0.547	0.532
S3	DL+Cab_Case1+WLX	-105.77	1266.76	-115.2	-0.058	0.029	-0.905
S4	DL+Cab_Case1+WLX	-106.59	-1284.13	119.32	0.383	0.016	-0.632

Table 6.2.A.2: Support Reaction For Maximum Value Fy

Member	L/C	Fx	Fy	Fz	Mx	My	Mz
S1	DL+Cab_Case2+WLX	-273.8	-1946.5	-92.49	1.534	-1.2	1.631
S2	DL+Cab_Case2+WLX	-260.01	1828.5	88.6	-1.124	-0.533	0.416
S3	DL+Cab_Case2+WLX	-155.84	1682.16	-143.05	-0.112	0.008	-1.047
S4	DL+Cab_Case2+WLX	-163.01	-1699.53	146.93	-0.126	0.641	0.160

Table 6.2.A.3: Support Reaction for Maximum Value Mx

Member	L/C	Fx	Fy	Fz	Mx	My	Mz
S1	DL+Cab_Case3+WLX	-264.48	1807.73	87.003	-1.689	-1.181	1.373
S2	DL+Cab_Case3+WLX	-265.56	-1925.6	-91.32	0.965	-0.549	0.697
S3	DL+Cab_Case3+WLX	-160.32	1661.5	-141.48	0.448	0.652	-0.191
S4	DL+Cab_Case3+WLX	-154.77	-1678.8	145.88	0.439	-0.007	-0.761

Table 6.2.A.4: Support Reaction for Maximum Value Mz

C. Member Forces & Support Reactions for Zone IV in Wind Analysis of Suspension Tower for Cross, Diagonal & K Braced Tower As Per IS 875:1987

Member	L/C	Fx	Fy	Fz	Mx	My	Mz
C1	DL+Cab_Case1+WLX	-383.42	4.169	-10.68	-0.004	34.19	12.36
C2	DL+Cab_Case1+WLX	-474.53	3.07	12.49	0.015	-39.92	9.23
B1	DL+Cab_Case1+WLX	488.4	-3.74	10.46	0.011	-34.7	-11.27
B2	DL+Cab_Case1+WLX	257.81	-3.19	-11.32	-0.007	36.95	-9.7

Table 6.3.A.1: MEMBER FORCES

Member	L/C	Fx	Fy	Fz	Mx	My	Mz
S1	DL+Cab_Case1+WLX	-215.04	-1526.7	-65.4	1.003	-0.58	0.801
S2	DL+Cab_Case1+WLX	-207.59	1408.8	61.34	-1.161	-0.547	0.532
S3	DL+Cab_Case1+WLX	-105.77	1266.7	-115.2	-0.058	0.029	-0.905
S4	DL+Cab_Case1+WLX	-106.59	-1284.1	119.3	0.383	0.016	-0.632

Table 6.3.A.2: Support Reaction For Maximum Value Fy

Member	L/C	Fx	Fy	Fz	Mx	My	Mz
S1	DL+Cab_Case2+WLX	-293.89	-2083.6	-101.3	1.738	-1.446	1.966
S2	DL+Cab_Case2+WLX	-277.56	1965.67	97.5	-1.104	-0.523	0.377
S3	DL+Cab_Case2+WLX	-172.54	1817.71	-152.13	-0.138	-0.006	-1.095
S4	DL+Cab_Case2+WLX	-182.2	-1835	155.93	-0.322	0.883	0.481

Table 6.3.A.3: Support Reaction For Maximum Value Mx

Member	L/C	Fx	Fy	Fz	Mx	My	Mz
S1	DL+Cab_Case3+WLX	-282.5	-2056.2	-99.78	0.944	-0.538	0.663
S2	DL+Cab_Case3+WLX	-283.94	1938.26	95.38	-1.893	-1.426	1.712
S3	DL+Cab_Case3+WLX	-178.94	1790.56	-150.05	0.644	0.893	0.224
S4	DL+Cab_Case3+WLX	-170.88	-1807.9	154.45	0.465	-0.021	-0.807

