Seismic Analysis of Multistorey Building With Floating Column

Prof. Shreyas Cholachgud[1], Mr.Jidnesh Patil[2], Mr. Ganesh Hivrale[3], Mr. Omkar Pachdunkar[4], Mr.Vijaykumar More[5]
[1]Assistant Professor, Dept of Civil Engineering
[2, 3, 4, 5]Dept of Civil Engineering
[1, 2, 3, 4, 5] Dhole Patil College of Engineering,Pune

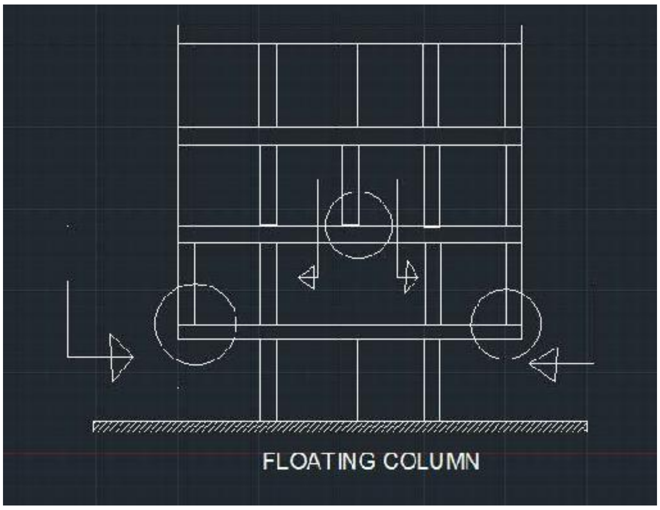
Abstract- *Structural engineering is a part of civil engineering dealing with the analysis and design of structures that support or resist loads. This project deals with the study of architectural drawing and the framing drawing of the building having floating columns and non-floating columns. In recent trend most of the residential as well as commercial buildings lowers floors contains large parking space, showrooms, etc. While the upper floors are occupied with conference rooms, banquet halls etc. All these amenities require huge uninterrupted space; thus, the concept of floating column was adopted. The load distribution of the floating columns and the various effects due to it is also being studied. The importance and effects due to the line of action of force are also studied. In this we are dealing with the comparative study of seismic analysis of multistore building with and without floating columns. The equivalent static analysis is carried out on the entire project mathematical 3D model using the software STAAD Pro V8i and the comparison of these models are being done. This will help us to find the various analytical properties of the structure and we may also have a very systematic and economical design of the structure. The floating column is a vertical member which at its lower-level rests on the beam which is a horizontal member. These beams carry this additional load to neighbour columns or the columns below it which ultimately increase the load on remaining columns. There are many buildings in which floating columns are practiced, especially above the ground floor, so as provide more open space.*

Keywords- Design of steel Structure, Analysis of Steel Tower, Wind Pressure Analysis, Transmission Tower Line, Modelling in Stadd-Pro, Analysis by Stadd-Pro

I. INTRODUCTION

In the load transfer path. Many urban multistorey buildings in India today have open first storey as an unavoidable feature. This is primarily being adopted to accommodate parking or reception lobbies in the first storey. Whereas the total seismic base shear as experienced by a building during an earthquake is dependent on its natural period, the seismic force distribution is dependent on the distribution of stiffness and mass along the height. The behavior of a building during earthquakes depends critically on its overall shape, size and geometry, in addition to how the earthquake forces are carried to the ground. The earthquake forces developed at different floor levels in a building need to be brought down along the height to the ground by the shortest path; any deviation or discontinuity in this load transfer path results in poor performance of the building. Buildings with vertical setbacks (like the hotel buildings with a few storeys wider than the rest) cause a sudden jump in earthquake forces at the level of discontinuity. Buildings that have fewer columns or walls in a particular storey or with unusually tall storey tend to damage or collapse which is initiated in that storey. Many buildings with an open ground storey intended for parking collapsed or were severely damaged in Gujarat during the 2001 Bhuj earthquake. Buildings with columns that hang or float on beams at an intermediate storey and do not go all the way to the foundation, have discontinuities.

What is floating column?