Table 6.3.A.4: Support Reaction for Maximum Value Mz

D. Member Forces & Support Reactions for Zone II in Wind Analysis of Suspension Tower for Cross, Diagonal & K Braced Tower As Per IS 875:2015

Member	L/C	Fx	Fy	Fz	Mx	My	Mz
C 1	DL+Cab_Case1+WLX	-721.37	6.708	-16.58	-0.012	53.385	19.94
C 2	DL+Cab_Case1+WLX	-862.2	4.547	18.75	0.039	-60.44	13.76
B 1	DL+Cab_Case1+WLX	-267.46	-77.75	11.18	0.059	-11.82	-78.68
B 2	DL+Cab_Case1+WLX	-155.73	-70.92	38.43	-0.004	-40.05	-70.05

Table 6.4.A.1: Member Forces

Member	L/C	Fx	Fy	Fz	Mx	My	Mz
S1	DL+Cab_Case1+WLX	-371.2	-2665.9	-122.9	2.04	-1.249	2.036
S2	DL+Cab_Case1+WLX	-356.4	2498.6	117.5	-1.94	-0.85	1.090
S3	DL+Cab_Case1+WLX	-199.69	2259.9	-196.3	-0.12	0.031	-1.368
S4	DL+Cab_Case1+WLX	-204.55	-2276.4	201.6	0.273	0.382	-0.417

Table 6.4.A.2: Support Reaction For Maximum Value Fy

Member	L/C	Fx	Fy	Fz	Mx	My	Mz
S1	DL+Cab_Case2+WLX	-366.4	-2665.5	-123.01	1.704	-0.873	1.4
S2	DL+Cab_Case2+WLX	-360.2	2498.2	117.4	-2.28	-1.22	1.63
S3	DL+Cab_Case2+WLX	-204.5	2260.3	-196.2	0.215	0.405	-0.815

S4	DL+Cab_Case2+WLX	-200.73	-2276.8	201.8	0.605	0.011	-0.96

Table 6.4.A.3: Support Reaction for Maximum Value Mx

Member	L/C	Fx	Fy	Fz	Mx	My	Mz
S1	DL+Cab_Case3+WLX	-348.67	-2681.6	-144.7	1.298	-0.496	1.238
S2	DL+Cab_Case3+WLX	-287.45	1741.7	46.98	-2.33	-1.209	1.484
S3	DL+Cab_Case3+WLX	-183.41	2281.05	-214.09	0.025	0.029	-1.262
S4	DL+Cab_Case3+WLX	-132.95	-1524.8	135.9	0.764	-0.001	-0.884

Table 6.4.A.4: Support Reaction for Maximum Value Mz

E. Member Forces & Support Reactions for Zone III in Wind Analysis of Suspension Tower for Cross, Diagonal & K Braced Tower as Per IS 875:2015

Member	L/C	Fx	Fy	Fz	Mx	My	Mz
C 1	DL+Cab_Case1+WLX	-829.4	6.961	-17.23	-0.012	55.63	20.7
C 2	DL+Cab_Case1+WLX	-975.2	4.776	19.34	0.04	-62.5	14.45
B 1	DL+Cab_Case1+WLX	-267.22	-80.76	10.72	0.06	-11.37	-81.7
B 2	DL+Cab_Case1+WLX	-155.02	-73.84	39.15	-0.006	-40.82	-72.9

Table 6.5.A.1: Member Forces

Member	L/C	Fx	Fy	Fz	Mx	My	Mz
S1	DL+Cab_Case1+WLX	-407.13	-2538.2	-140.09	2.345	-1.58	2.487
S2	DL+Cab_Case1+WLX	-388.3	2762.7	134.8	-1.94	-0.84	1.04
S3	DL+Cab_Case1+WLX	-230.3	2521.7	-213.8	-0.13	0.025	-1.434
S4	DL+Cab_Case1+WLX	-239.2	-2538.2	219.01	-0.018	0.715	0.011