A column is supposed to be a vertical member starting from foundation level and transferring the load to the ground. The term floating column is also a vertical element which (due to architectural design/ site situation) at its lower level (termination Level) rests on a beam which is a horizontal member. The beams in turn transfer the load to other columns below it. There are many projects in which floating columns are adopted, especially above the ground floor, where transfer girders are employed, so that more open space is available in the ground floor. These open spaces may be required for assembly hall or parking purposes. The transfer girders have to be designed and detailed properly, especially in earthquake zones. The column is a concentrated load on the beam which supports it. As far as analysis is concerned, the column is often assumed pinned at the base and is therefore taken as a point load on the transfer beam. STAAD Pro, ETABS and SAP2000 can be used to do the analysis of this type of structure. Floating columns are competent enough to carry gravity loading but the transfer girder must be of adequate dimensions (Stiffness) with very minimal deflection. Looking ahead, of course, one will continue to make buildings interesting rather than monotonous. However, this need not be done at the cost of poor behavior and earthquake safety of buildings. Architectural features that are detrimental to earthquake response of buildings should be avoided. If not, they must be minimized. When irregular features are included in buildings, a considerably higher level of engineering effort is required in the structural design and yet the building may not be as good as one with simple architectural features. Hence, the structures already made with these kinds of discontinuous members are endangered in seismic regions. But those structures cannot be demolished, rather study can be done to strengthen the structure or some remedial features can be suggested. The columns of the first storey can be made stronger, the stiffness of these columns can be increased by retrofitting or these may be provided with bracing to decrease the lateral deformation.

240 rk Avenue South in New York, United States

II. OBJECTIVES

a. To study the behavior of multi-storey buildings with floating columns under earthquake excitations.
b. To study different parameters such as axial load, moment distribution, importance of line of action of force and seismic factors for models.
c. To analyse behaviour of RCC framed buildings with floating columns and without floating columns using STAAD.Pro v8i.

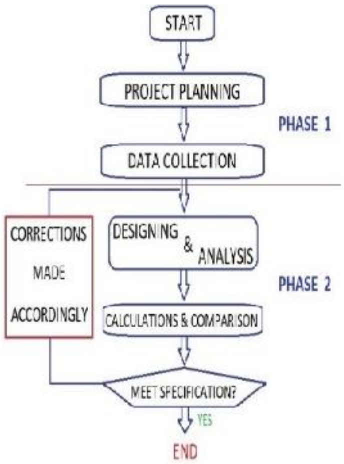
III. METHODOLOGY

a. Analysing different models of multistorey building using STAAD.Pro.
b. Analyse based on parameters such as base shear, storey drift, displacement, etc. Suggesting the best suitable model cases from all the structures**.**
c. Seismically active zones will be considered for analysis of buildings.
d. The building will be a G+6 storey RC framed building.
e. The analysis will be carried out by Response Spectrum Analysis method.
f. All the loads i.e dead load, live load, seismic load and load combinations are considered using IS 1893:2002.

stability of the structure.

0STEP : Project planning with collection of required data.
STEP : Designing & analysis of transmission tower under various load using STAAD. Pro.
STEP : Manual calculations under different wind speed for analysis of safety and stability.
STEP : Study and comparison for different types of Bracings of transmission tower.
STEP : Proper study and analysis of transmission tower to go for the Conclusion.

FLOWCHART:



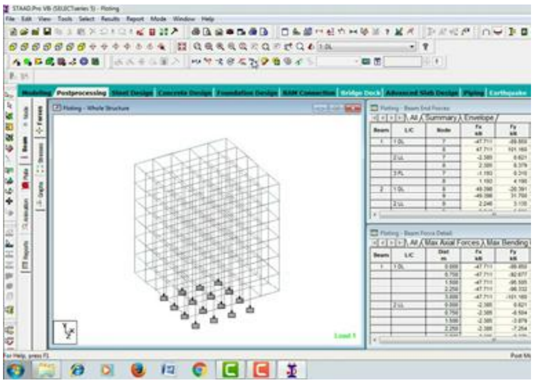


Fig.Design model of floating column building in Staad.pro

IV. MODELLING IN STAAD.PRO

Data:

- Height of the Tower: 21 m
- Centre to Centre spacing between the footings: 4m Centre to Centre.
- Support type: Fixed
- Wind speed: 39m/s, 44m/s, 49m/s

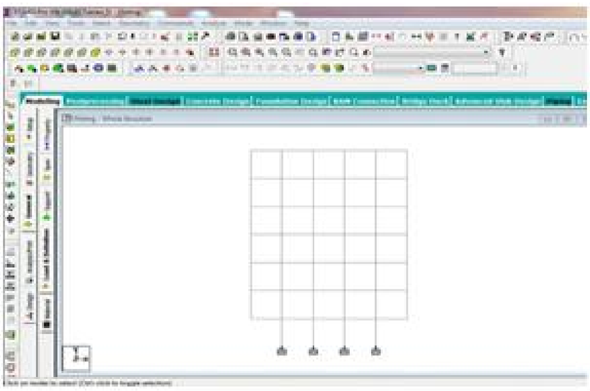


Figure 2 Fig.Isometric view of the Staad. Pro Model

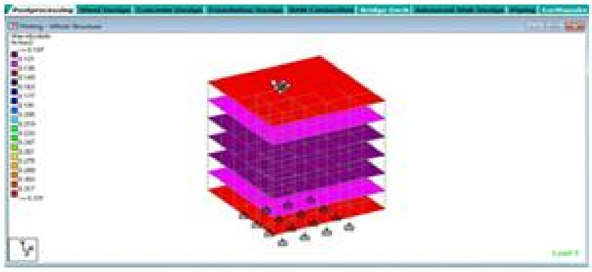


Fig. 3 Loading view of floating column building

V. ANALYSIS OF THE MODEL

The analysis of the model gave the following results depicting the displacements, Bending moment, Shear forces, stresses and various other results are obtained. Some of which are as shown:

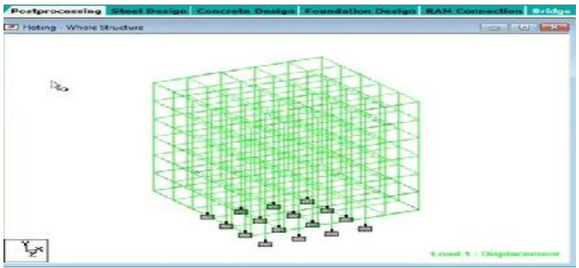


Figure 3 Fig. Displacement shown in green

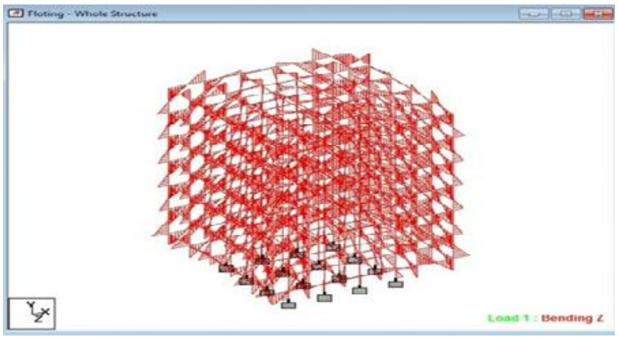


Figure 4 Bending Moment Diagram of the model

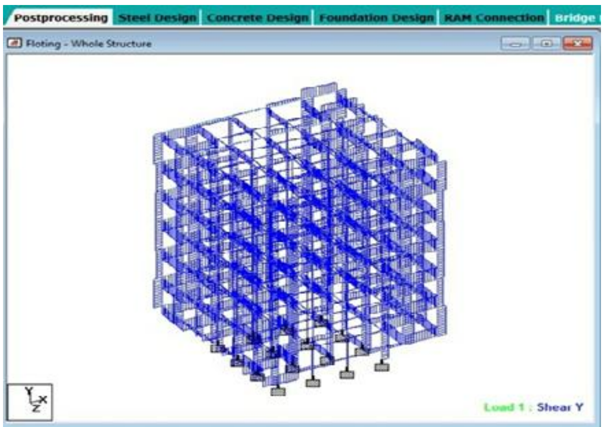
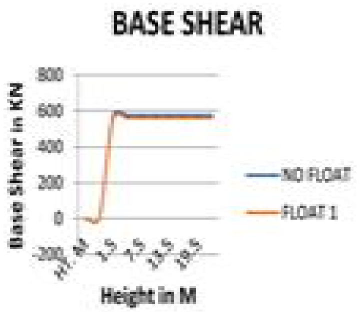