Table 6.5.A.2: Support Reaction For Maximum Value Fy

Member	L/C	Fx	Fy	Fz	Mx	My	Mz
S1	DL+Cab_Case2+WLX	-397.9	-2929.3	-140.1	1.701	-0.871	1.423
S2	DL+Cab_Case2+WLX	-395.68	2761.9	134.4	-2.584	-1.56	2.073
S3	DL+Cab_Case2+WLX	-239.61	2522.54	-213.6	0.509	0.74	-0.376
S4	DL+Cab_Case2+WLX	-231.9	-2539	219..3	0.617	0.006	-1.015

Table 6.5.A.3: Support Reaction For Maximum Value Mx

Member	L/C	Fx	Fy	Fz	Mx	My	Mz
S1	DL+Cab_Case3+WLX	-366.52	-2954.2	-178.53	0.911	-0.17	0.957
S2	DL+Cab_Case3+WLX	-269.4	1467.07	12.49	-2.72	-1.536	1.764
S3	DL+Cab_Case3+WLX	-201.57	2555.67	-244.6	0.13	0.041	-1.239
S4	DL+Cab_Case3+WLX	-114.9	-1252.29	106.07	0.88	-0.015	-0.91

Table 6.5.A.4: Support Reaction for Maximum Value Mz

F. Member Forces & Support Reactions for Zone IV in Wind Analysis of Suspension Tower for Cross, Diagonal & K Braced Tower as Per Is 875:2015

Member	L/C	Fx	Fy	Fz	Mx	My	Mz
C1	DL+Cab_Case1+WLX	-912.92	7.156	-17.74	-0.012	57.3	21.27
C2	DL+Cab_Case1+WLX	-1057.98	4.953	19.79	0.04	-64.11	14.98
B1	DL+Cab_Case1+WLX	-267.05	-83.68	10.36	0.061	-11.02	-84.03
B2	DL+Cab_Case1+WLX	-154.46	-76.1	39.7	-0.007	-41.43	-75.18

Table 6.6.A.1: MEMBER FORCES

Member	L/C	Fx	Fy	Fz	Mx	My	Mz
S1	DL+Cab_Case1+WLX	-435.48	-3135.7	-153.3	2.59	-1.867	2.884
S2	DL+Cab_Case1+WLX	-413.4	2968.43	148.2	-1.94	-0.846	1.002

S3	DL+Cab_Case1+WLX	-254.46	2725.51	-227.3	-0.145	0.018	-1.48
S4	DL+Cab_Case1+WLX	-266.52	-2741.97	232.51	-0.257	0.99	0.371

Table 6.6.A.2: SUPPORT REACTION FOR MAXIMUM VALUE Fy

Member	L/C	Fx	Fy	Fz	Mx	My	Mz
S1	DL+Cab_Case2+WLX	-422.6	-3134.6	-153.5	1.695	-0.867	1.379
S2	DL+Cab_Case2+WLX	-423.6	2967.2	147.7	-2.8	-1.837	2.442
S3	DL+Cab_Case2+WLX	-267.3	2726.6	-227.1	0.75	1.016	-0.009
S4	DL+Cab_Case2+WLX	-256.3	-2743.12	233.03	0.63	0	-1.061

Table 6.6.A.3: SUPPORT REACTION FOR MAXIMUM VALUE Mx

Member	L/C	Fx	Fy	Fz	Mx	My	Mz
S1	DL+Cab_Case3+WLX	-380-3	-3165.8	-205.14	0.585	0.99	0.725
S2	DL+Cab_Case3+WLX	-255.42	1253.8	-14.64	-3.055	-1.805	1.996
S3	DL+Cab_Case3+WLX	-215.67	2768.9	-268.5	0.212	0.053	-1.217
S4	DL+Cab_Case3+WLX	-101.03	-1040.65	82.73	0.970	-0.029	-0.934

Table 6.6.A.4: SUPPORT REACTION FOR MAXIMUM VALUE Mz

G. Member Forces & Support Reactions for Zone II in Wind Analysis of Suspension Tower for Cross, Diagonal & K Braced Tower as Per EN 1991-1-4:2005

Member	L/C	Fx	Fy	Fz	Mx	My	Mz
C 1	DL+Cab_Case1+WLX	-688.64	6.54	-16.82	-0.006	53.94	19.4
C 2	DL+Cab_Case1+WLX	-824.08	4.89	19.49	0.022	-62.4	14.68
B 1	DL+Cab_Case1+WLX	-273.95	-76.2	10.24	0.032	-11.09	-77.1
B 2	DL+Cab_Case1+WLX	-155.13	-71.84	34.3	-0.008	-34.97	-71.56

Table 6.7.A.1: MEMBER FORCES

Member	L/C	Fx	Fy	Fz	Mx	My	Mz
S1	DL+Cab_Case1+WLX	-365.03	-2594.5	-117.8	1.872	-1.285	1.771
S2	DL+Cab_Case1+WLX	-349.5	2417.6	111.8	-1.721	-0.815	0.721
S3	DL+Cab_Case1+WLX	-195.26	2201.5	-192.9	-0.117	0.034	-1.451
S4	DL+Cab_Case1+WLX	-200.8	-2227.5	198.9	0.22	0.456	-0.404

Table 6.7.A.2: SUPPORT REACTION FOR MAXIMUM VALUE Fy

Member	L/C	Fx	Fy	Fz	Mx	My	Mz
S1	DL+Cab_Case2+WLX	-359.2	-2578.5	-116.9	1.483	-0.841	1.176
S2	DL+Cab_Case2+WLX	-352.3	2401.5	110.6	-2.107	-1.257	1.376
S3	DL+Cab_Case2+WLX	-198.15	2185.6	-191.7	0.265	0.474	-0.804
S4	DL+Cab_Case2+WLX	-195.03	-2211.67	198.05	0.606	0.014	-1.032

Table 6.7.A.3: SUPPORT REACTION FOR MAXIMUM VALUE Mx

Member	L/C	Fx	Fy	Fz	Mx	My	Mz
S1	DL+Cab_Case3+WLX	-342.7	-2601.2	-141.5	0.943	-0.406	0.841
S2	DL+Cab_Case3+WLX	-290.9	1804.8	50.09	-2.27	-1.253	1.145
S3	DL+Cab_Case3+WLX	-179.25	2208.5	-210.4	0.014	0.052	-1.32
S4	DL+Cab_Case3+WLX	-139.59	-1615.14	139.9	0.659	0.021	-0.976

Table 6.7.A.4: SUPPORT REACTION FOR MAXIMUM VALUE Mz

H. Member Forces & Support Reactions for Zone III in Wind Analysis of Suspension Tower for Cross, Diagonal & K Braced Tower as Per EN 1991-1-4:2005

Member	L/C	Fx	Fy	Fz	Mx	My	Mz
C 1	DL+Cab_Case1+WLX	-688.64	6.54	-16.82	-0.006	53.94	19.4
C 2	DL+Cab_Case1+WLX	-824.08	4.89	19.49	0.022	-62.4	14.68
B 1	DL+Cab_Case1+WLX	-273.95	-76.2	10.24	0.032	-11.09	-77.1
B 2	DL+Cab_Case1+WLX	-155.13	-71.84	34.3	-0.008	-34.97	-71.56

Table 6.8.A.1: MEMBER FORCES

Member	L/C	Fx	Fy	Fz	Mx	My	Mz
S1	DL+Cab_Case1+WLX	-365.03	-2594.5	-117.8	1.872	-1.285	1.771
S2	DL+Cab_Case1+WLX	-349.5	2417.6	111.8	-1.721	-0.815	0.721
S3	DL+Cab_Case1+WLX	-195.26	2201.5	-192.9	-0.117	0.034	-1.451
S4	DL+Cab_Case1+WLX	-200.8	-2227.5	198.9	0.22	0.456	-0.404