Figure 5 Shear Force Diagram of the model



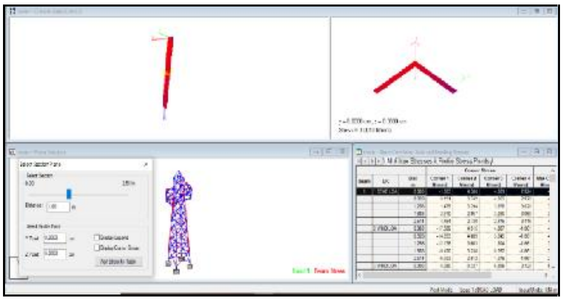


Figure 9:- Beam stresses

Table 1: Support Reactions Extracted from the software

Node	L/C	Horizontal FxkN	Vertical FykN	Horizontal FzkN	Moment Mx kN-m	My kN-m	MzkN-m
1	1 DEAD LOAD	4.825	59.97	4.807	-0.628	0	0.63
	2 WIND LOAD X	94.51	765.641	71.744	6.11	-14.523	8.228
	3 WIND LOAD Z	20.029	198.309	-124.26	0.039	0.024	0.23
2	1 DEAD LOAD	-4.822	59.965	4.801	-0.628	0	-0.63
	2 WIND LOAD X	198.928	-766.66	-66.356	-1.286	2.411	0.832
	3 WIND LOAD Z	-14.804	147.988	-44.135	-8.727	-11.712	2.557
3	1 DEAD LOAD	4.848	60.435	-4.804	0.628	0.001	0.629
	2 WIND LOAD X	143.29	859.179	-75.22	1.175	-2.069	-2.666
	3 WIND LOAD Z	-15.891	-198.349	36.828	1.775	-5.056	-1.869
4	1 DEAD LOAD	-4.852	60.44	-4.805	0.628	-0.001	-0.629
	2 WIND LOAD X	218.508	-858.161	69.831	-1.925	-17.912	-10.389
	3 WIND LOAD Z	10.666	-148.038	-30.3	-0.618	0.495	-0.717

Table 2:- Maximum Beam end Displacments

	Beam	L/C	Node	Horizontal X mm	Vertical Y mm	Horizontal Z mm	Resultant Resultant mm
Max X	41	2 WIND LOAD X	46	1.02	-0.595	0.315	1.222
Min X	9	2 WIND LOAD X	13	-43.499	0.712	-0.097	43.505
Max Y	163	2 WIND LOAD X	70	-28.999	10.967	-0.278	31.004
Min Y	167	2 WIND LOAD X	71	-28.656	-9.626	0.167	30.23
Max Z	66	3 WIND LOAD Z	55	-0.191	-0.393	2.101	2.145
Min Z	9	3 WIND LOAD Z	13	-0.216	0.619	-14.176	14.192
Max Rst	9	2 WIND LOAD X	13	-43.499	0.712	-0.097	43.505

Table 3: Governing Beam End forces

	Beam	L/C	Node	FxkN	FykN	FzkN	Mx kN-m	My kN-m	MzkN-m
Max Fx	30	2 WIND LOAD X	23	750.936	0.973	0.048	0.037	0.891	0.712
Min Fx	35	2 WIND LOAD X	28	-785.739	-1.102	-2.313	-0.003	5.343	-0.786
Max Fy	114	1 DEAD LOAD	6	3.31	4.622	0.849	0	-0.527	4.426
Min Fy	156	2 WIND LOAD X	67	45.316	-3.47	-2.082	0.024	-0.237	-1.43
Max Fz	174	2 WIND LOAD X	73	-2.568	-2.628	41.321	-0.025	-33.794	-2.056
Min Fz	80	2 WIND LOAD X	31	16.68	0.617	-38.166	-0.083	25.963	-0.351
Max Mx	31	2 WIND LOAD X	24	-332.385	-0.55	-1.217	0.111	2.478	-0.172
Min Mx	32	2 WIND LOAD X	25	-461.961	-0.509	3.656	-0.11	-3.956	-0.745
Max My	69	3 WIND LOAD Z	56	-3.624	0.955	30.103	0.028	37.432	-1.643
Min My	142	2 WIND LOAD X	59	20.152	-2.441	40.483	-0.083	-50.46	-1.587
Max Mz	114	1 DEAD LOAD	6	3.31	4.622	0.849	0	-0.527	4.426
Min Mz	39	2 WIND LOAD X	33	-715.079	2.993	2.322	-0.065	3.484	-4.329

V. DESIGN OF THE TOWER

The steel design of the transmission line tower is done using IS 802:1995. Hence the Section chosen is ISA 200×200×20