Table 6.8.A.2: SUPPORT REACTION FOR MAXIMUM VALUE Fy

Member	L/C	Fx	Fy	Fz	Mx	My	Mz
S1	DL+Cab_Case2+WLX	-359.2	-2578.5	-116.9	1.483	-0.841	1.176
S2	DL+Cab_Case2+WLX	-352.3	2401.5	110.6	-2.107	-1.257	1.376
S3	DL+Cab_Case2+WLX	-198.15	2185.6	-191.7	0.265	0.474	-0.804
S4	DL+Cab_Case2+WLX	-195.03	-2211.67	198.05	0.606	0.014	-1.032

Table 6.8.A.3: SUPPORT REACTION FOR MAXIMUM VALUE Mx

Member	L/C	Fx	Fy	Fz	Mx	My	Mz
S1	DL+Cab_Case3+WLX	-342.7	-2601.2	-141.5	0.943	-0.406	0.841
S2	DL+Cab_Case3+WLX	-290.9	1804.8	50.09	-2.27	-1.253	1.145
S3	DL+Cab_Case3+WLX	-179.25	2208.5	-210.4	0.014	0.052	-1.32
S4	DL+Cab_Case3+WLX	-139.59	-1615.14	139.9	0.659	0.021	-0.976

Table 6.8.A.4: SUPPORT REACTION FOR MAXIMUM VALUE Mz

I. Member Forces & Support Reactions for Zone IV in Wind Analysis of Suspension Tower for Cross, Diagonal & K Braced Tower as Per EN 1991-1-4:2005

Member	L/C	Fx	Fy	Fz	Mx	My	Mz
C 1	DL+Cab_Case1+WLX	-688.64	6.54	-16.82	-0.006	53.94	19.4
C 2	DL+Cab_Case1+WLX	-824.08	4.89	19.49	0.022	-62.4	14.68
B 1	DL+Cab_Case1+WLX	-273.95	-76.2	10.24	0.032	-11.09	-77.1
B 2	DL+Cab_Case1+WLX	-155.13	-71.84	34.3	-0.008	-34.97	-71.56

Table 6.9.A.1: MEMBER FORCES

Member	L/C	Fx	Fy	Fz	Mx	My	Mz
S1	DL+Cab_Case1+WLX	-365.03	-2594.5	-117.8	1.872	-1.285	1.771
S2	DL+Cab_Case1+WLX	-349.5	2417.6	111.8	-1.721	-0.815	0.721
S3	DL+Cab_Case1+WLX	-195.26	2201.5	-192.9	-0.117	0.034	-1.451
S4	DL+Cab_Case1+WLX	-200.8	-2227.5	198.9	0.22	0.456	-0.404

Table 6.9.A.2: SUPPORT REACTION FOR MAXIMUM VALUE Fy

Member	L/C	Fx	Fy	Fz	Mx	My	Mz
S1	DL+Cab_Case2+WLX	-359.2	-2578.5	-116.9	1.483	-0.841	1.176
S2	DL+Cab_Case2+WLX	-352.3	2401.5	110.6	-2.107	-1.257	1.376
S3	DL+Cab_Case2+WLX	-198.15	2185.6	-191.7	0.265	0.474	-0.804

S4	DL+Cab_Case2+WLX	-195.03	-2211.67	198.05	0.606	0.014	-1.032

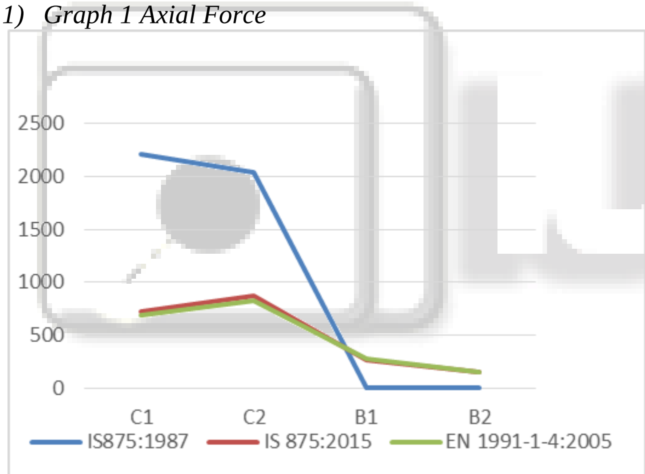
Table 6.9.A.3: SUPPORT REACTION FOR MAXIMUM VALUE Mx