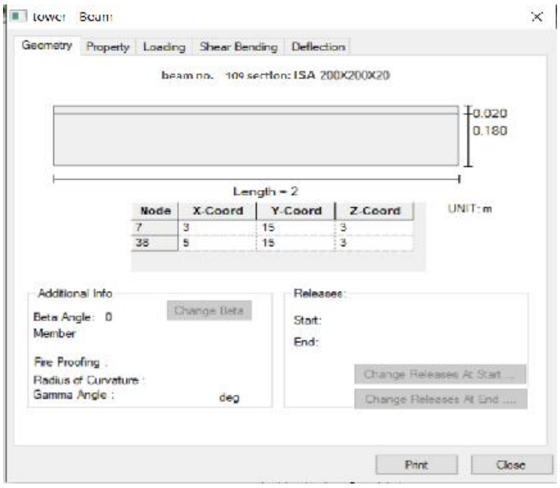


Figure10:- Geometry of the beam

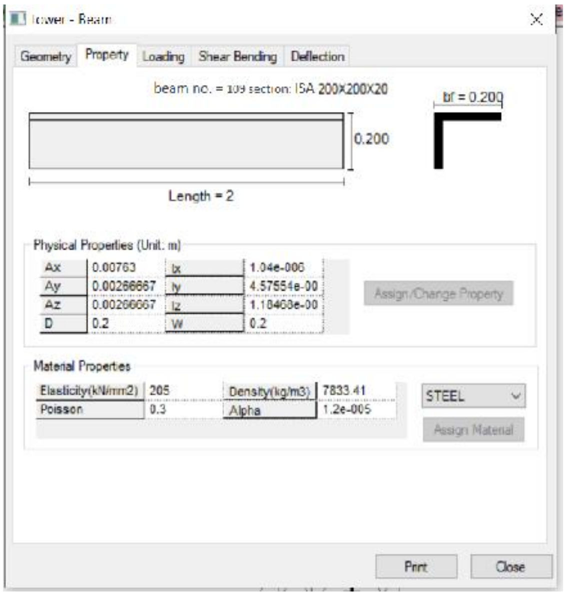


Figure 11:- Property of the beam

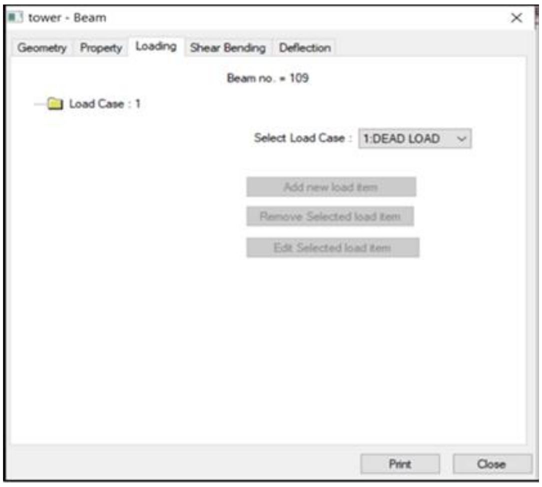


Figure 12:-Loading of the beam

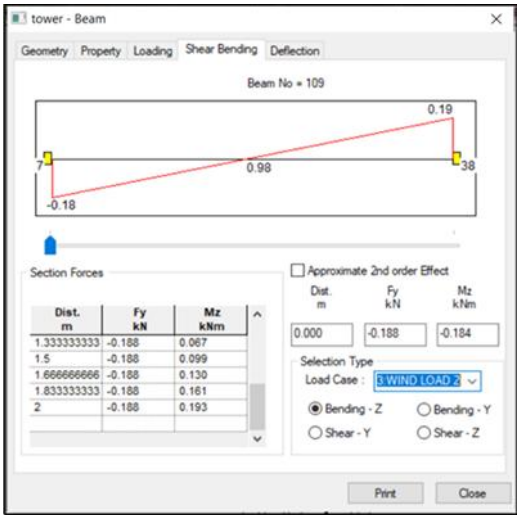


Figure13:-Shear bending of beam

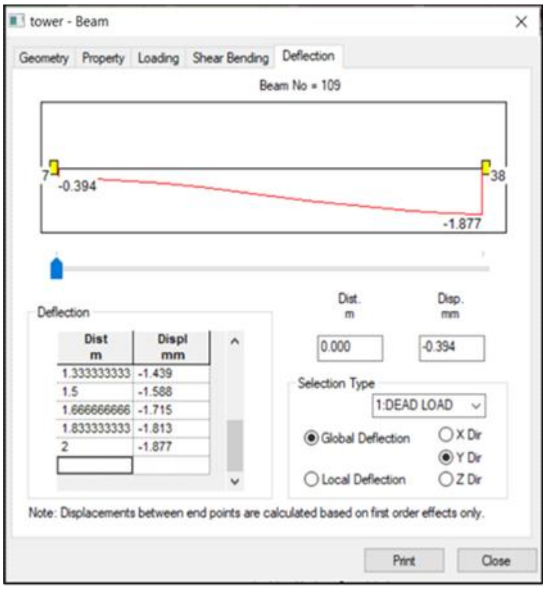


Figure 14:-Deflection of the beam

VI. RESULTS FOR WIND SPEED

Analysis of tower is carried out by considering all types of loading, different types of bracings systems. All loads are calculated manually as per IS 802 (part 1 and 2): 1995, IS 5613 (part 2): 1985, IS 875- 2015. The tower is analyzed and designed using STAAD Pro.

For wind speed 39 m/s

Nos	Types of structure	Failed members	Failed section's
01	Single web horizontal bracing	00	--
02	Single web diagonal pattern bracing	00	--
03	Warren type bracing	20-leg members 6-bracings	180x180x20 200x200x16 150x150x10

For wind speed 44m/s

Nos	Types of structure	Failed members	Failed section's
01	Single web horizontal bracing	00	--
02	Single web diagonal pattern bracing	00	--
03	Warren type bracing	13-leg members 6-bracings	180x180x20 200x200x16 150x150x10

For windspeed 47m/s

No's	Types of structure	Failed members	Failed section's
01	Single web horizontal bracing	00	--
02	Single web diagonal pattern bracing	01	200x200x16
03	Warren type bracing	20-leg members 6-bracings	180x180x20 200x200x16 150x150x10

VII. FOOTING DESIGN

The footing for the transmission line tower is designed in Staad foundation. For the four legs isolated footing for each is designed using the Indian Standards Codes.

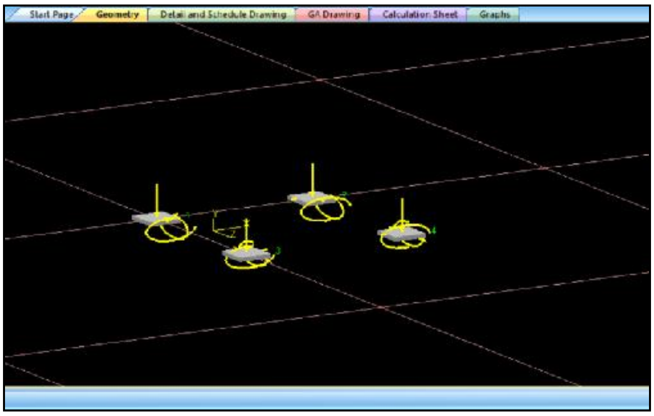


Figure 15:- Isolated footings geometry

Table 5:-Foundation Geometry

Footing	Group	Foundation Geometry		
-	-	Length	Width	Thickness
1	1	4.800 m	4.800 m	0.505 m
2	2	0.000 m	0.000 m	0.000 m
3	3	6.400 m	6.400 m	0.505 m
4	4	0.000 m	0.000 m	0.000 m