Member	L/C	Fx	Fy	Fz	Mx	My	Mz
S1	DL+Cab_Case3+WLX	-342.7	-2601.2	-141.5	0.943	-0.406	0.841
S2	DL+Cab_Case3+WLX	-290.9	1804.8	50.09	-2.27	-1.253	1.145
S3	DL+Cab_Case3+WLX	-179.25	2208.5	-210.4	0.014	0.052	-1.32
S4	DL+Cab_Case3+WLX	-139.59	-1615.14	139.9	0.659	0.021	-0.976

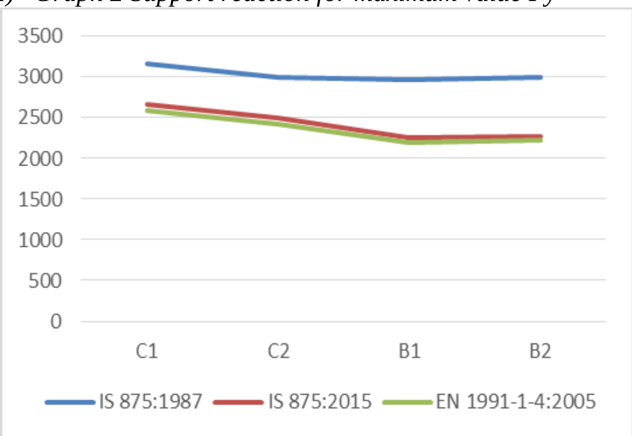
Table 6.9.A.4: SUPPORT REACTION FOR MAXIMUM VALUE Mz

J. Graphical Comparison of Results Zone II Suspension Tower

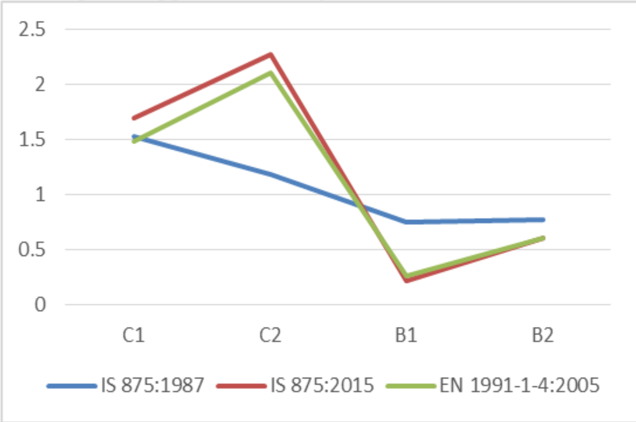
1) Graph 1 Axial Force



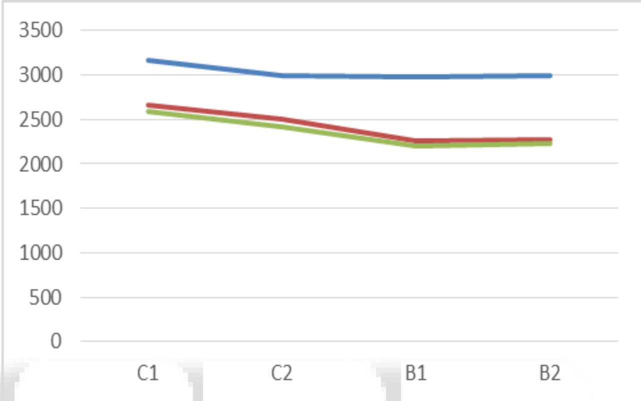
2) Graph 2 Support reaction for maximum value Fy