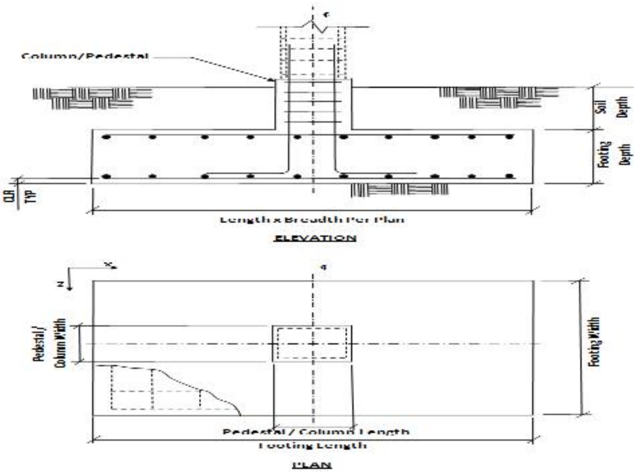


Figure 16:- Plan and Elevation of Footing

Table 6:- Footing Dimension

Design Type :	Calculate Dimension
Footing Thickness (Ft) :	305.000 mm
Footing Length - X (Fl) :	1000.000 mm
Footing Width - Z (Fw) :	1000.000 mm
Eccentricity along X (Oxd) :	0.000 mm
Eccentricity along Z (Ozd) :	0.000 mm

Table 7 Concrete and Rebar Properties

Unit Weight of Concrete :	25.000 kN/m^3
Strength of Concrete :	25.000 N/mm^2
Yield Strength of Steel :	415.000 N/mm^2
Minimum Bar Size :	T6
Maximum Bar Size :	T32
Minimum Bar Spacing :	50.000 mm
Maximum Bar Spacing :	500.000 mm
Pedestal Clear Cover (P, CL) :	50.000 mm
Footing Clear Cover (F, CL) :	50.000 mm

Table 8:-Soil Properties

Soil Type :	Drained
Unit Weight :	22.000 kN/m^3
Soil Bearing Capacity :	100.000 kN/m^2
Soil Surcharge :	0.000 kN/m^2
Depth of Soil above Footing :	0.000 mm
Cohesion :	0.000 kN/m^2
Min Percentage of Slab :	0.000

Table 9:-Sliding and Overturning

Coefficient of Friction :	0.500
Factor of Safety Against Sliding :	1.500
Factor of Safety Against Overturning :	1.500

Table 10:-Design Calculations

Length (L_2) =	4.800	m	Governing Load Case :	# 1
Width (W_2) =	4.800	m	Governing Load Case :	# 1
Depth (D_2) =	0.505	m	Governing Load Case :	# 1
Area (A_2) =	23.040	m^2		

Table 11:-Final Footing Dimensions

Reduction of force due to buoyancy =	0.000 kN	
Effect due to adhesion =	0.000 kN	
Area from initial length and width, A_o =	$L_o * W_o$ =	1.000 m^2
Min area required from bearing pressure, A_{min} =	P / q_{max} =	10.565 m^2

Table 12:-Summary of Adjusted Pressures at Four Corners

Load Case	Pressure at corner 1 (q_1) (kN/m^2)	Pressure at corner 2 (q_2) (kN/m^2)	Pressure at corner 3 (q_3) (kN/m^2)	Pressure at corner 4 (q_4) (kN/m^2)	Area of footing in uplift (A_u) (m^2)
2	**50.2961**	46.0101	41.4158	45.7018	0.000
2	50.2961	**46.0101**	41.4158	45.7018	0.000
2	50.2961	46.0101	**41.4158**	45.7018	0.000
2	50.2961	46.0101	41.4158	**45.7018**	0.000