3) Graph 3 Support reaction for maximum Mx

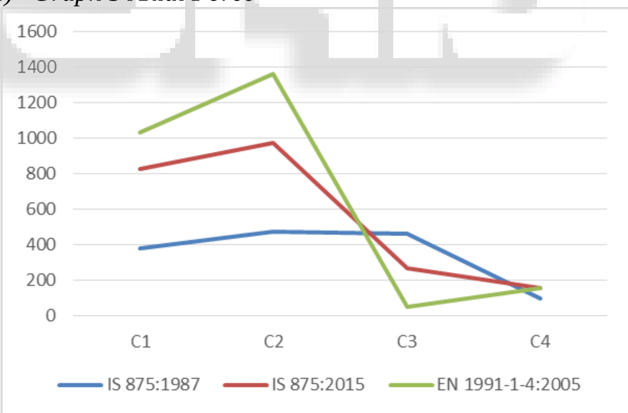


4) Graph 4 Support reaction for maximum Mz

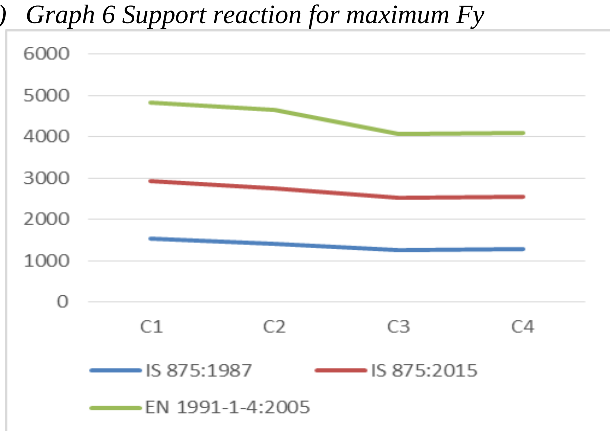


K. Zone III Suspension Tower

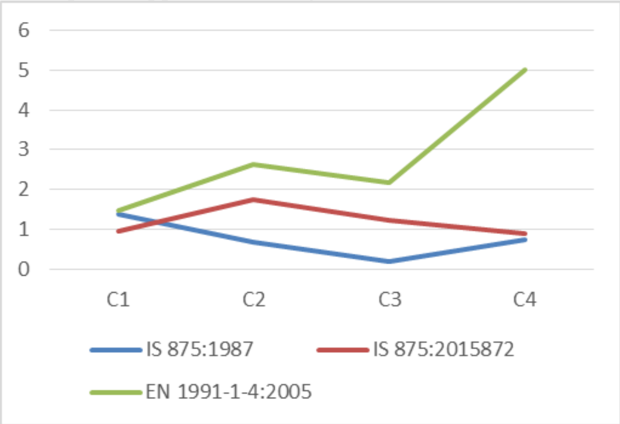
1) Graph 5 Axial Force



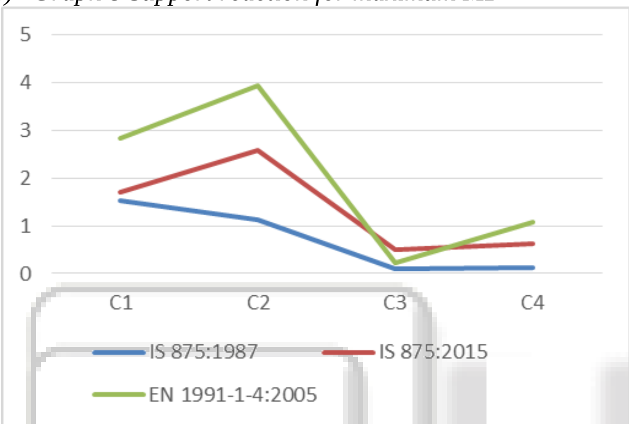
2) Graph 6 Support reaction for maximum Fy



3) *Graph 7 Support reaction for maximum Mx*

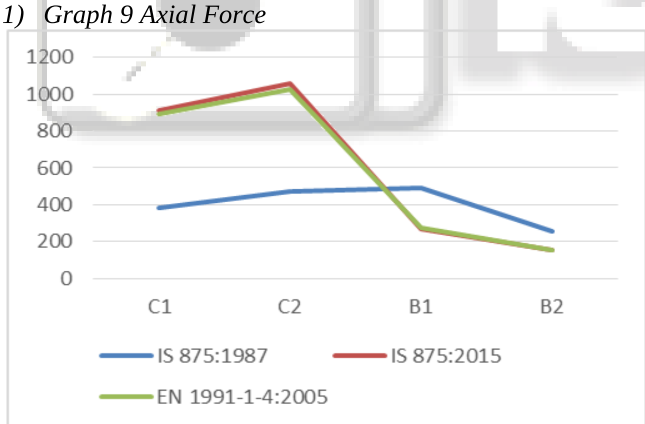


4) *Graph 8 Support reaction for maximum Mz*

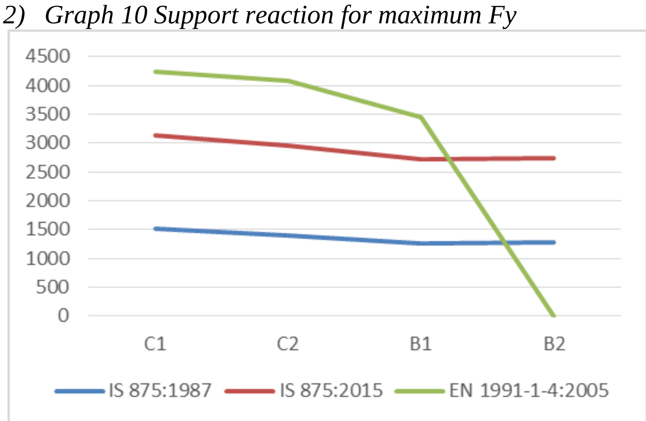


L. Zone IV Suspension Tower

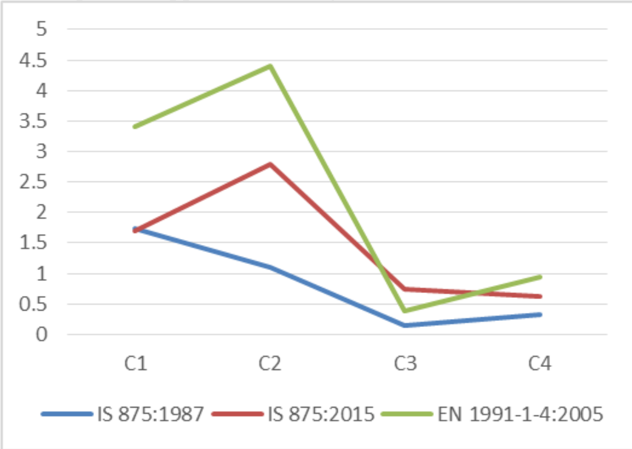
1) *Graph 9 Axial Force*



2) *Graph 10 Support reaction for maximum Fy*



3) *Graph 11 Support reaction for maximum Mx*



4) *Graph 12 Support reaction for maximum Mz*

VII. CONCLUSION

- From the studies it is seen that the Wind Pressure as per IS 875:2015 increases by 9.83% for zone II,40% for zone III,9.8% for zone IV respectively as compared to IS 875:1987.
- From the studies it is seen that the Wind Pressure as per IS 875:2015 increases by 20% for zone III and decreases by 8.2% for zone II and 6.4% for zone IV respectively as compared to EN 1991-1-4:2005.
- Axial force is increased in zone II,III,IV for C1 and C2 for IS 875:1987 for suspension and angle tower as compared to Is 875:2015. Result of IS 875:1987 and EN 1991-1-4:2005 is near about same.
- Support reaction for fy, Mx and Mz is also increased in IS 875:1987 as compared to 875:2015 and EN 1991-1-4:2005
- Therefore IS 875:2015 is safe for suspension and angle tower for zone II,III,IV.

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