Table13:-Summary of Adjusted Pressures at Four Corners

Load Case	Pressure at corner 1 (q_1) (kN/m²)	Pressure at corner 2 (q_2) (kN/m²)	Pressure at corner 3 (q_3) (kN/m²)	Pressure at corner 4 (q_4) (kN/m²)
2	**50.2961**	46.0101	41.4158	45.7018
2	50.2961	**46.0101**	41.4158	45.7018
2	50.2961	46.0101	**41.4158**	45.7018
2	50.2961	46.0101	41.4158	**45.7018**

Table 14Factor of safety against sliding

-	Factor of safety against sliding		Factor of safety against overturning	
Load Case No.	**Along X-Direction**	**Along Z-Direction**	**About X-Direction**	**About Z-Direction**
1	36.358	36.491	467.766	466.150
2	5.589	7.363	59.887	64.195
3	12.215	1.969	18.725	118.796

Table 15:-Critical load case and the governing factor of safety for overturning and sliding -X Direction

Critical Load Case for Sliding along X-Direction :	2
Governing Disturbing Force :	-94.510 kN
Governing Restoring Force :	528.261 kN
Minimum Sliding Ratio for the Critical Load Case :	5.589
Critical Load Case for Overturning about X-Direction :	3
Governing Overturning Moment :	62.711 kNm
Governing Resisting Moment :	1174.247 kNm
Minimum Overturning Ratio for the Critical Load Case :	18.725

Table 16:-Critical load case and the governing factor of safety for overturning and sliding -Z Direction

Critical Load Case for Sliding along Z-Direction :	3
Governing Disturbing Force :	124.260 kN
Governing Restoring Force :	244.639 kN
Minimum Sliding Ratio for the Critical Load Case :	1.969
Critical Load Case for Overturning about Z-Direction :	2
Governing Overturning Moment :	39.499 kNm
Governing Resisting Moment :	2535.605 kNm
Minimum Overturning Ratio for the Critical Load Case :	64.195

Table 17

Critical Load Case	= #2			
Area within critical perimeter A_m =		= 1.855	sq.m	
V_{max} =	$P_y \times (B \times H - A_m)$	= 703.998	kN	
V_m =	$\frac{V_{max}}{2 \times (b + h + 6 \times d) \times d}$	= 291.098	kN/m²	IS456
V_{t1} =	$\min(0.8\sqrt{f_{cu}}, 5)$	4000.000	kN/m²	2000
	$V_m <= V_{t1}$	hence, safe		
Critical Perimeter P_m =	$2 \times (b + h + 6 \times d)$	5.448	m	
V_{m1} =	$\frac{V_u}{P_m \times d}$	285.888	kN/m²	
V_1 =	$\min(pt_{reqd}, 3)$	0.145	N/mm2	
V_2 =	$\max\left(\frac{400}{d}, 1\right)$	1.000	N/mm2	
V_3 =	$\min\left(\frac{f_{cu}, 40}{25}\right)^{\frac{1}{3}}$	1.000	N/mm2	
V_c =	$\frac{0.79 \times (V1)^{\frac{1}{3}} \times (V2)^{\frac{1}{4}} \times (V3)}{1.25}$	332.234	kN/m²	
	$V_{m1} <= V_c$	hence, safe		
$l_{dp} >= l_d$		hence, safe		

VIII. CONCLUSIONS

Self-supporting transmission line tower is analyzed and designed using hot-rolled steel sections. Transmission

Line Towers constitute about 28 to 42 percent of the total cost of the Transmission Lines. Tower is designed and compared for weight parameters and absolute displacement variation along with its height.

1. Wind load has significant unfavourable influence on resistance of transmission tower subjected to ground motion.
2. Warren type bracing are not structurally stable as compare to other types of bracings.
3. Single web horizontal type bracings are structurally safe as compare to warren type and single web diagonal type bracing.

X bracing structural is light weight and more economical as compare to K bracing structure.

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